



# Application Note

## **BRT\_AN\_033**

# **BT81X Series Programming Guide**

**Version 2.2**

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This application note describes the process and practice required to program BT81X Series, (BT815/6 and **BT817/8** chips).

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## 1 Introduction

This document captures the programming details for the **BT81X** Series chips (BT815/6, BT817/8) including graphics commands, widget commands and configurations to control **BT81X** Series chips for smooth and vibrant screen effects.

The **BT81X** Series chips are graphics controllers with add-on features such as audio playback and touch capabilities. They consist of a rich set of graphics objects that can be used for displaying various menus and screen shots for a range of products including home appliances, toys, industrial machinery, home automation, elevators, and many more.

### 1.1 Scope

This document will be useful to understand the command set and demonstrate the ease of usage in the examples given for each specific instruction. In addition, it also covers various power modes, audio, and touch features as well as their usage.

The descriptions in this document are applicable to both BT815/6 and **BT817/8**, unless specified otherwise.

Within this document, the endianness of commands, register values, and data in **RAM\_G** are in *little-endian* format.

Information on pin settings, hardware characteristics and hardware configurations can be found in the BT815/6 or **BT817/8** data sheet.

### 1.2 Intended Audience

The intended audience of this document are Software Programmers and System Designers who develop graphical user interface (**GUI**) applications on any processor with an **SPI** master interface.

### 1.3 Conventions

All values are in decimal by default.

The values with **0x** are in hexadecimal.

The values with **0b'** are in binary.

Host refers to the **MCU/MPU** with SPI master interface connecting with **EVE**.

Host commands refer to the **EVE** specific commands defined in the Serial Data Protocol section of the datasheet.

### 1.4 API Reference Definitions

The following table provides the functionality and nomenclature of the APIs used in this document.

<b>wr8()</b>	write 8 bits to intended address location
<b>wr16()</b>	write 16 bits to intended address location
<b>wr32()</b>	write 32 bits to intended address location
<b>rd8()</b>	read 8 bits from intended address location
<b>rd16()</b>	read 16 bits from intended address location

<b>rd32()</b>	read 32 bits from intended address location
<b>cmd()</b>	write 32 bits data to command <b>FIFO</b> i.e. <b>RAM_CMD</b>
<b>cmd_*</b> ()	Write 32 bits commands with its necessary parameters to command <b>FIFO</b> i.e. <b>RAM_CMD</b> .
<b>dl()</b>	Write 32 bits display list command to <b>RAM_DL</b> .
<b>host_command()</b>	send host command in host command protocol

**Table 1 – API Reference Definitions**

## 1.5 What's new in BT81X Series?

Compared to the previous generation **FT81X** series, the BT81X Series introduces several enhanced features:

- ❖ QSPI NOR flash interface
- ❖ Adaptive Scalable Texture Compression(ASTC) format bitmap
- ❖ Unicode text display
- ❖ Animation support

The tables below captures the new and updated commands in BT81X for these features:

Coprocessor Commands	BT81X	Remarks
<i>CMD_ANIMDRAW</i> <i>CMD_ANIMFRAME</i> <i>CMD_ANIMSTART</i> <i>CMD_ANIMSTOP</i> <i>CMD_ANIMXY</i>	New	Animation feature related coprocessor commands
<i>CMD_APPENDF</i>	New	Append flash data to display list
<i>CMD_CLEARCACHE</i>	New	Clear the flash cache
<i>CMD_FLASHATTACH</i> <i>CMD_FLASHDETACH</i> <i>CMD_FLASHERASE</i> <i>CMD_FLASHFAST</i> <i>CMD_FLASHREAD</i> <i>CMD_FLASHSOURCE</i> <i>CMD_FLASHSPIDESEL</i> <i>CMD_FLASHSPIRX</i> <i>CMD_FLASHSPITX</i> <i>CMD_FLASHUPDATE</i> <i>CMD_FLASHWRITE</i>	New	Flash interface operation related coprocessor commands
<i>CMD_FILLWIDTH</i>	New	Set the line width for the text of cmd_text and cmd_button
<i>CMD_GRADIENTA</i>	New	Draw a smooth color gradient with transparency
<i>CMD_INFLATE2</i>	New	Decompress data into memory with more options: <b>OPT_FLASH, OPT_MEDIAIFO</b>
<i>CMD_RESETFONTS</i>	New	Loads a ROM font into a bitmap handle
<i>CMD_ROTATEAROUND</i>	New	Apply a rotation and scale around (x,y) for bitmap
<i>CMD_VIDEOSTARTF</i>	New	Initialize video frame decoder for the data in flash memory
<i>CMD_TEXT</i> <i>CMD_BUTTON</i> <i>CMD_TOGGLE</i>	Changed	Added option : <b>OPT_FORMAT</b>

<i>CMD_LOADIMAGE</i>	Changed	Supports data stored in flash
<i>CMD_PLAYVIDEO</i>		
<i>CMD_VIDEOSTARTF</i>		
<b>Display List</b>	<b>BT81X</b>	<b>Remarks</b>
BITMAP_SOURCE	Changed	Expand the address bit field to access <b>ASTC</b> bitmap in flash
BITMAP_TRANSFORM_A	Changed	Added new precision control : signed fixed point 1.15
BITMAP_TRANSFORM_B		
BITMAP_TRANSFORM_D		
BITMAP_TRANSFORM_E		
BITMAP_LAYOUT	Changed	Added a new valid value for format parameter: <b>GLFORMAT</b>
<i>BITMAP_EXT_FORMAT</i>	New	Support more bitmap formats, especially <b>ASTC</b> compression formats
<i>BITMAP_SWIZZLE</i>	New	Set the source for the r,g,b,a channels of a bitmap

**Table 2 – Updated Commands in BT81X**

## 1.6 What is new in BT817/8?

BT817/8 maintains backward compatibility with the previous BT815/6 ICs. Any application built for BT815/6 is able to run on the BT817/8 series without any changes. In short, BT817/8 is an improved version of BT815/6.

Compared to BT815/6, BT817/8 has a **1.5x** graphics engine performance improvement. In addition, it introduces many enhancements including:

- ❖ Programmable timing to adjust HSYNC and VSYNC timing, enabling interface to numerous displays
- ❖ Add Horizontal Scan out Filter to support non-square pixel LCD display
- ❖ Adaptive Hsync mode to delay the start of scanout line while keeping PCLK running
- ❖ Supports Animation in **RAM\_G**
- ❖ Enable constructing command list in **RAM\_G**
- ❖ New font cache mechanism for custom fonts whose glyph is in flash

To facilitate the features above, there are the new registers and commands introduced for the **BT817/8**. They can be found in this document with the note “**BT817/8 specific**”.

Besides that, two commands in BT815/6 are improved in **BT817/8**:

- **CMD\_GETPTR**
- **CMD\_GETPROPS**

However, these two commands are kept in same functionality for compatibility unless **CMD\_APILEVEL** is sent with parameter level 2.

## 2 Programming Model

**EVE** appears to the host MCU as a memory-mapped SPI device. The host MCU sends commands and data over the serial protocol described in the data sheet.

### 2.1 Address Space

All memory and registers are memory mapped into 22-bit address space with a 2-bit SPI command prefix: Prefix 0'b00 for read and 0'b10 for write to the address space, 0'b01 is reserved for Host Commands and 0'b11 undefined. Please refer to the datasheet about the serial data protocol used to read/write these addresses. The memory space definitions are provided in the following table:

Name	Start Address	End Address	Size (bytes)	Description
<b>RAM_G</b>	0x000000	0x0FFFFF	1024 Ki	General purpose graphics <b>RAM</b> , also called main memory in this document
<b>ROM_FONT</b>	0x1E0000	0x2FFFFB	1152 Ki	Font table and bitmap
<b>ROM_FONTROOT</b>	0x2FFFFC	0x2FFFFF	4	Font table pointer address
<b>RAM_DL</b>	0x300000	0x301FFF	8 Ki	Display list <b>RAM</b>
<b>RAM_REG</b>	0x302000	0x302FFF	4 Ki	Registers
<b>RAM_CMD</b>	0x308000	0x308FFF	4 Ki	Command <b>FIFO</b>
<b>RAM_ERR_REPORT</b>	0x309800	0x3098FF	128	Coprocessor fault report area
<b>Flash memory</b>	0x800000	Depending on attached flash chip, up to 0x107FFFF	Up to 256Mi	External NOR flash memory. It can <b>NOT</b> be addressed by <b>host</b> directly.  The address is used by the following commands only for rendering <b>ASTC</b> image only: <b>CMD_SETBITMAP</b> <b>BITMAP_SOURCE</b>

**Table 3 – Memory Map**

**Note:**

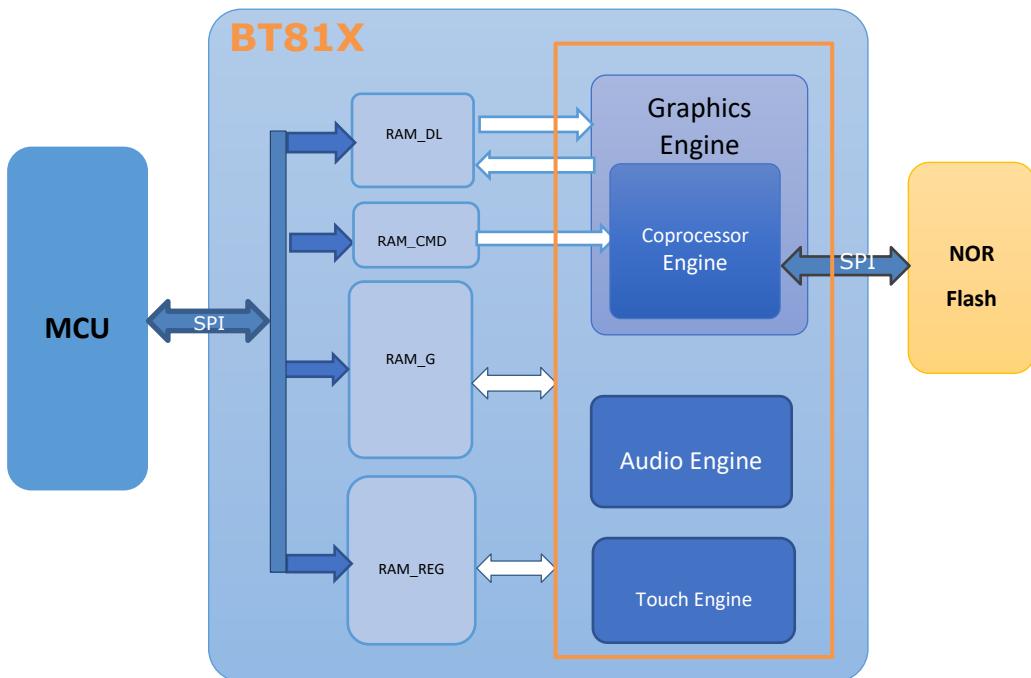
1. The addresses beyond this table are reserved and shall not be read or written unless otherwise specified.
2. To access the flash memory, host needs leverage the coprocessor commands, such as
  - o **CMD\_FLASHREAD**
  - o **CMD\_FLASHWRITE**
  - o **CMD\_FLASHUPDATE**
  - o .....

These commands uses **zero** based address to address the blocks of flash. See [\*\*Flash Interface\*\*](#) for more details.

## 2.2 Data Flow Diagram

Figure 1 describes the data flow between 1) **external components** (MCU and Flash) 2) **internal components of EVE**. Please note that the direct write from **MCU** to **RAM\_DL** requires careful actions to sync up the read/write pointers in the respective registers of **EVE** because coprocessor engine may also write the generated display list commands into **RAM\_DL**.

To save such effort, the better approach is to write the display list command to **RAM\_CMD** and make coprocessor update the **RAM\_DL** accordingly.



**Figure 1 – BT81X data flow**

The data here refers to the following items:

- **Display list** : Instructions for graphics engine to render the screen
- **Coprocessor command**: Predefined commands by coprocessor engine
- **Bitmap data**: Pixel representation in EVE defined formats: such as RGB565, ASTC etc.
- **JPEG/PNG stream**: Image data in PNG/JPEG format conforming to Eve requirement, for coprocessor engine to decode.
- **MJPEG stream**: The video data in MJPEG format conforming to Eve requirement for coprocessor engine to decode.
- **Audio stream**: uLaw, ADPCM, PCM encoded audio samples, for audio engine to decode
- **Flash image**: data to be programmed into flash or data read back from flash.
- **Register values**: read or write the registers.

## 2.3 Read Chip Identification Code (ID)

After reset or reboot, the chip ID can be read from address 0xC0000 to 0xC0003.

To read the chip identification code, users shall read 4 bytes of data from address 0xC0000 before the application overwrites this address, since it is located in **RAM\_G**.

The following table describes the data to be read:

<b>0xC0003</b>	<b>0xC0002</b>	<b>0xC0001</b>	<b>0xC0000</b>
0x00	0x01	0x10 for FT810 0x11 for FT811 0x12 for FT812 0x13 for FT813 0x15 for BT815 0x16 for BT816 <b>0x17 for BT817</b> <b>0x18 for BT818</b>	0x08

**Table 4 – Read Chip Identification Code**

## 2.4 Initialization Sequence during Boot Up

During EVE boot up, the following steps are required:

1. Send host command “**CLKEXT**” if the PLL input is from external crystal oscillator or external clock.
2. Send host command “**CLKSEL**” to select system clock frequency if the non-default system clock is to be used.  
By default the system clock is set to 60MHz. However, 72MHz is recommended for better performance.
3. Send Host command “**ACTIVE**”.
4. Send Host command “**RST\_PULSE**”
5. Read **REG\_ID** until **0x7C** is returned.
6. Read **REG\_CPURESET** till **EVE** goes into the working status, i.e., zero is returned.
7. Configure display control timing registers, except **REG\_PCLK**
8. Write first display list to **RAM\_DL**.
9. Write **REG\_DLSWAP** to start graphics engine rendering process with first display list
10. Enable backlight control for display panel
11. Write **REG\_PCLK** to configure the PCLK frequency of display panel, which leads to the output of the first display list

```

host_command(CLKEXT); //send command "CLKEXT" to use the external clock source
host_command(CLKSEL); //select the system clock frequency
host_command(ACTIVE); //send host command "ACTIVE" to wake up
msWait(300);          //wait 300 milliseconds

while (0x7C != rd8(REG_ID));
while (0x0 != rd16(REG_CPURESET)); //Check if EVE is in working status.

wr32(REG_FREQUENCY, 0x3938700); //Configure the system clock to 60MHz.

/* Configure display registers - demonstration for WVGA 800x480 resolution */
wr16(REG_HCYCLE, 928);
wr16(REG_HOFFSET, 88);
wr16(REG_HSYNC0, 0);
wr16(REG_HSYNC1, 48);
wr16(REG_VCYCLE, 525);
wr16(REG_VOFFSET, 32);
wr16(REG_VSYNC0, 0);
wr16(REG_VSYNC1, 3);
wr8(REG_SWIZZLE, 0);
wr8(REG_PCLK_POL, 1);

```

```

wr8(REG_CSPREAD, 0);
wr16(REG_HSIZE, 800);
wr16(REG_VSIZE, 480);

/* Write first display list to display list memory RAM_DL*/
wr32(RAM_DL+0,CLEAR_COLOR_RGB(0,0,0));
wr32(RAM_DL+4,CLEAR(1,1,1));
wr32(RAM_DL+8,DISPLAY());

wr8(REG_DLSWAP,DLSWAP_FRAME);//display list swap

/* Enable backlight of display panel */
#if defined(FT81X_ENABLE)
  wr16(REG_GPIOX_DIR, 0xffff);
  wr16(REG_GPIOX, 0xffff);
#else
  wr8(REG_GPIO_DIR,0xff);
  wr8(REG_GPIO,0xff);
#endif

wr8(REG_PCLK,2); //Configure the PCLK divisor to 2, i.e. PCLK = System CLK/2

```

#### Code Snippet 1 – Initialization Sequence

## 2.5 PWM Control

The PWM signal is controlled by two registers: **REG\_PWM\_HZ** and **REG\_PWM\_DUTY**.

**REG\_PWM\_HZ** specifies the PWM output frequency.

**REG\_PWM\_DUTY** specifies the PWM output duty cycle.

## 2.6 RGB Color Signal

The RGB color signal is carried over 24 signals - 8 each for red, green and blue. Several registers affect the operation of these signals. The order of these operations in the display output system is as follows:

**REG\_DITHER** enables color dither. To improve the image quality, **EVE** applies a  $2 \times 2$  color dither matrix to output pixels. The dither option improves half-tone appearance on displays, even on 1-bit displays.

**REG\_OUTBITS** gives the bit width of each color channel. The default is zero, meaning 8 bits each channel. Lower values mean that fewer bits are output for the color channel. This value also affects dither computation.

**REG\_SWIZZLE** controls the arrangement of the output color pins, to help PCB routing with different LCD panel arrangements. Bit 0 of the register causes the order of bits in each color channel to be reversed. Bits 1-3 control the RGB order. Bit 1 set causes R and B channels to be swapped. Bit 3 is rotate enable. If bit 3 is set, then (R, G, B) is rotated right if bit 2 is one, or left if bit 2 is zero. Please refer to BT817/8 datasheet for more details.

## 2.7 Touch Screen

The raw touch screen (x, y) values are available in register **REG\_TOUCH\_RAW\_XY**. The range of these values is 0-1023. If the touch screen is not being pressed, both registers read 0xFFFF.

These touch values are transformed into screen coordinates using the matrix in registers **REG\_TOUCH\_TRANSFORM\_A-F**. The post-transform coordinates are available in register **REG\_TOUCH\_SCREEN\_XY**. If the touch screen is not being pressed, both registers read 0x8000 (-32768). The values for **REG\_TOUCH\_TRANSFORM A-F** may be computed using an on-screen calibration process. If the screen is being touched, the screen coordinates are looked up in the screen's tag buffer, delivering a final 8-bit tag value, in **REG\_TOUCH\_TAG**. Because the tag lookup takes a full frame, and touch coordinates change continuously, the original (x, y) used for the tag lookup is also available in **REG\_TOUCH\_TAG\_XY**.

Screen touch pressure is available in **REG\_TOUCH\_RZ**. This register gives the resistance of the touch screen press, so lower values indicate more pressure. The register's range is 0 (maximum pressure) to 32767 (no touch). Because the values depend on the particular screen, and the instrument used for pressing (stylus, fingertip, gloved finger, etc.) a calibration or setup step shall be used to discover the useful range of resistance values.

**REG\_TOUCH\_MODE** controls the frequency of touch sampling. **TOUCHMODE\_CONTINUOUS** is continuous sampling. Writing **TOUCHMODE\_ONESHOT** causes a single sample to occur. **TOUCHMODE\_FRAME** causes a sample at the start of each frame. **TOUCHMODE\_OFF** stops all sampling.

**REG\_TOUCH\_ADC\_MODE** selects single-ended (**ADC\_SINGLE\_ENDED**) or differential (**ADC\_DIFFERENTIAL**) ADC operation. Single-ended consumes less power, differential gives more accurate positioning. **REG\_TOUCH\_CHARGE** specifies how long to drive the touchscreen voltage before sampling the pen detect input. The default value 3000 gives a delay of 0.3ms which is suitable for most screens.

**REG\_TOUCH\_RZTHRESH** specifies a threshold for touchscreen resistance. If the measured touchscreen resistance is greater than this threshold, then no touch is reported. The default value is 65535, so all touches are reported.

**REG\_TOUCH\_SETTLE** specifies how long to drive the touchscreen voltage before sampling the position. For screens with a large capacitance, this value should be increased. For low capacitance screens this value can be decreased to reduce "on" time and save power.

**REG\_TOUCH\_OVERSAMPLE** controls the oversampling factor used by the touchscreen system. Increase this value to improve noise rejection if necessary. For systems with low noise, this value can be lowered to reduce "on" time and save power.

Touch screen 32-bit register updates are atomic: all 32 bits are updated in a single cycle. So when reading an XY register, for example, both (x, y) values are guaranteed to be from the same sensing cycle. When the sensing cycle is complete, and the registers have been updated, the **INT\_CONV\_COMPLETE** interrupt is triggered.

As well as the above high-level samples, the direct 10-bit **ADC** values are available in two registers, **REG\_TOUCH\_DIRECT\_XY** and **REG\_TOUCH\_DIRECT\_Z1Z2**. These registers are laid out as follows:

	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0				
S																																				

The S field is 0 if a touch is being sensed, in which case all fields hold their sensed values. If S is 1, then no touch is sensed and all fields should be ignored.

## 2.8 Flash Interface

To access an attached flash chip, **EVE** provides the necessary registers to read/write flash with very high throughput. The graphics engine can fetch these graphics assets directly without going through the external host MCU, thus significantly off-loading the host MCU from feeding display contents.

The register **REG\_FLASH\_STATUS** indicates the state of the flash subsystem. During boot up, the flash state is **FLASH\_STATE\_INIT**. After detection has completed, flash is in the state **FLASH\_STATE\_DETACHED** or **FLASH\_STATE\_BASIC**, depending on whether an attached flash device was detected. If no device is detected, then all the SPI output signals are driven low. When the host MCU calls **CMD\_FLASHFAST**, the flash system attempts to go to full-speed mode, setting the state to **FLASH\_STATE\_FULL**. At any time, users can call **CMD\_FLASHDETACH** in order to disable the flash communications. This tri-states all flash signals, allowing a suitably connected MCU to drive the flash directly. Alternatively, in the detached state, commands **CMD\_FLASHSPIDESEL**, **CMD\_FLASHSPITX** and **CMD\_FLASHSPIRX** can be used to control the SPI bus. If detached, the host MCU can call **CMD\_FLASHATTACH** to re-establish communication with the flash device. Direct rendering of ASTC based bitmaps from flash is only possible in **FLASH\_STATE\_FULL**. After modifying the contents of flash, the MCU should clear the on-chip bitmap cache by calling **CMD\_CLEARCACHE**.

Command	DETACHED	BASIC	FULL	Operation
<b>CMD_FLASHERASE</b>		✓	✓	Erase all of flash
<b>CMD_FLASHWRITE</b>		✓	✓	Write data from <b>RAM_CMD</b> to blank flash
<b>CMD_FLASHUPDATE</b>		✓	✓	Read the flash and update to flash if different
<b>CMD_FLASHPROGRAM</b>		✓	✓	Write data from <b>RAM_G</b> to blank flash
<b>CMD_FLASHREAD</b>		✓	✓	Reads data from flash to main memory
<b>CMD_FLASHDETACH</b>		✓	✓	Detach from flash
<b>CMD_FLASHATTACH</b>	✓			Attach to flash
<b>CMD_FLASHFAST</b>		✓		Enter full-speed(fast) mode
<b>CMD_FLASHSPIDESEL</b>	✓			SPI bus: deselect device
<b>CMD_FLASHSPITX</b>	✓			SPI bus: write bytes
<b>CMD_FLASHSPIRX</b>	✓			SPI bus: read bytes

Table 5 – Flash Interface states and commands

To support different vendors of SPI NOR flash chips, the first block (4096 bytes) of the flash is reserved for the flash driver called **BLOB** file which is provided by **Bridgetek**. The **BLOB** file shall be programmed first so that flash state can enter into full-speed (fast) mode. Please refer to BT81x datasheet for more details.

## 2.9 Audio Routines

The audio engine has two functionalities: synthesize built-in sound effects with selected pitches and play back the audio data in **RAM\_G**.

### 2.9.1 Sound Effect

The audio engine has various sound data built-in to work as a sound synthesizer. Sample code to play C8 on the xylophone:

```
wr8(REG_VOL_SOUND, 0xFF); //set the volume to maximum
wr16(REG_SOUND, (0x6C<<8) | 0x41); // C8 MIDI note on xylophone
wr8(REG_PLAY, 1); // play the sound
```

Code Snippet 2 – Play C8 on the Xylophone

Sample code to stop sound play:

```
wr16(REG_SOUND, 0x0); //configure "silence" sound to be played
wr8(REG_PLAY, 1); //play sound
Sound_status = rd8(REG_PLAY); //1-play is going on, 0-play has finished
```

#### Code snippet 3 – Stop Playing Sound

To avoid a pop sound on reset or power state change, trigger a "mute" sound, and wait for it to complete (i.e. **REG\_PLAY** contains the value of 0). This sets the audio output pin to 0 levels. On reboot, the audio engine plays back the "unmute" sound.

```
wr16(REG_SOUND, 0x60); //configure "mute" sound to be played
wr8(REG_PLAY, 1); //play sound
Sound_status = rd8(REG_PLAY); //1-play is going on, 0-play has finished
```

#### Code snippet 4 – Avoid Pop Sound

**Note:** Refer to BT817/8 datasheet for more information on the sound synthesizer and audio playback.

### 2.9.2 Audio Playback

The audio engine supports an audio playback feature. For the audio data in the **RAM\_G** to play back, it requires the start address in **REG\_PLAYBACK\_START** to be 8 bytes aligned. In addition, the length of audio data specified by **REG\_PLAYBACK\_LENGTH** is required to be 8 Bytes aligned.

Three types of audio formats are supported: 4 Bit IMA ADPCM, 8 Bit signed PCM, 8 Bit u-Law. For IMA ADPCM format, please note the byte order: within one byte, the first sample (4 bits) shall be located from bit 0 to bit 3, while the second sample (4 bits) shall be located from bit 4 to bit 7.

To learn how to play back the audio data, please check the sample code below:

```
wr8(REG_VOL_PB, 0xFF); //configure audio playback volume
wr32(REG_PLAYBACK_START, 0); //configure audio buffer starting address
wr32(REG_PLAYBACK_LENGTH, 100*1024); //configure audio buffer length
wr16(REG_PLAYBACK_FREQ, 44100); //configure audio sampling frequency
wr8(REG_PLAYBACK_FORMAT, ULAWSAMPLES); //configure audio format
wr8(REG_PLAYBACK_LOOP, 0); //configure once or continuous playback
wr8(REG_PLAYBACK_PLAY, 1); //start the audio playback
```

#### Code Snippet 5 – Audio Playback

```
AudioPlay_Status = rd8(REG_PLAYBACK_PLAY); //1-audio playback is going on,
0-audio playback has finished
```

#### Code Snippet 6 – Check the status of Audio Playback

```
wr32(REG_PLAYBACK_LENGTH, 0); //configure the playback length to 0
wr8(REG_PLAYBACK_PLAY, 1); //start audio playback
```

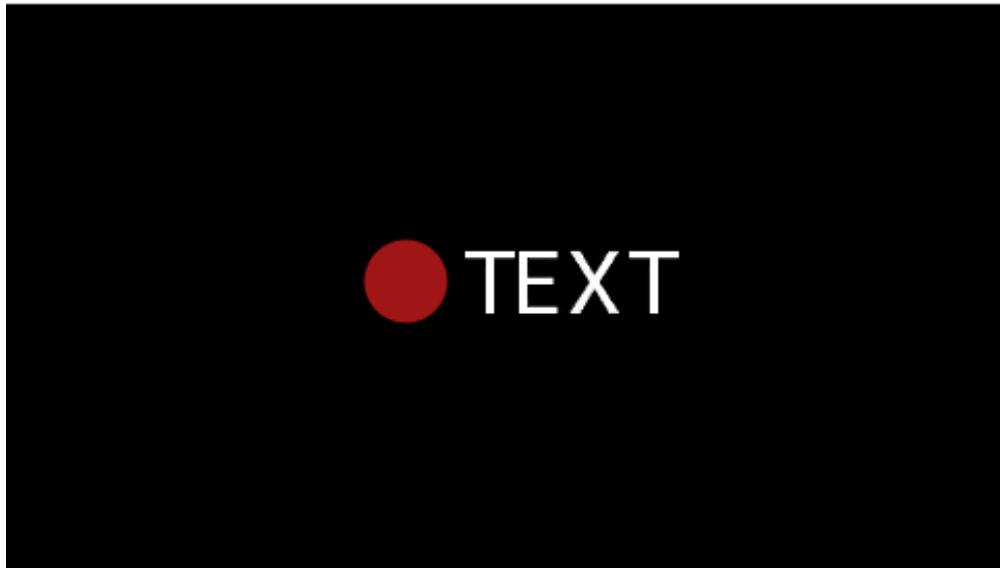
#### Code Snippet 7 – Stop the Audio Playback

## 2.10 Graphics Routines

This section describes graphics features and captures a few examples. Please note that the code in this section is for the purpose of illustrating the operation of Display Lists. Application will normally send the commands via **command FIFO (RAM\_CMD)** instead of writing directly to **RAM\_DL**.

### 2.10.1 Getting Started

The following example creates a screen with the text "TEXT" on it, with a red dot.



**Figure 2 – Getting Started Example**

The code to draw the screen is:

```

wr32(RAM_DL + 0, CLEAR(1, 1, 1));           // clear screen
wr32(RAM_DL + 4, BEGIN(BITMAPS));           // start drawing bitmaps
wr32(RAM_DL + 8, VERTEX2II(220, 110, 31, 'T')); // ASCII T in font 31
wr32(RAM_DL + 12, VERTEX2II(244, 110, 31, 'E')); // ASCII E in font 31
wr32(RAM_DL + 16, VERTEX2II(270, 110, 31, 'X')); // ASCII X in font 31
wr32(RAM_DL + 20, VERTEX2II(299, 110, 31, 'T')); // ASCII T in font 31
wr32(RAM_DL + 24, END());
wr32(RAM_DL + 28, COLOR_RGB(160, 22, 22)); // change colour to red
wr32(RAM_DL + 32, POINT_SIZE(320)); // set point size to 20 pixels in radius
wr32(RAM_DL + 36, BEGIN(POINTS)); // start drawing points
wr32(RAM_DL + 40, VERTEX2II(192, 133, 0, 0)); // red point
wr32(RAM_DL + 44, END());
wr32(RAM_DL + 48, DISPLAY()); // display the image

```

**Code Snippet 8 – Getting Started**

Upon loading the above drawing commands into **RAM\_DL**, register **REG\_DLSWAP** is required to be set to **0x02** in order to make the new display list active on the next frame refresh.

**Note:**

- The display list always starts at address **RAM\_DL**
- The address always increments by 4 bytes as each command is 32 bits wide.
- Command **CLEAR** is recommended to be used before any other drawing operation, in order to put the graphics engine in a known state. The end of the display list is always flagged with the command **DISPLAY**

## 2.10.2 Coordinate Range and Pixel Precision

Apart from the single pixel precision, **EVE** support a series of fractional pixel precision, which result in a different coordinate range. Users may trade the coordinate range against pixel precision. See **VERTEX\_FORMAT** for more details.

Please note that the maximum screen resolution which **EVE** can render is up to 2048 by 2048 in pixels only, regardless of which pixel precision is specified.

**VERTEX2F** and **VERTEX\_FORMAT** are the commands that enable the drawing operation to reach the full coordinate plane. The **VERTEX2II** command only allows positive screen coordinates. The **VERTEX2F** command allows negative coordinates. If the bitmap is partially off-screen, for example during a screen scroll, then it is necessary to specify negative screen coordinates.

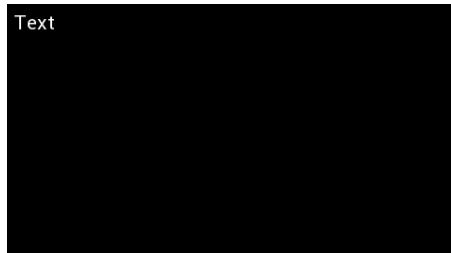
## 2.10.3 Screen Rotation

**REG\_ROTATE** controls the screen orientation. Changing the register value immediately causes the orientation of the screen to change. In addition, the coordinate system is also changed accordingly, so that all the display commands and coprocessor commands work in the rotated coordinate system.

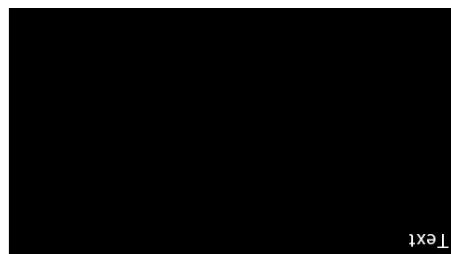
**Note:** The touch transformation matrix is not affected by setting **REG\_ROTATE**.

To adjust the touch screen accordingly, users are recommended to use **CMD\_SETROTATE** as opposed to setting **REG\_ROTATE**.

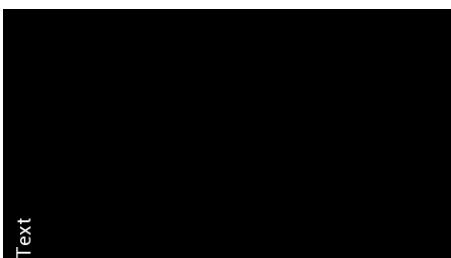
**REG\_ROTATE = 0** is the default landscape orientation:



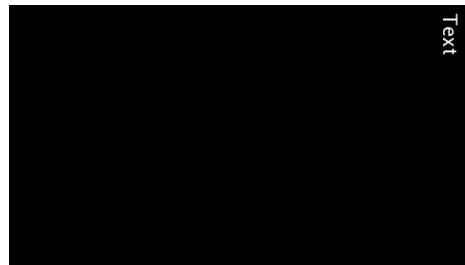
**REG\_ROTATE = 1** is inverted landscape:



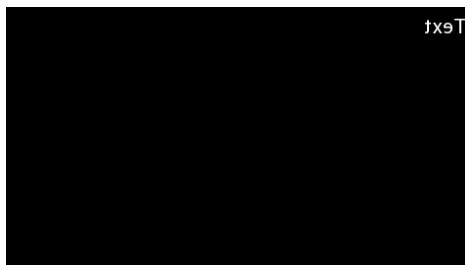
**REG\_ROTATE = 2** is portrait:



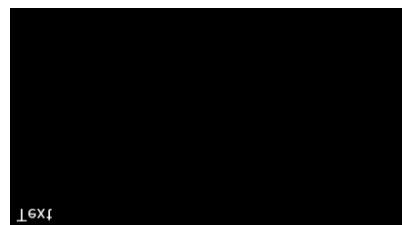
REG\_ROTATE = 3 is inverted portrait:



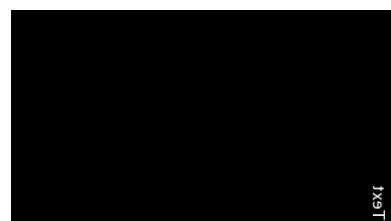
REG\_ROTATE = 4 is mirrored landscape:



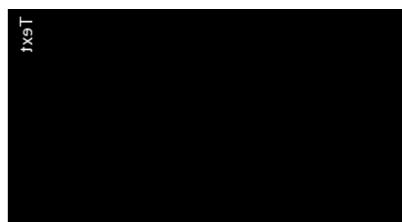
REG\_ROTATE = 5 is mirrored inverted landscape:



REG\_ROTATE = 6 is mirrored portrait:



REG\_ROTATE = 7 is mirrored inverted portrait:



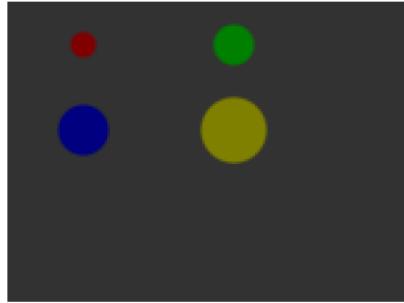
## 2.10.4 Drawing Pattern

The general pattern for drawing is driven by display list commands:

- **BEGIN** with one of the primitive types
- Input one or more vertices using “**VERTEX2I**” or “**VERTEX2F**”, which specify the placement of the primitive on the screen
- **END** to mark the end of the primitive.

### Examples

Draw points with varying radius from 5 pixels to 13 pixels with different colors:



```
//The VERTEX2F command gives the location of
the circle center
dl( COLOR_RGB(128, 0, 0) );
dl( POINT_SIZE(5 * 16) );
dl( BEGIN(POINTS) );
dl( VERTEX2F(30 * 16,17 * 16) );
dl( COLOR_RGB(0, 128, 0) );
dl( POINT_SIZE(8 * 16) );
dl( VERTEX2F(90 * 16, 17 * 16) );
dl( COLOR_RGB(0, 0, 128) );
dl( POINT_SIZE(10 * 16) );
dl( VERTEX2F(30 * 16, 51 * 16) );
dl( COLOR_RGB(128, 128, 0) );
dl( POINT_SIZE(13 * 16) );
dl( VERTEX2F(90 * 16, 51 * 16) );
```

Draw lines with varying sizes from 2 pixels to 6 pixels with different colors (line width size is from the center of the line to the boundary):



```
//The VERTEX2F commands are in pairs to define
the start and finish point of the line.
dl( COLOR_RGB(128, 0, 0) );
dl( LINE_WIDTH(2 * 16) );
dl( BEGIN(LINES) );
dl( VERTEX2F(30 * 16,38 * 16) );
dl( VERTEX2F(30 * 16,63 * 16) );
dl( COLOR_RGB(0, 128, 0) );
dl( LINE_WIDTH(4 * 16) );
dl( VERTEX2F(60 * 16,25 * 16) );
dl( VERTEX2F(60 * 16,63 * 16) );
dl( COLOR_RGB(128, 128, 0) );
dl( LINE_WIDTH(6 * 16) );
dl( VERTEX2F(90 * 16, 13 * 16) );
dl( VERTEX2F(90 * 16, 63 * 16) );
```

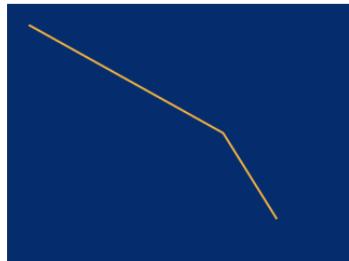
Draw rectangles with sizes of 5x25, 10x38 and 15x50 dimensions:

(Line width size is used for corner curvature, LINE\_WIDTH pixels are added in both directions in addition to the rectangle dimension):



```
//The VERTEX2F commands are in pairs to
define the top left and bottom right corners
of the rectangle.
dl( COLOR_RGB(128, 0, 0) );
dl( LINE_WIDTH(1 * 16) );
dl( BEGIN(RECTS) );
dl( VERTEX2F(28 * 16,38 * 16) );
dl( VERTEX2F(33 * 16,63 * 16) );
dl( COLOR_RGB(0, 128, 0) );
dl( LINE_WIDTH(5 * 16) );
dl( VERTEX2F(50 * 16,25 * 16) );
dl( VERTEX2F(60 * 16,63 * 16) );
dl( COLOR_RGB(128, 128, 0) );
dl( LINE_WIDTH(10 * 16) );
dl( VERTEX2F(83 * 16, 13 * 16) );
dl( VERTEX2F(98 * 16, 63 * 16) );
```

Draw line strips for sets of coordinates:



```
dl( CLEAR_COLOR_RGB(5, 45, 110) );
dl( COLOR_RGB(255, 168, 64) );
dl( CLEAR(1, 1, 1) );
dl( BEGIN(LINE_STRIP) );
dl( VERTEX2F(5 * 16,5 * 16) );
dl( VERTEX2F(50 * 16,30 * 16) );
dl( VERTEX2F(63 * 16,50 * 16) );
```

Draw Edge strips for above:



```
dl( CLEAR_COLOR_RGB(5, 45, 110) );
dl( COLOR_RGB(255, 168, 64) );
dl( CLEAR(1, 1, 1) );
dl( BEGIN(EDGE_STRIP_A) );
dl( VERTEX2F(5 * 16,5 * 16) );
dl( VERTEX2F(50 * 16,30 * 16) );
dl( VERTEX2F(63 * 16,50 * 16) );
```

Draw Edge strips for below:



```
dl( CLEAR_COLOR_RGB(5, 45, 110) );
dl( COLOR_RGB(255, 168, 64) );
dl( CLEAR(1, 1, 1) );
dl( BEGIN(EDGE_STRIP_B) );
dl( VERTEX2F(5 * 16,5 * 16) );
dl( VERTEX2F(50 * 16,30 * 16) );
dl( VERTEX2F(63 * 16,50 * 16) );
```

Draw Edge strips for right:



```
dl( CLEAR_COLOR_RGB(5, 45, 110) );
dl( COLOR_RGB(255, 168, 64) );
dl( CLEAR(1, 1, 1) );
dl( BEGIN(EDGE_STRIP_R) );
dl( VERTEX2F(5 * 16, 5 * 16) );
dl( VERTEX2F(50 * 16, 30 * 16) );
dl( VERTEX2F(63 * 16, 50 * 16) );
```

Draw Edge strips for left:



```
dl( CLEAR_COLOR_RGB(5, 45, 110) );
dl( COLOR_RGB(255, 168, 64) );
dl( CLEAR(1, 1, 1) );
dl( BEGIN(EDGE_STRIP_L) );
dl( VERTEX2F(5 * 16, 5 * 16) );
dl( VERTEX2F(50 * 16, 30 * 16) );
dl( VERTEX2F(63 * 16, 50 * 16) );
```

## 2.10.5 Bitmap Transformation Matrix

To achieve the bitmap transformation, the bitmap transform matrix below is specified and denoted as  $m$ :

$$m = \begin{bmatrix} BITMAP\_TRANSFORM\_A & BITMAP\_TRANSFORM\_B & BITMAP\_TRANSFORM\_C \\ BITMAP\_TRANSFORM\_D & BITMAP\_TRANSFORM\_E & BITMAP\_TRANSFORM\_F \end{bmatrix}$$

by default  $m = \begin{bmatrix} 1.0 & 0.0 & 0.0 \\ 0.0 & 1.0 & 0.0 \end{bmatrix}$ , which is named as the **identity matrix**.

The coordinates  $x'$   $y'$  after transforming are calculated in the following equation:

$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = m \times \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

i.e.:

$$\begin{aligned} x' &= x * A + y * B + C \\ y' &= x * D + y * E + F \end{aligned}$$

Where  $A, B, C, D, E, F$  stands for the values assigned by commands `BITMAP_TRANSFORM_A-F`.

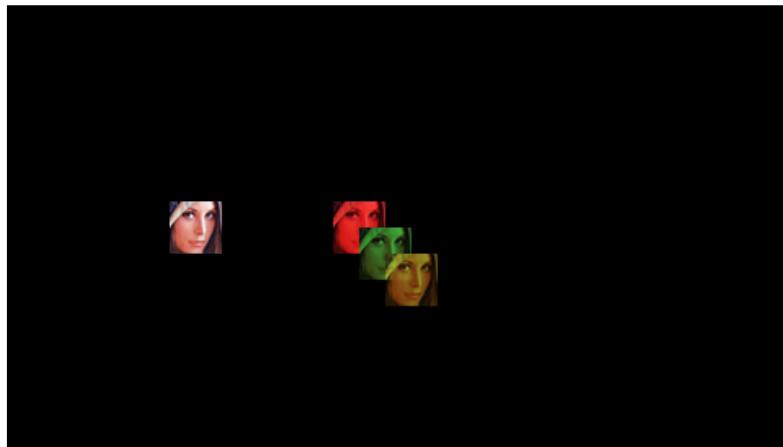
## 2.10.6 Color and Transparency

The same bitmap can be drawn in more places on the screen, in different colors and transparency:

```
dl(COLOR_RGB(255, 64, 64)); // red at (200, 120)
dl(VERTEX2II(200, 120, 0, 0));
dl(COLOR_RGB(64, 180, 64)); // green at (216, 136)
dl(VERTEX2II(216, 136, 0, 0));
dl(COLOR_RGB(255, 255, 64)); // transparent yellow at (232, 152)
dl(COLOR_A(150));
dl(VERTEX2II(232, 152, 0, 0));
```

### Code Snippet 9 – Color and Transparency

The **COLOR\_RGB** command changes the current drawing color, which colors the bitmap. If it is omitted, the default color RGB (255,255,255) will be used to render the bitmap in its original colors. The **COLOR\_A** command changes the current drawing alpha, changing the transparency of the drawing: an alpha of 0 means fully transparent and an alpha of 255 is fully opaque. Here a value of 150 gives a partially transparent effect.



## 2.10.7 Performance

The graphics engine has no frame buffer: it uses a dynamic compositing method to build up each display line during scan out. Because of this, there is a finite amount of time available to draw each line. This time depends on the scan out parameters (decided by **REG\_PCLK** and **REG\_HCYCLE**) but is never less than 2048 internal clock cycles.

Some performance limits:

- The display list length must be less than 2048 instructions, because the graphics engine fetches display list commands at a rate of one per clock.
- The usual performance of rendering pixels is 16 pixels per clock when the filter mode is in **NEAREST** mode, except for the following formats :
  - **TEXT8X8**,
  - **TEXTVGA**
  - **PALETTED4444/565**
 which renders 8 pixels per clock.
- For **BILINEAR** filtered pixels, the drawing rate will be reduced to ¼.

To summarize:

Filter Modes	Bitmap Formats	Drawing Rate
NEAREST	<b>TEXT8X8,</b> <b>TEXTVGA,</b> <b>PALETTED4444/565</b>	8 pixel per clock
NEAREST	The remaining formats not listed in the row above	16 pixel per clock
BILINEAR	<b>TEXT8X8,</b> <b>TEXTVGA,</b> <b>PALETTED4444/565</b>	2 pixel per clock
BILINEAR	The remaining formats not listed in the row above	4 pixel per clock

**Table 6 – Bitmap Rendering Performance**

### 3 Register Description

The registers are classified into the following groups according to their functionality:

- Graphics Engine Registers,
- Audio Engine Registers,
- Touch Engine Registers,
- Coprocessor Engine Registers,
- Special Registers,
- Miscellaneous Registers.

The detailed definition for each register is listed here. Most of registers are **32** bit wide and the special cases are marked separately. Reading from or writing to the reserved bits shall be always **zero**.

The bit fields marked **r/o** are read-only.

The bit fields marked **w/o** are write only.

The bit fields marked **r/w** are read-write.

The offset of registers are based on the address **RAM\_REG**.

#### 3.1 Graphics Engine Registers

REG_TAG Definition			
31		8   7	0
Reserved			r/o
Offset: 0x7C			Reset Value: 0x0
Bit 31 – 8: Reserved bits			
Bit 7 – 0: These bits are updated with the tag value. The tag value here is corresponding to the touching point coordinator given in REG_TAG_X and REG_TAG_Y.			
<b>Note:</b> Please note the difference between REG_TAG and REG_TOUCH_TAG. REG_TAG is updated based on the X, Y given by REG_TAG_X and REG_TAG_Y. REG_TOUCH_TAG is updated based on the current touching point captured from touch screen.			

**Register Definition 1 – REG\_TAG Definition**

REG_TAG_Y Definition			
31		11   10	0
Reserved			r/w
Offset: 0x78			Reset Value: 0x0
Bit 31 – 11: Reserved Bits			
Bit 10 – 0: These bits are set by the host as the Y coordinate of the touching point, which will enable the host to query the tag value. This register shall be used together with REG_TAG_X and REG_TAG. Normally, in the case where the host has already captured the touching point's coordinate; this register can be updated to query the tag value of respective touching point.			

**Register Definition 2 – REG\_TAG\_Y Definition**

REG_TAG_X Definition			
31		11   10	0
Reserved			r/w
Offset: 0x74			Reset Value: 0x0
Bit 31 – 11: Reserved Bits			
Bit 10 – 0: These bits are set by the host as the X coordinate of the touching point, which will enable the host to query the tag value. This register shall be used together with REG_TAG_Y and REG_TAG. Normally, in the case where the host has already captured the touching point's coordinate; this register can be updated to query the tag value of the respective touching point.			

**Register Definition 3 – REG\_TAG\_X Definition**

**REG\_PCLK Definition**

31	8   7	0
	Reserved	r/w

Offset: 0x70

Reset Value: 0x0

Bit 31 – 8: Reserved bits

Bit 7 – 0: These bits are set to divide the main clock for **PCLK**. If the main clock is 60Mhz and the value of these bits are set to 5, the **PCLK** will be set to 12 MHz If these bits are set to zero, it means there is no **PCLK** output.

**Register Definition 4 – REG\_PCLK Definition**
**REG\_PCLK\_POL Definition**

31	1	0
	reserved	r/w

Offset: 0x6C

Reset Value: 0x0

Bit 31 – 1: Reserved bits

Bit 0: This bit controls the polarity of **PCLK**. If it is set to zero, PCLK polarity is on the rising edge. If it is set to one, PCLK polarity is on the falling edge

**Register Definition 5 – REG\_PCLK\_POL Definition**
**REG\_CSPREAD Definition**

31	1	0
	reserved	r/w

Offset: 0x68

Reset Value: 0x1

Bit 31 – 1: Reserved bits

Bit 0: This bit controls the transition of RGB signals with PCLK active clock edge, which helps reduce the system noise. When it is zero, all the color signals are updated at the same time. When it is one, all the color signal timings are adjusted slightly so that fewer signals change simultaneously.

**Register Definition 6 – REG\_CSPREAD Definition**
**REG\_SWIZZLE Definition**

31	4   3	0
	Reserved	r/w

Offset: 0x64

Reset Value: 0x0

Bit 31 – 4: Reserved bits

Bit 3 – 0: These bits are set to control the arrangement of output RGB pins, which help support different LCD panels. Please see the datasheet for the exact definitions.

**Register Definition 7 – REG\_SWIZZLE Definition**
**REG\_DITHER Definition**

31	1	0
	reserved	r/w

Offset: 0x60

Reset Value: 0x1

Bit 31 – 1: Reserved bits

Bit 0: Set to 1 to enable dithering feature on RGB signals output. Set to 0 to disable dithering feature. Reading 1 from this bit means dithering feature is enabled. Reading 0 from this bit means dithering feature is disabled.

**Register Definition 8 – REG\_DITHER Definition**
**REG\_OUTBITS Definition**

31	9   8	0
	Reserved	r/w

Offset: 0x5C

Reset Value: 0x0

Bit 31 – 9: Reserved Bits

Bit 8 – 0: These 9 bits are split into 3 groups for Red, Green and Blue color output signals:

Bit 8 – 6: Red Color signal lines number. Value zero means 8 output signals.

Bit 5 – 3: Green Color signal lines number. Value zero means 8 output signals.

Bit 2 – 0: Blue color signal lines number. Value zero means 8 output signals.

Host can write these bits to control the number of output signals for each color.

**Register Definition 9 – REG\_OUTBITS Definition**

REG_ROTATE Definition		
31	3	2 0
Reserved		r/w
Offset: 0x58		Reset Value: 0x0
Bit 31 – 3: Reserved bits		
Bit 2 – 0: screen rotation control bits.		
0b'000: Default landscape orientation		
0b'001: Inverted landscape orientation		
0b'010: Portrait orientation		
0b'011: Inverted portrait orientation		
0b'100: Mirrored landscape orientation		
0b'101: Mirrored invert landscape orientation		
0b'110: Mirrored portrait orientation		
0b'111: Mirrored inverted portrait orientation		
<b>Note:</b> Setting this register will <b>NOT</b> affect touch transform matrix.		

#### **Register Definition 10 – REG\_ROTATE Definition**

REG_DLSWAP Definition		
31	2	1 0
Reserved		r/w
Offset: 0x54		Reset Value: 0x0
Bit 31 – 2: Reserved bits		
Bit 1 – 0: These bits can be set by the host to validate the display list buffer. The graphics engine will determine when to render the screen, depending on how these bits are set:		
0b'01: Graphics engine will render the screen immediately after current line is scanned out. It may cause tearing effect.		
0b'10: Graphics engine will render the screen immediately after current frame is scanned out.		
0b'00: Do not write this value into this register.		
0b'11: Do not write this value into this register.		
These bits can be also be read by the host to check the availability of the display list buffer. If the value is read as zero, the display list buffer is safe and ready to write. Otherwise, the host needs to wait till it becomes zero.		

#### **Register Definition 11 – REG\_DLSWAP Definition**

REG_VSYNC1 Definition		
31	12	11 0
Reserved		r/w
Offset: 0x50		Reset Value: 0xA
Bit 31 – 12: Reserved Bits		
Bit 11 – 0: These bits specify how many lines of signal VSYNC1 takes at the start of a new frame		

#### **Register Definition 12 – REG\_VSYNC1 Definition**

REG_VSYNC0 Definition		
31	12	11 0
Reserved		r/w
Offset: 0x4C		Reset Value: 0x0
Bit 31 – 12: Reserved Bits		
Bit 11 – 0: The value of these bits specify how many lines of signal VSYNC0 takes at the start of a new frame		

#### **Register Definition 13 – REG\_VSYNC0 Definition**

**REG\_VSIZE Definition**

31	12   11	0
Reserved		r/w

Offset: 0x48

Reset Value: 0x110

Bit 31 – 12: Reserved Bits

Bit 11 – 0: The value of these bits specify how many lines of pixels in one frame. The valid range is from 0 to 2047.

**Register Definition 14 – REG\_VSIZE Definition**
**REG\_VOFFSET Definition**

31	12   11	0
Reserved		r/w

Offset: 0x44

Reset Value: 0xC

Bit 31 – 12: Reserved Bits

Bit 11 – 0: The value of these bits specify how many lines taken after the start of a new frame.

**Register Definition 15 – REG\_VOFFSET Definition**
**REG\_VCYCLE Definition**

31	12   11	0
Reserved		r/w

Offset: 0x40

Reset Value: 0x124

Bit 31 – 12: Reserved Bits

Bit 11 – 0: The value of these bits specify how many lines in one frame.

**Register Definition 16 – REG\_VCYCLE Definition**
**REG\_HSYNC1 Definition**

31	12   11	0
Reserved		r/w

Offset: 0x3C

Reset Value: 0x29

Bit 31 – 12: Reserved Bits

Bit 11 – 0: The value of these bits specify how many PCLK cycles for HSYNC1 during start of line.

**Register Definition 17 – REG\_HSYNC1 Definition**
**REG\_HSYNC0 Definition**

31	12   11	0
Reserved		r/w

Offset: 0x38

Reset Value: 0x0

Bit 31 – 12: Reserved Bits

Bit 11 – 0: The value of these bits specify how many PCLK cycles for HSYNC0 during start of line.

**Register Definition 18 – REG\_HSYNC0 Definition**
**REG\_HSIZE Definition**

31	12   11	0
Reserved		r/w

Offset: 0x34

Reset Value: 0x1E0

Bit 31 – 12: Reserved Bits

Bit 11 – 0: These bits are used to specify the number of PCLK cycles per horizontal line.

**Register Definition 19 – REG\_HSIZE Definition**
**REG\_HOFFSET Definition**

31	12   11	0
Reserved		r/w

Offset: 0x30

Reset Value: 0x2B

Bit 31 – 12: Reserved Bits

Bit 11 – 0: These bits are used to specify the number of PCLK cycles before pixels are scanned out.

**Register Definition 20 – REG\_HOFFSET Definition**

REG_HCYCLE Definition		
31	12   11	0
Reserved		r/w
Offset: 0x2C		Reset Value: 0x224
Bit 31 – 12: Reserved Bits		
Bit 11 – 0: These bits are the number of total PCLK cycles per horizontal line scan.		

**Register Definition 21 – REG\_HCYCLE Definition**

### 3.2 Audio Engine Registers

REG_PLAY Definition		
31	1   0	0
reserved		r/w
Offset: 0x8C		Reset Value: 0x0
Bit 31 – 1: Reserved bits		
Bit 0: A write to this bit triggers the play of the synthesized sound effect specified in <b>REG_SOUND</b> .		
Reading value 1 in this bit means the sound effect is playing. To stop the sound effect, the host needs to select the silence sound effect by setting up <b>REG_SOUND</b> and set this register to play.		

**Register Definition 22 – REG\_PLAY Definition**

REG_SOUND Definition		
31	16   15	0
Reserved		r/w
Offset: 0x88		Reset Value: 0x0
Bit 31 – 16: Reserved bits		
Bit 15 – 0: These bits are used to select the synthesized sound effect. They are split into two groups: Bit 15 – 8 and Bit 7 – 0.		
Bit 15 – 8: The MIDI note for the sound effect defined in Bits 0 – 7.		
Bit 7 – 0: These bits define the sound effect. Some of them are pitch adjustable and the pitch is defined in Bits 8 – 15. Some of them are not pitch adjustable and the Bits 8 – 15 will be ignored.		

**Note:** Please refer to the section “Sound Synthesizer” in BT81X datasheet for details of this register.

**Register Definition 23 – REG\_SOUND Definition**

REG_VOL_SOUND Definition		
31	8   7	0
Reserved		r/w
Offset: 0x84		Reset Value: 0xFF
Bit 31 – 8: Reserved bits		
Bit 7 – 0: These bits control the volume of the synthesizer sound. The default value 0xFF is highest volume. The value zero means mute.		

**Register Definition 24 – REG\_VOL\_SOUND Definition**

REG_VOL_PB Definition		
31	8   7	0
Reserved		r/w
Offset: 0x84		Reset Value: 0xFF
Bit 31 – 8: Reserved bits		
Bit 7 – 0: These bits control the volume of the audio file playback. The default value 0xFF is highest volume. The value zero means mute.		

**Register Definition 25 – REG\_VOL\_PB Definition**

## REG\_PLAYBACK\_PLAY Definition

31	1	0
Reserved		r/w
Offset: 0xCC	Reset Value: 0x0	
Bit 31 – 1: Reserved bits		
Bit 0: A write to this bit triggers the start of audio playback, regardless of writing 0 or 1. It will read back 1 when playback is on-going, and 0 when playback completes.		

**Note:** Please refer to the section “Audio Playback” in BT81X datasheet for details of this register.

## Register Definition 26 – REG\_PLAYBACK\_PLAY Definition

## REG\_PLAYBACK\_LOOP Definition

31	1	0
Reserved		r/w
Offset: 0xC8	Reset Value: 0x0	
Bit 31 – 1: Reserved bits		
Bit 0: this bit controls the audio engine to play back the audio data in <b>RAM_G</b> from the start address once it consumes all the data. A value of 1 means LOOP is enabled, a value of 0 means LOOP is disabled.		

**Note:** Please refer to the section “Audio Playback” in BT81X datasheet for details of this register.

## Register Definition 27 – REG\_PLAYBACK\_LOOP Definition

## REG\_PLAYBACK\_FORMAT Definition

31	2	1	0
Reserved			r/w
Offset: 0xC4	Reset Value: 0x0		
Bit 31 – 2: Reserved bits			
Bit 1 – 0: These bits define the format of the audio data in <b>RAM_G</b> .			
0b'00: Linear Sample format			
0b'01: uLaw Sample format			
0b'10: 4 bit IMA ADPCM Sample format			
0b'11: Undefined.			

**Note:** Please refer to the section “Audio Playback” in BT81X datasheet for details of this register.

## Register Definition 28 – REG\_PLAYBACK\_FORMAT Definition

## REG\_PLAYBACK\_FREQ Definition

31	16	15	0
Reserved			r/w
Offset: 0xC0	Reset Value: 0x1F40		
Bit 31 – 16: Reserved bits			
Bit 15 – 0: These bits specify the sampling frequency of audio playback data. Unit is in Hz.			

**Note:** Please refer to the section “Audio Playback” in BT81X datasheet for details of this register.

## Register Definition 29 – REG\_PLAYBACK\_FREQ Definition

## REG\_PLAYBACK\_READPTR Definition

31	20	19	0
reserved			r/w
Offset: 0xBC	Reset Value: 0x0		
Bit 31 – 20: Reserved bits			
Bit 19 – 0: These bits are updated by the audio engine while playing audio data from RAM_G. It is the current audio data address which is playing back. The host can read this register to check if the audio engine has consumed all the audio data.			

**Note:** Please refer to the section “Audio Playback” in BT81X datasheet for details of this register.

## Register Definition 30 – REG\_PLAYBACK\_READPTR Definition

REG_PLAYBACK_LENGTH Definition			
31	20	19	0
reserved		r/w	
Offset: 0xB8			Reset Value: 0x0
Bit 31 – 20: Reserved bits			
Bit 19 – 0: These bits specify the length of audio data in <b>RAM_G</b> to playback, starting from the address specified in <b>REG_PLAYBACK_START</b> register.			
<b>Note:</b> Please refer to the section "Audio Playback" in BT81X datasheet for details of this register.			

#### **Register Definition 31 – REG\_PLAYBACK\_LENGTH Definition**

REG_PLAYBACK_START Definition			
31	20	19	0
reserved		r/w	
Offset: 0xB4			Reset Value: 0x0
Bit 31 – 20: Reserved bits			
Bit 19 – 0: These bits specify the start address of audio data in <b>RAM_G</b> to playback.			
<b>Note:</b> Please refer to the section "Audio Playback" in BT81X datasheet for details of this register.			

#### **Register Definition 32 – REG\_PLAYBACK\_START Definition**

REG_PLAYBACK_PAUSE Definition			
7		1	0
reserved		r/w	
Offset: 0x5EC			Reset Value: 0x0
Bit 7 – 1: Reserved bits			
Bit 0: Audio playback control bit. Writing 1 to pause the playback, writing 0 to start the playback.			
<b>Note:</b> Please refer to the section "Audio Playback" in BT81X datasheet for details of this register.			

#### **Register Definition 33 – REG\_PLAYBACK\_PAUSE Definition**

### 3.3 Flash Registers

REG_FLASH_STATUS Definition			
7		2	1
reserved		r/o	
Offset: 0x5F0			Reset Value: 0x0
Bit 7 – 2: Reserved bits			
Bit 1 – 0: These bits reflect the current status of attached flash.			
<b>0b'00:</b> FLASH_STATUS_INIT			
<b>0b'01:</b> FLASH_STATUS_DETACHED			
<b>0b'10:</b> FLASH_STATUS_BASIC			
<b>0b'11:</b> FLASH_STATUS_FULL			
<b>Note:</b> Please refer to the section "SPI NOR Flash Interface" in BT817/8 datasheet for details.			

#### **Register Definition 34 – REG\_FLASH\_STATUS Definition**

REG_FLASH_SIZE Definition			
31		0	
	r/o		
Offset: 0x7024			Reset Value: 0x0
Bit 31 – 0: The value indicates the capacity of attached flash, in Mbytes.			
<b>Note:</b> Please refer to the section "SPI NOR Flash Interface" in BT817/8 datasheet for details			

#### **Register Definition 35 – REG\_FLASH\_SIZE Definition**

## 3.4 Touch Screen Engine Registers

### 3.4.1 Overview

EVE supports screen touch functionality by either **Resistive Touch Engine (RTE)** or **Capacitive Touch Screen Engine (CTSE)**. BT815/BT817 has **CTSE** built-in while BT816/BT818 has **RTE** built-in.

### 3.4.2 Common Registers

This chapter describes the common registers which are effective to both RTE and CTSE.

Offset	Register Name	Description
0x150 – 0x164	REG_TOUCH_TRANSFORM_A~F	Transform coefficient matrix coefficient
0x168	REG_TOUCH_CONFIG	Configuration register

**Table 7 – Common Registers Summary**

REG_TOUCH_CONFIG Definition													
31		16	15	14	13	12	11	10		4	3	2	1 0
	reserved	r/o	r/w	rsvd	r/w	r/w	r/w	r/w		r/w	r/w	r/w	r/w
Offset: 0x168		Reset Value: 0x8381 (BT816/818) or 0x381(BT815/817)											
Bit 31 – 16: Reserved bits													
Bit 15: Working mode of touch engine. 0: capacitive 1: resistive													
Bit 14: 1: Enable the host mode. 0: Normal mode													
Bit 13: Reserved bit													
Bit 12: Ignore short-circuit protection. For resistive touch screen only.													
Bit 11: Enable low-power mode(for FocalTech only)													
Bit 10 – 4: I2C address of capacitive touch screen module: 0b'0111000 for FocalTech/Hycontek 0b'1011101 for Goodix													
Bit 3: Reserved.													
Bit 2: Suppress 300ms startup (for FocalTech only)													
Bit 1 – 0: Sampling clocks(for resistive touch screen only)													

**Register Definition 36 – REG\_TOUCH\_CONFIG Definition**

REG_TOUCH_TRANSFORM_F Definition													0
31	30		16	15									
r/w		r/w								r/w			
Offset: 0x164		Reset Value: 0x0											
Bit 31 : The sign bit for fixed point number													
Bit 30 – 16: The value of these bits represents the integer part of the fixed point number.													
Bit 15 – 0: The value of these bits represents the fractional part of the fixed point number.													
<b>Note:</b> This register represents a fixed point number and the default value is +0.0 after reset.													

**Register Definition 37 – REG\_TOUCH\_TRANSFORM\_F Definition**

**REG\_TOUCH\_TRANSFORM\_E Definition**

31	30	16	15	0
r/w		r/w		r/w

Offset: 0x160

Reset Value: 0x10000

Bit 31 : The sign bit for fixed point number

Bit 30 – 16: The value of these bits represents the integer part of the fixed point number.

Bit 15 – 0: The value of these bits represents the fractional part of the fixed point number.

**Note:** This register represents a fixed point number and the default value is +1.0 after reset.
**Register Definition 38 – REG\_TOUCH\_TRANSFORM\_E Definition**
**REG\_TOUCH\_TRANSFORM\_D Definition**

31	30	16	15	0
r/w		r/w		r/w

Offset: 0x15C

Reset Value: 0x0

Bit 31 : The sign bit for fixed point number

Bit 30 – 16: The value of these bits represents the integer part of the fixed point number.

Bit 15 – 0 : The value of these bits represents the fractional part of the fixed point number.

**Note:** This register represents a fixed point number and the default value is +0.0 after reset.
**Register Definition 39 – REG\_TOUCH\_TRANSFORM\_D Definition**
**REG\_TOUCH\_TRANSFORM\_C Definition**

31	30	16	15	0
r/w		r/w		r/w

Offset: 0x158

Reset Value: 0x0

Bit 31 : The sign bit for fixed point number

Bit 30 – 16: The value of these bits represents the integer part of the fixed point number.

Bit 15 – 0: The value of these bits represents the fractional part of the fixed point number.

**Note:** This register represents fixed point number and the default value is +0.0 after reset.
**Register Definition 40 – REG\_TOUCH\_TRANSFORM\_C Definition**
**REG\_TOUCH\_TRANSFORM\_B Definition**

31	30	16	15	0
r/w		r/w		r/w

Offset: 0x154

Reset Value: 0x0

Bit 31: The sign bit for fixed point number

Bit 30 – 16: The value of these bits represents the integer part of the fixed point number.

Bit 15 – 0: The value of these bits represents the fractional part of the fixed point number.

**Note:** This register represents a fixed point number and the default value is +0.0 after reset.
**Register Definition 41 – REG\_TOUCH\_TRANSFORM\_B Definition**
**REG\_TOUCH\_TRANSFORM\_A Definition**

31	30	16	15	0
r/w		r/w		r/w

Offset: 0x150

Reset Value: 0x10000

Bit 31 : The sign bit for fixed point number

Bit 30 – 16: The value of these bits represents the integer part of the fixed point number.

Bit 15 – 0: The value of these bits represents the fractional part of the fixed point number.

**Note:** This register represents a fixed point number and the default value is +1.0 after reset.
**Register Definition 42 – REG\_TOUCH\_TRANSFORM\_A Definition**

### 3.4.3 Resistive Touch Engine

All the registers available in **RTE** are identical to FT810.

Offset	Register Name	Description
0x104	REG_TOUCH_MODE	Touch screen sampling Mode
0x108	REG_TOUCH_ADC_MODE	Select ADC working mode
0x10C	REG_TOUCH_CHARGE	Touch screen charge time, unit of 6 clocks
0x110	REG_TOUCH_SETTLE	Touch screen settle time, unit of 6 clocks
0x114	REG_TOUCH_OVERSAMPLE	Touch screen oversample factor
0x118	REG_TOUCH_RZTHRESH	Touch screen resistance threshold
0x11C	REG_TOUCH_RAW_XY	Touch screen raw x,y(16,16)
0x120	REG_TOUCH_RZ	Touch screen resistance
0x124	REG_TOUCH_SCREEN_XY	Touch screen x,y(16,16)
0x128	REG_TOUCH_TAG_XY	coordinate used to calculate the tag of touch point
0x12C	REG_TOUCH_TAG	Touch screen Tag result

**Table 8 – RTE Registers Summary**

REG_TOUCH_TAG Definition		
31	8   7	0
	Reserved	r/o
Offset: 0x12C		Reset Value: 0x0
Bit 31 – 8: Reserved Bits		
Bit v7 – 0: These bits are set as the tag value of the specific graphics object on the screen which is being touched. These bits are updated once when all the lines of the current frame are scanned out to the screen.		
<b>Note:</b> The valid tag value is from 1 to 255 and the default value of this register is zero, meaning there is no touch by default.		

**Register Definition 43 – REG\_TOUCH\_TAG Definition**

REG_TOUCH_TAG_XY Definition		
31	16   15	0
	r/o	r/o
Offset: 0x128		Reset Value: 0x0
Bit 31 – 16: The value of these bits are X coordinates of the touch screen to look up the tag result.		
Bit 15 – 0: The value of these bits are the Y coordinates of the touch screen to look up the tag result.		
<b>Note:</b> Host can read this register to check the coordinates used by the touch engine to update the tag register <b>REG_TOUCH_TAG</b> .		

**Register Definition 44 – REG\_TOUCH\_TAG\_XY Definition**

REG_TOUCH_SCREEN_XY Definition		
31	16   15	0
	r/o	r/o
Offset: 0x124		Reset Value: 0x80008000
Bit 31 – 16: The value of these bits is the X coordinates of the touch screen. After doing calibration, it shall be within the width of the screen size. If the touch screen is not being touched, it shall be 0x8000.		
Bit 15 – 0: The value of these bits is the Y coordinates of the touch screen. After doing calibration, it shall be within the width of the screen size. If the touch screen is not being touched, it shall be 0x8000.		

**Register Definition 45 – REG\_TOUCH\_SCREEN\_XY Definition**

**REG\_TOUCH\_DIRECT\_Z1Z2 Definition**

31	26	25	16	15	10	9	0
reserved		r/o		reserved		r/o	

Offset: 0x190 Reset Value: NA

Bit 31 – 26 : Reserved Bits

 Bit 25 – 16 : 10 bit **ADC** value for touch screen resistance Z1

Bit 15 – 10 : Reserved Bits

 Bit 9 – 0 : 10 bit **ADC** value for touch screen resistance Z2

**Note:** To know it is touched or not, please check the 31<sup>st</sup> bit of **REG\_TOUCH\_DIRECT\_XY**. Touch engine will do the post-processing for these **Z1** and **Z2** values and update the result in **REG\_TOUCH\_RZ**.

**Register Definition 46 – REG\_TOUCH\_DIRECT\_Z1Z2 Definition**
**REG\_TOUCH\_DIRECT\_XY Definition**

31	30	26	25	16	15	10	9	0
r/o	reserved		r/o		reserved		r/o	

Offset: 0x18C Reset Value: 0x0

Bit 31: If this bit is zero, it means a touch is being sensed and the two fields above contain the sensed data. If this bit is one, it means no touch is being sensed and the data in the two fields above shall be ignored.

Bit 30 – 26 : Reserved Bits

 Bit 25 – 16 : 10 bit **ADC** value for touch screen resistance **Z1**

Bit 15 – 10 : Reserved Bits

 Bit 9 – 0 : 10 bit **ADC** value for touch screen resistance **Z2**
**Register Definition 47 – REG\_TOUCH\_DIRECT\_XY**
**REG\_TOUCH\_RZ Definition**

31		16	15	0
	Reserved		r/o	

Offset: 0x120 Reset Value: 0x7FFF

Bit 31 – 16: Reserved Bits

Bit 15 – 0: These bits measures the touching pressure on the touch screen. The valid value is from 0 to 0x7FFF. The highest value(0x7FFF) means no touch and the lowest value (0) means the maximum touching pressure.

**Register Definition 48 – REG\_TOUCH\_RZ Definition**
**REG\_TOUCH\_RAW\_XY Definition**

31		16	15	0
	r/o		r/o	

Offset: 0x11C Reset Value: 0xFFFFFFFF

Bit 31 – 16: These bits are the raw X coordinates before going through calibration process. The valid range is from 0 to 1023. If there is no touch on screen, the value shall be 0xFFFF.

Bit 15 – 0: These bits are the raw Y coordinates of the touch screen before going through calibration process. The valid range is from 0 to 1023. If there is no touch on screen, the value shall be 0xFFFF.

**Note:** The coordinates in this register have not mapped into the screen coordinates. To get the screen coordinates, please refer to **REG\_TOUCH\_SCREEN\_XY**.

**Register Definition 49 – REG\_TOUCH\_RAW\_XY Definition**

**REG\_TOUCH\_RZTHRESH Definition**

31	16	15	0
Reserved		r/w	

Offset: 0x118

Reset Value: 0xFFFF

Bit 31 – 16: Reserved Bits.

Bit 15 – 0: These bits control the touch screen resistance threshold. The host can adjust the touch screen touching sensitivity by setting this register. The default value after reset is 0xFFFF and it means the lightest touch will be accepted by the RTE. The host can set this register by doing experiments. The typical value is 1200.

**Register Definition 50 – REG\_TOUCH\_RZTHRESH Definition**
**REG\_TOUCH\_OVERSAMPLE Definition**

31	4	3	0
reserved		r/w	

Offset: 0x114

Reset Value: 0x7

Bit 31 – 4: Reserved Bits.

Bit 3 – 0: These bits control the touch screen oversample factor. The higher value of this register causes more accuracy with more power consumption, but may not be necessary. The valid range is from 1 to 15.

**Register Definition 51 – REG\_TOUCH\_OVERSAMPLE Definition**
**REG\_TOUCH\_SETTLE Definition**

31	4	3	0
reserved		r/w	

Offset: 0x110

Reset Value: 0x3

Bit 31 – 4: Reserved Bits.

Bit 3 – 0: These bits control the touch screen settle time, in the unit of 6 clocks. The default value is 3, meaning the settle time is 18 (3\*6) system clock cycles.

**Register Definition 52 – REG\_TOUCH\_SETTLE Definition**
**REG\_TOUCH\_CHARGE Definition**

31	16	15	0
Reserved		r/w	

Offset: 0x10C

Reset Value: 0x1770

Bit 31 – 16: Reserved Bits.

Bit 15 – 0: These bits control the touch screen charge time, in the unit of 6 clocks. The default value is 6000, meaning the charge time is (6000\*6) system clock cycles.

**Register Definition 53 – REG\_TOUCH\_CHARGE Definition**
**REG\_TOUCH\_ADC\_MODE Definition**

31	2	1	0
reserved		r/w	

Offset: 0x108

Reset Value: 0x1

Bit 31 – 1 : Reserved bits

Bit 0: The host can set this bit to control the ADC sampling mode, as per:

- 0: Single Ended mode. It causes lower power consumption but with less accuracy.
- 1: Differential Mode. It causes higher power consumption but with more accuracy.

**Register Definition 54 – REG\_TOUCH\_ADC\_MODE Definition**

REG_TOUCH_MODE Definition		
31	2   1	0
	reserved	r/w
Offset: 0x104		Reset Value: 0x3
Bit 31 – 2: Reserved bits		
Bit 1 – 0: The host can set these two bits to control the touch screen sampling mode of touch engine, as per:		
0b'00: Off mode. No sampling happens. RTE stops working.		
0b'01: Single mode. Cause one single sample to occur.		
0b'10: Frame mode. Cause a sample at the start of each frame.		
0b'11: Continuous mode. Up to 1000 times per seconds. Default mode after reset.		

#### Register Definition 55 – REG\_TOUCH\_MODE Definition

### 3.4.4 Capacitive Touch Engine

Capacitive Touch Screen Engine (**CTSE**) has the following features:

- I<sup>2</sup>C interface to Capacitive Touch Panel Module (**CTPM**)
- Detects up to 5 touch points at the same time
- Supports CTPM with Focaltech and Goodix touch controller.
- Supports touch host mode. Please refer to the datasheet for details.
- Compatibility mode for single touching point and extended mode for multi-touching points.

After reset or boot up, **CTSE** works in compatibility mode and only one touch point is detected. In extended mode, it can detect up to **five** touch points simultaneously.

CTSE makes use of the same registers set **REG\_TOUCH\_TRANSFORM\_A~F** to transform the raw coordinates to a calibrated screen coordinate, regardless of whether it is in compatibility mode or extended mode.

**Note:** The calibration process of the touch screen should only be performed in compatibility mode.

Offset	Register Name	Description
0x104	<b>REG_CTOUCH_MODE</b>	Touch screen sampling Mode
0x108	<b>REG_CTOUCH_EXTENDED</b>	Select ADC working mode
0x11C	<b>REG_CTOUCH_TOUCH1_XY</b>	Coordinate of second touch point
0x120	<b>REG_CTOUCH_TOUCH4_Y</b>	Y coordinate of fifth touch point
0x124	<b>REG_CTOUCH_TOUCH_XY</b>	Coordinate of first touch point
0x128	<b>REG_CTOUCH_TAG_XY</b>	coordinate used to calculate the tag of first touch point
0x12C	<b>REG_CTOUCH_TAG</b>	Touch screen Tag result of fist touch point
0x130	<b>REG_CTOUCH_TAG1_XY</b>	XY used to tag of second touch point
0x134	<b>REG_CTOUCH_TAG1</b>	Tag result of second touch point
0x138	<b>REG_CTOUCH_TAG2_XY</b>	XY used to tag of third touch point
0x13C	<b>REG_CTOUCH_TAG2</b>	Tag result of third touch point
0x140	<b>REG_CTOUCH_TAG3_XY</b>	XY used to tag of fourth touch point
0x144	<b>REG_CTOUCH_TAG3</b>	Tag result of fourth touch point
0x148	<b>REG_CTOUCH_TAG4_XY</b>	XY used to tag of fifth touch point
0x14C	<b>REG_CTOUCH_TAG4</b>	Tag result of fifth touch point
0x16C	<b>REG_CTOUCH_TOUCH4_X</b>	X coordinate of fifth touch point
0x18C	<b>REG_CTOUCH_TOUCH2_XY</b>	Third touch point coordinate
0x190	<b>REG_CTOUCH_TOUCH3_XY</b>	Fourth touch point coordinate

Table 9 – CTSE Registers Summary

The following tables define the registers provided by **CTSE**:

REG_CTOUCH_MODE Definition		
31	2	1 0
	Reserved	r/w
Offset: 0x104		Reset Value: 0x3
Bit 31 – 2 : Reserved bits		
Bit 1 – 0: The host can set these two bits to control the touch screen sampling mode of the touch engine, as per:		
0b'00: Off mode. No sampling happens. <b>CTSE</b> stops working.		
0b'01: Not defined.		
0b'10: Not defined.		
0b'11: On mode.		

#### Register Definition 56 – REG\_CTOUCH\_MODE Definition

REG_CTOUCH_EXTEND Definition		
31	1	0
	reserved	r/w
Offset: 0x108		Reset Value: 0x1
Bit 31 – 1 : Reserved bits		
Bit 0: This bit controls the detection mode of the touch engine, as per:		
0: Extended mode, multi-touch detection mode		
1: Compatibility mode, single touch detection mode		

#### Register Definition 57 – REG\_CTOUCH\_EXTENDED Definition

REG_CTOUCH_TOUCH_XY Definition		
31	16	15 0
	r/o	r/o
Offset: 0x124		Reset Value: 0x80008000
Bit 31 – 16: The value of these bits is X coordinate of the first touch point		
Bit 15 - 0: The value of these bits is Y coordinate of the first touch point.		
<b>Note:</b> This register is applicable for extended mode and compatibility mode. For compatibility mode, it reflects the position of the only touch point		

#### Register Definition 58 – REG\_CTOUCH\_TOUCH\_XY Definition

REG_CTOUCH_TOUCH1_XY Definition		
31	16	15 0
	r/o	r/o
Offset: 0x11C		Reset Value: 0x80008000
Bit 31 – 16: The value of these bits is X coordinate of the second touch point		
Bit 15 - 0: The value of these bits is Y coordinate of the second touch point.		
<b>Note:</b> This register is only applicable in the extended mode		

#### Register Definition 59 – REG\_CTOUCH\_TOUCH1\_XY Definition

REG_CTOUCH_TOUCH2_XY Definition		
31	16	15 0
	r/o	r/o
Offset: 0x18C		Reset Value: 0x80008000
Bit 31 – 16: The value of these bits is X coordinates of the third touch point		
Bit 15 - 0: The value of these bits is Y coordinates of the third touch point.		
<b>Note:</b> This register is only applicable in the extended mode		

#### Register Definition 60 – REG\_CTOUCH\_TOUCH2\_XY Definition

**REG\_CTOUCH\_TOUCH3\_XY Definition**

31	16   15	0
r/o		r/o

Offset: 0x190

Reset Value: 0x80008000

Bit 31 – 16: The value of these bits is X coordinate of the fourth touch point

Bit 15 - 0: The value of these bits is Y coordinate of the fourth touch point.

**Note:** This register is only applicable in the extended mode

**Register Definition 61 – REG\_CTOUCH\_TOUCH3\_XY Definition**
**REG\_CTOUCH\_TOUCH4\_X Definition**

15	0
r/o	

Offset: 0x16C

Reset Value: 0x8000

Bit 15 – 0: The value of these bits is X coordinate of the fifth touch point.

**Note:** This register is only applicable in the extended mode. It is a 16 bit register.

**Register Definition 62 – REG\_CTOUCH\_TOUCH4\_X Definition**
**REG\_CTOUCH\_TOUCH4\_Y Definition**

15	0
r/o	

Offset: 0x120

Reset Value: 0x8000

Bit 15 – 0: The value of these bits is Y coordinate of the fifth touch point.

**Note:** This register is only applicable in the extended mode. It is a 16 bit register.

**Register Definition 63 – REG\_CTOUCH\_TOUCH4\_Y Definition**
**REG\_CTOUCH\_RAW\_XY Definition**

31	16   15	0
r/o		r/o

Offset: 0x11C

Reset Value: 0xFFFFFFFF

Bit 31 – 16: The value of these bits is the X coordinate of a touch point before going through calibration process

Bit 15 - 0: The value of these bits is the Y coordinate of a touch point before going through calibration process

**Note:** This register is only applicable in the compatibility mode

**Register Definition 64 – REG\_CTOUCH\_RAW\_XY Definition**
**REG\_CTOUCH\_TAG Definition**

31	8   7	0
Reserved		r/o

Offset: 0x12C

Reset Value: 0x0

Bit 31 – 8: Reserved Bits

 Bit 7 – 0: These bits are set as the tag value of the specific graphics object on the screen which is being touched. These bits are updated once when all the lines of the current frame are scanned out to the screen. It works in both extended mode and compatibility mode. In extended mode, it is the tag of the **first** touch point , i.e., the tag value mapping to the coordinate in

**REG\_CTOUCH\_TAG\_XY**

**Note:** The valid tag value range is from 1 to 255, therefore the default value of this register is zero, meaning there is no touch by default. In extended mode, it refers to the first touch point

**Register Definition 65 – REG\_CTOUCH\_TAG Definition**

**REG\_CTOUCH\_TAG1 Definition**

31	8 7	0
Reserved		r/o

Offset: 0x134

Reset Value: 0x0

Bit 31 – 8: Reserved Bits

Bit 7 – 0: These bits are set as the tag value of the specific graphics object on the screen which is being touched. It is the **second** touch point in extended mode. These bits are updated once when all the lines of the current frame are scanned out to the screen.

**Note:** The valid tag value range is from 1 to 255, therefore the default value of this register is zero, meaning there is no touch by default. This register is only applicable in the extended mode.

**Register Definition 66 – REG\_CTOUCH\_TAG1 Definition**
**REG\_CTOUCH\_TAG2 Definition**

31	8 7	0
Reserved		r/o

Offset: 0x13C

Reset Value: 0x0

Bit 31 – 8: Reserved Bits

Bit 7 – 0: These bits are set as the tag value of the specific graphics object on the screen which is being touched. It is the **third** touch point in extended mode. These bits are updated once when all the lines of the current frame are scanned out to the screen.

**Note:** The valid tag value range is from 1 to 255, therefore the default value of this register is zero, meaning there is no touch by default. This register is only applicable in the extended mode.

**Register Definition 67 – REG\_CTOUCH\_TAG2 Definition**
**REG\_CTOUCH\_TAG3 Definition**

31	8 7	0
Reserved		r/o

Offset: 0x144

Reset Value: 0x0

Bit 31 – 8: Reserved Bits

Bit 7 – 0: These bits are set as the tag value of the specific graphics object on the screen which is being touched. It is the **fourth** touch point in extended mode. These bits are updated once when all the lines of the current frame are scanned out to the screen.

**Note:** The valid tag value range is from 1 to 255, therefore the default value of this register is zero, meaning there is no touch by default. This register is only applicable in the extended mode.

**Register Definition 68 – REG\_CTOUCH\_TAG3 Definition**
**REG\_CTOUCH\_TAG4 Definition**

31	8 7	0
Reserved		r/o

Offset: 0x14C

Reset Value: 0x0

Bit 31 – 8: Reserved Bits

Bit 7 – 0: These bits are set as the tag value of the specific graphics object on the screen which is being touched. It is the **fifth** touch point in extended mode. These bits are updated once when all the lines of the current frame are scanned out to the screen.

**Note:** The valid tag value range is from 1 to 255, therefore the default value of this register is zero, meaning there is no touch by default. This register is only applicable in the extended mode.

**Register Definition 69 – REG\_CTOUCH\_TAG4 Definition**

REG_CTOUCH_TAG_XY Definition		
31	16   15	0
r/o		r/o
Offset: 0x128		Reset Value: 0x0
Bit 31 – 16: The value of these bits is X coordinate of the touch screen, used by the touch engine to look up the tag result.		
Bit 15 – 0: The value of these bits is Y coordinate of the touch screen, used by the touch engine to look up the tag result.		
<b>Note:</b> The Host can read this register to check the coordinates used by the touch engine to update the tag register REG_CTOUCH_TAG.		

#### Register Definition 70 – REG\_CTOUCH\_TAG\_XY Definition

REG_CTOUCH_TAG1_XY Definition		
31	16   15	0
r/o		r/o
Offset: 0x130		Reset Value: 0x0
Bit 31 – 16: The value of these bits is X coordinate of the touch screen to look up the tag result.		
Bit 15 – 0: The value of these bits is Y coordinate of the touch screen to look up the tag result.		
<b>Note:</b> The Host can read this register to check the coordinates used by the touch engine to update the tag register REG_CTOUCH_TAG1.		

#### Register Definition 71 – REG\_CTOUCH\_TAG1\_XY Definition

REG_CTOUCH_TAG2_XY Definition		
31	16   15	0
r/o		r/o
Offset: 0x138		Reset Value: 0x0
Bit 31 – 16: The value of these bits is X coordinate of the touch screen to look up the tag result.		
Bit 15 – 0: The value of these bits is Y coordinate of the touch screen to look up the tag result.		
<b>Note:</b> The Host can read this register to check the coordinates used by the touch engine to update the tag register REG_CTOUCH_TAG2.		

#### Register Definition 72 – REG\_CTOUCH\_TAG2\_XY Definition

REG_CTOUCH_TAG3_XY Definition		
31	16   15	0
r/o		r/o
Offset: 0x140		Reset Value: 0x0
Bit 31 – 16: The value of these bits is X coordinate of the touch screen to look up the tag result.		
Bit 15 – 0: The value of these bits is Y coordinate of the touch screen to look up the tag result.		
<b>Note:</b> The Host can read this register to check the coordinates used by the touch engine to update the tag register REG_CTOUCH_TAG3.		

#### Register Definition 73 – REG\_CTOUCH\_TAG3\_XY Definition

REG_CTOUCH_TAG4_XY Definition		
31	16   15	0
r/o		r/o
Offset: 0x148		Reset Value: 0x0
Bit 31 – 16: The value of these bits is X coordinate of the touch screen to look up the tag result.		
Bit 15 – 0: The value of these bits is Y coordinate of the touch screen to look up the tag result.		
<b>Note:</b> The Host can read this register to check the coordinates used by the touch engine to update the tag register REG_CTOUCH_TAG4.		

#### Register Definition 74 – REG\_CTOUCH\_TAG4\_XY Definition

### 3.4.5 Calibration

The calibration process is initiated by **CMD\_CALIBRATE** and works with both the **RTE** and **CTSE**, but is only available in the compatibility mode of the **CTSE**. However, the results of the calibration process are applicable to both compatibility mode and extended mode. As such, users are recommended to finish the calibration process before entering into extended mode.

After the calibration process is complete, the registers **REG\_TOUCH\_TRANSFORM\_A-F** will be updated accordingly.

## 3.5 Coprocessor Engine Registers

REG_CMD_DL Definition		
31	13	12 0
Reserved		r/w
Offset: 0x100		Reset Value: 0x0
Bit 31 – 13: Reserved Bits		
Bit 12 – 0: These bits indicate the offset from <b>RAM_DL</b> of the display list commands generated by the coprocessor engine. The coprocessor engine depends on these bits to determine the address in the display list buffer of generated display list commands. It will update this register as long as the display list commands are generated into the display list buffer. By setting this register properly, the host can specify the starting address in the display list buffer for the coprocessor engine to generate display commands. The valid value range is from 0 to 8191 (sizeof( <b>RAM_DL</b> )-1).		

**Register Definition 75 – REG\_CMD\_DL Definition**

REG_CMD_WRITE Definition		
31	12	11 0
Reserved		r/w
Offset: 0xFC		Reset Value: 0x0
Bit 31 – 12: Reserved Bits		
Bit 11 – 0: These bits are updated by the <b>MCU</b> to inform the coprocessor engine of the ending address of valid data feeding into its <b>FIFO</b> . Typically, the host will update this register after it has downloaded the coprocessor commands into its FIFO. The valid range is from 0 to 4095, i.e. within the size of the <b>FIFO</b> .		
<b>Note:</b> The <b>FIFO</b> size of the command buffer is 4096 bytes and each coprocessor instruction is of 4 bytes in size. The value to be written into this register must be 4 bytes aligned.		

**Register Definition 76 – REG\_CMD\_WRITE Definition**

REG_CMD_READ Definition		
31	12	11 0
Reserved		r/o
Offset: 0xF8		Reset Value: 0x0
Bit 31 – 12: Reserved Bits		
Bit 11 – 0: These bits are updated by the coprocessor engine as long as the coprocessor engine fetched the command from its FIFO. The host can read this register to determine the FIFO fullness of the coprocessor engine. The valid value range is from 0 to 4095. In the case of an error, the coprocessor engine writes 0xFF to this register.		
<b>Note:</b> The host shall not write into this register unless in an error recovery case. The default value is zero after the coprocessor engine is reset.		

**Register Definition 77 – REG\_CMD\_READ Definition**

**REG\_CMDB\_SPACE Definition**

31	12   11	0
Reserved		r/o

Offset: 0x574

Reset Value: 0xFFC

Bit 31 – 12: Reserved Bits

Bit 11 – 0: These bits are updated by the coprocessor engine to indicate the free space in RAM\_CMD. The host can read this register to determine how many bytes are available to be written into **RAM\_CMD** before writing to **RAM\_CMD**.

**Note:** The host shall not write into this register unless in an error recovery case. The default value is zero after the coprocessor engine is reset.

**Register Definition 78 – REG\_CMDB\_SPACE Definition**
**REG\_CMDB\_WRITE Definition**

31	0
w/o	

Offset: 0x578

Reset Value: 0x0

Bit 31 – 0: The data or command to be written into **RAM\_CMD**. The Host can issue one write transfer with this register address to transfer data less than or equal to the amount of **REG\_CMDB\_SPACE** to make bulky data transfer possible.

**Note:** This register helps programmers write to the coprocessor **FIFO(RAM\_CMD)**. It was introduced from the FT810 series chip. Always write this register with 4 bytes aligned data.

**Register Definition 79 – REG\_CMDB\_WRITE Definition**

### 3.6 Miscellaneous Registers

In this chapter, the miscellaneous registers covers backlight control, interrupt, GPIO, and other functionality registers.

**REG\_CPURESET Definition**

31	3   2   1   0
reserved	r/w

Offset: 0x20

Reset Value: 0x0

Bit 31 – 3: Reserved Bits

Bit 2: Control the reset of audio engine.

Bit 1: Control the reset of touch engine.

Bit 0: Control the reset of coprocessor engine.

**Note:** Write 1 to reset the corresponding engine. Write 0 to go back to normal working status.

Reading 1 means the engine is in reset status, and reading zero means the engine is in working status.

**Register Definition 80 – REG\_CPURESET Definition**
**REG\_MACRO\_1 Definition**

31	0
r/w	

Offset: 0xDC

Reset Value: 0x0

Bit 31 – 0: Display list command macro 1. The value of this register will be copied over to **RAM\_DL** to replace the display list command **MACRO** if its parameter is 1.

**Register Definition 81 – REG\_MACRO\_1 Definition**
**REG\_MACRO\_0 Definition**

31	0
r/w	

Offset: 0xD8

Reset Value: 0x0

Bit 31 – 0: Display list command macro 0. The value of this register will be copied over to **RAM\_DL** to replace the display list command **MACRO** if its parameter is 0.

**Register Definition 82 – REG\_MACRO\_0 Definition**

**REG\_PWM\_DUTY Definition**

31	8   7	0
Reserved		r/w

Offset: 0xD4

Reset Value: 0x80

Bit 31 – 8: Reserved Bits

Bit 7 – 0: These bits define the backlight PWM output duty cycle. The valid range is from 0 to 128. 0 means backlight completely off, 128 means backlight in max brightness.

**Register Definition 83 – REG\_PWM\_DUTY Definition**
**REG\_PWM\_HZ Definition**

31	14   13	0
Reserved		r/w

Offset: 0xD0

Reset Value: 0xFA

Bit 31 – 14: Reserved Bits

Bit 13 – 0: These bits define the backlight PWM output frequency in **Hz**. The default is 250 Hz after reset. The valid frequency is from 250Hz to 10000Hz.

**Register Definition 84 – REG\_PWM\_HZ Definition**
**REG\_INT\_MASK Definition**

31	8   7	0
Reserved		r/w

Offset: 0xB0

Reset Value: 0xFF

Bit 31 – 8: Reserved Bits

Bit 7 – 0: These bits are used to mask the corresponding interrupt. 1 means to enable the corresponding interrupt source, 0 means to disable the corresponding interrupt source. After reset, all the interrupt source are eligible to trigger an interrupt by default.

**Note:** Refer to the section “Interrupts” in BT817/8 datasheet for more details.

**Register Definition 85 – REG\_INT\_MASK Definition**
**REG\_INT\_EN Definition**

31	1   0	
Reserved		r/w

Offset: 0xAC

Reset Value: 0x0

Bit 31 – 1: Reserved bits

Bit 0: The host can set this bit to 1 to enable the global interrupt. To disable the global interrupt, the host can set this bit to 0.

**Note:** Refer to the section “Interrupts” in BT817/8 datasheet for more details.

**Register Definition 86 – REG\_INT\_EN Definition**
**REG\_INT\_FLAGS Definition**

31	8   7	0
Reserved		r/w

Offset: 0xA8

Reset Value: 0x0

Bit 31 – 8: Reserved Bits

Bit 7 – 0: These bits are interrupt flags. The host can read these bits to determine which interrupt takes place. These bits are cleared automatically by reading. The host shall not write to this register.

**Note:** Refer to the section “Interrupts” in BT817/8 datasheet for more details.

**Register Definition 87 – REG\_INT\_FLAGS Definition**
**REG\_GPIO\_DIR Definition**

31	8   7   6   2   1   0	
Reserved		r/w   reserved   r/w

Offset: 0x90

Reset Value: 0x0

Bit 31 – 8: Reserved Bits

 Bit 7: It controls the direction of pin **DISP**.

Bit 6 – 2: Reserved Bits

Bit 1: It controls the direction of **GPIO1**.

Bit 0: It controls the direction of **GPIO0**.

**Note:** 1 is for output, 0 is for input direction. This register is a legacy register for backward compatibility only

#### Register Definition 88 – REG\_GPIO\_DIR Definition

##### REG\_GPIO Definition

31	8   7   6   5   4   3   2   1   0
Reserved	r/w

Offset: 0x94

Reset Value: 0x0

Bit 31 – 8: Reserved Bits

Bit 7 : It controls the high or low level of pin **DISP**.

Bit 6-5: Drive strength settings for pins **GPIO0,GPIO1, CTP\_RST\_N**:

- 0b'00:5mA – default,
- 0b'01:10mA,
- 0b'10:15mA,
- 0b'11:20mA

Bit 4: Drive strength settings for pins **PCLK, DISP,VSYNC,HSYNC,DE, R,G,B, BACKLIGHT**:

0b'0: 1.2mA – default, 0b'1: 2.4mA

Bit 3-2: Drive Strength Setting for pins **MISO, MOSI, INT\_N**:

- 0b'00:5mA – default,
- 0b'01:10mA,
- 0b'10:15mA,
- 0b'11:20mA

Bit 1: It controls the high or low level of pin **GPIO1**.

Bit 0: It controls the high or low level of pin **GPIO0**.

**Note:** Refer to BT817/8 datasheet. This register is a legacy register for backward compatibility only.

#### Register Definition 89 – REG\_GPIO Definition

##### REG\_GPIOX\_DIR Definition

31	16   15   14	4   3   0
Reserved	r/w	reserved r/w

Offset: 0x98

Reset Value: 0x8000

Bit 31 – 16: Reserved Bits

Bit 15: It controls the direction of pin **DISP**. The default value is 1, meaning output.

Bit 14 – 4: Reserved Bits

Bit 3: It controls the direction of **GPIO3**.

Bit 2: It controls the direction of **GPIO2**.

Bit 1: It controls the direction of **GPIO1**.

Bit 0: It controls the direction of **GPIO0**.

**Note:** 1 is for output,0 is for input direction

#### Register Definition 90 – REG\_GPIOX\_DIR Definition

##### REG\_GPIO\_X Definition

31	16   15   14   13   12   11   10   9   8   4   3   0								
Reserved	r/w				reserved	r/w			

Offset: 0x9C

Reset Value: 0x8000

Bit 31 – 16: Reserved Bits

Bit 15: It controls the high or low level of pin **DISP**. 1 for high level (default) and 0 for low level.

Bit 14-13: Drive strength settings for pins **GPIO0,GPIO1,GPIO2,GPIO3, CTP\_RST\_N**:

- 0b'00:5mA – default,
- 0b'01:10mA,
- 0b'10:15mA,
- 0b'11:20mA

Bit 12: Drive strength settings for pins **PCLK, DISP,VSYNC,HSYNC,DE, R,G,B, BACKLIGHT**:

- 0b'0: 1.2mA – default, 0b'1: 2.4mA

Bit 11-10: Drive Strength Setting for pins **MISO, MOSI, INT\_N,IO2, IO3, SPIM\_SCLK**,

**SPIM\_SS\_N, SPIM\_MOSI, SPIM\_MISO, SPIM\_IO2, SPIM\_IO3:**

0b'00:5mA – default,  
 0b'01:10mA,  
 0b'10:15mA,  
 0b'11:20mA

Bit 9: It controls the type of pin **INT\_N**.

0b'0: Open Drain – default,  
 0b'1: Push-pull

Bit 8 – 4: Reserved Bits

Bit 3: It controls the high or low level of pin **GPIO3**.

Bit 2: It controls the high or low level of pin **GPIO2**.

Bit 1: It controls the high or low level of pin **GPIO1**.

Bit 0: It controls the high or low level of pin **GPIO0**.

**Note:** Refer to BT817/8 datasheet for more details.

**Register Definition 91 – REG\_GPIOX Definition**
**REG\_FREQUENCY Definition**

31	0
	r/w

Offset: 0xC Reset Value: 0x3938700

Bit 31 – 0: The main clock frequency is 60MHz by default. The value is in Hz. If the host selects the alternative frequency, this register must be updated accordingly.

**Register Definition 92 – REG\_FREQUENCY Definition**
**REG\_CLOCK Definition**

31	0
	r/o

Offset: 0x8 Reset Value: 0x0

Bit 31 – 0: These bits are set to zero after reset. The register counts the number of main clock cycles since reset. If the main clock's frequency is 60Mhz, it will wrap around after about 71 seconds.

**Register Definition 93 – REG\_CLOCK Definition**
**REG\_FRAMES Definition**

31	0
	r/o

Offset: 0x4 Reset Value: 0x0

Bit 31 – 0: These bits are set to zero after reset. The register counts the number of screen frames. If the refresh rate is 60Hz, it will wrap up till about 828 days after reset.

**Register Definition 94 – REG\_FRAMES Definition**
**REG\_ID Definition**

31	8	7	0
	Reserved		r/o

Offset: 0x0 Reset Value: 0x7C

Bit 31 – 8: Reserved Bits

Bit 7 – 0: These bits are the built-in ID of the chip. The value shall always be **0x7C**. The host can read this to determine if the chip belongs to the **EVE** series and is in working mode after booting up.

**Register Definition 95 – REG\_ID Definition**

**REG\_SPI\_WIDTH Definition**

31		3	2	1	0
	Reserved				r/w
Offset: 0x180	Reset Value: 0x0				
Bit 31 – 3: Reserved Bits					
Bit 2: Extra dummy on SPI read transfer. Writing 1 to enable one extra dummy byte on SPI read transfer.					
Bit 1 – 0: SPI data bus width:					
0b'00: 1 bit – default					
0b'01: 2 bit (Dual-SPI)					
0b'10: 4 bit (Quad-SPI)					
0b'11: undefined					

**Note:** Refer to BT81Xdatasheet for more details.

**Register Definition 96 – REG\_SPI\_WIDTH Definition**
**REG\_ADAPTIVE\_FRAMERATE Definition**

7		1	0
	Reserved		r/w
Offset: 0x57C	Reset Value: 0x1		
Bit 7 – 1: Reserved bits			
Bit 0: Reduce the framerate during complex drawing.			
0: Disable			
1: Enable			

**Note:** Please check if the LCD panel datasheet supports the variable frame rate.

**Register Definition 97 – REG\_ADAPTIVE\_FRAMERATE Definition**
**REG\_UNDERRUN Definition**

31			0
		r/o	
Offset: 0x60C	Reset Value: 0x0		
Bit 31 – 0: It counts underrun lines. When a line underruns, it is incremented. An application can sample it on each frame swap to determine if the previous frame suffered an underrun.			
<b>Note:</b> BT817/8 specific register.			

**Register Definition 98 – REG\_UNDERRUN Definition**
**REG\_AH\_HCYCLE\_MAX Definition**

31	12	11	0
	Reserved		r/w
Offset: 0x610	Reset Value: 0x0		
Bit 11 – 0: The maximum PCLK count of horizontal line when adaptive HSYNC is enabled.			
Value 0 means adaptive HSYNC feature is disabled.			
The valid value shall be greater than <b>REG_HCYCLE</b> .			
Bit 31 – 12: Reserved bits			
<b>Note:</b> BT817/8 specific register.			

**Register Definition 99 – REG\_AH\_HCYCLE\_MAX Definition**

**REG\_PCLK\_FREQ Definition**

31	11	10	9	8	0
Reserved		r/w		r/w	

Offset: 0x614

Reset Value: 0x8A1

Bit 31 – 11: Reserved bits

 Bit 10 – 9: Configure the range of output fractional **PCLK** frequency for **EXTSYNC** mode. Refer to BT817/8 datasheet for details.

 Bit 8 – 0: Configure the output fractional **PCLK** frequency for **EXTSYNC** mode, i.e., **REG\_PCLK** is set to 1. Refer to BT817/8 datasheet for details.

**Note:** **BT817/8** specific register.

 Coprocessor command **CMD\_PCLKFREQ** is recommended to set up the correct value of this register, which is more intuitive and easier to use.

**Register Definition 100 – REG\_PCLK\_FREQ Definition**
**REG\_PCLK\_2X Definition**

7	1	0
Reserved		r/w

Offset: 0x618

Reset Value: 0x0

 Bit 0: graphics engine outputs 1 or 2 pixels per **PCLK**.

0 means 1 pixel per clock,

1 means 2 pixel per clock.

Bit 7 – 1: Reserved bits.

**Note:** **BT817/8** specific register. When graphics engine outputs 2 pixels per **PCLK**, the values loaded in the following registers must be even:

- REG\_HSIZE
- REG\_HOFFSET
- REG\_HCYCLE
- REG\_HSYNC0
- REG\_HSYNC1

**Register Definition 101 – REG\_PCLK\_2X Definition**

### 3.7 Special Registers

 The registers listed here are not located in **RAM\_REG**. They are located in special addresses.

**REG\_TRACKER Definition**

31	16	15	8	7	0
r/o		reserved		r/o	

Offset: 0x7000

Reset Value: 0x0

 Bit 31 – 16: These bits are set to indicate the tracking value for the tracked graphics objects. The coprocessor calculates the tracking value that the touching point takes within the predefined range. Please check the **CMD\_TRACK** for more details.

Bit 15 – 8: Reserved Bits

Bit 7 – 0: These bits are set to indicate the tag value of a graphics object which is being touched.

**Register Definition 102 – REG\_TRACKER Definition**
**REG\_TRACKER\_1 Definition**

31	16	15	8	7	0
r/o		reserved		r/o	

Offset: 0x7004

Reset Value: 0x0

 Bit 31 – 16: These bits are set to indicate the tracking value for the tracked graphics objects. The coprocessor calculates the tracking value that the touching point takes within the predefined range. Please check the **CMD\_TRACK** for more details.

Bit 15 – 8: Reserved Bits

Bit 7 – 0: These bits are set to indicate the tag value of a graphics object which is being touched as the second point.

**Note:** It is only applicable for extended mode of CTSE.

**Register Definition 103 – REG\_TRACKER\_1 Definition**

**REG\_TRACKER\_2 Definition**

31	16   15	8   7	0
r/o	reserved	r/o	

Offset: 0x7008

Reset Value: 0x0

Bit 31 – 16: These bits are set to indicate the tracking value for the tracked graphics objects. The coprocessor calculates the tracking value that the touching point takes within the predefined range. Please check the **CMD\_TRACK** for more details.

Bit 15 – 8: Reserved Bits

Bit 7 – 0: These bits are set to indicate the tag value of a graphics object which is being touched as the third point.

**Note:** It is only applicable for extended mode of CTSE.

**Register Definition 104 – REG\_TRACKER\_2 Definition**
**REG\_TRACKER\_3 Definition**

31	16   15	8   7	0
r/o	reserved	r/o	

Offset: 0x700C

Reset Value: 0x0

Bit 31 – 16: These bits are set to indicate the tracking value for the tracked graphics objects. The coprocessor calculates the tracking value that the touching point takes within the predefined range. Please check the **CMD\_TRACK** for more details.

Bit 15 – 8: Reserved Bits

Bit 7 – 0: These bits are set to indicate the tag value of a graphics object which is being touched as the fourth point.

**Note:** It is only applicable for extended mode of CTSE.

**Register Definition 105 – REG\_TRACKER\_3 Definition**
**REG\_TRACKER\_4 Definition**

31	16   15	8   7	0
r/o	reserved	r/o	

Offset: 0x7010

Reset Value: 0x0

Bit 31 – 16: These bits are set to indicate the tracking value for the tracked graphics objects. The coprocessor calculates the tracking value that the touching point takes within the predefined range. Please check the **CMD\_TRACK** for more details.

Bit 15 – 8: Reserved Bits

Bit 7 – 0: These bits are set to indicate the tag value of a graphics object which is being touched as the fifth point.

**Note:** It is only applicable for extended mode of CTSE.

**Register Definition 106 – REG\_TRACKER\_4 Definition**
**REG\_MEDIAFIFO\_READ Definition**

31	0
r/o	

Offset: 0x7014

Reset Value: 0x0

Bit 31 – 0: The value specifies the read pointer pointing to the address in **RAM\_G** as the media **FIFO**.

**Register Definition 107 – REG\_MEDIAFIFO\_READ Definition**
**REG\_MEDIAFIFO\_WRITE Definition**

31	0
w/o	

Offset: 0x7018

Reset Value: 0x0

Bit 31 – 0: The value specifies the write pointer pointing to the address in **RAM\_G** as the media **FIFO**.

**Register Definition 108 – REG\_MEDIAFIFO\_WRITE Definition**

**REG\_PLAY\_CONTROL Definition**

7	1	0
Reserved		r/w

Offset: 0x714E

Reset Value: 0x0

Bit 7 – 0: video playback control

**Note:** Writing 0xFF to this register to exit the video.

**Register Definition 109 – REG\_PLAY\_CONTROL Definition**
**REG\_ANIM\_ACTIVE Definition**

31	0
r/o	

Offset: 0x702C

Reset Value: 0x0

Bit 31 – 0: 32-bit mask of currently playing animations. Each bit indicates the active state of animation channel. 0 means animation ends and 1 means animation runs.

**Note:** Only applicable for the animation channel is played with **ANIM\_ONCE** flag.

**Register Definition 110 – REG\_ANIM\_ACTIVE Definition**
**REG\_COPRO\_PATCH\_PTR Definition**

15	0
r/o	

Offset: 0x7162

 Reset Value: **NA**

Bit 15 – 0: The address of coprocessor patch pointer.

**Note:** This register shall be only used for the coprocessor recovery purpose. Refer to [Coprocessor Faults](#).

**Register Definition 111 – REG\_COPRO\_PATCH\_PTR Definition**

## 4 Display List Commands

The graphics engine takes the instructions from display list memory **RAM\_DL** in the form of commands. Each command is 4 bytes long and one display list can be filled with up to 2048 commands as the size of **RAM\_DL** is 8K bytes. The graphics engine performs the respective operation according to the definition of commands.

### 4.1 Graphics State

The graphics state which controls the effects of a drawing action is stored in the graphics context. Individual pieces of state can be changed by the appropriate display list commands and the entire current state can be saved and restored using the **SAVE\_CONTEXT** and **RESTORE\_CONTEXT** commands.

Note that the bitmap drawing state is special: Although the bitmap handle is part of the graphics context, the parameters for each bitmap handle are not part of the graphics context. They are neither saved nor restored by **SAVE\_CONTEXT** and **RESTORE\_CONTEXT**. These parameters are changed using the **BITMAP\_SOURCE**, **BITMAP\_LAYOUT/BITMAP\_LAYOUT\_H** and **BITMAP\_SIZE/BITMAP\_SIZE\_H** commands. Once these parameters are set up, they can be utilized at any display list by referencing the same bitmap handle until they were changed.

**SAVE\_CONTEXT** and **RESTORE\_CONTEXT** are comprised of a 4-level stack in addition to the current graphics context. The table below details the various parameters in the graphics context.

Parameters	Default values	Commands
func & ref	ALWAYS, 0	ALPHA_FUNC
func & ref	ALWAYS, 0	STENCIL_FUNC
Src & dst	SRC_ALPHA, ONE_MINUS_SRC_ALPHA	BLEND_FUNC
Cell value	0	CELL
Alpha value	0	COLOR_A
Red, Blue, Green colors	(255,255,255)	COLOR_RGB
Line width in 1/16 pixels	16	LINE_WIDTH
Point size in 1/16 pixels	16	POINT_SIZE
Width & height of scissor	HSIZE,2048	SCISSOR_SIZE
Starting coordinates of scissor	(x, y) = (0,0)	SCISSOR_XY
Current bitmap handle	0	BITMAP_HANDLE
Bitmap transform coefficients	+1.0,0,0,0,+1.0,0	BITMAP_TRANSFORM_A-F
Stencil clear value	0	CLEAR_STENCIL
Tag clear value	0	CLEAR_TAG
Mask value of stencil	255	STENCIL_MASK
spass and sfail	KEEP,KEEP	STENCIL_OP
Tag buffer value	255	TAG
Tag mask value	1	TAG_MASK
Alpha clear value	0	CLEAR_COLOR_A
RGB clear color	(0,0,0)	CLEAR_COLOR_RGB
Palette source address	RAM_G	PALETTE_SOURCE
Units of pixel precision	1/16 pixel	VERTEX_FORMAT, VERTEX2F

Table 10 – Graphics Context

### 4.2 Command Encoding

Each display list command has a 32-bit encoding. The most significant bits of the code determine the command. Command parameters (if any) are present in the least significant bits. Any bits marked as "reserved" must be zero.

## 4.3 Command Groups

### 4.3.1 Setting Graphics State

<b>ALPHA_FUNC</b>	set the alpha test function
<b>BITMAP_EXT_FORMAT</b>	specify the extended format of the bitmap
<b>BITMAP_HANDLE</b>	set the bitmap handle
<b>BITMAP_LAYOUT/</b> <b>BITMAP_LAYOUT_H</b>	set the source bitmap memory format and layout for the current handle
<b>BITMAP_SIZE/</b> <b>BITMAP_SIZE_H</b>	set the screen drawing of bitmaps for the current handle
<b>BITMAP_SOURCE</b>	set the source address for bitmap graphics. It can be a flash address.
<b>BITMAP_SWIZZLE</b>	specify the color channel swizzle for a bitmap
<b>BITMAP_TRANSFORM_A-F</b>	set the components of the bitmap transform matrix
<b>BLEND_FUNC</b>	set pixel arithmetic function
<b>CELL</b>	set the bitmap cell number for the VERTEX2F command
<b>CLEAR</b>	clear buffers to preset values
<b>CLEAR_COLOR_A</b>	set clear value for the alpha channel
<b>CLEAR_COLOR_RGB</b>	set clear values for red, green and blue channels
<b>CLEAR_STENCIL</b>	set clear value for the stencil buffer
<b>CLEAR_TAG</b>	set clear value for the tag buffer
<b>COLOR_A</b>	set the current color alpha
<b>COLOR_MASK</b>	enable or disable writing of color components
<b>COLOR_RGB</b>	set the current color red, green and blue
<b>LINE_WIDTH</b>	set the line width
<b>POINT_SIZE</b>	set point size
<b>RESTORE_CONTEXT</b>	restore the current graphics context from the context stack
<b>SAVE_CONTEXT</b>	push the current graphics context on the context stack
<b>SCISSOR_SIZE</b>	set the size of the scissor clip rectangle
<b>SCISSOR_XY</b>	set the top left corner of the scissor clip rectangle
<b>STENCIL_FUNC</b>	set function and reference value for stencil testing
<b>STENCIL_MASK</b>	control the writing of individual bits in the stencil planes
<b>STENCIL_OP</b>	set stencil test actions
<b>TAG</b>	set the current tag value
<b>TAG_MASK</b>	control the writing of the tag buffer
<b>VERTEX_FORMAT</b>	set the precision of VERTEX2F coordinates
<b>VERTEX_TRANSLATE_X</b>	specify the vertex transformation's X translation component
<b>VERTEX_TRANSLATE_Y</b>	specify the vertex transformation's Y translation component
<b>PALETTE_SOURCE</b>	Specify the base address of the palette

### 4.3.2 Drawing Actions

<b>BEGIN</b>	start drawing a graphics primitive
<b>END</b>	finish drawing a graphics primitive
<b>VERTEX2F</b>	supply a vertex with fractional coordinates
<b>VERTEX2II</b>	supply a vertex with unsigned coordinates

### 4.3.3 Execution Control

<b>NOP</b>	No Operation
<b>JUMP</b>	execute commands at another location in the display list
<b>MACRO</b>	execute a single command from a macro register
<b>CALL</b>	execute a sequence of commands at another location in the display list
<b>RETURN</b>	return from a previous CALL command
<b>DISPLAY</b>	end the display list

## 4.4 ALPHA\_FUNC

Specify the alpha test function

### Encoding

31	24	23	11	10	8	7	0
<b>0x09</b>		<b>reserved</b>		<b>func</b>		<b>ref</b>	

### Parameters

#### func

Specifies the test function, one of NEVER, LESS, LEQUAL, GREATER, GEQUAL, EQUAL, NOTEQUAL, or ALWAYS. The initial value is ALWAYS (7)

NAME	VALUE
NEVER	0
LESS	1
LEQUAL	2
GREATER	3
GEQUAL	4
EQUAL	5
NOTEQUAL	6
ALWAYS	7

#### ref

Specifies the reference value for the alpha test. The initial value is 0

### Graphics context

The values of func and ref are part of the graphics context, as described in section [4.1](#)

### See also

None

## 4.5 BEGIN

Begin drawing a graphics primitive

### Encoding

31	24	23	4	3	0
<b>0x1F</b>		<b>reserved</b>		<b>prim</b>	

### Parameters

#### prim

The graphics primitive to be executed. The valid values are defined as below:

Name	Value	Description
BITMAPS	1	Bitmap drawing primitive
POINTS	2	Point drawing primitive
LINES	3	Line drawing primitive
LINE_STRIP	4	Line strip drawing primitive
EDGE_STRIP_R	5	Edge strip right side drawing primitive
EDGE_STRIP_L	6	Edge strip left side drawing primitive

EDGE_STRIP_A	7	Edge strip above drawing primitive
EDGE_STRIP_B	8	Edge strip below side drawing primitive
RECTS	9	Rectangle drawing primitive

**Table 11 – Graphics Primitive Definition**

### Description

All primitives supported are defined in the table above. The primitive to be drawn is selected by the **BEGIN** command. Once the primitive is selected, it will be valid till the new primitive is selected by the **BEGIN** command.

Please note that the primitive drawing operation will not be performed until **VERTEX2II** or **VERTEX2F** is executed.

### Examples

Drawing points, lines and bitmaps:



```

dl( BEGIN(POINTS) );
dl( VERTEX2II(50, 5, 0, 0) );
dl( VERTEX2II(110, 15, 0, 0) );
dl( BEGIN(LINES) );
dl( VERTEX2II(50, 45, 0, 0) );
dl( VERTEX2II(110, 55, 0, 0) );
dl( BEGIN(BITMAPS) );
dl( VERTEX2II(50, 65, 31, 0x45) );
dl( VERTEX2II(110, 75, 31, 0x46) );

```

### Graphics context

None

### See also

END

## 4.6 BITMAP\_EXT\_FORMAT

Specify the extended format of the bitmap

### Encoding

31	24 23	16 15	0
<b>0x2E</b>	<b>reserved</b>	<b>format</b>	

### Parameters

#### format

Bitmap pixel format.

### Description

If **BITMAP\_LAYOUT** specifies a format for **GLFORMAT**, then the format is taken from **BITMAP\_EXT\_FORMAT** instead.

Valid values for the field format are:

Format Name	Value	Bits per Pixel
ARGB1555	0	16
L1	1	1
L4	2	4
L8	3	8
RGB332	4	8
ARGB2	5	8
ARGB4	6	16
RGB565	7	16
TEXT8X8	9	8
TEXTVGA	10	8
BARGRAPH	11	8
PALETTED565	14	8
PALETTED4444	15	8
PALETTED8	16	8
L2	17	2
COMPRESSED_RGBA_ASTC_4x4_KHR	37808	8.00
COMPRESSED_RGBA_ASTC_5x4_KHR	37809	6.40
COMPRESSED_RGBA_ASTC_5x5_KHR	37810	5.12
COMPRESSED_RGBA_ASTC_6x5_KHR	37811	4.27
COMPRESSED_RGBA_ASTC_6x6_KHR	37812	3.56
COMPRESSED_RGBA_ASTC_8x5_KHR	37813	3.20
COMPRESSED_RGBA_ASTC_8x6_KHR	37814	2.67
COMPRESSED_RGBA_ASTC_8x8_KHR	37815	2.00
COMPRESSED_RGBA_ASTC_10x5_KHR	37816	2.56
COMPRESSED_RGBA_ASTC_10x6_KHR	37817	2.13
COMPRESSED_RGBA_ASTC_10x8_KHR	37818	1.60
COMPRESSED_RGBA_ASTC_10x10_KHR	37819	1.28
COMPRESSED_RGBA_ASTC_12x10_KHR	37820	1.07
COMPRESSED_RGBA_ASTC_12x12_KHR	37821	0.89

**Table 12 – Bitmap formats and bits per pixel**

#### Graphics context

None

#### See also

[BITMAP\\_LAYOUT](#)

## 4.7 BITMAP\_HANDLE

Specify the bitmap handle

#### Encoding

31	24 23		54	0
<b>0x05</b>		<b>reserved</b>		<b>handle</b>

## Parameters

### handle

Bitmap handle. The initial value is 0. The valid value range is from 0 to 31.

## Description

By default, bitmap handles 16 to 31 are used for built-in font and 15 is used as scratch bitmap handle by coprocessor engine commands **CMD\_GRADIENT**, **CMD\_BUTTON** and **CMD\_KEYS**.

## Graphics context

The value of handle is part of the graphics context, as described in section 4.1.

## See also

[BITMAP\\_LAYOUT](#), [BITMAP\\_SIZE](#)

## 4.8 BITMAP\_LAYOUT

Specify the source bitmap memory format and layout for the current handle.

## Encoding

31	24 23	19 18	9 8	0
<b>0x07</b>		<b>format</b>	<b>linestride</b>	<b>height</b>

## Parameters

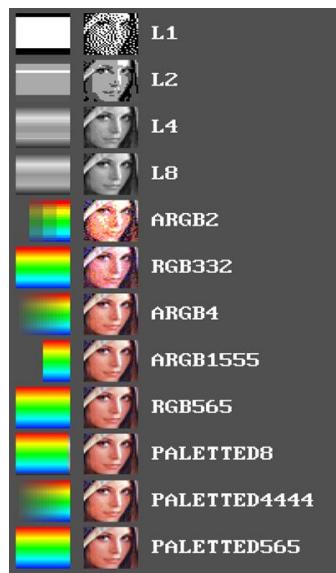
### format

Bitmap pixel format. The valid range is from 0 to 17 and defined as per the table below.

Name	Value	Bits/pixel	Alpha bits	Red bits	Green bits	Blue bits
<b>ARGB1555</b>	0	16	1	5	5	5
<b>L1</b>	1	1	1	0	0	0
<b>L4</b>	2	4	4	0	0	0
<b>L8</b>	3	8	8	0	0	0
<b>RGB32</b>	4	8	0	3	3	2
<b>ARGB2</b>	5	8	2	2	2	2
<b>ARGB4</b>	6	16	4	4	4	4
<b>RGB565</b>	7	16	0	5	6	5
<b>TEXT8X8</b>	9	-	-	-	-	-
<b>TEXTVGA</b>	10	-	-	-	-	-
<b>BARGRAPH</b>	11	-	-	-	-	-
<b>PALETTED565</b>	14	8	0	5	6	5
<b>PALETTED4444</b>	15	8	4	4	4	4
<b>PALETTED8</b>	16	8	8	8	8	8
<b>L2</b>	17	2	2	0	0	0
<b>GLFORMAT</b>	31	<b>Check BITMAP_EXT_FORMAT</b>				

Table 13 – BITMAP\_LAYOUT Format List

Examples of various supported bitmap formats (except **TEXTVGA**) are shown as below:



**BARGRAPH** – render data as a bar graph. Looks up the x coordinate in a byte array, then gives an opaque pixel if the byte value is less than y, otherwise a transparent pixel. The result is a bar graph of the bitmap data. A maximum of 256x256 size bitmap can be drawn using the BARGRAPH format. Orientation, width and height of the graph can be altered using the bitmap transform matrix.

**TEXT8X8** – lookup in a fixed 8x8 font. The bitmap is a byte array present in the graphics ram and each byte indexes into an internal 8x8 CP437<sup>1</sup> font (built-in bitmap handles 16 & 17 are used for drawing TEXT8X8 format). The result is that the bitmap acts like a character grid. A single bitmap can be drawn which covers all or part of the display; each byte in the bitmap data corresponds to one 8x8 pixel character cell.

**TEXTVGA** – lookup in a fixed 8x16 font with TEXTVGA syntax. The bitmap is a TEXTVGA array present in the graphics ram, each element indexes into an internal 8x16 CP437 font (built-in bitmap handles 18 & 19 are used for drawing TEXTVGA format with control information such as background color, foreground color and cursor etc.). The result is that the bitmap acts like a TEXTVGA grid. A single bitmap can be drawn which covers all or part of the display; each TEXTVGA data type in the bitmap corresponds to one 8x16 pixel character cell.

**linestride** – Bitmap line strides, in bytes. This represents the amount of memory used for each line of bitmap pixels.

<sup>1</sup> [https://en.wikipedia.org/wiki/Code\\_page\\_437](https://en.wikipedia.org/wiki/Code_page_437)

For **L1**, **L2**, **L4** format, the necessary data has to be padded to make it byte aligned. Normally, it can be calculated with the following formula:

$$\text{linestride} = \text{width} * \text{byte/pixel}$$

For example, if one bitmap is 64x32 pixels in L4 format, the line stride shall be  
 $(64 * 1/2 = 32)$

**height** - Bitmap height, in lines

### Description

For more details about memory layout according to pixel format, refer to the figures below:

<b>L1 Format</b>							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Pixel 0	Pixel 1	Pixel 2	Pixel 3	Pixel 4	Pixel 5	Pixel 6	Pixel 7

<b>L2 Format</b>							
Bit 7	6	Bit 5	4	Bit 3	2	Bit 1	0
Pixel 0		Pixel 1			Pixel 2		Pixel 3

<b>L4 Format</b>							
7			4	3			0
Pixel 0						Pixel 1	

<b>L8 Format</b>							
7							0
Pixel 0						Pixel 1	

**Table 14 – L1/L2/L4/L8 Pixel Format**

<b>ARGB2 Format</b>							
7	6	5	4	3	2	1	0
Alpha Chanel		Red Channel		Green Channel		Blue Channel	

### RGB332 Format

7	5	4	2	1	0
Red Channel		Green Channel		Blue Channel	

**Table 15 – ARGB2/RGB332 Pixel Format**

<b>RGB565/PALETTED565 Format</b>							
15	11	10	8	7	5	4	0
Red Channel		Green Channel		Blue Channel			

**Table 16 – RGB565/PALETTED565 Pixel Format**

<b>ARGB1555 Format</b>							
15	14	10	9	8	7	5	4
Alpha Chanel		Red Channel		Green Channel		Blue Channel	

### ARGB4/PALETTED4444 Format

15	12	11	8	7	4	3	0
Alpha Chanel		Red Channel		Green Channel		Blue Channel	

**Table 17 – ARGB1555/ARGB4/PALETTED4444 Pixel Format**

PALETTED8 Format							
31	24	23	16	15	8	7	0
Alpha Chanel		Red Channel		Green Channel		Blue Channel	

**Table 18 – PALETTED8 Pixel Format**

## Graphics Context

None

**Note:** **PALETTED8** format is supported indirectly and it is different from **PALETTED** format in FT80X. To render Alpha, Red, Green and Blue channels, multi-pass drawing action is required.

The following display list snippet shows:

```
//addr_pal is the starting address of palette lookup table in RAM_G
//bitmap source(palette indices) is starting from address 0

dl(BITMAP_HANDLE(0))
dl(BITMAP_LAYOUT(PALETTED8, width, height))
dl(BITMAP_SIZE(NEAREST, BORDER, BORDER, width, height))

dl(BITMAP_SOURCE(0)) //bitmap source(palette indices)

dl(BEGIN(BITMAPS))
dl(BLEND_FUNC(ONE, ZERO))

//Draw Alpha channel
dl(COLOR_MASK(0,0,0,1))
dl(PALETTE_SOURCE(addr_pal+3))
dl(VERTEX2II(0, 0, 0, 0))

//Draw Red channel
dl(BLEND_FUNC(DST_ALPHA, ONE_MINUS_DST_ALPHA))
dl(COLOR_MASK(1,0,0,0))
dl(PALETTE_SOURCE(addr_pal+2))
dl(VERTEX2II(0, 0, 0, 0))

//Draw Green channel
dl(COLOR_MASK(0,1,0,0))
dl(PALETTE_SOURCE(addr_pal + 1))
dl(VERTEX2II(0, 0, 0, 0))

//Draw Blue channel
dl(COLOR_MASK(0,0,1,0))
dl(PALETTE_SOURCE(addr_pal))
dl(VERTEX2II(0, 0, 0, 0))
```

**Code Snippet 10 – PALETTED8 Drawing Example**

## See also

[BITMAP HANDLE](#), [BITMAP SIZE](#), [BITMAP SOURCE](#), [PALETTE SOURCE](#)

## 4.9 BITMAP\_LAYOUT\_H

Specify the 2 most significant bits of the source bitmap memory format and layout for the current handle.

### Encoding

31	24	23		4	3	2	1	0
<b>0x28</b>			<b>reserved</b>			<b>linestride</b>	<b>height</b>	

### Parameters

#### **linestride**

The 2 most significant bits of the 12-bit line stride parameter value specified to **BITMAP\_LAYOUT**.

#### **height**

The 2 most significant bits of the 11-bit height parameter value specified to **BITMAP\_LAYOUT**.

### Description

This command is the extension command of **BITMAP\_LAYOUT** for bitmap larger than 511 by 511 pixels.

### Examples

NA

### See also

[BITMAP\\_LAYOUT](#)

## 4.10 BITMAP\_SIZE

Specify the screen drawing of bitmaps for the current handle

### Encoding

31	24	23	21	20	19	18	17	9	8	0
<b>0x08</b>		<b>reserved</b>	<b>filter</b>	<b>wrapx</b>	<b>wrappy</b>		<b>width</b>		<b>height</b>	

### Parameters

#### **filter**

Bitmap filtering mode, one of NEAREST or BILINEAR.

The value of NEAREST is 0 and the value of BILINEAR is 1.

#### **wrapx**

Bitmap x wrap mode, one of REPEAT or BORDER

The value of BORDER is 0 and the value of REPEAT is 1.

#### **wrappy**

Bitmap y wrap mode, one of REPEAT or BORDER

The value of BORDER is 0 and the value of REPEAT is 1.

**width**

Drawn bitmap width, in pixels. From 1 to 511. Zero has special meaning.

**height**

Drawn bitmap height, in pixels. From 1 to 511. Zero has special meaning.

**Description**

This command controls the drawing of bitmaps: the on-screen size of the bitmap, the behavior for wrapping, and the filtering function. Please note that if wrapx or wrapy is **REPEAT** then the corresponding memory layout dimension (BITMAP\_LAYOUT line stride or height) must be power of two, otherwise the result is undefined.

For width and height, the value from 1 to 511 means the bitmap width and height in pixel. The value zero has the special meaning if there are no **BITMAP\_SIZE\_H** present before or a high bit in **BITMAP\_SIZE\_H** is zero: it means 2048 pixels, other than 0 pixels.

## 4.11 BITMAP\_SIZE\_H

Specify the 2 most significant bits of bitmaps dimension for the current handle.

**Encoding**

31	24	23		4	3	2	1	0
0x29			reserved		width	height		

**Parameters****width**

2 most significant bits of bitmap width. The initial value is zero.

**Height**

2 most significant bits of bitmap height. The initial value is zero.

**Description**

This command is the extension command of **BITMAP\_SIZE** for bitmap larger than 511 by 511 pixels.

**Graphics context**

None

**See also**

[BITMAP\\_HANDLE](#), [BITMAP\\_LAYOUT](#), [BITMAP\\_SOURCE](#), [BITMAP\\_SIZE](#)

## 4.12 BITMAP\_SOURCE

Specify the source address of bitmap data in **RAM\_G** or **flash memory**.

### Encoding

31	24	23	0
<b>0x01</b>			<b>addr</b>

### Parameters

#### addr

Bitmap address in **RAM\_G** or **flash memory**, aligned with respect to the bitmap format. For example, if the bitmap format is **RGB565/ARGB4/ARGB1555**, the bitmap source shall be aligned to 2 bytes.

### Description

The bitmap source address specifies the address of the bitmap graphic data. If bit 23 is 0, then bits 0-22 give the byte address in **RAM\_G**. If bit 23 is 1, then bits 0-22, multiplied by 32, specifies the byte address in external flash memory.

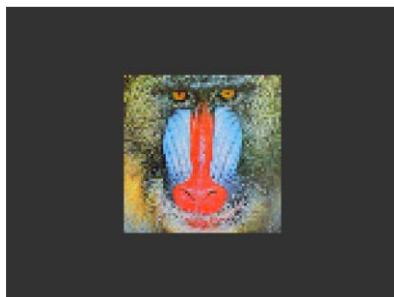
Note that in some rare cases when setting bitmap source address in **RAM\_G** where the bitmap source address may be negative (such as loading a font which begins at address **RAM\_G+0** and has pointer to raw data calculated to be negative) the value passed to **BITMAP\_SOURCE** should be masked so that only bits 0-22 are written to ensure that bit 23 is not written to 1.

For example, if **addr** is **(0x800000 | 422)**, the byte address in external flash memory refers to **13504(422\*32)**.

However, only bitmap data of ASTC specific format can be rendered directly from flash memory. For the bitmap data of any non-ASTC specific format in flash memory, **CMD\_FLASHREAD** is required to copy the data from flash into **RAM\_G** so that EVE can render it correctly.

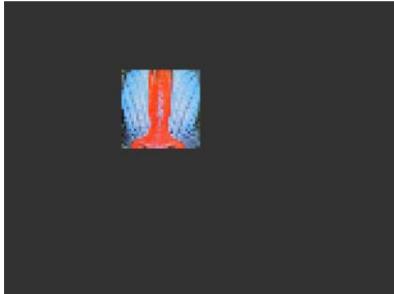
### Examples

Drawing a 64 x 64 bitmap, loaded at address 0:



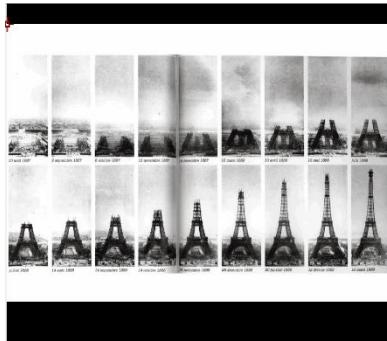
```
d1( BITMAP_SOURCE(0) );
d1( BITMAP_LAYOUT(RGB565, 128, 64) );
d1( BITMAP_SIZE(NEAREST, BORDER, BORDER,
64, 64) );
d1( BEGIN(BITMAPS) );
d1( VERTEX2II(48, 28, 0, 0) );
```

Using the same graphics data, but with source and size changed to show only a 32 x 32 detail:



```
d1( BITMAP_SOURCE(128 * 16 + 32) );
d1( BITMAP_LAYOUT(RGB565, 128, 64) );
d1( BITMAP_SIZE(NEAREST, BORDER, BORDER, 32,
32) );
d1( BEGIN(BITMAPS) );
d1( VERTEX2II(48, 28, 0, 0) );
```

Display one 800x480 image by using extended display list commands mentioned above:



```

dl (BITMAP_HANDLE(0));
dl (BITMAP_SOURCE(0));
dl (BITMAP_SIZE_H(1, 0));
dl (BITMAP_SIZE(NEAREST, BORDER, BORDER, 288,
480));
dl (BITMAP_LAYOUT_H(1, 0));
dl (BITMAP_LAYOUT(ARGB1555, 576, 480));
dl (BEGIN(BITMAPS));
dl (VERTEX2II(76, 25, 0, 0));
dl (END());

```

## Graphics context

None

## See also

[BITMAP\\_LAYOUT](#), [BITMAP\\_SIZE](#)

## 4.13 BITMAP\_SWIZZLE

Set the source for the red, green, blue and alpha channels of a bitmap.

### Encoding

31	24 23		12 11 9 8 6 5 3 2 0
<b>0x2f</b>		<b>reserved</b>	r g b a

### Parameters

**r**  
red component source channel

**g**  
green component source channel

**b**  
blue component source channel

**a**  
alpha component source channel

### Description

Bitmap swizzle allows the channels of the bitmap to be exchanged or copied into the final color channels. Each final color component can be sourced from any of the bitmap color components, or can be set to zero or one. Valid values for each source are:

Name	Value	Description
<b>ZERO</b>	<b>0</b>	Set the source channel to zero
<b>ONE</b>	<b>1</b>	Set the source channel to 1
<b>RED</b>	<b>2</b>	Specify <b>RED</b> component as source channel

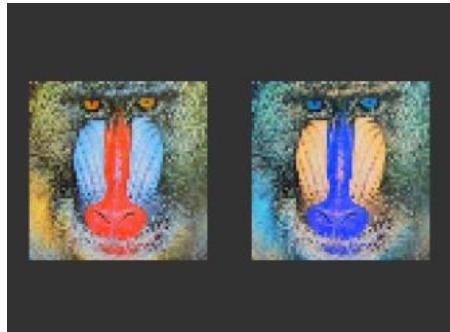
<b>GREEN</b>	<b>3</b>	Specify <b>GREEN</b> component as source channel
<b>BLUE</b>	<b>4</b>	Specify <b>BLUE</b> component as source channel
<b>ALPHA</b>	<b>5</b>	Specify <b>ALPHA</b> component as source channel

Bitmap swizzle is only applied when the format parameter of **BITMAP\_LAYOUT** is specified as **GLFORMAT**. Otherwise the four components are in their default order. The default swizzle is (RED, GREEN, BLUE, ALPHA)

**Note:** Please refer to OpenGL API specification for more details

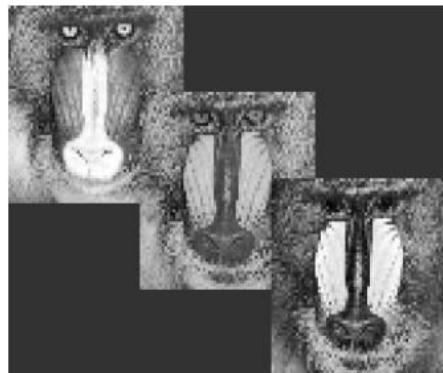
### Examples

Bitmap drawn with default swizzle, and with red/blue exchanged:



```
dl(BITMAP_SOURCE(0));
dl(BITMAP_LAYOUT(GLFORMAT, 128, 64));
dl(BITMAP_EXT_FORMAT(RGB565));
dl(BITMAP_SIZE(NEAREST, BORDER, BORDER, 64,
64));
dl(BEGIN(BITMAPS));
dl(BITMAP_SWIZZLE(RED,           GREEN,           BLUE,
ALPHA));
dl(VERTEX2II(8, 28, 0, 0));
dl(BITMAP_SWIZZLE(BLUE,           GREEN,           RED,
ALPHA));
dl(VERTEX2II(88, 28, 0, 0));
```

Red, green, and blue channels extracted to create three grayscale images:



```
dl(BITMAP_LAYOUT(GLFORMAT, 128, 64));
dl(BITMAP_EXT_FORMAT(RGB565));
dl(BEGIN(BITMAPS));
dl(BITMAP_SWIZZLE(RED, RED, RED, ALPHA));
dl(VERTEX2II(0, 0, 0, 0));
dl(BITMAP_SWIZZLE(GREEN, GREEN, GREEN,
ALPHA));
dl(VERTEX2II(48, 28, 0, 0));
dl(BITMAP_SWIZZLE(BLUE, BLUE, BLUE,
ALPHA));
dl(VERTEX2II(96, 56, 0, 0));
```

### Graphics Context

None

### See also

None

## 4.14 BITMAP\_TRANSFORM\_A

Specify the A coefficient of the bitmap transform matrix.

### Encoding

31	24	23	18	17	16	0
<b>0x15</b>		<b>reserved</b>	<b>p</b>		<b>v</b>	

### Parameters

**p**

Precision control: 0 is 8.8, 1 is 1.15. The initial value is 0.

**v**

A component of the bitmap transform matrix, in signed 8.8 or 1.15 fixed point form. The initial value is 256.

**Note:** The parameters of this command are changed in BT81X.

### Description

BITMAP\_TRANSFORM\_A-F coefficients are used to perform bitmap transform functionalities such as scaling, rotation and translation. These are similar to OpenGL transform functionality.

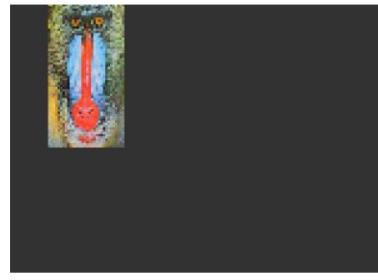
### Examples

A value of 0.5 (128) causes the bitmap appear double width:



```
dl( BITMAP_SOURCE(0) );
dl( BITMAP_LAYOUT(RGB565, 128, 64) );
dl( BITMAP_TRANSFORM_A(128) );
dl( BITMAP_SIZE(NEAREST, BORDER, BORDER, 128, 128) );
dl( BEGIN(BITMAPS) );
dl( VERTEX2II(16, 0, 0, 0) );
```

A value of 2.0 (512) gives a half-width bitmap:



```
dl( BITMAP_SOURCE(0) );
dl( BITMAP_LAYOUT(RGB565, 128, 64) );
dl( BITMAP_TRANSFORM_A(512) );
dl( BITMAP_SIZE(NEAREST, BORDER, BORDER, 128, 128) );
dl( BEGIN(BITMAPS) );
dl( VERTEX2II(16, 0, 0, 0) );
```

### Graphics Context

The value of p,v is part of the graphics context, as described in section 4.1

### See also

None

## 4.15 BITMAP\_TRANSFORM\_B

Specify the b coefficient of the bitmap transform matrix

### Encoding

31	24	23	18	17	16	0
<b>0x16</b>		<b>reserved</b>	<b>p</b>		<b>v</b>	

### Parameters

#### **p**

Precision control: 0 is 8.8, 1 is 1.15. The initial value is 0.

#### **v**

The component of the bitmap transform matrix, in signed 8.8 or 1.15 fixed point form. The initial value is 0.

### Description

BITMAP\_TRANSFORM\_A-F coefficients are used to perform bitmap transform functionalities such as scaling, rotation and translation. These are similar to OpenGL transform functionality.

**Note:** The parameters of this command are changed in BT81X.

### Graphics context

The value of p, v is part of the graphics context, as described in section 4.1.

### See also

None

## 4.16 BITMAP\_TRANSFORM\_C

Specify the c coefficient of the bitmap transform matrix

### Encoding

31	24 23	0
<b>0x17</b>		<b>c</b>

### Parameters

#### **c**

The c component of the bitmap transform matrix, in signed 15.8 bit fixed-point form. The initial value is 0.

### Description

BITMAP\_TRANSFORM\_A-F coefficients are used to perform bitmap transform functionalities such as scaling, rotation and translation. These are similar to OpenGL transform functionality.

### Graphics context

The value of c is part of the graphics context, as described in section 4.1.

### See also

None

## 4.17 BITMAP\_TRANSFORM\_D

Specify the d coefficient of the bitmap transform matrix

### Encoding

31	24	23	18	17	16	0
<b>0x18</b>		<b>reserved</b>	<b>p</b>		<b>v</b>	

### Parameters

**p**

Precision control: 0 is 8.8, 1 is 1.15. The initial value is 0.

**v**

The d component of the bitmap transform matrix, in signed 8.8 or 1.15 fixed point form. The initial value is 0.

**Note:** The parameters of this command are changed in BT81X.

### Description

BITMAP\_TRANSFORM\_A-F coefficients are used to perform bitmap transform functionalities such as scaling, rotation and translation. These are similar to OpenGL transform functionality.

### Graphics context

The value of p,v of the graphics context, as described in section [4.1](#).

### See also

None

## 4.18 BITMAP\_TRANSFORM\_E

Specify the E coefficient of the bitmap transform matrix.

### Encoding

31	24	23	18	17	16	0
<b>0x19</b>		<b>reserved</b>	<b>p</b>		<b>v</b>	

### Parameters

**p**

Precision control: 0 is 8.8, 1 is 1.15. The initial value is 0.

**v**

The e component of the bitmap transform matrix, in signed 8.8 or 1.15 fixed point form. The initial value is 256.

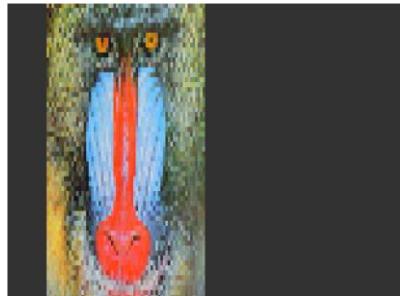
### Description

BITMAP\_TRANSFORM\_A-F coefficients are used to perform bitmap transform functionalities such as scaling, rotation and translation. These are similar to OpenGL transform functionality.

**Note:** The parameters of this command are changed in BT81X.

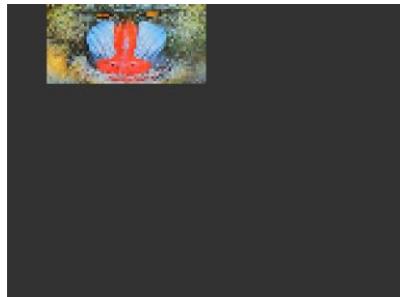
## Examples

A value of 0.5 (128) causes the bitmap appear double height:



```
dl( BITMAP_SOURCE(0) );
dl( BITMAP_LAYOUT(RGB565, 128, 64) );
dl( BITMAP_TRANSFORM_E(128) );
dl( BITMAP_SIZE(NEAREST, BORDER, BORDER, 128,
128) );
dl( BEGIN(BITMAPS) );
dl( VERTEX2II(16, 0, 0, 0) );
```

A value of 2.0 (512) gives a half-height bitmap:



```
dl( BITMAP_SOURCE(0) );
dl( BITMAP_LAYOUT(RGB565, 128, 64) );
dl( BITMAP_TRANSFORM_E(512) );
dl( BITMAP_SIZE(NEAREST, BORDER, BORDER, 128,
128) );
dl( BEGIN(BITMAPS) );
dl( VERTEX2II(16, 0, 0, 0) );
```

## Graphics context

The value of p and v of the graphics context, as described in section [4.1](#)

### See also

None

## 4.19 BITMAP\_TRANSFORM\_F

Specify the f coefficient of the bitmap transform matrix

### Encoding

31	24	23	0
<b>0x1A</b>		<b>f</b>	

### Parameters

**f**

The f component of the bitmap transform matrix, in signed 15.8 bit fixed-point form. The initial value is 0.

### Description

**BITMAP\_TRANSFORM\_A-F** coefficients are used to perform bitmap transform functionalities such as scaling, rotation and translation. These are similar to **OpenGL** transformation functionality.

### Graphics context

The value of f is part of the graphics context, as described in section [4.1](#).

## See also

None

## 4.20 BLEND\_FUNC

Specify pixel arithmetic

### Encoding

31	24	23		6	5	32	0
<b>0x0B</b>			<b>reserved</b>		<b>src</b>	<b>dst</b>	

### Parameters

#### src

Specifies how the source blending factor is computed. One of ZERO, ONE, SRC\_ALPHA, DST\_ALPHA, ONE\_MINUS\_SRC\_ALPHA or ONE\_MINUS\_DST\_ALPHA. The initial value is SRC\_ALPHA (2).

#### dst

Specifies how the destination blending factor is computed, one of the same constants as src. The initial value is ONE\_MINUS\_SRC\_ALPHA(4)

Name	Value	Description
ZERO	0	Check OpenGL definition
ONE	1	Check OpenGL definition
SRC_ALPHA	2	Check OpenGL definition
DST_ALPHA	3	Check OpenGL definition
ONE_MINUS_SRC_ALPHA	4	Check OpenGL definition
ONE_MINUS_DST_ALPHA	5	Check OpenGL definition

**Table 19 – BLEND\_FUNC Constant Value Definition**

### Description

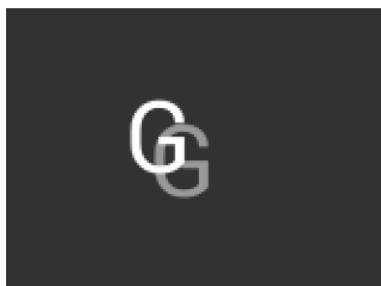
The blend function controls how new color values are combined with the values already in the color buffer. Given a pixel value source and a previous value in the color buffer destination, the computed color is:

$$\text{source} \times \text{src} + \text{destination} \times \text{dst}$$

For each color channel: red, green, blue and alpha.

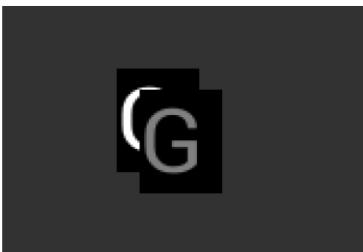
### Examples

The default blend function of (SRC\_ALPHA, ONE\_MINUS\_SRC\_ALPHA) causes drawing to overlay the destination using the alpha value:



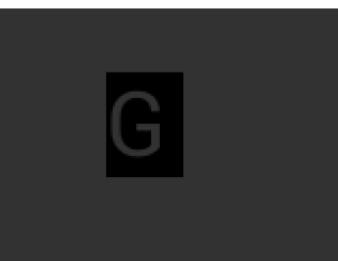
```
dl( BEGIN(BITMAPS) );
dl( VERTEX2II(50, 30, 31, 0x47) );
dl( COLOR_A( 128 ) );
dl( VERTEX2II(60, 40, 31, 0x47) );
```

A destination factor of zero means that destination pixels are not used:



```
dl( BEGIN(BITMAPS) );
dl( BLEND_FUNC(SRC_ALPHA, ZERO) );
dl( VERTEX2II(50, 30, 31, 0x47) );
dl( COLOR_A( 128 ) );
dl( VERTEX2II(60, 40, 31, 0x47) );
```

Using the source alpha to control how much of the destination to keep:



```
dl( BEGIN(BITMAPS) );
dl( BLEND_FUNC(ZERO, SRC_ALPHA) );
dl( VERTEX2II(50, 30, 31, 0x47) );
```

### Graphics context

The values of src and dst are part of the graphics context, as described in section [4.1](#).

### See also

[COLOR\\_A](#)

## 4.21 CALL

Execute a sequence of commands at another location in the display list

### Encoding

31	24 23	16 15	0
<b>0x1D</b>	<b>reserved</b>	<b>dest</b>	

### Parameters

#### dest

The offset of the destination address from **RAM\_DL** which the display command is to be switched. **EVE** has the stack to store the return address. To come back to the next command of source address, the **RETURN** command can help.

The valid range is from 0 to 8191.

### Description

CALL and RETURN have a 4 level stack in addition to the current pointer. Any additional CALL/RETURN done will lead to unexpected behavior.

### Graphics context

None

### See also

[JUMP, RETURN](#)

## 4.22 CELL

Specify the bitmap cell number for the **VERTEX2F** command.

### Encoding

31	24 23		7	6	0
<b>0x06</b>		<b>reserved</b>		<b>cell</b>	

### Parameters

#### cell

bitmap cell number. The initial value is 0

### Graphics context

The value of cell is part of the graphics context, as described in section [4.1](#).

### See also

None

## 4.23 CLEAR

Clear buffers to preset values

### Encoding

31	24 23		3	2	1	0
<b>0x26</b>		<b>reserved</b>		<b>c</b>	<b>s</b>	<b>t</b>

### Parameters

#### c

Clear color buffer. Setting this bit to 1 will clear the color buffer to the preset value. Setting this bit to 0 will maintain the color buffer with an unchanged value. The preset value is defined in command **CLEAR\_COLOR\_RGB** for RGB channel and **CLEAR\_COLOR\_A** for alpha channel.

#### s

Clear stencil buffer. Setting this bit to 1 will clear the stencil buffer to the preset value. Setting this bit to 0 will maintain the stencil buffer with an unchanged value. The preset value is defined in command **CLEAR\_STENCIL**.

#### t

Clear tag buffer. Setting this bit to 1 will clear the tag buffer to the preset value. Setting this bit to 0 will maintain the tag buffer with an unchanged value. The preset value is defined in command **CLEAR\_TAG**.

### Description

The scissor test and the buffer write masks affect the operation of the clear. Scissor limits the cleared rectangle, and the buffer write masks limit the affected buffers. The state of the alpha function, blend function, and stenciling do not affect the clear.

## Examples

To clear the screen to bright blue:



```
dl( CLEAR_COLOR_RGB(0, 0, 255) );
dl( CLEAR(1, 0, 0) );
```

To clear part of the screen to gray, part to blue using scissor rectangles:



```
dl( CLEAR_COLOR_RGB(100, 100, 100) );
dl( CLEAR(1, 1, 1) );
dl( CLEAR_COLOR_RGB(0, 0, 255) );
dl( SCISSOR_SIZE(30, 120) );
dl( CLEAR(1, 1, 1) );
```

## Graphics context

None

## See also

[CLEAR\\_COLOR\\_A](#), [CLEAR\\_STENCIL](#), [CLEAR\\_TAG](#), [CLEAR\\_COLOR\\_RGB](#)

## 4.24 CLEAR\_COLOR\_A

Specify clear value for the alpha channel

### Encoding

31	24	23	8	7	0
<b>0x0F</b>		<b>reserved</b>		<b>alpha</b>	

### Parameters

#### alpha

Alpha value used when the color buffer is cleared. The initial value is 0.

## Graphics context

The value of alpha is part of the graphics context, as described in section [4.1](#).

## See also

[CLEAR\\_COLOR\\_RGB](#), [CLEAR](#)

## 4.25 CLEAR\_COLOR\_RGB

Specify clear values for red, green and blue channels

### Encoding

31	24 23	16 15	8 7	0
<b>0x02</b>	<b>red</b>	<b>blue</b>	<b>green</b>	

### Parameters

#### red

Red value used when the color buffer is cleared. The initial value is 0.

#### green

Green value used when the color buffer is cleared. The initial value is 0.

#### blue

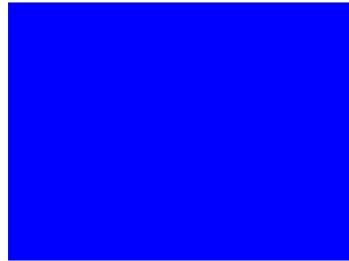
Blue value used when the color buffer is cleared. The initial value is 0.

### Description

Sets the color values used by a following **CLEAR**.

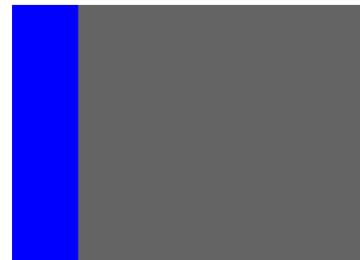
### Examples

To clear the screen to bright blue:



```
dl( CLEAR_COLOR_RGB(0, 0, 255) );
dl( CLEAR(1, 1, 1) );
```

To clear part of the screen to gray, part to blue using scissor rectangles:



```
dl( CLEAR_COLOR_RGB(100, 100, 100) );
dl( CLEAR(1, 1, 1) );
dl( CLEAR_COLOR_RGB(0, 0, 255) );
dl( SCISSOR_SIZE(30, 120) );
dl( CLEAR(1, 1, 1) );
```

### Graphics context

The values of red, green and blue are part of the graphics context, as described in section [4.1](#).

### See also

[CLEAR\\_COLOR\\_A](#), [CLEAR](#)

## 4.26 CLEAR\_STENCIL

Specify clear value for the stencil buffer

### Encoding

31	24	23	8	7	0
<b>0x11</b>		<b>reserved</b>		<b>s</b>	

### Parameters

**s**

Value used when the stencil buffer is cleared. The initial value is 0

### Graphics context

The value of s is part of the graphics context, as described in section [4.1](#).

### See also

[CLEAR](#)

## 4.27 CLEAR\_TAG

Specify clear value for the tag buffer

### Encoding

31	24	23	8	7	0
<b>0x12</b>		<b>reserved</b>		<b>t</b>	

### Parameters

**t**

Value used when the tag buffer is cleared. The initial value is 0.

### Graphics context

The value of s is part of the graphics context, as described in section [4.1](#).

### See also

[TAG](#), [TAG\\_MASK](#), [CLEAR](#)

## 4.28 COLOR\_A

Set the current color alpha

### Encoding

31	24	23	8	7	0
<b>0x10</b>		<b>reserved</b>		<b>alpha</b>	

### Parameters

**alpha**

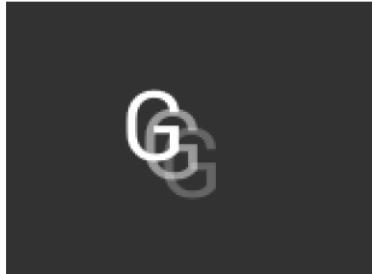
Alpha for the current color. The initial value is 255

## Description

Sets the alpha value applied to drawn elements – points, lines, and bitmaps. How the alpha value affects image pixels depends on BLEND\_FUNC; the default behavior is a transparent blend.

## Examples

Drawing three characters with transparency 255, 128, and 64:



```
dl( BEGIN(BITMAPS) );
dl( VERTEX2II(50, 30, 31, 0x47) );
dl( COLOR_A( 128 ) );
dl( VERTEX2II(58, 38, 31, 0x47) );
dl( COLOR_A( 64 ) );
dl( VERTEX2II(66, 46, 31, 0x47) );
```

## Graphics context

The value of alpha is part of the graphics context, as described in section [4.1](#).

## See also

[COLOR\\_RGB](#), [BLEND\\_FUNC](#)

## 4.29 COLOR\_MASK

Enable or disable writing of color components

### Encoding

31	24	23	4	3	2	1	0		
<b>0x20</b>			<b>reserved</b>			<b>r</b>	<b>g</b>	<b>b</b>	<b>a</b>

### Parameters

**r**

Enable or disable the red channel update of the color buffer. The initial value is 1 and means enable.

**g**

Enable or disable the green channel update of the color buffer. The initial value is 1 and means enable.

**b**

Enable or disable the blue channel update of the color buffer. The initial value is 1 and means enable.

**a**

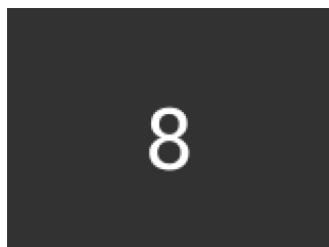
Enable or disable the alpha channel update of the color buffer. The initial value is 1 and means enable.

## Description

The color mask controls whether the color values of a pixel are updated. Sometimes it is used to selectively update only the red, green, blue or alpha channels of the image. More often, it is used to completely disable color updates while updating the tag and stencil buffers.

## Examples

Draw an '8' digit in the middle of the screen. Then paint an invisible 40-pixel circular touch area into the tag buffer:



```
dl( BEGIN(BITMAPS) );
dl( VERTEX2II(68, 40, 31, 0x38) );
dl( POINT_SIZE(40 * 16) );
dl( COLOR_MASK(0, 0, 0, 0) );
dl( BEGIN(POINTS) );
dl( TAG( 0x38 ) );
dl( VERTEX2II(80, 60, 0, 0) );
```

## Graphics context

The values of r, g, b and a are part of the graphics context, as described in section [4.1](#).

### See also

[TAG\\_MASK](#)

## 4.30 COLOR\_RGB

Set the current color red, green and blue.

### Encoding

31	24	23	16	15	8	7	0
<b>0x04</b>		<b>red</b>		<b>blue</b>		<b>green</b>	

### Parameters

#### red

Red value for the current color. The initial value is 255

#### green

Green value for the current color. The initial value is 255

#### blue

Blue value for the current color. The initial value is 255

### Description

Sets the red, green and blue values of the color buffer which will be applied to the following draw operation.

## Examples

Drawing three characters with different colors:



```
dl( BEGIN(BITMAPS) );
dl( VERTEX2II(50, 38, 31, 0x47) );
dl( COLOR_RGB( 255, 100, 50 ) );
dl( VERTEX2II(80, 38, 31, 0x47) );
dl( COLOR_RGB( 50, 100, 255 ) );
dl( VERTEX2II(110, 38, 31, 0x47) );
```

### Graphics context

The values of red, green and blue are part of the graphics context, as described in section [4.1](#).

### See also

[COLOR A](#)

## 4.31 DISPLAY

End the display list. All the commands following this command will be ignored.

### Encoding

31	24	23	0
0x0		<b>reserved</b>	

### Parameters

None

### Graphics context

None

### See also

None

## 4.32 END

End drawing a graphics primitive.

### Encoding

31	24	23	0
0x21		<b>reserved</b>	

### Parameters

None

### Description

It is recommended to have an **END** for each **BEGIN**. However, advanced users may avoid the usage of **END** in order to save space for extra graphics instructions in RAM\_DL.

### Graphics context

None

### See also

[BEGIN](#)

## 4.33 JUMP

Execute commands at another location in the display list

### Encoding

31	24 23	16 15	0
<b>0x1E</b>	<b>reserved</b>	<b>dest</b>	

### Parameters

#### dest

Display list address (offset from RAM\_DL) to be jumped. The valid range is from 0 to 8191.

### Graphics context

None

### See also

[CALL](#)

## 4.34 LINE\_WIDTH

Specify the width of lines to be drawn with primitive LINES in 1/16 pixel precision.

### Encoding

31	24 23	12 11	0
<b>0x0E</b>	<b>reserved</b>	<b>width</b>	

### Parameters

#### width

Line width in 1/16 pixel precision. The initial value is 16.

### Description

Sets the width of drawn lines. The width is the distance from the center of the line to the outermost drawn pixel, in units of 1/16 pixel. The valid range is from 1 to 4095. i.e. from 1 to 255 pixels.

Please note the LINE\_WIDTH command will affect the LINES, LINE\_STRIP, RECTS, EDGE\_STRIP\_A/B/R/L primitives.

**Note:** The lines are drawn with the requested width, but below around 6 the pixels get very dark and hard to see. Half pixel lines (width 8) are totally usable.

### Examples

The second line is drawn with a width of 80, for a 5 pixel radius:



```

dl( BEGIN(LINES) );
dl( VERTEX2F(16 * 10, 16 * 30) );
dl( VERTEX2F(16 * 150, 16 * 40) );
dl( LINE_WIDTH(80) );
dl( VERTEX2F(16 * 10, 16 * 80) );
dl( VERTEX2F(16 * 150, 16 * 90) );

```

### Graphics context

The value of width is part of the graphics context, as described in section [4.1](#).

### See also

None

## 4.35 MACRO

Execute a single command from a macro register.

### Encoding

31	24	23	10
<b>0x25</b>		<b>reserved</b>	<b>m</b>

### Parameters

**m**

Macro registers to read. Value 0 means the content in **REG\_MACRO\_0** is to be fetched and inserted in place. Value 1 means **REG\_MACRO\_1** is to be fetched and inserted in place. The content of **REG\_MACRO\_0** or **REG\_MACRO\_1** shall be a valid display list command, otherwise the behavior is undefined.

### Graphics context

None

### See also

None

## 4.36 NOP

No operation.

### Encoding

31	24	23	0
<b>0x2D</b>		<b>reserved</b>	

### Parameters

None

### Description

Does nothing. May be used as a spacer in display lists, if required.

### Graphics context

None

### See also

None

## 4.37 PALETTE\_SOURCE

Specify the base address of the palette.

### Encoding

31	24	23	22	21	0
<b>0x2A</b>	<b>reserved</b>			<b>addr</b>	

### Parameters

#### addr

Address of palette in **RAM\_G**, 2-byte alignment is required if pixel format is **PALETTE4444** or **PALETTE565**. The initial value is **RAM\_G**.

### Description

Specify the base address in **RAM\_G** for palette

### Graphics context

The value of addr is part of the graphics context

### See also

None

## 4.38 POINT\_SIZE

Specify the radius of points

### Encoding

31	24	23	13	12	0
<b>0x0D</b>		<b>reserved</b>		<b>size</b>	

### Parameters

#### size

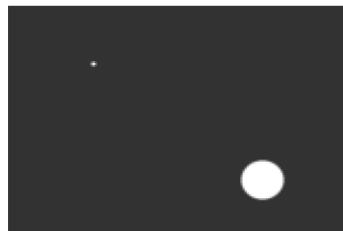
Point radius in 1/16 pixel precision. The initial value is 16. The valid range is from zero to 8191, i.e. from 0 to 511 pixels.

### Description

Sets the size of drawn points. The width is the distance from the center of the point to the outermost drawn pixel, in units of 1/16 pixels.

### Examples

The second point is drawn with a width of 160, for a 10 pixel radius:



```
d1( BEGIN(POINTS) );
d1( VERTEX2II(40, 30, 0, 0) );
d1( POINT_SIZE(160) );
d1( VERTEX2II(120, 90, 0, 0) );
```

## Graphics context

The value of size is part of the graphics context, as described in section [4.1](#).

### See also

None

## 4.39 RESTORE\_CONTEXT

Restore the current graphics context from the context stack.

### Encoding

31	24 23	0
<b>0x23</b>		<b>reserved</b>

### Parameters

None

### Description

Restores the current graphics context, as described in section [4.1](#). Four levels of **SAVE** and **RESTORE** stacks are available. Any extra **RESTORE\_CONTEXT** will load the default values into the present context.

### Examples

Saving and restoring context means that the second 'G' is drawn in red, instead of blue:



```
dl( BEGIN(BITMAPS) );
dl( COLOR_RGB( 255, 0, 0 ) );
dl( SAVE_CONTEXT() );
dl( COLOR_RGB( 50, 100, 255 ) );
dl( VERTEX2II(80, 38, 31, 0x47) );
dl( RESTORE_CONTEXT() );
dl( VERTEX2II(110, 38, 31, 0x47) );
```

## Graphics context

None

### See also

[SAVE\\_CONTEXT](#)

## 4.40 RETURN

Return from a previous **CALL** command.

### Encoding

31	24 23	0
<b>0x24</b>		<b>reserved</b>

### Parameters

None

### Description

**CALL** and **RETURN** have 4 levels of stack in addition to the current pointer. Any additional **CALL/RETURN** done will lead to unexpected behavior.

### Graphics context

None

### See also

[CALL](#)

## 4.41 SAVE\_CONTEXT

Push the current graphics context on the context stack

### Encoding

31	24 23	0
<b>0x22</b>		<b>reserved</b>

### Parameters

None

### Description

Saves the current graphics context, as described in section [4.1](#). Any extra **SAVE\_CONTEXT** will throw away the earliest saved context.

### Examples

Saving and restoring context means that the second 'G' is drawn in red, instead of blue:



```

dl( BEGIN(BITMAPS) );
dl( COLOR_RGB( 255, 0, 0 ) );
dl( SAVE_CONTEXT() );
dl( COLOR_RGB( 50, 100, 255 ) );
dl( VERTEX2II(80, 38, 31, 0x47) );
dl( RESTORE_CONTEXT() );
dl( VERTEX2II(110, 38, 31, 0x47)
);

```

## Graphics context

None

### See also

[RESTORE\\_CONTEXT](#)

## 4.42 SCISSOR\_SIZE

Specify the size of the scissor clip rectangle.

### Encoding

31	24	23	12	11	0
<b>0x1C</b>			<b>width</b>		<b>height</b>

### Parameters

#### width

The width of the scissor clip rectangle, in pixels. The initial value is 2048.  
The value of zero will cause zero output on screen.  
The valid range is from zero to 2048.

#### height

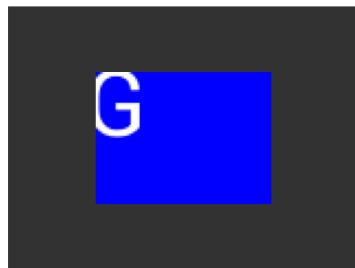
The height of the scissor clip rectangle, in pixels. The initial value is 2048.  
The value of zero will cause zero output on screen.  
The valid range is from zero to 2048.

### Description

Sets the width and height of the scissor clip rectangle, which limits the drawing area.

### Examples

Setting a 40 x 30 scissor rectangle clips the clear and bitmap drawing:



```
dl( SCISSOR_XY(40, 30) );
dl( SCISSOR_SIZE(80, 60) );
dl( CLEAR_COLOR_RGB(0, 0, 255) );
dl( CLEAR(1, 1, 1) );
dl( BEGIN(BITMAPS) );
dl( VERTEX2II(35, 20, 31, 0x47) );
```

### Graphics context

The values of width and height are part of the graphics context [4.1](#).

### See also

None

## 4.43 SCISSOR\_XY

Specify the top left corner of the scissor clip rectangle.

### Encoding

31	24	23	22	21	11	10	0
<b>0x1B</b>	<b>reserved</b>			<b>x</b>		<b>y</b>	

### Parameters

**x**

The unsigned x coordinate of the scissor clip rectangle, in pixels. The initial value is 0. The valid range is from zero to 2047.

**y**

The unsigned y coordinates of the scissor clip rectangle, in pixels. The initial value is 0. The valid range is from zero to 2047.

### Description

Sets the top-left position of the scissor clip rectangle, which limits the drawing area.

### Examples

Setting a 40 x 30 scissor rectangle clips the clear and bitmap drawing:



```
dl( SCISSOR_XY(40, 30) );
dl( SCISSOR_SIZE(80, 60) );
dl( CLEAR_COLOR_RGB(0, 0, 255) );
dl( CLEAR(1, 1, 1) );
dl( BEGIN(BITMAPS) );
dl( VERTEX2II(35, 20, 31, 0x47) );
```

### Graphics context

The values of x and y are part of the graphics context 4.1

### See also

None

## 4.44 STENCIL\_FUNC

Set function and reference value for stencil testing.

### Encoding

31	24 23	20 19	16 15	8 7	0
<b>0x0A</b>	<b>reserved</b>	<b>func</b>		<b>ref</b>	<b>mask</b>

### Parameters

#### func

Specifies the test function, one of **NEVER**, **LESS**, **LEQUAL**, **GREATER**, **GEQUAL**, **EQUAL**, **NOTEQUAL**, or **ALWAYS**. The initial value is **ALWAYS**.

About the value of these constants, refer to **ALPHA\_FUNC**.

#### ref

Specifies the reference value for the stencil test. The initial value is 0.

#### mask

Specifies a mask that is ANDed with the reference value and the stored stencil value. The initial value is 255

### Description

Stencil test rejects or accepts pixels depending on the result of the test function defined in func parameter, which operates on the current value in the stencil buffer against the reference value.

### Examples

Refer to [STENCIL\\_OP](#).

### Graphics context

The values of func, ref and mask are part of the graphics context, as described in section [4.1](#).

### See also

[STENCIL\\_OP](#), [STENCIL\\_MASK](#)

## 4.45 STENCIL\_MASK

Control the writing of individual bits in the stencil planes

### Encoding

31	24 23	8 7	0
<b>0x13</b>	<b>reserved</b>		<b>mask</b>

### Parameters

#### mask

The mask used to enable writing stencil bits. The initial value is 255

### Graphics context

The value of mask is part of the graphics context, as described in section [4.1](#).

## See also

[STENCIL\\_FUNC, STENCIL\\_OP, TAG\\_MASK](#)

## 4.46 STENCIL\_OP

Set stencil test actions.

### Encoding

31	24	23	6	5	3	2	0
0x0C			reserved			sfail	spass

### Parameters

#### sfail

Specifies the action to take when the stencil test fails, one of KEEP, ZERO, REPLACE, INCR, DECR, and INVERT. The initial value is KEEP (1)

#### spass

Specifies the action to take when the stencil test passes, one of the same constants as sfail. The initial value is KEEP (1)

Name	Value	Description
ZERO	0	check OpenGL definition
KEEP	1	check OpenGL definition
REPLACE	2	check OpenGL definition
INCR	3	check OpenGL definition
DECR	4	check OpenGL definition
INVERT	5	check OpenGL definition

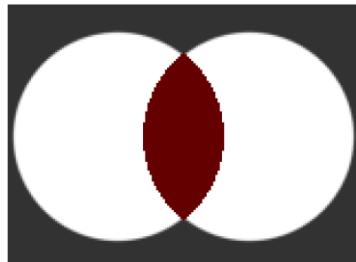
**Table 20 – STENCIL\_OP Constants Definition**

### Description

The stencil operation specifies how the stencil buffer is updated. The operation selected depends on whether the stencil test passes or not.

### Examples

Draw two points, incrementing stencil at each pixel, then draw the pixels with value 2 in red:



```
dl( STENCIL_OP(INCR, INCR) );
dl( POINT_SIZE(760) );
dl( BEGIN(POINTS) );
dl( VERTEX2II(50, 60, 0, 0) );
dl( VERTEX2II(110, 60, 0, 0) );
dl( STENCIL_FUNC(EQUAL, 2, 255) );
dl( COLOR_RGB(100, 0, 0) );
dl( VERTEX2II(80, 60, 0, 0) );
```

### Graphics context

The values of sfail and spass are part of the graphics context, as described in section [4.1](#).

### See also

[STENCIL FUNC, STENCIL MASK](#)

## 4.47 TAG

Attach the tag value for the following graphics objects drawn on the screen. The initial tag buffer value is 255.

### Encoding

31	24	23	8	7	0
<b>0x03</b>		<b>reserved</b>		<b>s</b>	

### Parameters

**s**

Tag value. Valid value range is from 1 to 255.

### Description

The initial value of the tag buffer is specified by command **CLEAR\_TAG** and takes effect by issuing command **CLEAR**. The **TAG** command can specify the value of the tag buffer that applies to the graphics objects when they are drawn on the screen. This **TAG** value will be assigned to all the following objects, unless the **TAG\_MASK** command is used to disable it. Once the following graphics objects are drawn, they are attached with the tag value successfully. When the graphics objects attached with the tag value are touched, the register **REG\_TOUCH\_TAG** will be updated with the tag value of the graphics object being touched.

If there are no TAG commands in one display list, all the graphics objects rendered by the display list will report the tag value as 255 in **REG\_TOUCH\_TAG** when they are touched.

### Graphics context

The value of s is part of the graphics context, as described in section [4.1](#).

### See also

[CLEAR\\_TAG, TAG\\_MASK](#)

## 4.48 TAG\_MASK

Control the writing of the tag buffer

### Encoding

31	24	23	1	0
<b>0x14</b>		<b>reserved</b>		<b>mask</b>

### Parameters

**mask**

Allow updates to the tag buffer. The initial value is one and it means the tag buffer is updated with the value given by the TAG command. Therefore, the following graphics objects will be attached to the tag value given by the TAG command.

The value zero means the tag buffer is set as the default value, rather than the value given by **TAG** command in the display list.

## Description

Every graphics object drawn on screen is attached with the tag value which is defined in the tag buffer. The tag buffer can be updated by the **TAG** command.

The default value of the tag buffer is determined by **CLEAR\_TAG** and **CLEAR** commands. If there is no **CLEAR\_TAG** command present in the display list, the default value in tag buffer shall be 0.

**TAG\_MASK** command decides whether the tag buffer takes the value from the default value of the tag buffer or the TAG command of the display list.

## Graphics context

The value of mask is part of the graphics context, as described in section [4.1](#).

## See also

[TAG](#), [CLEAR\\_TAG](#), [STENCIL\\_MASK](#), [COLOR\\_MASK](#)

## 4.49 VERTEX2F

Start the operation of graphics primitives at the specified screen coordinate, in the pixel precision defined by **VERTEX\_FORMAT**.

## Encoding

31	30	29	15	14	0
<b>0x1</b>		<b>x</b>			<b>y</b>

## Parameters

**x**

Signed x-coordinate in units of pixel precision defined in command **VERTEX\_FORMAT**, which by default is 1/16 pixel precision.

**y**

Signed y-coordinate in units of pixel precision defined in command **VERTEX\_FORMAT**, which by default is 1/16 pixel precision.

## Description

The pixel precision depends on the value of **VERTEX\_FORMAT**. The maximum range of coordinates depends on pixel precision and is described in the **VERTEX\_FORMAT** instruction.

## Graphics context

None

## See also

[VERTEX FORMAT](#)

## 4.50 VERTEX2II

Start the operation of graphics primitive at the specified coordinates in pixel precision.

### Encoding

31	30 29	21 20	12 11	7 6	0
<b>0x2</b>	<b>x</b>	<b>y</b>	<b>handle</b>	<b>cell</b>	

### Parameters

#### x

X-coordinate in pixels, unsigned integer ranging from 0 to 511.

#### y

Y-coordinate in pixels, unsigned integer ranging from 0 to 511.

#### handle

Bitmap handle. The valid range is from 0 to 31.

#### cell

Cell number. Cell number is the index of the bitmap with same bitmap layout and format. For example, for handle 31, the cell 65 means the character "A" in built in font 31.

**Note:** The handle and cell parameters are ignored unless the graphics primitive is specified as bitmap by command **BEGIN(BITMAPS)**, prior to this command.

### Description

To draw the graphics primitives beyond the coordinate range [(0,0), (511, 511)], use VERTEX2F instead.

### Graphics context

None

### See also

[BITMAP\\_HANDLE](#), [CELL](#), [VERTEX2F](#)

## 4.51 VERTEX\_FORMAT

Set the precision of **VERTEX2F** coordinates.

### Encoding

31	24 23	32	0
<b>0x27</b>	<b>reserved</b>	<b>frac</b>	

### Parameters

#### frac

Number of fractional bits in X, Y coordinates. Valid range is from 0 to 4. The initial value is 4.

## Description

**VERTEX2F** uses 15 bit signed numbers for its (X,Y) coordinate. This command controls the interpretation of these numbers by specifying the number of fractional bits.

By varying the format, an application can trade range against precision.

Frac value	Unit of pixel precision	VERTEX2F range
0	1 pixel	-16384 to 16383
1	½ pixel	-8192 to 8191
2	¼ pixel	-4096 to 4095
3	1/8 pixel	-2048 to 2047
4	1/16 pixel	-1024 to 1023

**Table 21 – VERTEX\_FORMAT and Pixel Precision**

## Graphics context

The value of **frac** is part of the graphics context

## See also

[VERTEX2F](#), [VERTEX\\_TRANSLATE\\_X](#), [VERTEX\\_TRANSLATE\\_Y](#)

## 4.52 VERTEX\_TRANSLATE\_X

Specify the vertex transformations X translation component.

## Encoding

31	24	23	17	16	0
<b>0x2B</b>		<b>reserved</b>		<b>x</b>	

## Parameters

**x**

Signed x-coordinate in 1/16 pixel. The initial value is 0.

## Description

Specifies the offset added to vertex X coordinates. This command allows drawing to be shifted on the screen. It applies to both **VERTEX2F** and **VERTEX2II** commands.

## Graphics context

The value of x is part of the graphics context

## See also

NONE

## 4.53 VERTEX\_TRANSLATE\_Y

Specify the vertex transformation's Y translation component.

### Encoding

31	24 23	17 16	0
<b>0x2C</b>	<b>reserved</b>		<b>y</b>

### Parameters

#### y

Signed y-coordinate in 1/16 pixel. The initial value is 0

### Description

Specifies the offset added to vertex Y coordinates. This command allows drawing to be shifted on the screen. It applies to both **VERTEX2F** and **VERTEX2II** commands.

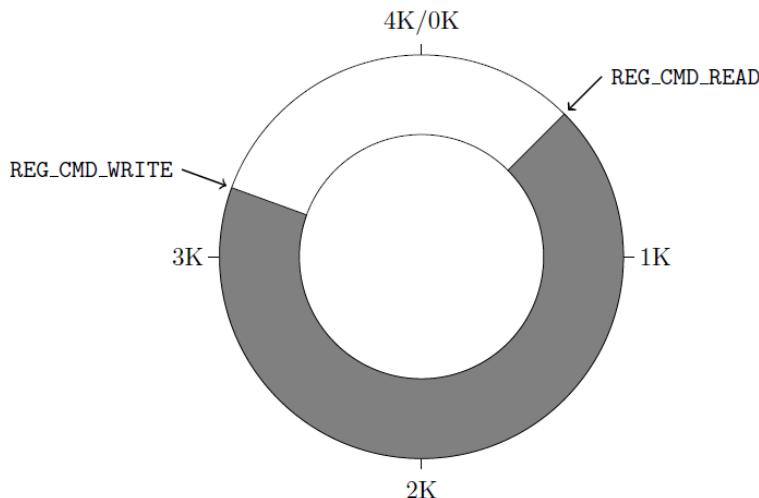
### Graphics context

The value of y is part of the graphics context

## 5 Coprocessor Engine

### 5.1 Command FIFO

The coprocessor engine is fed via a 4K byte **FIFO** called **RAM\_CMD**. The MCU writes coprocessor commands or display list commands into the **FIFO**, and the coprocessor engine reads and executes the commands. The MCU updates the register **REG\_CMD\_WRITE** to indicate that there are new commands in the **FIFO**, and the coprocessor engine updates **REG\_CMD\_READ** after the commands have been executed. Therefore, when **REG\_CMD\_WRITE** is equal to **REG\_CMD\_READ**, it indicates the **FIFO** is empty and all the commands are executed without error.



To compute the free space, the MCU can apply the following formula:

$$\begin{aligned} fullness &= (REG\_CMD\_WRITE - REG\_CMD\_READ) \bmod 4096 \\ free\ space &= (4096 - 4) - fullness; \end{aligned}$$

This calculation does not report 4096 bytes of free space, to prevent completely wrapping the circular buffer and making it appear empty.

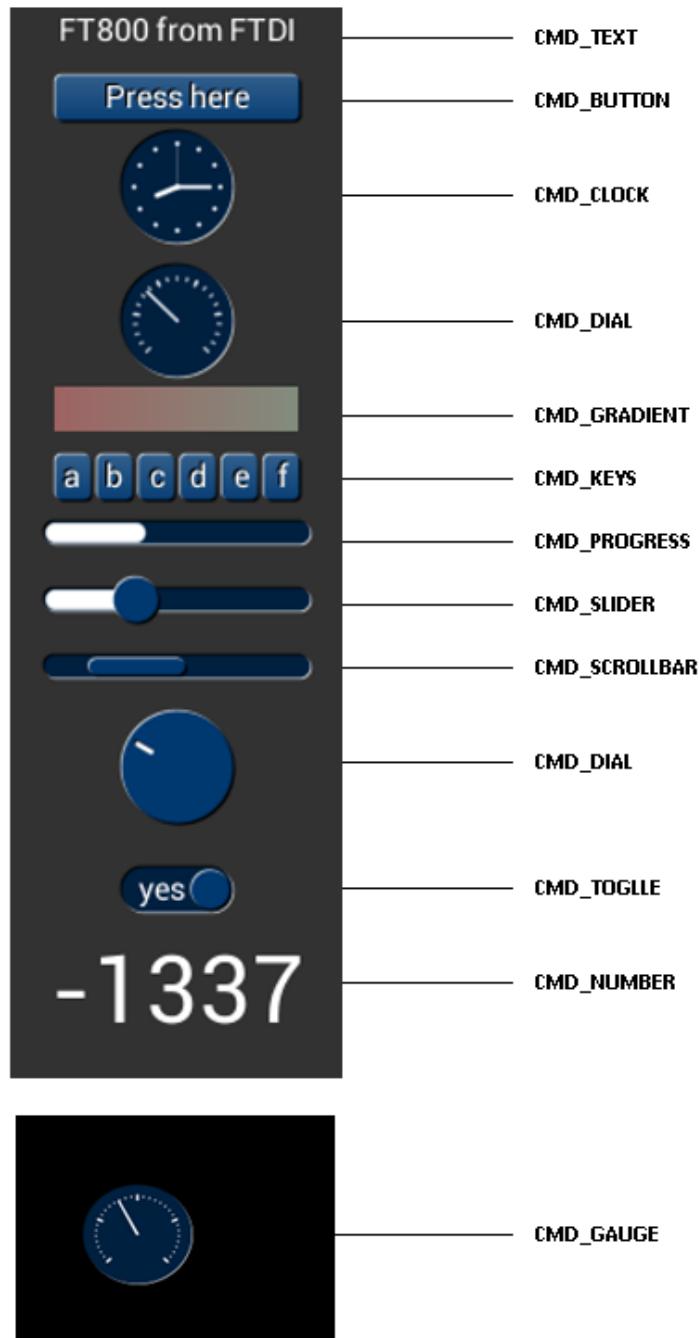
If enough space is available in the FIFO, the MCU writes the commands at the appropriate location in the **FIFO**, and then updates **REG\_CMD\_WRITE**. To simplify the MCU code, **EVE** automatically wraps continuous writes from the top address (**RAM\_CMD** + 4095) back to the bottom address (**RAM\_CMD** + 0) if the starting address of a write transfer is within **RAM\_CMD**.

FIFO entries are always 4 bytes wide – it is an error for either **REG\_CMD\_READ** or **REG\_CMD\_WRITE** to have a value that is not a multiple of 4 bytes. Each command issued to the coprocessor engine may take 1 or more words: the length depends on the command itself, and any appended data. Some commands are followed by variable-length data, so the command size may not be a multiple of 4 bytes. In this case the coprocessor engine ignores the extra 1, 2 or 3 bytes and continues reading the next command at the following 4 byte boundary.

To offload work from the MCU for checking the free space in the circular buffer, **EVE** offers a pair of registers **REG\_CMDB\_SPACE** and **REG\_CMDB\_WRITE**. It enables the MCU to write commands and data to the coprocessor in a bulk transfer, without computing the free space in the circular buffer and increasing the address. As long as the amount of data to be transferred is less than the value in the register **REG\_CMDB\_SPACE**, the MCU is able to safely write all the data to **REG\_CMDB\_WRITE** in one write transfer. All writes to **REG\_CMDB\_WRITE** are appended to the command **FIFO** and may be of any length that is a multiple of 4 bytes. To determine the free space of **FIFO**, reading **REG\_CMDB\_SPACE** and checking if it is equal to 4092 is easier and faster than comparing **REG\_CMD\_WRITE** and **REG\_CMD\_READ**.

## 5.2 Widgets

The Coprocessor engine provides pre-defined widgets for users to construct screen designs easily. The picture below illustrates the commands to render widgets and effects.



**Figure 3 – Widget List**

### 5.2.1 Common Physical Dimensions

This section contains the common physical dimensions of the widgets, unless it is specified in the widget introduction.

- All rounded corners have a radius that is computed from the font used for the widget (curvature of lowercase 'o' character).

$$\text{Radius} = \text{font height} * 3 / 16$$

- All 3D shadows are drawn with:
  - (1) Highlight offsets 0.5 pixels above and left of the object
  - (2) Shadow offsets 1.0 pixel below and right of the object.
- For widgets such as progress bar, scrollbar and slider, the output will be a vertical widget in the case where width and height parameters are of same value.

## 5.2.2 Color Settings

Coprocessor engine widgets are drawn with the color designated by the precedent commands: **CMD\_FGCOLOR**, **CMD\_BGCOLOR** and **COLOR\_RGB**. The coprocessor engine will determine to render the different areas of the widgets in different colors according to these commands.

Usually, **CMD\_FGCOLOR** affects the interaction area of coprocessor engine widgets if they are designed for interactive UI elements, for example, **CMD\_BUTTON**, **CMD\_DIAL**. **CMD\_BGCOLOR** applies the background color of widgets with the color specified. Please see the table below for more details.

Widget	CMD_FGCOLOR	CMD_BGCOLOR	COLOR_RGB
<b>CMD_TEXT</b>	NO	NO	YES
<b>CMD_BUTTON</b>	YES	NO	YES(label)
<b>CMD_GAUGE</b>	NO	YES	YES(needle and mark)
<b>CMD_KEYS</b>	YES	NO	YES(text)
<b>CMD_PROGRESS</b>	NO	YES	YES
<b>CMD_SCROLLBAR</b>	YES(Inner bar)	YES(Outer bar)	NO
<b>CMD_SLIDER</b>	YES(Knob)	YES(Right bar of knob)	YES(Left bar of knob)
<b>CMD_DIAL</b>	YES(Knob)	NO	YES(Marker)
<b>CMD_TOGGLE</b>	YES(Knob)	YES(Bar)	YES(Text)
<b>CMD_NUMBER</b>	NO	NO	YES
<b>CMD_CALIBRATE</b>	YES(Animating dot)	YES(Outer dot)	NO
<b>CMD_SPINNER</b>	NO	NO	YES

Table 22 – Widgets Color Setup Table

## 5.2.3 Caveat

The behavior of widgets is not defined if the parameter values are out of the valid range.

## 5.3 Interaction with RAM\_DL

If the coprocessor command is to generate respective display list commands, the coprocessor engine will write them to **RAM\_DL**. The current write location in **RAM\_DL** is held in the register **REG\_CMD\_DL**. Whenever the coprocessor engine writes a word to the display list, it increments the register **REG\_CMD\_DL**. The special command **CMD\_DLSTART** sets **REG\_CMD\_DL** to zero, for the start of a new display list.

All display list commands can also be written to command **FIFO**. The coprocessor engine has the intelligence to differentiate and copy them into the current display list location specified by **REG\_CMD\_DL**. For example, the following code snippet writes a small display list:

```
cmd(CMD_DLSTART); // start a new display list
cmd(CLEAR_COLOR_RGB(255, 100, 100)); // set clear color
cmd(CLEAR(1, 1, 1)); // clear screen

cmd(DISPLAY()); // display
```

Of course, this display list could have been written directly to RAM\_DL. The advantage of this technique is that you can mix low-level operations and high level coprocessor engine commands in a single stream:

```

cmd(CMD_DLSTART);                                // start a new display list
cmd(CLEAR_COLOR_RGB(255, 100, 100));            // set clear color
cmd(CLEAR(1, 1, 1));                            // clear screen
cmd_button(20, 20,                               // x, y
           60, 60,                                // width, height in pixels
           30,                                     // font 30
           0,                                      // default options
           "OK!");                                // Label of button
cmd(DISPLAY());                                 // Mark the end of display list

```

### 5.3.1 Synchronization between MCU & Coprocessor Engine

At some points, it is necessary to wait until the coprocessor engine has processed all outstanding commands. When the coprocessor engine completes the last outstanding command in the command buffer, it raises the **INT\_CMDEMPTY** interrupt. Another approach to detecting synchronization is that the MCU can poll **REG\_CMD\_READ** until it is equal to **REG\_CMD\_WRITE**.

One situation that requires synchronization is to read the value of **REG\_CMD\_DL**, when the MCU needs to do direct writes into the display list. In this situation the MCU should wait until the coprocessor engine is idle before reading **REG\_CMD\_DL**.

## 5.4 ROM and RAM Fonts

Fonts in **EVE** are treated as a set of bitmap-graphics with metrics block indexed by handles from 0 to 31. The following commands are using fonts:

- **CMD\_BUTTON**
- **CMD\_KEYS**
- **CMD\_TOGGLE**
- **CMD\_TEXT**
- **CMD\_NUMBER**

For any EVE series Ics **prior to** BT81X Series, only **ASCII** characters are possible to be displayed by the commands above. There is one font metrics block associated with each font, which is called "legacy font metrics block" below. With it, up to 128 characters for each font are ready to be used. In BT81X Series, extended font metrics block is introduced to support a full range of **Unicode** characters with **UTF-8** coding points (note: the **CMD\_KEYS** command does not support Unicode characters).

### 5.4.1 Legacy Font Metrics Block

For each font, there is one 148-bytes font metrics block associated with it.

The format of the 148-bytes font metrics block is as below:

Address	Size	Value	Description
p + 0	128	Width	width of each font character, in pixels
p + 128	4	Format	bitmap format as defined in <b>BITMAP_EXT_FORMAT</b> , except <b>TEXTVGA</b> , <b>TEXT8X8</b> , <b>BARGRAPH</b> and <b>PALETTED</b> formats.
P + 132	4	line stride	font bitmap line stride, in bytes
p + 136	4	pixel width	font screen width, in pixels
p + 140	4	pixel height	font screen height, in pixels
p + 144	4	Gptr	pointer to glyph data in memory

**Table 23 – Legacy Font Metrics Block**

For ROM fonts, these blocks are located in built-in **ROM**, in an array of length 19. The address of this array is held in ROM location **ROM\_FONTROOT**.

For custom fonts, these blocks shall be located in **RAM\_G**.

### 5.4.2 Example to find the width of character

To find the width of character 'g' (ASCII 0x67) in ROM font 34:

read 32-bit pointer *p* from **ROM\_FONTROOT**

widths = *p* + (148 \* (34 - 16)) (table starts at font 16)

read byte from memory at widths[0x67]

### 5.4.3 Extended Font Metrics Block

The extended font metrics block is a new feature introduced in **BT81X** series, which can handle fonts with a full range of **Unicode** code points. It shall reside at **RAM\_G**.

The font block is variable-sized, depending on the number of characters.

Address	Size	Value	Description
<i>p</i> + 0	4	signature	Must be <b>0x0100AAFF</b>
<i>p</i> + 4	4	size	Total size of the font block, in bytes
<i>p</i> + 8	4	format	Bitmap format, as defined in <b>BITMAP_EXT_FORMAT</b> , except TextVGA, Text8x8, BarGraph and Palettes formats.
<i>P</i> + 12	4	swizzle	Bitmap swizzle value, see <b>BITMAP_SWIZZLE</b>
<i>p</i> + 16	4	layout_width	Font bitmap line stride, in bytes
<i>p</i> + 20	4	layout_height	Font bitmap height, in pixels
<i>p</i> + 24	4	pixel_width	Font screen width, in pixels
<i>p</i> + 28	4	pixel_height	Font screen height, in pixels
<i>p</i> + 32	4	start_of_Graphic_data	Pointer to font graphic data in memory, including flash.
<i>P</i> + 36	4	number_of_characters	Total number of characters in font: <i>N</i> (multiple of 128)
<i>p</i> + 40	4 x [N/128]	gptr	Offsets to glyph data
<i>p</i> + 40 + 4 x [N/128]	4 x [N/128]	wptr	Offsets to width data
<i>p</i> + 40 + 8 x [N/128]	<i>N</i>	width_data	Width data, one byte per character

**Table 24 – Extended Font Metrics Block**

The table gptr contains offsets to graphic data. There is one offset for every 128 code points. The offsets are all relative to the start\_of\_graphic\_data. The start\_of\_graphic\_data may be an address in **RAM\_G** or flash, specified in the same way as **BITMAP\_SOURCE**. Similarly the table wptr contains offsets to width data, but the offsets are relative to *p*, the start of the font block itself. So to find the bitmap address and width of a code point *cp*, please refer to the pseudo-code below:

```

struct xfont {
    uint32_t signature,
    uint32_t size,
    uint32_t format,
    uint32_t swizzle,
    uint32_t layout_width,
    uint32_t layout_height,
    uint32_t pixel_width,
    uint32_t pixel_height,
    uint32_t start_of_graphic_data;
    uint32_t number_of_characters;
    uint32_t gptr[];
    uint32_t wptr[];
    uint8_t width_data[N];
};

uint32_t cp_address(xfont *xf, uint32_t cp)
{
    uint32_t bytes_per_glyph;
    bytes_per_glyph = xf->layout_width * xf->layout_height;

    if (xf->start_of_graphic_data >= 0x800000)
        //if the graphic data is in flash
        return (xf->start_of_graphic_data +
            xf->gptr[cp / 128] +
            bytes_per_glyph * (cp % 128) / 32);
    else
        //if the graphic data is in RAM_G
        return (xf->start_of_graphic_data +
            xf->gptr[cp / 128] +
            bytes_per_glyph * (cp % 128));
}

uint32_t cp_width(xfont *xf, uint32_t cp)
{
    return *(uint8_t*)xf +
        xf->wptr[cp / 128] +
        (cp % 128));
}

```

#### 5.4.4 ROM Fonts (Built-in Fonts)

In total, there are 19 **ROM** fonts numbered from 16 to 34.

By default, **ROM** fonts 16 to 31 are attached to bitmap handles 16 to 31 and users may use these fonts by specifying bitmap handle from 16 to 31.

To use ROM font 32 to 34, the user needs to call [CMD\\_ROMFONT](#) to assign the bitmap handle with the ROM font number. Refer to [CMD\\_ROMFONT](#) for more details. To reset ROM fonts to default bitmap handle, use [CMD\\_RESETFONTS](#).

For **ROM** fonts 16 to 34 (except 17 and 19), each font includes 95 printable **ASCII** characters from 0x20 to 0x7E inclusive. All these characters are indexed by its corresponding **ASCII** value. For ROM fonts 17 and 19, each font includes 127 printable **ASCII** characters from 0x80 to 0xFF, inclusive. All these characters are indexed using value from 0x0 to 0x7F, i.e., code 0 maps to **ASCII** character 0x80 and code 0x7F maps to **ASCII** character 0xFF. Users are required to handle this mapping manually.

The picture below shows the **ROM** font effects:

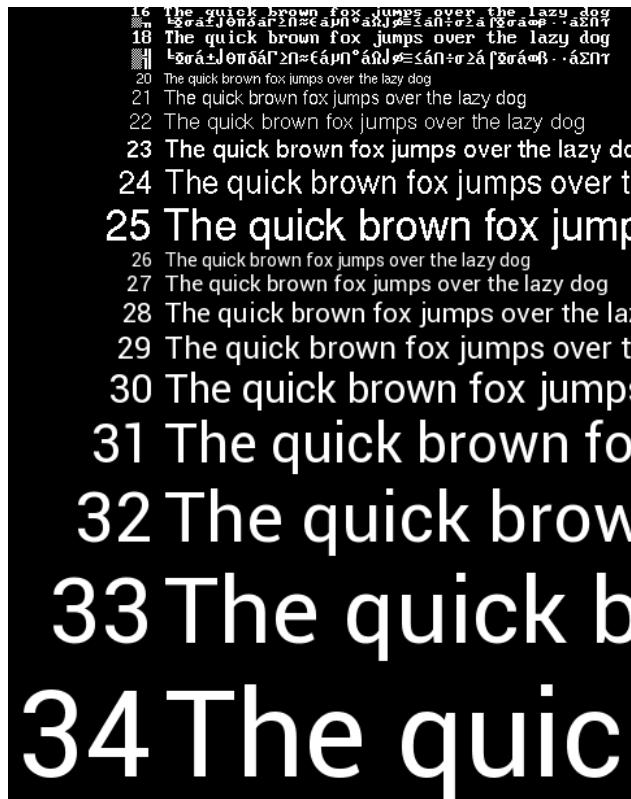


Figure 4 – ROM Font List

#### 5.4.5 Using Custom Font

Users can define custom fonts by following the steps below:

- Select a bitmap handle 0-31
- Load the font bitmap(glyph) into **RAM\_G** or **flash memory**
- Create or load a font metrics block in **RAM\_G**

Then either:

1. Set up bitmap parameters by using display list command:
    - **BITMAP\_SOURCE**,
    - **BITMAP\_LAYOUT/BITMAP\_LAYOUT\_H**,
    - **BITMAP\_SIZE/BITMAP\_SIZE\_H**
    - **BITMAP\_EXT\_FORMAT** if font is based on ASTC format bitmaps
- or:
- using the coprocessor command **CMD\_SETBITMAP**.
2. Use command **CMD\_SETFONT** to register the new font with the handle 0-31
- or:
- Use command **CMD\_SETFONT2** to register the new font with the handle 0-31.  
**(Recommended method)**

After this setup, the font's handle 0-31 can be used as a font argument of coprocessor commands.

## 5.5 Animation support

Based on **ASTC** format of bitmap data, BT81X can play back the animation efficiently with minimum **MCU** effort and memory usage. To achieve that, the animation data and object are defined. The utility has been provided to generate these animation assets.

The animation data consists of a sequence of display list fragments. Each fragment must be 64-byte aligned, and has a length that is a multiple of 4. The animation object is also 64-byte aligned, and contains:

- a signature
- a frame count
- an array of references to the display list fragments.

```
// A fragment is: a pointer to display list data, and a size
struct fragment {
    uint32_t nbytes; // must be 4-byte aligned
    uint32_t ptr;    // must be 64-byte aligned
};

struct animation_header {
    uint32_t signature; // always ANIM_SIGNATURE (0xAAAA0100)
    uint32_t num_frames;
    struct fragment table[num_frames];
};
```

Note that a fragment can appear multiple times in a table, for example for animation that is slower than the frame rate. Fragments contain regular display list commands. The fragment code is appended to the display list as follows in order that the fragment can:

1. change graphics state,
2. load and use any bitmaps using the current bitmap handle.

Typically the bitmap data for a fragment also resides in flash and a typical display list to show the fragment is as below:

```
SAVE_CONTEXT
BITMAP_HANDLE(scratch_handle)
<fragment>
RESTORE_CONTEXT
```

Animations can run in channels. A channel keeps track of the animation state. There are 32 animation channels. Each channel can handle one animation. The animation commands are:

- |   |  |
|---|--|
| <ul style="list-style-type: none"> <li>• <b>CMD_ANIMFRAME</b></li> <li>• <b>CMD_ANIMSTART</b></li> <li>• <b>CMD_ANIMSTOP</b></li> <li>• <b>CMD_ANIMXY</b></li> <li>• <b>CMD_ANIMDRAW</b></li> </ul> | <ul style="list-style-type: none"> <li>- render one frame of an animation</li> <li>- start an animation</li> <li>- stop animation</li> <li>- set the (x; y) coordinates of an animation</li> <li>- draw active animations</li> </ul> |
|---|--|

All animation functions accept a channel number 0-31. Register **REG\_ANIM\_ACTIVE** to indicate the state of animation channels.

In BT815/6, animation objects and data are only limited to be in flash and requires flash in the fast/full mode when it is running. In BT817/8, animation objects and data is also allowed to be in **RAM\_G**. Therefore, there are the following commands introduced:

- |   |  |
|---|--|
| <ul style="list-style-type: none"> <li>• <b>CMD_ANIMFRAMERAM</b></li> </ul> | <ul style="list-style-type: none"> <li>- render one frame of an animation in <b>RAM_G</b></li> </ul> |
|---|--|

- **CMD\_ANIMSTARTRAM** - start an animation in **RAM\_G**

In addition, another command **CMD\_RUNANIM** is also introduced in **BT817/8** to simplify the playing back animation.

### Examples 1:

```
/*
play back an animation once in flash
**/

//set up an channel 1
cmd_animstart(1,4096, ANIM_ONCE);
cmd_animxy(400, 240); //The center of animation

//draw each frame in the animation object in a while loop.
while (0 == rd32(REG_DL_SWAP)) {
    cmd_dlstart();
    cmd_animdraw();

    cmd_swap();

    if (0 == rd32(REG_ANIM_ACTIVE))
        break;
}

cmd_animstop(1);
```

### Examples 2:

```
/*
play back the animation from frame to frame using cmd_animframe.
FRAME_COUNT is the number of frames to be rendered.
**/
for (int i = 0; i < FRAME_COUNT; i++)
{
    cmd_dlstart();
    cmd(CLEAR(1,1,1));
    cmd_animframe(400,240, 4096, i); //draw the ith frame.
    cmd(DISPLAY());
    cmd_swap();
}
```

## 5.6 String Formatting

Some coprocessor commands, such as **CMD\_TEXT,CMD\_BUTTON,CMD\_TOGGLE**, accept a zero-terminated string argument. This string may contain UTF-8 characters, if the selected font contains the appropriate code points.

If the **OPT\_FORMAT** option is given in the command, then the string is interpreted as a printf-style format string. The supported formatting is a subset of standard C99. The output string may be up to 256 bytes in length. Arguments to the format string follow the string and its padding. They are always 32-bit, and aligned to 32-bit boundaries. So for example the command:

```
cmd_text(0, 0, 26, OPT_FORMAT, "%d", 237);
```

Should be serialized as:

Offset	Size (in bytes)	Value	Remarks
0	4	0xFFFFFFFF0C	<b>CMD_TEXT</b>
4	2	0	X coordinate
6	2	0	Y coordinate
8	2	26	Font handle
10	2	OPT_FORMAT	Options
12	1	'%'	Format specifier
13	1	'd'	Conversion specifier
14	1	0	Padding bytes for 32 bits alignment
15	1	0	
16	4	237	Integer

The format string is composed of zero or more directives: ordinary characters (not %), which are copied unchanged to the output stream; and conversion specifications, each of which results in fetching zero or more subsequent arguments from the input stream. Each conversion specification is introduced by the character specifier. In between there may be (in this order) zero or more flags, an optional minimum field width and an optional precision.

### 5.6.1 The Flag Characters

The character % is followed by zero or more of the following flags:

Flag	Description
0	The value should be zero padded. For d, I, u, o, x, and X conversions, the converted value is padded on the left with zeros rather than blanks. If the 0 and-- flags both appear, the 0 flag is ignored. For other conversions, the behavior is undefined.
-	The converted value is to be left adjusted on the field boundary. (The default is right justification.) The converted value is padded on the right with blanks, rather than on the left with blanks or zeros
' ' (a space)	A blank should be left before a positive number (or empty string) produced by a signed conversion
+	A sign (+ or -) should always be placed before a number produced by a signed conversion. By default a sign is used only for negative numbers.

### 5.6.2 The Field Width

An optional decimal digit string (with nonzero first digit) specifying a minimum field width. If the converted value has fewer characters than the field width, it will be padded with spaces on the left (or right, if the left-adjustment flag has been given). Instead of a decimal digit string one may

write '\*' to specify that the field width is given in the next argument. A negative field width is taken as a '-' flag followed by a positive field width. In no case does a nonexistent or small field width cause truncation of a field; if the result of a conversion is wider than the field width, the field is expanded to contain the conversion result.

### 5.6.3 The Precision

An optional precision, in the form of a period ('.') followed by an optional decimal digit string. Instead of a decimal digit string one may write '\*' to specify that the field width is given in the next argument. If the precision is given as just '.', the precision is taken to be zero. This gives the minimum number of digits to appear for d, i, u, o, x, and X conversions, the number of digits to appear after the radix character for a, A, e, E, f, and F conversions, the maximum number of significant digits for g and G conversions, or the maximum number of characters to be printed from a string for s and S conversions.

### 5.6.4 The Conversion Specifier

A character that specifies the type of conversion to be applied. The conversion specifiers and their meanings are:

Specifiers	Meaning
d,i	The integer argument is converted to signed decimal notation. The precision, if any, gives the minimum number of digits that must appear; if the converted value requires fewer digits, it is padded on the left with zeros
u, o, x, X	The unsigned integer argument is converted to unsigned octal (o), unsigned decimal (u), or unsigned hexadecimal (x and X) notation. The letters abcdef are used for x conversions; the letters ABCDEF are used for X conversions. The precision, if any, gives the minimum number of digits that must appear; if the converted value requires fewer digits, it is padded on the left with zeros.
c (lower case)	The integer argument is treated as a <b>Unicode</b> code point, and encoded as <b>UTF-8</b>
s (lower case)	<b>The argument is expected to be an address of RAM_G storing an array of characters.</b> Characters from the array are written up to (but not including) a terminating null byte; if a precision is specified, no more than the number specified are written. If a precision is given, no null byte need be present; if the precision is not specified, or is greater than the size of the array, the array must contain a terminating null byte.
%	A '%' is written. No argument is converted. The complete conversion specification is '%%'.

**Table 25 – String Format Specifier**

**Examples:**

Format string	Output	Assumption
"%3d%% complete", c	51% complete	int c = 51
"base address %06x", a	base address 12a000	int a = 0x12a000
"%+5.3umV", mv	+1947 mV	unsigned int mv = 1947
"Temp %d%.1d degree", t / 10, t % 10	Temp 68.0 degrees	int c = 680
"%s %d times", RAM_G + 4, nTimes	Hello 5 times	"RAM_G+4" is the starting address of the string int nTimes = 5

## 5.7 Coprocessor Faults

Some commands can cause coprocessor faults. These faults arise because the coprocessor cannot continue. For example:

- An invalid JPEG is supplied to **CMD\_LOADIMAGE**
- An invalid data stream is supplied to **CMD\_INFLATE/CMD\_INFLATE2**
- An attempt is made to write more than 2048 instructions into a display list

In the fault condition, the coprocessor:

1. writes a 128-byte diagnostic string to memory starting at **RAM\_ERR\_REPORT**.
2. sets **REG\_CMD\_READ** to 0xffff (an illegal value because all command buffer data is 32-bit aligned),
3. raises the **INT\_CMDEMPTY** interrupt
4. stops accepting new commands

The diagnostic string gives details of the problem, and the command that triggered it. The string is up to 128 bytes long, including the terminating 0x00. It always starts with the text "ERROR" For example, after a fault the memory buffer might contain:

```

45 52 52 4F 52 3a 20 69 6c 6c 65 67 61 6c 20 6f |ERROR: illegal o|
70 74 69 6f 6e 20 69 6e 20 63 6d 64 5f 69 6e 66 |ption in cmd_inf|
6c 61 74 65 32 28 29 00 00 00 00 00 00 00 00 00 00 |late2().....|
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 |.....|
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 |.....|
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 |.....|
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 |.....|
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 |.....|
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 |.....|

```

The possible errors are:

Error string	Remarks
display list overflow	more than 2048 drawing operations in the display list
illegal font or bitmap handle	valid handles are 0-31
out of channel	The animation channels are used up
uninitialized font	font should be set up with <b>CMD_ROMFONT</b> or <b>CMD_SETFONT2</b>
illegal alignment	flash commands only support certain alignments
illegal option	a command's option(parameter) was not recognized
invalid animation	the animation object or frame is not valid
invalid animation channel	animation channel number is not valid
invalid base	a number base was given outside the range 2-36
unsupported JPEG	the <b>JPEG</b> image is not supported (e.g. progressive)
invalid size	a radius, width, or height was negative or zero
corrupted JPEG	the <b>JPEG</b> image data is corrupted
unsupported PNG	the <b>PNG</b> image is not supported
corrupted PNG	the <b>PNG</b> image data is corrupted
image type not recognized	the image is not a <b>PNG</b> or <b>JPG</b>
display list must be empty	<b>CMD_CLEARCACHE</b> was called with a non-empty display list
unknown bitmap format	<b>CMD_SETBITMAP</b> was called with a unknown bitmap format
corrupted DEFLATE data	the <b>DEFLATE</b> data is corrupted
corrupted AVI	the <b>AVI</b> data is corrupted

invalid format character	an invalid character appeared in a format
invalid format string	the format conversion specifier was not found
format buffer overflow	the format output buffer used more than 256 bytes

**Table 26 – Coprocessor Faults Strings**

When the host MCU encounters the fault condition, it can recover as follows:

1. Read **REG\_COPRO\_PATCH\_PTR** into a local variable “*patch\_address*”.
2. Set **REG\_CPURESET** to 1, to hold the coprocessor engine in the reset condition
3. Set **REG\_CMD\_READ**, **REG\_CMD\_WRITE**, **REG\_CMD\_DL** to zero
4. Set **REG\_CPURESET** to 0, to restart the coprocessor engine
5. Write the variable “*patch\_address*” of step 1 to **REG\_COPRO\_PATCH\_PTR**.
6. To enable coprocessor access flash content, send commands “**CMD\_FLASHATTACH**” following “**CMD\_FLASHFAST**”. It will make sure flash enters full speed mode.
7. Restore **REG\_PCLK** to the original value if the error string is ‘*display list must be empty*’ because **REG\_PCLK** is set to zero when that specific error takes place.

## 5.8 Coprocessor Graphics State

The coprocessor engine maintains a small amount of internal states for graphics drawing. This state is set to the default at coprocessor engine reset, and by **CMD\_COLDSTART**. The state values are not affected by **CMD\_DLSTART** or **CMD\_SWAP**, so an application need only set them once at startup.

State	Default	Commands
background color	dark blue (0x002040)	<b>CMD_BGCOLOR</b>
foreground color	light blue (0x003870)	<b>CMD_FGCOLOR</b>
gradient color	white (0xFFFFFFFF)	<b>CMD_GRADCOLOR</b>
Spinner	None	<b>CMD_SPINNER</b>
object trackers	all disabled	<b>CMD_TRACK</b>
interrupt timer	None	<b>CMD_INTERRUPT</b>
bitmap transform matrix: $\begin{bmatrix} A & B & C \\ D & E & F \end{bmatrix}$	$\begin{bmatrix} 1.0 & 0.0 & 0.0 \\ 0.0 & 1.0 & 0.0 \end{bmatrix}$	<b>CMD_LOADIDENTITY</b> , <b>CMD_TRANSLATE</b> , <b>CMD_SCALE</b> , <b>CMD_ROTATE</b> , <b>CMD_ROTATEAROUND</b>
Scratch bitmap handle	15	<b>CMD_SETSCRATCH</b>
Font pointers 0-15	Undefined	<b>CMD_SETFONT</b> , <b>CMD_SETFONT2</b>
Font pointer 16-31	ROM fonts 16-31	<b>CMD_SETFONT</b> , <b>CMD_SETFONT2</b> , <b>CMD_ROMFONT</b>
base of number	10	<b>CMD_SETBASE</b>
Media FIFO	Address is zero and length is zero	<b>CMD_MIDEAFIFO</b> ,

**Table 27 – Coprocessor Engine Graphics State**

## 5.9 Parameter OPTION

The following table defines the parameter "OPTION" mentioned in this chapter.

Name	Value	Description	Commands
OPT_3D	0	3D effect	<b>CMD_BUTTON,</b> <b>CMD_CLOCK,</b> <b>CMD_KEYS,</b> <b>CMD_GAUGE,</b> <b>CMD_SLIDER,</b> <b>CMD_DIAL,</b> <b>CMD_TOGGLE,</b> <b>CMD_PROGRESS,</b> <b>CMD_SCROLLBAR</b>
OPT_RGB565	0	Decode the source image to RGB565 format	<b>CMD_LOADIMAGE</b>
OPT_MONO	1	Decode the source JPEG image to L8 format, i.e., monochrome	<b>CMD_LOADIMAGE</b>
OPT_NODL	2	No display list commands generated	<b>CMD_LOADIMAGE</b>
OPT_FLAT	256	No 3D effect	<b>CMD_BUTTON,</b> <b>CMD_CLOCK,</b> <b>CMD_KEYS,</b> <b>CMD_GAUGE,</b> <b>CMD_SLIDER,</b> <b>CMD_DIAL,</b> <b>CMD_TOGGLE,</b> <b>CMD_PROGRESS,</b> <b>CMD_SCROLLBAR</b>
OPT_SIGNED	256	The number is treated as a 32 bit signed integer	<b>CMD_NUMBER</b>
OPT_CENTERX	512	Horizontally-centred style	<b>CMD_KEYS,</b> <b>CMD_TEXT,</b> <b>CMD_NUMBER</b>
OPT_CENTERY	1024	Vertically centred style	<b>CMD_KEYS,</b> <b>CMD_TEXT,</b> <b>CMD_NUMBER</b>
OPT_CENTER	1536	horizontally and vertically centred style	<b>CMD_KEYS,</b> <b>CMD_TEXT,</b> <b>CMD_NUMBER</b>
OPT_RIGHTX	2048	Right justified style	<b>CMD_KEYS,</b> <b>CMD_TEXT,</b> <b>CMD_NUMBER</b>
OPT_NOBACK	4096	No background drawn	<b>CMD_CLOCK,</b> <b>CMD_GAUGE</b>
OPT_FILL	8192	Breaks the text at spaces into multiple lines, with maximum width set by <b>CMD_FILLWIDTH</b> .	<b>CMD_BUTTON,</b> <b>CMD_TEXT</b>
OPT_FLASH	64	Fetch the data from flash memory	<b>CMD_INFLATE2,</b> <b>CMD_LOADIMAGE,</b> <b>CMD_PLAYVIDEO</b>
OPT_FORMAT	4096	Flag of string formatting	<b>CMD_TEXT,</b> <b>CMD_BUTTON,</b> <b>CMD_TOGGLE</b>
OPT_NOTICKS	8192	No Ticks	<b>CMD_CLOCK,</b> <b>CMD_GAUGE</b>
OPT_NOHM	16384	No hour and minute hands	<b>CMD_CLOCK</b>
OPT_NOPOINTER	16384	No pointer	<b>CMD_GAUGE</b>
OPT_NOSECS	32768	No second hands	<b>CMD_CLOCK</b>
OPT_NOHANDS	49152	No hands	<b>CMD_CLOCK</b>
OPT_NOTEAR	4	Synchronize video updates to the display blanking interval, avoiding	<b>CMD_PLAYVIDEO</b>

Name	Value	Description	Commands
		horizontal "tearing" artefacts.	
OPT_FULLSCREEN	8	Zoom the video so that it fills as much of the screen as possible.	<b>CMD_PLAYVIDEO</b>
OPT_MEDIAFIFO	16	source video/image/compressed(zlib) data from the defined media FIFO	<b>CMD_PLAYVIDEO</b> <b>CMD_VIDEOFRAME</b> <b>CMD_LOADIMAGE</b> <b>CMD_INFLATE2</b>
OPT_OVERLAY	128	Append the video bitmap to an existing display list	<b>CMD_PLAYVIDEO</b>
OPT_SOUND	32	Decode the audio data	<b>CMD_PLAYVIDEO</b>
OPT_DITHER	256	Enable dithering feature in decoding PNG process	<b>CMD_LOADIMAGE</b>

**Table 28 – Parameter OPTION Definition**

## 5.10 Resources Utilization

The coprocessor engine does not change the state of the graphics engine. That is, graphics states such as color and line width are not to be changed by the coprocessor engine.

However, the widgets do reserve some hardware resources, which the user must take into account:

- Bitmap handle 15 is used by the 3D-effect buttons, keys and gradient, unless it is set to another bitmap handle using **CMD\_SETSCRATCH**.
- One graphics context is used by objects, and the effective stack depth for **SAVE\_CONTEXT** and **RESTORE\_CONTEXT** commands is 3 levels.

## 5.11 Command list

In BT817/8, coprocessor adds a new feature “command list”, which enables user to construct a series of coprocessor command or display list at **RAM\_G**. There are the following new commands to facilitate:

- **CMD\_NEWMIST**
- **CMD\_CALLLIST**
- **CMD\_RETURN**
- **CMD\_ENDLIST**

The examples can be found in the sections of the commands above.

## 5.12 Command Groups

These commands begin and finish the display list:

- **CMD\_DLSTART**-- start a new display list
- **CMD\_SWAP**-- swap the current display list

Commands to draw graphics objects:

- **CMD\_TEXT**-- draw a **UTF-8** text string
- **CMD\_BUTTON**-- draw a button with a **UTF-8** label.
- **CMD\_CLOCK**-- draw an analog clock
- **CMD\_BGCOLOR**-- set the background color
- **CMD\_FGCOLOR**-- set the foreground color
- **CMD\_GRADCOLOR** – set up the highlight color used in 3D effects for **CMD\_BUTTON** and **CMD\_KEYS**
- **CMD\_GAUGE**-- draw a gauge
- **CMD\_GRADIENT**-- draw a smooth color gradient
- **CMD\_KEYS**-- draw a row of keys
- **CMD\_PROGRESS**-- draw a progress bar

- **CMD\_SCROLLBAR**-- draw a scroll bar
- **CMD\_SLIDER**-- draw a slider
- **CMD\_DIAL**-- draw a rotary dial control
- **CMD\_TOGGLE**-- draw a toggle switch with **UTF-8** labels
- **CMD\_NUMBER**-- draw a decimal number
- **CMD\_SETBASE**-- set the base for number output
- **CMD\_FILLWIDTH**-- set the text fill width

Commands to operate on **RAM\_G**:

- **CMD\_MEMCRC**-- compute a **CRC-32** for **RAM\_G**
- **CMD\_MEMZERO**-- write zero to **RAM\_G**
- **CMD\_MEMSET**-- fill **RAM\_G** with a byte value
- **CMD\_MEMWRITE**-- write bytes into **RAM\_G**
- **CMD\_MEMCPY**-- copy a block of **RAM\_G**
- **CMD\_APPEND**-- append more commands to display list

Commands for loading data into **RAM\_G**:

- **CMD\_INFLATE** - decompress data into **RAM\_G**
- **CMD\_INFLATE2** - decompress data into **RAM\_G** with more options
- **CMD\_LOADIMAGE**-- load a JPEG/PNG image into **RAM\_G**
- **CMD\_MEDIAFIFO**-- set up a streaming media FIFO in **RAM\_G**
- **CMD\_VIDEOFRAME** - load video frame from **RAM\_G** or flash memory.

Commands for setting the bitmap transform matrix:

- **CMD\_LOADIDENTITY**-- set the current matrix to identity
- **CMD\_TRANSLATE**-- apply a translation to the current matrix
- **CMD\_SCALE**-- apply a scale to the current matrix
- **CMD\_ROTATE**-- apply a rotation to the current matrix
- **CMD\_ROTATEAROUND**-- apply a rotation and scale around the specified pixel
- **CMD\_SETMATRIX**-- write the current matrix as a bitmap transform
- **CMD\_GETMATRIX**-- retrieves the current matrix coefficients

Commands for flash operation:

- **CMD\_FLASHERASE** - Erase all of flash
- **CMD\_FLASHWRITE** - Write data to flash
- **CMD\_FLASHUPDATE** - write data to flash, erasing if necessary
- **CMD\_FLASHDETACH** - detach from flash
- **CMD\_FLASHATTACH** - attach to flash
- **CMD\_FLASHFAST** - enter full-speed mode
- **CMD\_FLASHSPIDESEL** -SPI bus: deselect device
- **CMD\_FLASHTX** - SPI bus: write bytes
- **CMD\_FLASHRX** - SPI bus: read bytes
- **CMD\_CLEARCACHE** - clear the flash cache
- **CMD\_FLASHSOURCE** - specify the flash source address for the following coprocessor commands
- **CMD\_VIDEOSTARTF** - initialize video frame decoder
- **CMD\_APPENDF** - Read data from flash to **RAM\_DL**

Commands for video playback:

- **CMD\_VIDEOSTART** - Initialize the video frame decoder
- **CMD\_VIDEOSTARTF** -Initialize the video frame decoder for video data in flash
- **CMD\_VIDEOFRAME** - Load video frame data
- **CMD\_PLAYVIDEO**-- play back motion-**JPEG** encoded AVI video

Commands for animation:

- **CMD\_ANIMFRAME** – render one frame of an animation
- **CMD\_ANIMFRAMERAM** – render one frame in **RAM\_G** of an animation
- **CMD\_ANIMSTART** – start an animation
- **CMD\_ANIMSTOP** – stop animation
- **CMD\_ANIMXY** – set the (x,y) coordinates of an animation
- **CMD\_ANIMDRAW** – draw active animation

Other commands:

- **CMD\_COLDSTART**-- set coprocessor engine state to default values
- **CMD\_INTERRUPT**-- trigger interrupt INT\_CMDFLAG
- **CMD\_REGREAD**-- read a register value
- **CMD\_CALIBRATE**-- execute the touch screen calibration routine
- **CMD\_ROMFONT** – load a ROM font into bitmap handle
- **CMD\_SETROTATE**-- Rotate the screen and set up transform matrix accordingly
- **CMD\_SETBITMAP** – Set up display list commands for specified bitmap
- **CMD\_SPINNER**-- start an animated spinner
- **CMD\_STOP**-- stop any spinner, screensaver or sketch
- **CMD\_SCREENSAVER**-- start an animated screensaver
- **CMD\_SKETCH**-- start a continuous sketch update
- **CMD\_SNAPSHOT**-- take a snapshot of the current screen
- **CMD\_SNAPSHOT2**-- take a snapshot of part of the current screen with more format option
- **CMD\_LOGO**-- play device logo animation

## 5.13 CMD\_APILEVEL

This command sets the API level used by the coprocessor.

### C prototype

```
void cmd_apilevel( uint32_t level );
```

### Parameter

#### level

API level to use. Level 1 is BT815 compatible, and is the default. Level 2 is BT817/8.

### Command layout

+0	<b>CMD_APILEVEL (0xFFFF FF63)</b>
+4	level

### Description

To use the BT817/8 specific commands or other improvement, level 2 has to be sent.

### Example

```
//At startup, the API level is 1. To set it to 2:  
cmd_apilevel(2);
```

**Note:** BT817/8 specific command

## 5.14 CMD\_DLSTART

This command starts a new display list. When the coprocessor engine executes this command, it waits until the current display list is ready for writing, and then sets **REG\_CMD\_DL** to zero.

### C prototype

```
void cmd_dlstart( );
```

### Command layout

+0	<b>CMD_DLSTART (0xFFFF FF00)</b>
----	----------------------------------

### Examples

NA

## 5.15 CMD\_INTERRUPT

This command is used to trigger Interrupt CMDFLAG. When the coprocessor engine executes this command, it triggers interrupt, which will set the bit field **CMDFLAG** of REG\_INT\_FLAGS, unless the corresponding bit in REG\_INT\_MASK is zero.

### C prototype

```
void cmd_interrupt( uint32_t ms );
```

### Parameters

#### ms

The delay before the interrupt triggers, in milliseconds. The interrupt is guaranteed not to fire before this delay. If ms are zero, the interrupt fires immediately.

### Command layout

+0	<b>CMD_INTERRUPT(0xFFFF FF02)</b>
+4	ms

### Examples

```
//To trigger an interrupt after a JPEG has finished loading:  
cmd_loadimage();  
//...  
cmd_interrupt(0); // previous load image complete, trigger interrupt  
  
//To trigger an interrupt in 0.5 seconds:  
cmd_interrupt(500);  
//...
```

## 5.16 CMD\_COLDSTART

This command sets the coprocessor engine to default reset states.

### C prototype

```
void cmd_coldstart( );
```

### Command layout

+0	<b>CMD_COLDSTART(0xFFFF FF32)</b>
----	-----------------------------------

## Examples

Change to a custom color scheme, and then restore the default colors:



```
cmd_fgcolor(0x00c040);
cmd_gradcolor(0x000000);
cmd_button( 2, 32, 76, 56, 26,0, "custom" );
cmd_coldstart();
cmd_button( 82, 32, 76, 56, 26,0, "default");
```

## 5.17 CMD\_SWAP

This command is used to swap the current display list. When the coprocessor engine executes this command, it requests a display list swap immediately after the current display list is scanned out. Internally, the coprocessor engine implements this command by writing to **REG\_DLSWAP** with **DLSWAP\_FRAME**.

This coprocessor engine command will not generate any display list command into display list memory RAM\_DL. It is expected to be used with **CMD\_DLSTART** in pair.

### C prototype

```
void cmd_swap( );
```

### Command layout

+0	<b>CMD_SWAP(0xFFFF FF01)</b>
----	------------------------------

## Examples

NA

## 5.18 CMD\_APPEND

This command appends more commands resident in **RAM\_G** to the current display list memory address where the offset is specified in **REG\_CMD\_DL**.

### C prototype

```
void cmd_append(  uint32_t ptr,
                  uint32_t num );
```

### Parameters

#### ptr

Starting address of source commands in RAM\_G

#### num

Number of bytes to copy. This must be a multiple of 4.

### Command layout

+0	<b>CMD_APPEND(0xFFFF FF1E)</b>
+4	ptr
+8	num

### Description

After appending is done, the coprocessor engine will increase the **REG\_CMD\_DL** by num to make sure the display list is in order.

### Examples

```
cmd_dlstart();
cmd_append(0, 40); // copy 10 commands from main memory address 0
cmd(DISPLAY); // finish the display list
cmd_swap();
```

## 5.19 CMD\_REGREAD

This command is used to read a register value.

### C prototype

```
void cmd_regread( uint32_t ptr,
                  uint32_t result );
```

### Parameters

#### ptr

Address of the register to be read

#### result

The register value which has been read from the ptr address. **OUTPUT** parameter.  
 Write a dummy 32-bit value 0x00000000 for this parameter and the Co-Processor will replace this value with the result after the command has been executed.  
 After execution, the host should then read the address of this parameter in **RAM\_CMD** to get the result value.

### Command layout

+0	<b>CMD_REGREAD(0xFFFF FF19)</b>
+4	ptr
+8	result

### Examples

```
//To capture the exact time when a command completes:
uint16_t x = rd16(REG_CMD_WRITE);
cmd_regread(REG_CLOCK, 0);
//...
printf("%08x\n", rd32(RAM_CMD + (x + 8) % 4096));
```

## 5.20 CMD\_MEMWRITE

This command writes the following bytes into the memory. This command can be used to set register values, or to update memory contents at specific times.

### C prototype

```
void cmd_memwrite( uint32_t ptr,
                   uint32_t num );
```

### Parameters

#### ptr

The memory address to be written

**num**

Number of bytes to be written.

### Description

The data byte should immediately follow in the command buffer. If the number of bytes is not a multiple of 4, then 1, 2 or 3 bytes should be appended to ensure 4-byte alignment of the next command, these padding bytes can have any value. The completion of this function can be detected when the value of **REG\_CMD\_READ** is equal to **REG\_CMD\_WRITE**.

**Note:** If using this command improperly, it may corrupt the memory.

### Command layout

+0	<b>CMD_MEMWRITE(0xFFFF FF1A)</b>
+4	ptr
+8	num
+12 ...n	byte <sub>0</sub> ... byte <sub>n</sub>

### Examples

```
//To change the backlight brightness to 0x64 (half intensity) for a particular
screen shot:
//...
cmd_swap(); // finish the display list
cmd_dlstart(); // wait until after the swap
cmd_memwrite(REG_PWM_DUTY, 4); // write to the PWM_DUTY register
cmd(100);
```

## 5.21 CMD\_INFLATE

This command is used to decompress the following compressed data into **RAM\_G**. The data should have been compressed with the **DEFLATE** algorithm, e.g. with the **ZLIB** library. This is particularly useful for loading graphics data.

### C prototype

```
void cmd_inflate( uint32_t ptr );
```

### Parameters

**ptr**

Destination address in **RAM\_G**. The data byte should immediately follow in the command buffer.

### Description

If the number of bytes is not a multiple of 4, then 1, 2 or 3 bytes should be appended to ensure 4-byte alignment of the next command. These padding bytes can have any value

### Command layout

+0	<b>CMD_INFLATE(0xFFFF FF22)</b>
+4	ptr
+8 ...n	byte <sub>0</sub> ... byte <sub>n</sub>

### Examples

To load graphics data to main memory address 0x8000:

```
cmd_inflate(0x8000);  
// zlib-compressed data follows
```

## 5.22 CMD\_INFLATE2

This command is used to decompress the following compressed data into **RAM\_G**. The data may be supplied in the command buffer, the media **FIFO**, or from flash memory. The data should have been compressed with the **DEFLATE** algorithm, e.g. with the **ZLIB** library. This is particularly useful for loading graphics data.

### C prototype

```
void cmd_inflate2( uint32_t ptr,  
                    uint32_t options );
```

### Parameters

#### ptr

destination address to put the decompressed data.

#### options

If option **OPT\_MEDIIFO** is given, the compressed data is sourced from the media **FIFO**. If option **OPT\_FLASH** is given, then flash memory is the source. When flash is the source, call **CMD\_FLASHSOURCE** before this command to specify the address. See [CMD\\_FLASHSOURCE](#). Otherwise, giving **zero** value and the compressed data shall be followed immediately.

### Description

If the number of bytes is not a multiple of 4, then 1, 2 or 3 bytes should be appended to ensure 4-byte alignment of the next command. These padding bytes can have any value.

### Command layout

+0	<b>CMD_INFLATE2(0xFFFF FF50)</b>
+4	ptr
+8	options
+9....+n	byte <sub>1</sub> ...byte <sub>n</sub>

## 5.23 CMD\_LOADIMAGE

This command is used to load a JPEG or PNG image. Decompress the following **JPEG** or **PNG** image data into an **EVE** specific bitmap, in **RAM\_G**. The image data should be in the following formats:

- Regular baseline **JPEG (JFIF)**
- **PNG** with bit-depth 8 only and no interlace

### C prototype

```
void cmd_loadimage( uint32_t ptr,  
                     uint32_t options );
```

### Parameters

#### ptr

Destination address

### options

Option **OPT\_MONO** forces the bitmap to be monochrome in **L8** format. Otherwise, the image is loaded depends on the type of input image:

For **JPEG** images, the bitmap is loaded as either a **RGB565** or **L8** format bitmap, depending on the original image. If **OPT\_MONO** is given, **L8** is used.

For **PNG** images, the **PNG** standard defines several image color formats. Each format is loaded as a bitmap as follows:

Color type	Format	Remarks
0	Grayscale	loads as <b>L8</b>
2	Truecolor	loads as <b>RGB565</b>
3	Indexed	loads as <b>PALETTED565</b> or <b>PALETTED4444</b>
4	Grayscale and alpha	not supported
6	Truecolor and alpha	loads as <b>ARGB4</b>

Option **OPT\_FULLSCREEN** causes the bitmap to be scaled so that it fills as much of the screen as possible.

If option **OPT\_MEDIIFO** is given, the media FIFO is used for the image data source.

If option **OPT\_FLASH** is given, then the flash memory is the image data source.

If neither option **OPT\_MEDIIFO** nor option **OPT\_FLASH** is given, then the byte data shall immediately follow in the command **FIFO**. When flash is the source, call **CMD\_FLASHSOURCE** before this command to specify the address. See [CMD\\_FLASHSOURCE](#).

To minimize the programming effort to render the loaded image, there are a set of display list commands generated and appended to the current display list, unless **OPT\_NODL** is given.

### Description

The data byte should immediately follow in the command FIFO if **OPT\_MEDIIFO** or **OPT\_FLASH** is **NOT** set. If the number of bytes is not a multiple of 4, then 1, 2 or 3 bytes should be appended to ensure 4-byte alignment of the next command. These padding bytes can have any value. The application on the host processor has to parse the JPEG/PNG header to get the properties of the JPEG/PNG image and decide to decode. Behavior is unpredictable in cases of non-baseline JPEG images or the output data generated is more than the **RAM\_G** size.

**Note:** If the loading image is in PNG format, the top 42K bytes from address 0xF5800 of **RAM\_G** will be overwritten as temporary data buffer for decoding process.

### Command layout

<b>+0</b>	<b>CMD_LOADIMAGE(0xFFFF FF24)</b>
+4	ptr
+8	options
+12	byte 0
+13	byte 1
...	...
+n	byte n

### Examples

To load a JPEG image at address 0 then draw the bitmap at (10, 20) and (100, 20):

```
cmd_loadimage(0, 0);  
...  
cmd(BEGIN(BITMAPS));  
cmd(VERTEX2II(10, 20, 0, 0)); // draw bitmap at (10,20)  
cmd(VERTEX2II(100, 20, 0, 0)); // draw bitmap at (100,20)
```

## 5.24 CMD\_MEDIIFO

This command is to set up a streaming media FIFO. Allocate the specified area of **RAM\_G** and set it up as streaming media **FIFO**, which is used by:

- **MJPEG** video play-back : **CMD\_PLAYVIDEO/CMD\_VIDEOFRAME**
- **JPEG/PNG** image decoding: **CMD\_LOADIMAGE**
- Compressed data by zlib: **CMD\_INFLATE2**

if the option **OPT\_MEDIIFO** is selected.

### C prototype

```
void cmd_medififo (  uint32_t ptr,
                      uint32_t size );
```

### Parameters

**ptr**  
starting address of media **FIFO**

**size**  
number of bytes of media **FIFO**

### Command layout

<b>+0</b>	<b>CMD_MEDIIFO (0xFFFF FF39)</b>
+4	ptr
+8	size

### Examples

To set up a 64-Kbyte FIFO at the top of **RAM\_G** for JPEG streaming and report the initial values of the read and write pointers:

```
cmd_medififo(0x100000 - 65536, 65536);           //0x100000 is the top of RAM_G
printf("R=%08xW=%08x\n",rd32(REG_MEDIAIFO_READ),rd32(REG_MEDIAIFO_WRITE));
```

It prints:

R=0x000F000 W=0x00F000

## 5.25 CMD\_PLAYVIDEO

This command plays back **MJPEG**-encoded AVI video.

Playback starts immediately, and the command completes when playback ends. The playback may be paused or terminated by writing to **REG\_PLAY\_CONTROL**. The register's value controls playback as follows:

- -1 exit playback
- 0 pause playback
- 1 play normally

During the command execution, the **RGB565** bitmap will be created at starting address of **RAM\_G**, and is  $2 \times W \times H$  bytes in size, where  $W$  and  $H$  are the width and height of the video. If **OPT\_SOUND** is given then a 32 Kbyte audio buffer follows the bitmap. It means that area of **RAM\_G** will be overwritten by **CMD\_PLAYVIDEO**.

## C prototype

```
void cmd_playvideo (uint32_t opts);
```

### Parameters

**opts:** The options of playing video

**OPT\_FULLSCREEN:** zoom the video so that it fills as much of the screen as possible.

**OPT\_MEDIIFO:** instead of sourcing the AVI video data from the command buffer, source it from the media FIFO in **RAM\_G**.

**OPT\_FLASH:** Source video data from flash. When flash is the source, call **CMD\_FLASHSOURCE** before this command to specify the address. See **CMD\_FLASHSOURCE**.

**OPT\_NOTEAR:** Synchronize video updates to the display blanking interval, avoiding horizontal tearing artifacts.

**OPT\_SOUND:** Decode the audio data encoded in the data following, if any.

**OPT\_OVERLAY:** Append the video bitmap to an existing display list, instead of starting a new display list.

**OPT\_NODL:** Will not change the current display list. There should already be a display list rendering the video bitmap.

### data

The video data to be played unless **opts** is assigned with **OPT\_MEDIIFO** or **OPT\_FLASH**.

### Command layout

+0	<b>CMD_PLAYVIDEO (0xFFFF FF3A)</b>
+4	opts
+8~ +n	byte <sub>1</sub> ... byte <sub>n</sub>

Data following parameter “opts” shall be padded to 4 bytes aligned with zero.

**Note:** For the audio data encoded into AVI video, three formats are supported:

#### 4 Bit IMA ADPCM, 8 Bit signed PCM, 8 Bit u-Law

In addition, 16 Bit PCM is partially supported by dropping off less significant 8 bits in each audio sample.

### Examples

To play back an AVI video, full-screen:

```
cmd_playvideo (OPT_FULLSCREEN | OPT_NOTEAR) ;  
//... append AVI data ...
```

## 5.26 CMD\_VIDEOSTART

This command is used to initialize video frame decoder. The video data should be supplied using the media FIFO. This command processes the video header information from the media FIFO, and completes when it has consumed it.

### C prototype

```
void cmd_videostart( );
```

### Parameters

None

### Command layout

+0	CMD_VIDEOSTART (0xFFFF FF40)
----	------------------------------

### Examples

To load frames of video at address 4:

```
cmd_videostart();  
cmd_videoframe(4, 0);
```

## 5.27 CMD\_VIDEOFRAME

This command is used to load the next frame of a video. The video data should be supplied in the media **FIFO** or flash memory. This command extracts the next frame of video, and completes when it has consumed it.

### C prototype

```
void cmd_videoframe( uint32_t dst,  
                     uint32_t ptr );
```

### Parameters

#### dst

Memory location to load the frame data, this will be located in **RAM\_G**.

#### ptr

Completion pointer. The command writes the 32-bit word at this location. It is set to 1 if there is at least one more frame available in the video. 0 indicates that this is the last frame. The value of ptr shall be within **RAM\_G**.

### Command layout

+0	CMD_VIDEOFRAME (0xFFFF FF41)
+4	dst
+8	ptr

### Examples

To load frames of video at address 4:

```
videostart();  
do {  
    videoframe(4, 0);  
    //... display frame ...  
} while (rd32(0) != 0);
```

## 5.28 CMD\_MEMCRC

This command computes a CRC-32 for a block of **RAM\_G** memory.

### C prototype

```
void cmd_memcrc( uint32_t ptr,  
                  uint32_t num,  
                  uint32_t result );
```

### Parameters

**ptr**

Starting address of the memory block

**num**

Number of bytes in the source memory block

**result**

Output parameter; written with the CRC-32 after command execution.

### Command layout

+0	<b>CMD_MEMCRC(0xFFFF FF18)</b>
+4	ptr
+8	num
+12	result

### Examples

To compute the CRC-32 of the first 1K byte of memory, first record the value of **REG\_CMD\_WRITE**, execute the command, wait for completion, then read the 32-bit value at result:

```
uint16_t x = rd16(REG_CMD_WRITE);  
cmd_crc(0, 1024, 0);  
  
//wait till the command is complete  
printf("CRC result is %08x\n", rd32(RAM_CMD + (x + 12) % 4096));
```

## 5.29 CMD\_MEMZERO

This command is used to write zero to a block of memory.

### C prototype

```
void cmd_memzero( uint32_t ptr, uint32_t num );
```

### Parameters

**ptr**

Starting address of the memory block

**num**

Number of bytes in the memory block

### Command layout

+0	<b>CMD_MEMZERO(0xFFFF FF1C)</b>
+4	ptr
+8	num

### Examples

```
//To erase the first 1K of main memory:  
cmd_memzero(0, 1024);
```

## 5.30 CMD\_MEMSET

This command is used to fill memory with a byte value

### C prototype

```
void cmd_memset( uint32_t ptr,  
                 uint32_t value,  
                 uint32_t num );
```

### Parameters

#### ptr

Starting address of the memory block

#### value

Value to be written to memory

#### num

Number of bytes in the memory block

### Command layout

+0	<b>CMD_MEMSET(0xFFFF FF1B)</b>
+4	ptr
+8	value
+12	num

### Examples

```
//To write 0xff the first 1K of main memory:  
cmd_memset(0, 0xff, 1024);
```

## 5.31 CMD\_MEMCPY

This command is used to copy a block of memory.

### C prototype

```
void cmd_memcpy( uint32_t dest,  
                 uint32_t src,  
                 uint32_t num );
```

### Parameters

#### dest

address of the destination memory block

#### src

address of the source memory block

**num**

number of bytes to copy

**Command layout**

+0	<b>CMD_MEMCPY(0xFFFF FF1D)</b>
+4	dst
+8	src
+12	num

**Examples**

```
//To copy 1K byte of memory from 0 to 0x8000:  
cmd_memcpy(0x8000, 0, 1024);
```

## 5.32 CMD\_BUTTON

This command is used to draw a button with a UTF-8 label.

**C prototype**

```
void cmd_button( int16_t x,  
                 int16_t y,  
                 int16_t w,  
                 int16_t h,  
                 int16_t font,  
                 uint16_t options,  
                 const char* s );
```

**Parameters****x**

X-coordinate of button top-left, in pixels

**y**

Y-coordinate of button top-left, in pixels

**w**

width of button, in pixels

**h**

height of button, in pixels

**font**

bitmap handle to specify the font used in the button label. [See ROM and RAM Fonts](#).

**options**

By default, the button is drawn with a 3D effect and the value is zero. **OPT\_FLAT** removes the 3D effect. The value of **OPT\_FLAT** is 256.

**s**

Button label. It must be one string terminated with null character, i.e. "\0" in C language. UTF-8 encoded. If **OPT\_FILL** is not given then the string may contain newline (\n) characters, indicating line breaks. See 5.6 String Formatting.

**Description**

Refer to [Coprocessor engine widgets physical dimensions](#) for more information.

**Command layout**

+0	CMD_BUTTON(0xFFFF FF0D)
+4	x
+6	y
+8	w
+10	h
+12	font
+14	options
+16	s
+17	...
...	...
+n	0

### Examples

A 140x100 pixel button with large text:



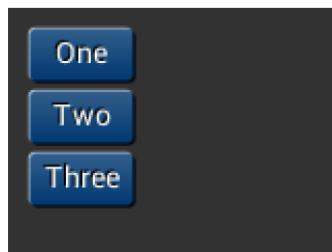
```
cmd_button(10, 10, 140, 100, 31, 0, "Press!");
```

Without the 3D look:



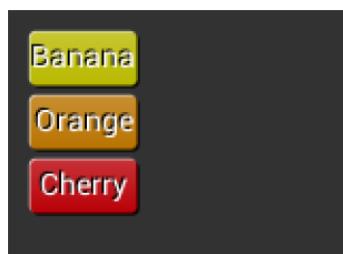
```
cmd_button(10, 10, 140, 100, 31, OPT_FLAT,  
"Press!");
```

Several smaller buttons:



```
cmd_button(10, 10, 50, 25, 26, 0, "One");  
cmd_button(10, 40, 50, 25, 26, 0, "Two");  
cmd_button(10, 70, 50, 25, 26, 0, "Three");
```

Changing button color



```
cmd_fgcolor(0xb9b900),  
cmd_button(10, 10, 50, 25, 26, 0, "Banana");  
cmd_fgcolor(0xb97300),  
cmd_button(10, 40, 50, 25, 26, 0, "Orange");  
cmd_fgcolor(0xb90007),  
cmd_button(10, 70, 50, 25, 26, 0, "Cherry");
```

## 5.33 CMD\_CLOCK

This command is used to draw an analog clock.

### C prototype

```
void cmd_clock( int16_t x,  
                int16_t y,  
                int16_t r,  
                uint16_t options,  
                uint16_t h,  
                uint16_t m,  
                uint16_t s,  
                uint16_t ms );
```

### Parameters

**x**

x-coordinate of clock center, in pixels

**y**

y-coordinate of clock center, in pixels

**r**

the radius of clock, in pixels

**options**

By default the clock dial is drawn with a 3D effect and the name of this option is OPT\_3D. Option OPT\_FLAT removes the 3D effect.

With option OPT\_NOBACK, the background is not drawn.

With option OPT\_NOTICKS, the twelve hour ticks are not drawn.

With option OPT\_NOSECS, the seconds hand is not drawn.

With option OPT\_NOHANDS, no hands are drawn.

With option OPT\_NOHM, no hour and minutes hands are drawn.

**h**

hours

**m**

minutes

**s**

seconds

**ms**

milliseconds

### Description

The details of the physical dimensions are:

- The 12 tick marks are placed on a circle of radius  $r*(200/256)$ .
- Each tick is a point of radius  $r*(10/256)$
- The seconds hand has length  $r*(200/256)$  and width  $r*(3/256)$
- The minutes hand has length  $r*(150/256)$  and width  $r*(9/256)$
- The hours hand has length  $r*(100/256)$  and width  $r*(12/256)$

Refer to [Coprocessor engine widgets physical dimensions](#) for more information.

## Command layout

+0	<b>CMD_CLOCK(0xFFFF FF14)</b>
+4	x
+6	y
+8	r
+10	options
+12	h
+14	m
+16	s
+18	ms

## Examples

A clock with radius 50 pixels, showing a time of 8.15:



```
cmd_clock(80, 60, 50, 0, 8, 15, 0, 0);
```

Setting the background color



```
cmd_bgcolor(0x401010);
cmd_clock(80, 60, 50, 0, 8, 15, 0, 0);
```

Without the 3D look:



```
cmd_clock(80, 60, 50, OPT_FLAT, 8, 15, 0, 0);
```

The time fields can have large values. Here the hours are ( $7 \times 3600$ s) and minutes are ( $38 \times 60$ s), and seconds is 59. Creating a clock face showing the time as 7.38.59:



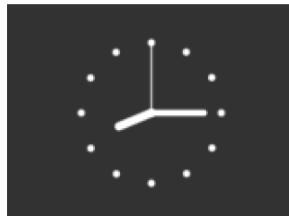
```
cmd_clock(80, 60, 50, 0, 0, 0, (7 * 3600) + (38 * 60)
+ 59, 0);
```

No seconds hand:



```
cmd_clock(80, 60, 50, OPT_NOSECS, 8, 15, 0, 0);
```

No Background:



```
cmd_clock(80, 60, 50, OPT_NOBACK, 8, 15, 0, 0);
```

No ticks:



```
cmd_clock(80, 60, 50, OPT_NOTICKS, 8, 15, 0, 0);
```

No hands:



```
cmd_clock(80, 60, 50, OPT_NOHANDS, 8, 15, 0, 0);
```

## 5.34 CMD\_FGCOLOR

This command is used to set the foreground color.

### C prototype

```
void cmd_fgcolor( uint32_t c );
```

### Parameters

**c**

New foreground color, as a 24-bit RGB number.

Red is the most significant 8 bits, blue is the least. So 0xff0000 is bright red.

Foreground color is applicable for things that the user can move such as handles and buttons.

### Command layout

+0	<b>CMD_FGCOLOR(0xFFFF FF0A)</b>
+4	c

### Examples

The top scrollbar uses the default foreground color, the others with a changed color:



```
cmd_scrollbar(20, 30, 120, 8, 0, 10, 40, 100);
cmd_fgcolor(0x703800);
cmd_scrollbar(20, 60, 120, 8, 0, 30, 40, 100);
cmd_fgcolor(0x387000);
cmd_scrollbar(20, 90, 120, 8, 0, 50, 40, 100);
```

## 5.35 CMD\_BGCOLOR

This command is used to set the background color

### C prototype

```
void cmd_bgcolor( uint32_t c );
```

### Parameters

**c**

New background color, as a 24-bit RGB number.

Red is the most significant 8 bits, blue is the least. So 0xff0000 is bright red.

Background color is applicable for things that the user cannot move E.g. behind gauges and sliders etc.

### Command layout

+0	<b>CMD_BGCOLOR(0xFFFF FF09)</b>
+4	c

### Examples

The top scrollbar uses the default background color, the others with a changed color:



```
cmd_scrollbar(20, 30, 120, 8, 0, 10, 40, 100);
cmd_bgcolor(0x402000);
cmd_scrollbar(20, 60, 120, 8, 0, 30, 40, 100);
cmd_bgcolor(0x202020);
cmd_scrollbar(20, 90, 120, 8, 0, 50, 40, 100);
```

## 5.36 CMD\_GRADCOLOR

This command is used to set the 3D Button Highlight Color

### C prototype

```
void cmd_gradcolor( uint32_t c );
```

### Parameters

**c**

New highlight gradient color, as a 24-bit RGB number.

White is the default value, i.e., 0xFFFFFFFF.

Red is the most significant 8 bits, blue is the least. So 0xFF0000 is bright red.

Gradient is supported only for Button and Keys widgets.

### Command layout

+0	<b>CMD_GRADCOLOR(0xFFFF FF34)</b>
+4	c

### Examples

Changing the gradient color: white, red, green and blue:



```
cmd_fgcolor(0x101010);
cmd_button( 2, 2, 76, 56, 31, 0, "W");
cmd_gradcolor(0xff0000);
cmd_button( 82, 2, 76, 56, 31, 0, "R");
cmd_gradcolor(0x00ff00);
cmd_button( 2, 62, 76, 56, 31, 0, "G");
cmd_gradcolor(0x0000ff);
cmd_button( 82, 62, 76, 56, 31, 0, "B");
```

The gradient color is also used for keys:



```
cmd_fgcolor(0x101010);
cmd_keys(10, 10, 140, 30, 26, 0, "abcde");
cmd_gradcolor(0xff0000);
cmd_keys(10, 50, 140, 30, 26, 0, "fghij");
```

## 5.37 CMD\_GAUGE

This command is used to draw a Gauge.

### C prototype

```
void cmd_gauge( int16_t x,
                int16_t y,
                int16_t r,
                uint16_t options,
                uint16_t major,
                uint16_t minor,
                uint16_t val,
                uint16_t range );
```

### Parameters

**x**

X-coordinate of gauge center, in pixels

**y**

Y-coordinate of gauge center, in pixels

**r**

Radius of the gauge, in pixels

### options

By default the gauge dial is drawn with a 3D effect and the value of options is zero. OPT\_FLAT removes the 3D effect. With option OPT\_NOBACK, the background is not drawn. With option OPT\_NOTICKS, the tick marks are not drawn. With option OPT\_NOPOINTER, the pointer is not drawn.

**major**

Number of major subdivisions on the dial, 1-10

**minor**

Number of minor subdivisions on the dial, 1-10

**val**

Gauge indicated value, between 0 and range, inclusive

**range**

Maximum value

### Description

The details of physical dimension are:

- The tick marks are placed on a 270 degree arc, clockwise starting at south-west position
- Minor ticks are lines of width  $r*(2/256)$ , major  $r*(6/256)$
- Ticks are drawn at a distance of  $r*(190/256)$  to  $r*(200/256)$
- The pointer is drawn with lines of width  $r*(4/256)$ , to a point  $r*(190/256)$  from the center
- The other ends of the lines are each positioned 90 degrees perpendicular to the pointer direction, at a distance  $r*(3/256)$  from the center

Refer to [Coprocessor engine widgets physical dimensions](#) for more information.

### Command layout

+0	CMD_GAUGE(0xFFFF FF13)
+4	x
+6	y
+8	r
+10	options
+12	major
+14	minor
+16	value
+18	range

### Examples

A gauge with radius 50 pixels, five divisions of four ticks each, indicates 30%:



```
cmd_gauge(80, 60, 50, 0, 5, 4, 30, 100);
```

Without the 3D look:



```
cmd_gauge(80, 60, 50, OPT_FLAT, 5, 4, 30, 100);
```

Ten major divisions with two minor divisions each:



```
cmd_gauge(80, 60, 50, 0, 10, 2, 30, 100);
```

Setting the minor divisions to 1 makes them disappear:



```
cmd_gauge(80, 60, 50, 0, 10, 1, 30, 100);
```

Setting the major divisions to 1 gives minor division only:



```
cmd_gauge(80, 60, 50, 0, 1, 10, 30, 100);
```

A smaller gauge with a brown background:



```
cmd_bgcolor(0x402000);
cmd_gauge(80, 60, 25, 0, 5, 4, 30, 100);
```

Scale 0-1000, indicating 1000:



```
cmd_gauge(80, 60, 50, 0, 5, 2, 1000, 1000);
```

Scaled 0-65535, indicating 49152:



```
cmd_gauge(80, 60, 50, 0, 4, 4, 49152, 65535);
```

No background:



```
cmd_gauge(80, 60, 50, OPT_NOBACK, 4, 4, 49152,
65535);
```

No tick marks:



```
cmd_gauge(80, 60, 50, OPT_NOTICKS, 4, 4, 49152,
65535);
```

No pointer:



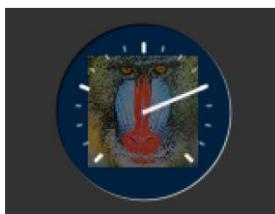
```
cmd_gauge(80, 60, 50, OPT_NOPOINTER, 4, 4, 49152,
65535);
```

Drawing the gauge in two passes, with bright red for the pointer:



```
GAUGE_0 = OPT_NOPOINTER;
GAUGE_1 = OPT_NOBACK | OPT_NOTICKS;
cmd_gauge(80, 60, 50, GAUGE_0, 4, 4, 49152, 65535);
cmd(COLOR_RGB(255, 0, 0));
cmd_gauge(80, 60, 50, GAUGE_1, 4, 4, 49152, 65535);
```

Add a custom graphic to the gauge by drawing its background, a bitmap, and then its foreground:



```
GAUGE_0 = OPT_NOPOINTER | OPT_NOTICKS;
GAUGE_1 = OPT_NOBACK;
cmd_gauge(80, 60, 50, GAUGE_0, 4, 4, 49152, 65535);
cmd(COLOR_RGB(130, 130, 130));
cmd(BEGIN(BITMAPS));
cmd(VERTEX2II(80 - 32, 60 - 32, 0, 0));
cmd(COLOR_RGB(255, 255, 255));
cmd_gauge(80, 60, 50, GAUGE_1, 4, 4, 49152, 65535);
```

## 5.38 CMD\_GRADIENT

This command is used to draw a smooth color gradient.

### C prototype

```
void cmd_gradient( int16_t x0,
int16_t y0,
uint32_t rgb0,
int16_t x1,
int16_t y1,
uint32_t rgb1 );
```

## Parameters

### x0

x-coordinate of point 0, in pixels

### y0

y-coordinate of point 0, in pixels

### rgb0

Color of point 0, as a 24-bit RGB number. Red is the most significant 8 bits, Blue is the least. So 0xff0000 is bright red.

### x1

x-coordinate of point 1, in pixels

### y1

y-coordinate of point 1, in pixels

### rgb1

Color of point 1, same definition as **rgb0**.

## Description

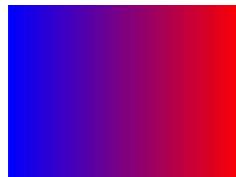
All the color step values are calculated based on smooth curve interpolated from the RGB0 to RGB1 parameter. The smooth curve equation is independently calculated for all three colors and the equation used is  $R0 + t * (R1 - R0)$ , where it is interpolated between 0 and 1. Gradient must be used with Scissor function to get the intended gradient display.

## Command layout

<b>+0</b>	<b>CMD_GRAGIENT(0xFFFF FF0B)</b>
+4	x0
+6	y0
+8	rgb0
+12	x1
+14	y1
+16	rgb1

## Examples

A horizontal gradient from blue to red



```
cmd_gradient(0, 0, 0x0000ff, 160, 0, 0xff0000);
```

A vertical gradient



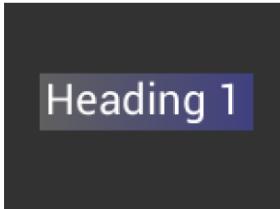
```
cmd_gradient(0, 0, 0x808080, 0, 120, 0x80ff40);
```

The same colors in a diagonal gradient



```
cmd_gradient(0, 0, 0x808080, 160, 120, 0x80ff40);
```

Using a scissor rectangle to draw a gradient stripe as a background for a title:



```
cmd(SCISSOR_XY(20, 40));
cmd(SCISSOR_SIZE(120, 32));
cmd_gradient(20, 0, 0x606060, 140, 0, 0x404080);
cmd_text(23, 40, 29, 0, "Heading 1");
```

## 5.39 CMD\_GRADIENTA

This command is used to draw a smooth color gradient with transparency. The two points have RGB color values, and alpha values which specify their opacity in the range 0x00 to 0xff.

### C prototype

```
void cmd_gradienta( int16_t x0,
                     int16_t y0,
                     uint32_t argb0,
                     int16_t x1,
                     int16_t y1,
                     uint32_t argb1 );
```

### Parameters

#### x0

x-coordinate of point 0, in pixels

#### y0

y-coordinate of point 0, in pixels

#### argb0

color of point 0, as a 32-bit ARGB number. A is the most significant 8 bits, B is the least. So 0x80ff0000 is 50% transparent bright red, and 0xff0000ff is solid blue.

#### x1

x-coordinate of point 1, in pixels

#### y1

y-coordinate of point 1, in pixels

#### argb1

color of point 1

### Description

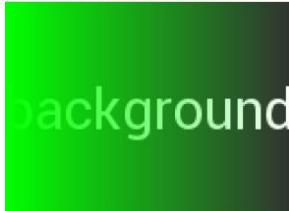
All the color step values are calculated based on smooth curve interpolated from the RGB0 to RGB1 parameter. The smooth curve equation is independently calculated for all three colors and the equation used is  $R0 + t * (R1 - R0)$ , where it is interpolated between 0 and 1. Gradient must be used with scissor function to get the intended gradient display.

## Command layout

+0	<b>CMD_GRADIENTA(0xFFFF FF57)</b>
+4	x0
+6	y0
+8	argb0
+12	x1
+14	y1
+16	argb1

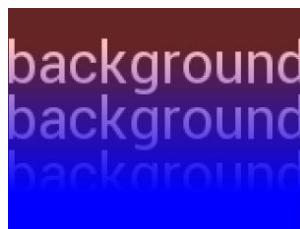
## Examples

A solid green gradient, transparent on the right:



```
cmd_text(80, 60, 30, OPT_CENTER, "background");
cmd_gradienta(0,0,0xff00ff00,160,0,0x0000ff00);
```

A vertical gradient from transparent red to solid blue:



```
cmd_text(80, 30, 30, OPT_CENTER, "background");
cmd_text(80, 60, 30, OPT_CENTER, "background");
cmd_text(80, 90, 30, OPT_CENTER, "background");
cmd_gradienta(0,20,0x40ff0000,0,100,0xff0000ff);
```

## 5.40 CMD\_KEYS

This command is used to draw a row of keys.

### C prototype

```
void cmd_keys( int16_t x,
               int16_t y,
               int16_t w,
               int16_t h,
               int16_t font,
               uint16_t options,
               const char* s );
```

### Parameters

**x**  
 x-coordinate of keys top-left, in pixels

**y**  
 y-coordinate of keys top-left, in pixels

**font**  
 Bitmap handle to specify the font used in key label. The valid range is from 0 to 31

### options

By default the keys are drawn with a 3D effect and the value of option is zero. OPT\_FLAT removes the 3D effect. If OPT\_CENTER is given the keys are drawn at minimum size centered within the w x h rectangle. Otherwise the keys are expanded so that they completely fill the

available space. If an ASCII code is specified, that key is drawn "pressed"-- i.e. in background color with any 3D effect removed.

**w**

The width of the keys

**h**

The height of the keys

**s**

key labels, one character per key. The TAG value is set to the ASCII value of each key, so that key presses can be detected using the REG\_TOUCH\_TAG register.

## Description

The details of physical dimension are:

- The gap between keys is 3 pixels
- For **OPT\_CENTERX** case, the keys are (font width + 1.5) pixels wide, otherwise keys are sized to fill available width

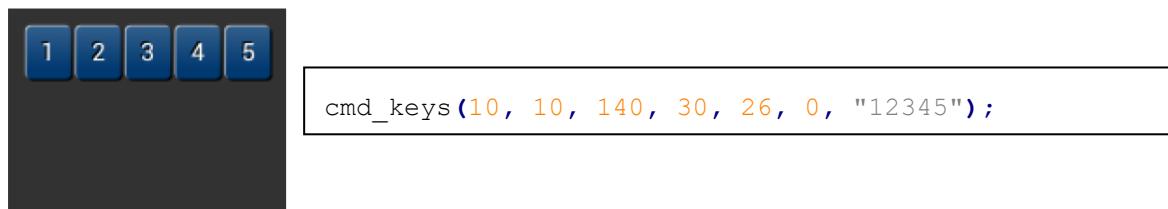
Refer to [Coprocessor engine widgets physical dimensions](#) for more information.

## Command layout

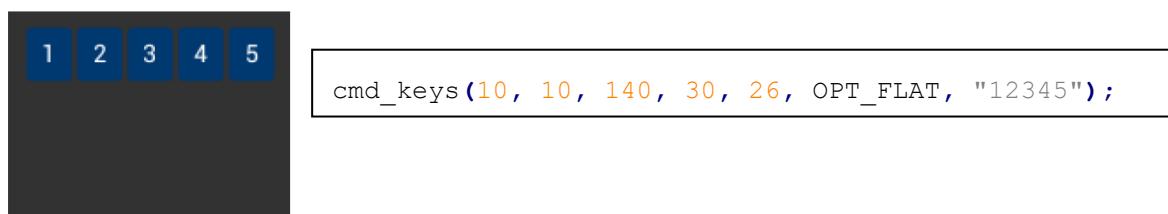
+0	CMD_KEYS(0xFFFF FF0E)
+4	x
+6	y
+8	w
+10	h
+12	font
+14	options
+16	s
...	...
+n	0

## Examples

A row of keys:



Without the 3D look:



Default vs. centered:



```
cmd_keys(10, 10, 140, 30, 26, 0, "12345");
cmd_keys(10, 60, 140, 30, 26, OPT_CENTER,
"12345");
```

Setting the options to show "" key pressed "" is ASCII code 0x32):



```
cmd_keys(10, 10, 140, 30, 26, 0x32, "12345");
```

A calculator-style keyboard using font 29:



```
cmd_keys(22, 1, 116, 28, 29, 0, "789");
cmd_keys(22, 31, 116, 28, 29, 0, "456");
cmd_keys(22, 61, 116, 28, 29, 0, "123");
cmd_keys(22, 91, 116, 28, 29, 0, "0.");
```

A compact keyboard drawn in font 20:



```
cmd_keys(2, 2, 156, 21, 20, OPT_CENTER,
"qwertyuiop");
cmd_keys(2, 26, 156, 21, 20, OPT_CENTER,
"asdfghijkl");
cmd_keys(2, 50, 156, 21, 20, OPT_CENTER, "zxcvbnm");
cmd_button(2, 74, 156, 21, 20, 0, "");
```

Showing the f (ASCII 0x66) key pressed:



```
k = 0x66;
cmd_keys(2, 2, 156, 21, 20, k | OPT_CENTER,
"qwertyuiop");
cmd_keys(2, 26, 156, 21, 20, k | OPT_CENTER,
"asdfghijkl");
cmd_keys(2, 50, 156, 21, 20, k | OPT_CENTER,
"zxcvbnm");
Cmd_button(2, 74, 156, 21, 20, 0, "");
```

## 5.41 CMD\_PROGRESS

This command is used to draw a progress bar.

### C prototype

```
void cmd_progress( int16_t x,
                   int16_t y,
                   int16_t w,
                   int16_t h,
                   uint16_t options,
                   uint16_t val,
                   uint16_t range );
```

### Parameters

#### x

x-coordinate of progress bar top-left, in pixels

#### y

y-coordinate of progress bar top-left, in pixels

#### w

width of progress bar, in pixels

#### h

height of progress bar, in pixels

#### options

By default the progress bar is drawn with a 3D effect and the value of options is zero. Options OPT\_FLAT remove the 3D effect and its value is 256

#### val

Displayed value of progress bar, between 0 and range inclusive

#### range

Maximum value

### Description

The details of physical dimensions are--

- x,y,w,h give outer dimensions of progress bar. Radius of barI is  $\min(w,h)/2$
- Radius of inner progress line is  $r*(7/8)$

Refer to [Coprocessor engine widgets physical dimensions](#) for more information.

### Command layout

+0	CMD_PROGRESS(0xFFFF FF0F)
+4	X
+6	Y
+8	W
+10	h
+12	options
+14	val
+16	range

## Examples

A progress bar showing 50% completion:



```
cmd_progress(20, 50, 120, 12, 0, 50, 100);
```

Without the 3D look:



```
cmd_progress(20, 50, 120, 12, OPT_FLAT, 50, 100);
```

A 4 pixel high bar, range 0-65535, with a brown background:



```
cmd_bgcolor(0x402000);
cmd_progress(20, 50, 120, 4, 0, 9000, 65535);
```

## 5.42 CMD\_SCROLLBAR

This command is used to draw a scroll bar.

### C prototype

```
void cmd_scrollbar( int16_t x,
                     int16_t y,
                     int16_t w,
                     int16_t h,
                     uint16_t options,
                     uint16_t val,
                     uint16_t size,
                     uint16_t range );
```

### Parameters

**x**

x-coordinate of scroll bar top-left, in pixels

**y**

y-coordinate of scroll bar top-left, in pixels

**w**

Width of scroll bar, in pixels. If width is greater than height, the scroll bar is drawn horizontally

**h**

Height of scroll bar, in pixels. If height is greater than width, the scroll bar is drawn vertically

### options

By default the scroll bar is drawn with a 3D effect and the value of options is zero. Options OPT\_FLAT remove the 3D effect and its value is 256

### val

Displayed value of scroll bar, between 0 and range inclusive

### range

Maximum value

## Description

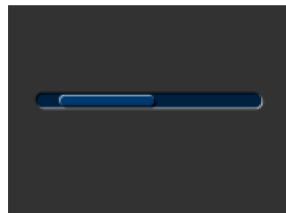
Refer to CMD\_PROGRESS for more information on physical dimension.

## Command layout

+0	CMD_SCROLLBAR(0xFFFF FF11)
+4	x
+6	y
+8	w
+10	h
+12	options
+14	val
+16	size
+18	range

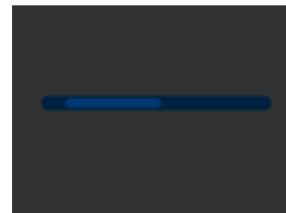
## Examples

A scroll bar indicating 10-50%:



```
cmd scrollbar(20, 50, 120, 8, 0, 10, 40, 100);
```

Without the 3D look:



```
cmd_scrollbar(20, 50, 120, 8, OPT_FLAT, 10, 40, 100);
```

A brown-themed vertical scroll bar:



```
cmd_bgcolor(0x402000);
cmd_fgcolor(0x703800);
cmd_scrollbar(140, 10, 8, 100, 0, 10, 40, 100);
```

## 5.43 CMD\_SLIDER

This command is to draw a slider.

### C prototype

```
void cmd_slider( int16_t x,  
                  int16_t y,  
                  int16_t w,  
                  int16_t h,  
                  uint16_t options,  
                  uint16_t val,  
                  uint16_t range );
```

### Parameters

**x**

x-coordinate of slider top-left, in pixels

**y**

y-coordinate of slider top-left, in pixels

**w**

width of slider, in pixels. If width is greater than height, the scroll bar is drawn horizontally

**h**

height of slider, in pixels. If height is greater than width, the scroll bar is drawn vertically

**options**

By default the slider is drawn with a 3D effect. OPT\_FLAT removes the 3D effect

**val**

Displayed value of slider, between 0 and range inclusive

**range**

Maximum value

### Description

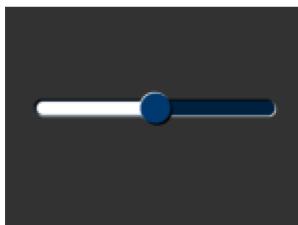
Refer to CMD\_PROGRESS for more information on physical dimension.

### Command layout

+0	CMD_SLIDER(0xFFFF FF10)
+4	x
+6	y
+8	w
+10	h
+12	options
+14	val
+16	range

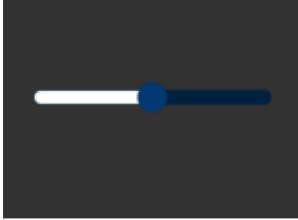
## Examples

A slider set to 50%:



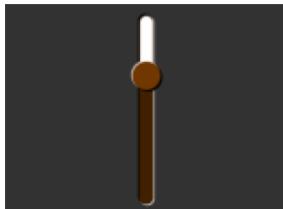
```
cmd slider(20, 50, 120, 8, 0, 50, 100);
```

Without the 3D look:



```
cmd slider(20, 50, 120, 8, OPT_FLAT, 50, 100);
```

A brown-themed vertical slider with range 0-65535:



```
cmd_bgcolor(0x402000);
cmd_fgcolor(0x703800);
cmd_slider(76, 10, 8, 100, 0, 20000, 65535);
```

## 5.44 CMD\_DIAL

This command is used to draw a rotary dial control.

### C prototype

```
void cmd_dial( int16_t x,
               int16_t y,
               int16_t r,
               uint16_t options,
               uint16_t val );
```

### Parameters

**x**  
x-coordinate of dial center, in pixels

**y**  
y-coordinate of dial center, in pixels

**r**  
radius of dial, in pixels.

### options

By default the dial is drawn with a 3D effect and the value of options is zero. Options OPT\_FLAT remove the 3D effect and its value is 256

### val

Specify the position of dial points by setting value between 0 and 65535 inclusive. 0 means that the dial points straight down, 0x4000 left, 0x8000 up, and 0xc000 right.

## Description

The details of physical dimension are

- The marker is a line of width  $r*(12/256)$ , drawn at a distance  $r*(140/256)$  to  $r*(210/256)$  from the center

Refer to [Coprocessor engine widgets physical dimensions](#) for more information.

## Command layout

<b>+0</b>	<b>CMD_DIAL(0xFFFF FF2D)</b>
+4	x
+6	y
+8	r
+10	options
+12	val

## Examples

A dial set to 50%:



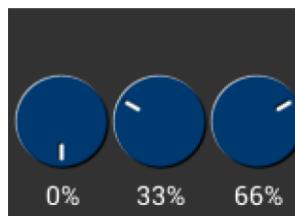
```
cmd_dial(80, 60, 55, 0, 0x8000);
```

Without the 3D look:



```
cmd_dial(80, 60, 55, OPT_FLAT, 0x8000);
```

Dials set to 0%, 33% and 66%:



```
cmd_dial(28, 60, 24, 0, 0x0000);
cmd_text(28, 100, 26, OPT_CENTER, "0%");
cmd_dial(80, 60, 24, 0, 0x5555);
cmd_text(80, 100, 26, OPT_CENTER, "33%");
cmd_dial(132, 60, 24, 0, 0xaaaa);
cmd_text(132, 100, 26, OPT_CENTER, "66%");
```

## 5.45 CMD\_TOGGLE

This command is used to draw a toggle switch with UTF-8 labels.

### C prototype

```
void cmd_toggle( int16_t x,
                 int16_t y,
                 int16_t w,
                 int16_t font,
                 uint16_t options,
                 uint16_t state,
                 const char* s );
```

### Parameters

#### x

x-coordinate of top-left of toggle, in pixel

#### y

y-coordinate of top-left of toggle, in pixels

#### w

width of toggle, in pixels

#### font

Font to use for text, 0-31. See [ROM and RAM Fonts](#)

#### options

By default the toggle is drawn with a 3D effect and the value of options is zero. Options **OPT\_FLAT** remove the 3D effect and its value is 256

#### state

State of the toggle: 0 is off, 65535 is on.

#### s

string labels for toggle,UTF-8 encoding. A character value of 255 (in C it can be written as '\xff') separates the label strings. See 5.6 [String Formatting](#).

### Description

The details of physical dimension are:

- Widget height (h) is font height \* (20/16) pixel.
- Outer bar radius (r) is font height \* (10/16) pixel.
- Knob radius is (r-1.5) pixel, where r is the outer bar radius above.
- The center of outer bar's left round head is at (x, y + r/2) coordinate.

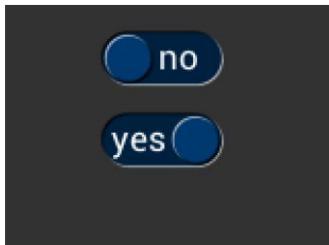
Refer to [Coprocessor engine widgets physical dimensions](#) for more information.

### Command layout

+0	CMD_TOGGLE(0xFFFF FF12)
+4	x
+6	y
+8	w
+10	font
+12	options
+14	state
+16	s

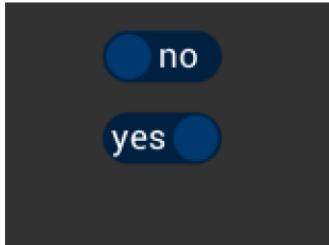
## Examples

Using a medium font, in the two states:



```
cmd_toggle(60, 20, 33, 27, 0, 0, "no" "\xff"
"yes");
cmd_toggle(60, 60, 33, 27, 0, 65535, "no" "\xff"
"yes");
```

Without the 3D look:



```
cmd_toggle(60, 20, 33, 27, OPT_FLAT, 0, "no" "\xff"
"yes");
cmd_toggle(60, 60, 33, 27, OPT_FLAT, 65535, "no"
"\xff" "yes");
```

With different background and foreground colors:



```
cmd_bgcolor(0x402000);
cmd_fgcolor(0x703800);
cmd_toggle(60, 20, 33, 27, 0, 0, "no" "\xff"
"yes");
cmd_toggle(60, 60, 33, 27, 0, 65535, "no" "\xff"
"yes");
```

## 5.46 CMD\_FILLWIDTH

This command sets the pixel fill width for **CMD\_TEXT,CMD\_BUTTON,CMD\_BUTTON** with the **OPT\_FILL** option.

### C prototype

```
void cmd_fillwidth( uint32_t s );
```

### Parameters

**s**  
line fill width, in pixels

### Command layout

+0	<b>CMD_FILLWIDTH(0xFFFF FF58)</b>
+4	s

## Examples

Long text split into lines of no more than 160 pixels:

This text  
doesn't fit  
on one line

```
cmd_fillwidth(160);
cmd_text(0, 0, 30, OPT_FILL, "This text doesn't
fit on one line");
```

## 5.47 CMD\_TEXT

This command is used to draw a UTF-8 Text string.

### C prototype

```
void cmd_text(    int16_t x,
                  int16_t y,
                  int16_t font,
                  uint16_t options,
                  const char* s );
```

### Parameters

#### x

x-coordinate of text base, in pixels

#### y

y-coordinate of text base, in pixels

#### font

Font to use for text, 0-31. See [ROM and RAM Fonts](#)

#### options

By default (x,y) is the top-left pixel of the text and the value of options is zero.

**OPT\_CENTERX** centers the text horizontally, **OPT\_CENTERY** centers it vertically.

**OPT\_CENTER** centers the text in both directions.

**OPT\_RIGHTX** right-justifies the text, so that the x is the rightmost pixel.

**OPT\_FORMAT** processes the text as a format string, see String formatting.

**OPT\_FILL** breaks the text at spaces into multiple lines, with maximum width set by **CMD\_FILLWIDTH**.

#### s

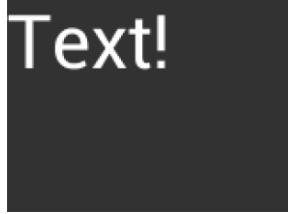
Text string, UTF-8 encoding. If **OPT\_FILL** is not given then the string may contain newline (\n) characters, indicating line breaks. See 5.6 String Formatting

### Command layout

+0	<b>CMD_TEXT(0xFFFF FF0C)</b>
+4	x
+6	y
+8	font
+10	options
+12	s
..	..
..	0 (null character to terminate string)

### Examples

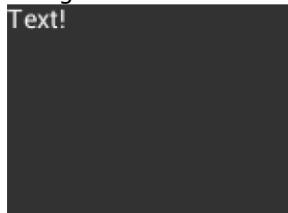
Plain text at (0,0) in the largest font:



Text!

```
cmd_text(0, 0, 31, 0, "Text!");
```

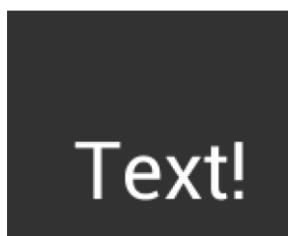
Using a smaller font:



Text!

```
cmd_text(0, 0, 26, 0, "Text!");
```

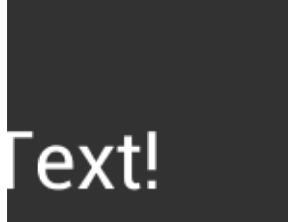
Centered horizontally:



Text!

```
cmd_text(80, 60, 31, OPT_CENTERX, "Text!");
```

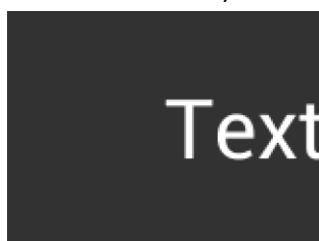
Right-justified:



Text!

```
cmd_text(80, 60, 31, OPT_RIGHTX, "Text!");
```

Centered vertically:



Text!

```
cmd_text(80, 60, 31, OPT_CENTERY, "Text!");
```

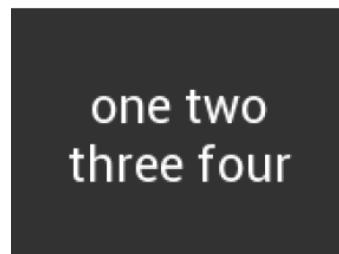
Centered both horizontally and vertically:



Text!

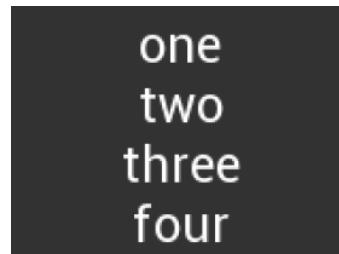
```
cmd_text(80, 60, 31, OPT_CENTER, "Text!");
```

Text with explicit newline:



```
cmd_text(80, 60, 29, OPT_CENTER, "one\ntwo\nthree\nfour");
```

Text split into lines and centered:



```
cmd_fillwidth(80);  
cmd_text(80, 60, 29, OPT_FILL | OPT_CENTER, "one\ntwo three four");
```

## 5.48 CMD\_SETBASE

This command is used to set the base for number output.

### C prototype

```
void cmd_setbase( uint32_t b );
```

### Parameters

#### b

Numeric base, valid values are from 2 to 36:

2 for binary,

8 for octal,

10 for decimal,

16 for hexadecimal

### Description

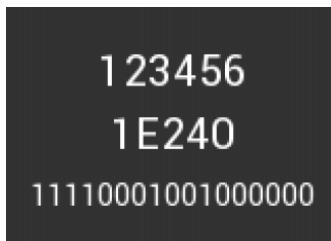
Set up numeric base for **CMD\_NUMBER**

### Command layout

+0	<b>CMD_SETBASE(0xFFFF FF38)</b>
+4	b

### Examples

The number 123456 displayed in decimal, hexadecimal and binary:



```
cmd_number(80, 30, 28, OPT_CENTER, 123456);  
cmd_setbase(16);  
cmd_number(80, 60, 28, OPT_CENTER, 123456);  
cmd_setbase(2);  
cmd_number(80, 90, 26, OPT_CENTER, 123456);
```

## 5.49 CMD\_NUMBER

This command is used to draw a number.

### C prototype

```
void cmd_number(int16_t x,  
                int16_t y,  
                int16_t font,  
                uint16_t options,  
                int32_t n );
```

### Parameters

**x**

x-coordinate of text base, in pixels

**y**

y-coordinate of text base, in pixels

**font**

font to use for text, 0-31. See ROM and RAM Fonts

**options**

By default (x,y) is the top-left pixel of the text.

OPT\_CENTERX centers the text horizontally,

OPT\_CENTERY centers it vertically.

OPT\_CENTER centers the text in both directions.

OPT\_RIGHTX right-justifies the text, so that the x is the rightmost pixel.

By default the number is displayed with no leading zeroes, but if a width 1-9 is specified in the options, then the number is padded if necessary with leading zeroes so that it has the given width. If OPT\_SIGNED is given, the number is treated as signed, and prefixed by a minus sign if negative.

**n**

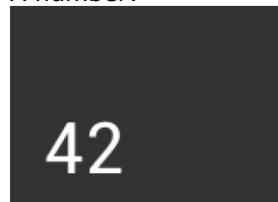
The number to display, is either unsigned or signed 32-bit, in the base specified in the preceding [CMD\\_SETBASE](#). If no CMD\_SETBASE appears before **CMD\_NUMBER**, it will be in decimal base.

### Command layout

+0	<b>CMD_NUMBER(0xFFFF FF2E)</b>
+4	x
+6	y
+8	font
+10	options
+12	n

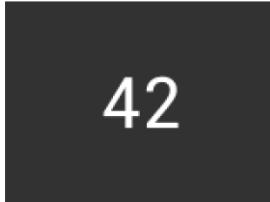
### Examples

A number:



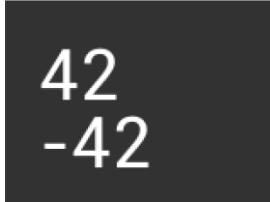
```
cmd number(20, 60, 31, 0, 42);
```

Centered:



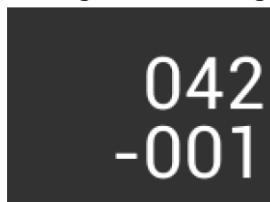
```
cmd_number(80, 60, 31, OPT_CENTER, 42);
```

Signed output of positive and negative numbers:



```
cmd_number(20, 20, 31, OPT_SIGNED, 42);
cmd_number(20, 60, 31, OPT_SIGNED, -42);
```

Forcing width to 3 digits, right-justified



```
cmd_number(150, 20, 31, OPT_RIGHTX | 3, 42);
cmd_number(150, 60, 31, OPT_SIGNED | OPT_RIGHTX | 3,
           -1);
```

## 5.50 CMD\_LOADIDENTITY

This command instructs the coprocessor engine to set the current matrix to the identity matrix, so that the coprocessor engine is able to form the new matrix as requested by CMD\_SCALE, CMD\_ROTATE,CMD\_TRANSLATE command.

For more information on the identity matrix, refer to the [Bitmap Transformation Matrix](#) section.

### C prototype

```
void cmd_loadidentity();
```

### Command layout

+0	<b>CMD_LOADIDENTITY(0xFFFF FF26)</b>
----	--------------------------------------

## 5.51 CMD\_SETMATRIX

The coprocessor engine assigns the value of the current matrix to the bitmap transform matrix of the graphics engine by generating display list commands, i.e., BITMAP\_TRANSFORM\_A-F. After this command, the following bitmap rendering operation will be affected by the new transform matrix.

### C prototype

```
void cmd_setmatrix();
```

### Command layout

+0	<b>CMD_SETMATRIX(0xFFFF FF2A)</b>
----	-----------------------------------

## 5.52 CMD\_GETMATRIX

This command retrieves the current matrix within the context of the coprocessor engine. Note the matrix within the context of the coprocessor engine will not apply to the bitmap transformation until it is passed to the graphics engine through **CMD\_SETMATRIX**.

### C prototype

```
void cmd_getmatrix( int32_t a,  
                     int32_t b,  
                     int32_t c,  
                     int32_t d,  
                     int32_t e,  
                     int32_t f );
```

### Parameters

**a**

output parameter; written with matrix coefficient a. See the parameter a of the command BITMAP\_TRANSFORM\_A for formatting.

**b**

output parameter; written with matrix coefficient b. See the parameter b of the command BITMAP\_TRANSFORM\_B for formatting.

**c**

output parameter; written with matrix coefficient c. See the parameter c of the command BITMAP\_TRANSFORM\_C for formatting.

**d**

output parameter; written with matrix coefficient d. See the parameter d of the command BITMAP\_TRANSFORM\_D for formatting.

**e**

output parameter; written with matrix coefficient e. See the parameter e of the command BITMAP\_TRANSFORM\_E for formatting.

**f**

output parameter; written with matrix coefficient f. See the parameter f of the command BITMAP\_TRANSFORM\_F for formatting.

### Command layout

+0	<b>CMD_GETMATRIX(0xFFFF FF33)</b>
+4	a
+8	b
+12	c
+16	d
+20	e
+24	f

## 5.53 CMD\_GETPTR

This command returns the first unallocated memory location.

At API level 1, the allocation pointer is advanced by the following commands:

- cmd\_inflate
- cmd\_inflate2

At API level 2, the allocation pointer is also advanced by:

- cmd\_loadimage
- cmd\_playvideo
- cmd\_videoframe
- cmd\_endlist

### C prototype

```
void cmd_getptr( uint32_t result );
```

### Parameters

#### result

The first unallocated memory location.

### Command layout

+0	<b>CMD_GETPTR (0xFFFF FF23)</b>
+4	result

### Examples

```
cmd_inflate(1000); //Decompress the data into RAM_G + 1000
.....
//Following the zlib compressed data
While(rd16(REG_CMD_WRITE) != rd16(REG_CMD_READ)); //Wait till the compression was done

uint16_t x = rd16(REG_CMD_WRITE);
uint32_t ending_address = 0;
cmd_getptr(0);
ending_address = rd32(RAM_CMD + (x + 4) & 4096);
```

## 5.54 CMD\_GETPROPS

This command returns the source address and size of the bitmap loaded by the previous **CMD\_LOADIMAGE**.

### C prototype

```
void cmd_getprops( uint32_t ptr, uint32_t width, uint32_t height);
```

### Parameters

#### ptr

Source address of bitmap.

#### Note :

At API Level 2 this parameter returns the source address of the decoded image data in RAM\_G

At API level 1, this parameter has different meaning based on the input image format of CMD\_LOADIMAGE: For JPEG, it is the source address of the decoded image data in RAM\_G. For PNG, it is the first unused address in RAM\_G after decoding process.

It is an output parameter.

#### width

The width of the image which was decoded by the last CMD\_LOADIMAGE before this command.

It is an output parameter.

#### height

The height of the image which was decoded by the last CMD\_LOADIMAGE before this command.

It is an output parameter

### Command layout

<b>+0</b>	<b>CMD_GETPROPS (0xFFFF FF25)</b>
+4	wtr
+8	width
+12	height

### Description

This command is used to retrieve the properties of the image which is decoded by **CMD\_LOADIMAGE**. Respective image properties are updated by the coprocessor after this command is executed successfully.

### Examples

Please refer to the [CMD\\_GETPTR](#).

## 5.55 CMD\_SCALE

This command is used to apply a scale to the current matrix.

### C prototype

```
void cmd_scale( int32_t sx,
                int32_t sy );
```

### Parameters

#### **sx**

x scale factor, in signed 16. 16 bit fixed-point Form.

#### **sy**

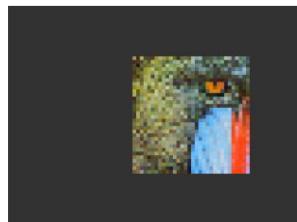
y scale factor, in signed 16. 16 bit fixed-point form.

### Command layout

<b>+0</b>	<b>CMD_SCALE(0xFFFF FF28)</b>
+4	sx
+8	sy

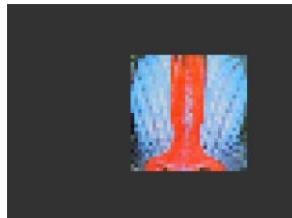
### Examples

To zoom a bitmap 2X:



```
cmd(BEGIN(BITMAPS));
cmd_loadidentity();
cmd_scale(2 * 65536, 2 * 65536);
cmd_setmatrix();
cmd_VERTEX2II(68, 28, 0, 0);
```

To zoom a bitmap 2X around its center:



```
cmd(BEGIN(BITMAPS));
cmd_loadidentity();
cmd_translate(65536 * 32, 65536 * 32);
cmd_scale(2 * 65536, 2 * 65536);
cmd_translate(65536 * -32, 65536 * -32);
cmd_setmatrix();
```

## 5.56 CMD\_ROTATE

This command is used to apply a rotation to the current matrix.

### C prototype

```
void cmd_rotate( int32_t a );
```

### Parameters

**a**

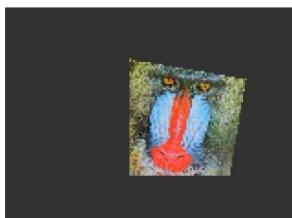
Clockwise rotation angle, in units of 1/65536 of a circle

### Command layout

+0	<b>CMD_ROTATE(0xFFFF FF29)</b>
+4	a

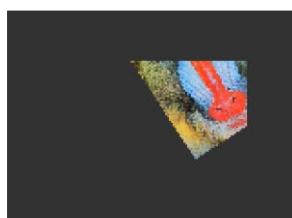
### Examples

To rotate the bitmap clockwise by 10 degrees with respect to the top left of the bitmap:



```
cmd(BEGIN(BITMAPS));
cmd_loadidentity();
cmd_rotate(10 * 65536 / 360);
cmd_setmatrix();
cmd(VERTEX2II(68, 28, 0, 0));
```

To rotate the bitmap counter clockwise by 33 degrees around the top left of the bitmap:



```
cmd(BEGIN(BITMAPS));
cmd_loadidentity();
cmd_rotate(-33 * 65536 / 360);
cmd_setmatrix();
cmd(VERTEX2II(68, 28, 0, 0));
```

Rotating a 64 x 64 bitmap around its center:



```
cmd(BEGIN(BITMAPS));
cmd_loadidentity();
cmd_translate(65536 * 32, 65536 * 32);
cmd_rotate(90 * 65536 / 360);
cmd_translate(65536 * -32, 65536 * -32);
cmd_setmatrix();
cmd(VERTEX2II(68, 28, 0, 0));
```

## 5.57 CMD\_ROTATEAROUND

This command is used to apply a rotation and scale around a specified coordinate.

### C prototype

```
void cmd_rotatearound( int32_t x,
                      int32_t y,
                      int32_t a,
                      int32_t s );
```

### Parameters

**x**  
center of rotation/scaling, x-coordinate

**y**  
center of rotation/scaling, x-coordinate

**a**  
clockwise rotation angle, in units of 1/65536 of a circle

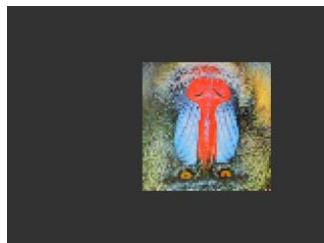
**s**  
scale factor, in signed 16.16 bit fixed-point form

### Command layout

+0	<b>CMD_ROTATEAROUND(0xFFFF FF51)</b>
+4	x
+8	y
+12	a
+16	s

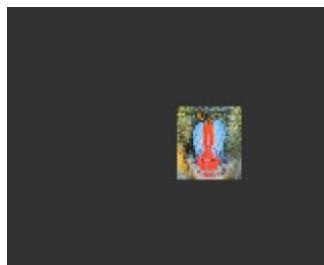
### Examples

Rotating a 64 x 64 bitmap around its center:



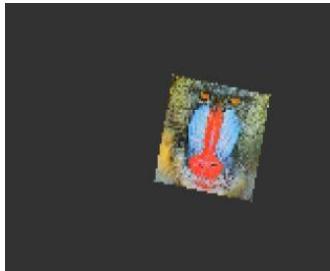
```
cmd(BEGIN(BITMAPS));
cmd_loadidentity();
cmd_rotatearound(32,32, 180 * 65536 /360,
65536 *1);
cmd_setmatrix();
cmd(VERTEX2II(68, 28, 0, 0));
```

To halve the bitmap size, again around the center:



```
cmd(BEGIN(BITMAPS));
cmd_loadidentity();
cmd_rotatearound(32, 32, 0, 0.5 * 65536);
cmd_setmatrix();
cmd(VERTEX2II(68, 28, 0, 0));
```

A combined 11 degree rotation and shrink by 0.75



```
cmd(BEGIN(BITMAPS));
cmd_loadidentity();
cmd_rotatearound(32, 32, 11*65536/360, 0.75
* 65536);
cmd_setmatrix();
cmd(VERTEX2II(68, 28, 0, 0));
```

## 5.58 CMD\_TRANSLATE

This command is used to apply a translation to the current matrix.

### C prototype

```
void cmd_translate( int32_t tx,
                    int32_t ty );
```

### Parameters

#### tx

x translate factor, in signed 16.16 bit fixed-point Form.

#### ty

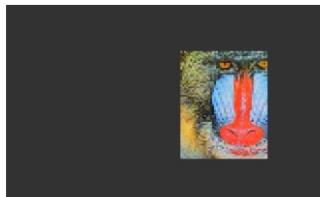
y translate factor, in signed 16.16 bit fixed-point form.

### Command layout

<b>+0</b>	<b>CMD_TRANSLATE(0xFFFF FF27)</b>
+4	tx
+8	ty

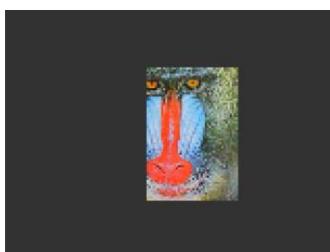
### Examples

To translate the bitmap 20 pixels to the right:



```
cmd(BEGIN(BITMAPS));
cmd_loadidentity();
cmd_translate(20 * 65536, 0);
cmd_setmatrix();
cmd(VERTEX2II(68, 28, 0, 0));
```

To translate the bitmap 20 pixels to the left:



```
cmd(BEGIN(BITMAPS));
cmd_loadidentity();
cmd_translate(-20 * 65536, 0);
cmd_setmatrix();
cmd(VERTEX2II(68, 28, 0, 0));
```

## 5.59 CMD\_CALIBRATE

This command is used to execute the touch screen calibration routine. The calibration procedure collects three touches from the touch screen, then computes and loads an appropriate matrix into **REG\_TOUCH\_TRANSFORM\_A-F**. To use the function, create a display list and include **CMD\_CALIBRATE**. The coprocessor engine overlays the touch targets on the current display list, gathers the calibration input and updates **REG\_TOUCH\_TRANSFORM\_A-F**.

Please note that this command only applies to RTE and compatibility mode of CTSE.

### C prototype

```
void cmd_calibrate( uint32_t result );
```

### Parameters

#### result

output parameter; written with 0 on failure of calibration.

### Description

The completion of this function is detected when the value of **REG\_CMD\_READ** is equal to **REG\_CMD\_WRITE**.

### Command layout

+0	<b>CMD_CALIBRATE(0xFFFF FF15)</b>
+4	result

### Examples

```
cmd_dlstart();
cmd(CLEAR(1,1,1));
cmd_text(80, 30, 27, OPT_CENTER, "Please tap on 'the dot'");
cmd_calibrate();
```

## 5.60 CMD\_CALIBRATESUB

This command is used to execute the touch screen calibration routine for a sub-window. Like **CMD\_CALIBRATE**, except that instead of using the whole screen area, uses a smaller sub-window specified for the command. This is intended for panels which do not use the entire defined surface.

Please note that this command only applies to RTE and compatibility mode of CTSE.

### C prototype

```
void cmd_calibratesub( uint16_t x,
                      uint16_t y,
                      uint16_t w,
                      uint16_t h,
                      uint32_t result );
```

### Parameters

#### x

x-coordinate of top-left of subwindow, in pixels.

#### y

y-coordinate of top-left of subwindow, in pixels.

**w**

width of subwindow, in pixels.

**h**

height of subwindow, in pixels.

**result**

output parameter; written with 0 on failure.

## Command layout

<b>+0</b>	<b>CMD_CALIBRATESUB(0xFFFF FF60)</b>
+4	x
+6	y
+8	w
+10	h
+12	result

**Note:** BT817/8 specific command

## Examples

```
cmd_dlstart();
cmd(CLEAR(1,1,1));
cmd_text(600, 140, 31, OPT_CENTER, "Please tap on the dot");
//Calibrate a touch screen for 1200x280 screen
cmd_calibratesub(0,0, 1200,280,0);
```

## 5.61 CMD\_SETROTATE

This command is used to rotate the screen.

### C prototype

```
void cmd_setrotate( uint32_t r );
```

### Parameters

**r**

The value from 0 to 7. The same definition as the value in **REG\_ROTATE**. Refer to the section [Rotation](#) for more details.

### Description

**CMD\_SETROTATE** sets **REG\_ROTATE** to the given value *r*, causing the screen to rotate. It also appropriately adjusts the touch transform matrix so that coordinates of touch points are adjusted to rotated coordinate system.

## Command layout

<b>+0</b>	<b>CMD_SETROTATE (0xFFFF FF36)</b>
+4	r

## Examples

```
cmd_setrotate(2); //Put the display in portrait mode
```

## 5.62 CMD\_SPINNER

This command is used to start an animated spinner. The spinner is an animated overlay that shows the user that some task is continuing. To trigger the spinner, create a display list and then use CMD\_SPINNER. The coprocessor engine overlays the spinner on the current display list, swaps the display list to make it visible, then continuously animates until it receives CMD\_STOP. REG\_MACRO\_0 and REG\_MACRO\_1 registers are utilized to perform the animation kind of effect. The frequency of point's movement is with respect to the display frame rate configured.

Typically for 480x272 display panels the display rate is ~60fps. For style 0 and 60fps, the point repeats the sequence within 2 seconds. For style 1 and 60fps, the point repeats the sequence within 1.25 seconds. For style 2 and 60fps, the clock hand repeats the sequence within 2 seconds. For style 3 and 60fps, the moving dots repeat the sequence within 1 second. Note that only one of **CMD\_SKETCH**, **CMD\_SCREENSAVER**, or **CMD\_SPINNER** can be active at one time.

### C prototype

```
void cmd_spinner( int16_t x,
                  int16_t y,
                  uint16_t style,
                  uint16_t scale );
```

### Command layout

<b>+0</b>	<b>CMD_SPINNER(0xFFFF FF16)</b>
+4	x
+6	y
+8	style
+10	scale

### Parameters

**x**  
The X coordinate of top left of spinner

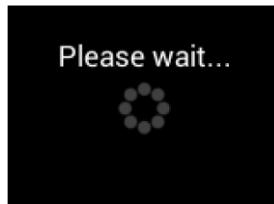
**y**  
The Y coordinate of top left of spinner

**style**  
The style of spinner. Valid range is from 0 to 3.

**scale**  
The scaling coefficient of spinner. 0 means no scaling.

### Examples

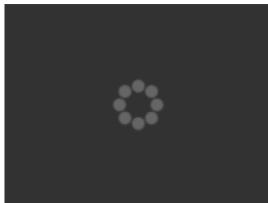
Create a display list, then start the spinner:



```
cmd_dlstart();
cmd(CLEAR(1,1,1));
cmd_text(80, 30, 27, OPT_CENTER, "Please
wait...");  

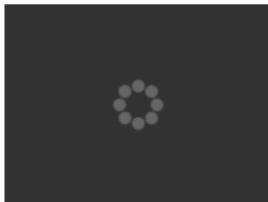
cmd_spinner(80, 60, 0, 0);
```

Spinner style 0, a circle of dots:



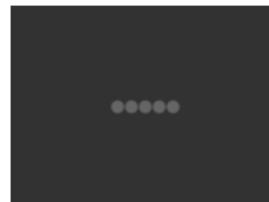
```
cmd_spinner(80, 60, 0, 0);
```

Spinner style 0, a circle of dots:



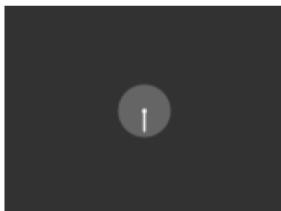
```
cmd_spinner(80, 60, 0, 0);
```

Style 1, a line of dots:



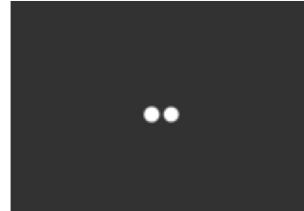
```
cmd_spinner(80, 60, 1, 0);
```

Style 2, a rotating clock hand:



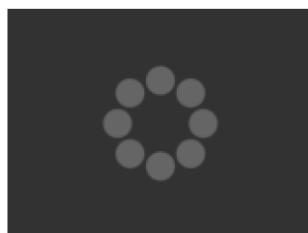
```
cmd_spinner(80, 60, 2, 0);
```

Style 3, two orbiting dots:



```
cmd_spinner(80, 60, 3, 0);
```

Half screen, scale:



```
cmd_spinner(80, 60, 0, 1);
```

Full screen, scale 2:



```
cmd_spinner(80, 60, 0, 2);
```

## 5.63 CMD\_SCREENSAVER

This command is used to start an animated screensaver. After the screensaver command, the coprocessor engine continuously updates **REG\_MACRO\_0** with **VERTEX2F** with varying (x,y) coordinates. With an appropriate display list, this causes a bitmap to move around the screen without any MCU work. Command **CMD\_STOP** stops the update process. Note that only one of **CMD\_SKETCH**, **CMD\_SCREENSAVER**, or **CMD\_SPINNER** can be active at one time.

### C prototype

```
void cmd_screensaver( );
```

### Description

**REG\_MACRO\_0** is updated with respect to frame rate (depending on the display registers configuration). Typically for a 480x272 display the frame rate is around 60 frames per second.

### Command layout

+0	CMD_SCREENSAVER(0xFFFF FF2F)
----	------------------------------

### Examples

To start the screensaver, create a display list using a MACRO instruction – the coprocessor engine will update it continuously:



```
cmd_screensaver();
cmd(BITMAP_SOURCE(0));
cmd(BITMAP_LAYOUT(RGB565, 128, 64));
cmd(BITMAP_SIZE(NEAREST,BORDER,BORDER, 40, 30));
cmd(BEGIN(BITMAPS));
cmd(MACRO(0));
cmd(DISPLAY());
```

## 5.64 CMD\_SKETCH

This command is used to start a continuous sketch update. The Coprocessor engine continuously samples the touch inputs and paints pixels into a bitmap, according to the given touch (x, y). This means that the user touch inputs are drawn into the bitmap without any need for MCU work. **CMD\_STOP** is to be sent to stop the sketch process.

Note that only one of **CMD\_SKETCH**, **CMD\_SCREENSAVER**, or **CMD\_SPINNER** can be active at one time.

### C prototype

```
void cmd_sketch( int16_t x,
                 int16_t y,
                 uint16_t w,
                 uint16_t h,
                 uint32_t ptr,
                 uint16_t format );
```

### Parameters

**x**

x-coordinate of sketch area top-left, in pixels

**y**

y-coordinate of sketch area top-left, in pixels

**w**

Width of sketch area, in pixels

**h**

Height of sketch area, in pixels

**ptr**

Base address of sketch bitmap

**format**

Format of sketch bitmap, either L1 or L8

**Note:** The update frequency of bitmap data located at ptr depends on the sampling frequency of the built-in ADC circuit, which is up to 1000 Hz.

### Command layout

+0	CMD_SKETCH(0xFFFF FF30)
+4	x
+6	y
+8	w
+10	h
+12	ptr
+16	format

### Examples

To start sketching into a 480x272 L1 bitmap:

```
cmd_memzero(0, 480 * 272 / 8);
cmd_sketch(0, 0, 480, 272, 0, L1);

//Then to display the bitmap
cmd(BITMAP_SOURCE(0));
cmd(BITMAP_LAYOUT(L1, 60, 272));
cmd(BITMAP_SIZE(NEAREST, BORDER, BORDER, 480, 272));
cmd(BEGIN(BITMAPS));
cmd(VERTEX2II(0, 0, 0, 0));

//Finally, to stop sketch updates
cmd_stop();
```

## 5.65 CMD\_STOP

This command is to inform the coprocessor engine to stop the periodic operation, which is triggered by **CMD\_SKETCH**, **CMD\_SPINNER** or **CMD\_SCREENSAVER**.

### C prototype

```
void cmd_stop();
```

### Command layout

+0	CMD_STOP(0xFFFF FF17)
----	-----------------------

### Description

For **CMD\_SPINNER** and **CMD\_SCREENSAVER**, **REG\_MACRO\_0** and **REG\_MACRO\_1** updating will be stopped.

For **CMD\_SKETCH**, the bitmap data in **RAM\_G** updating will be stopped.

## Examples

See [CMD\\_SKETCH](#), [CMD\\_SPINNER](#), [CMD\\_SCREENSAVER](#).

## 5.66 CMD\_SETFONT

CMD\_SETFONT is used to register one custom defined bitmap font into the coprocessor engine. After registration, the coprocessor engine is able to use the bitmap font with corresponding commands.

Note that **CMD\_SETFONT** does not set up the font's bitmap parameters. The MCU should do this before using the font. For further details about how to set up a custom font, refer to ROM and RAM Fonts.

### C prototype

```
void cmd_setfont( uint32_t font,
                  uint32_t ptr );
```

### Command layout

+0	<b>CMD_SETFONT(0xFFFF FF2B)</b>
+4	font
+8	ptr

### Parameters

#### font

The bitmap handle from 0 to 31

#### ptr

The metrics block address in **RAM\_G**. 4 bytes aligned is required.

## Examples

With a suitable font metrics block loaded in **RAM\_G** at address 1000, to set it up for use with objects as font 7:

```
cmd(BITMAP_LAYOUT(L8, 16, 10));
cmd(BITMAP_SIZE(NEAREST, BORDER, BORDER, 16, 10));
cmd(BITMAP_SOURCE(1000));
cmd_setfont(7, 1000);
cmd_button(20, 20,
           120, 40,
           7,
           0,
           "custom font!");
```

// x,y  
 // width,height in pixels  
 // font 7, just loaded  
 // default options, 3D style

## 5.67 CMD\_SETFONT2

This command is used to set up a custom font. To use a custom font with the coprocessor objects, create the font definition data in **RAM\_G** and issue **CMD\_SETFONT2**, as described in ROM and RAM Fonts.

Note that **CMD\_SETFONT2** sets up the font's bitmap parameters by appending commands **BITMAP\_SOURCE**, **BITMAP\_LAYOUT** and **BITMAP\_SIZE** to the current display list.

For details about how to set up a custom font, refer to [ROM and RAM Fonts](#).

### C prototype

```
void cmd_setfont2 (uint32_t font,
                  uint32_t ptr,
                  uint32_t firstchar );
```

### Command layout

+0	<b>CMD_SETFONT2(0xFFFF FF3B)</b>
+4	font
+8	ptr
+12	firstchar

### Parameters

#### font

The bitmap handle from 0 to 31

#### ptr

32 bit aligned memory address in **RAM\_G** of font metrics block

#### firstchar

The **ASCII** value of first character in the font. **For an extended font block, this should be zero.**

### Examples

With a suitable font metrics block loaded in RAM\_G at address 100000, first character's ASCII value 32, to use it for font 20:



```
cmd_setfont2(20, 100000, 32);
cmd_button(15, 30, 130, 20, 18, 0, "This is font 18");
cmd_button(15, 60, 130, 20, 20, 0, "This is font 20");
```

## 5.68 CMD\_SETSCRATCH

This command is used to set the scratch bitmap for widget use. Graphical objects use a bitmap handle for rendering. By default this is bitmap handle 15. This command allows it to be set to any bitmap handle. This command enables user to utilize bitmap handle 15 safely.

### C prototype

```
void cmd_setscratch( uint32_t handle);
```

### Parameters

#### handle

bitmap handle number, 0~31

### Command layout

+0	<b>CMD_SETSCRATCH (0xFFFF FF3C)</b>
+4	handle

## Examples

With the setscratch command, set the handle 31, handle 15 is available for application use, for example as a font:



```
cmd_setscratch(31);
cmd_setfont2(15, 100000, 32);
cmd_button(15, 30, 130, 20, 15, 0, "This is font 15");

//Restore bitmap handle 31 to ROM Font number 31.
cmd_romfont(31, 31);
```

## 5.69 CMD\_ROMFONT

This command is to load a ROM font into bitmap handle. By default ROM fonts 16-31 are loaded into bitmap handles 16-31. This command allows any ROM font 16-34 to be loaded into any bitmap handle.

### C prototype

```
void cmd_romfont (uint32_t font,
                  uint32_t romslot );
```

### Parameters

#### font

bitmap handle number , 0~31

#### romslot

ROM font number, 16~34

### Command layout

<b>+0</b>	<b>CMD_ROMFONT (0xFFFF FF3F)</b>
+4	font
+8	romslot

## Examples

Loading hardware fonts 31-34 into bitmap handle 1:



```
cmd_romfont(1, 31);
cmd_text( 0, 0, 1, 0, "31");
cmd_romfont(1, 32);
cmd_text( 0, 60, 1, 0, "32");
cmd_romfont(1, 33);
cmd_text(80,-14, 1, 0, "33");
cmd_romfont(1, 34);
cmd_text(60, 32, 1, 0, "34");
```

## 5.70 CMD\_RESETFONTS

This command loads bitmap handles 16-31 with their default fonts.

### C prototype

```
void cmd_resetfonts();
```

## Parameters

NA

## Command layout

+0	CMD_RESETFONTS (0xFFFF FF52)
----	------------------------------

## Examples

NA

## 5.71 CMD\_TRACK

This command is used to track touches for a graphics object. **EVE** can assist the **MCU** in tracking touches on graphical objects. For example touches on dial objects can be reported as angles, saving MCU computation. To do this the MCU draws the object using a chosen tag value, and registers a track area for that tag. From then on any touch on that object is reported in **REG\_TRACKER**, and multiple touches (if supported by the touch panel) in **REG\_TRACKER\_1**, **REG\_TRACKER\_2**, **REG\_TRACKER\_3**, **REG\_TRACKER\_4**.

The MCU can detect any touch on the object by reading the 32-bit value in the five registers above. The low 8 bits give the current tag, or zero if there is no touch. The high sixteen bits give the tracked value. For a rotary tracker - used for clocks, gauges and dials - this value is the angle of the touch point relative to the object center, in units of 1/65536 of a circle. 0 means that the angle is straight down, 0x4000 left, 0x8000 up, and 0xc000 right.

For a linear tracker - used for sliders and scrollbars - this value is the distance along the tracked object, from 0 to 65535.

**Note:** Multiple touch points are only available in BT81X Series with capacitive displays connected.

## C prototype

```
void cmd_track( int16_t x,  
                int16_t y,  
                int16_t w,  
                int16_t h,  
                int16_t tag );
```

## Parameters

### x

For linear tracker functionality, x-coordinate of track area top-left, in pixels.  
For rotary tracker functionality, x-coordinate of track area center, in pixels.

### y

For linear tracker functionality, y-coordinate of track area top-left, in pixels.  
For rotary tracker functionality, y-coordinate of track area center, in pixels.

### w

Width of track area, in pixels.

### h

Height of track area, in pixels.

**Note:** A w and h of (1,1) means that the tracker is rotary, and reports an angle value in **REG\_TRACKER**. A w and h of (0,0) disables the track functionality of the coprocessor engine. Other values mean that the tracker is linear, and reports values along its length from 0 to 65535 in **REG\_TRACKER**

**tag**

tag of the graphics object to be tracked, 1-255

**Command layout**

+0	<b>CMD_TRACK(0xFFFF FF2C)</b>
+4	x
+6	y
+8	w
+10	h
+12	tag

**Description**

The Coprocessor engine tracks the graphics object in rotary tracker mode and linear tracker mode:

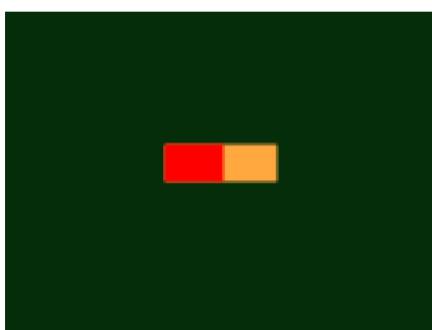
- rotary tracker mode – Track the angle between the touch point and the center of the graphics object specified by the tag value. The value is in units of 1/65536 of a circle. 0 means that the angle is straight down, 0x4000 left, 0x8000 up, and 0xC000 right from the center.

Linear tracker mode – If parameter w is greater than h, track the relative distance of the touch point to the width of the graphics object specified by the tag value. If parameter w is not greater than h, track the relative distance of touch points to the height of the graphics object specified by the tag value. The value is in units of 1/65536 of the width or height of the graphics object. The distance of the touch point refers to the distance from the top left pixel of graphics object to the coordinate of the touch point.

Please note that the behavior of **CMD\_TRACK** is not defined if the center of the track object (in case of rotary track) or top left of the track object (in case of linear track) is outside the visible region in display panel.

**Examples**

Horizontal track of rectangle dimension 40x12 pixels and the present touch is at 50%:

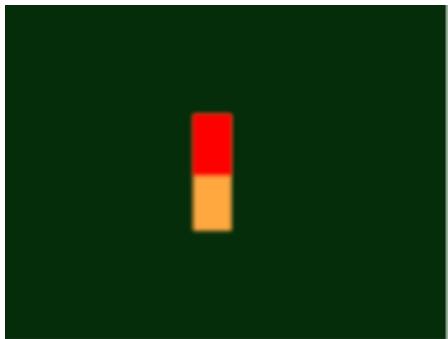


```

dl( CLEAR_COLOR_RGB(5, 45, 110) );
dl( COLOR_RGB(255, 168, 64) );
dl( CLEAR(1, 1, 1) );
dl( BEGIN(RECTS) );
dl( VERTEX2F(60 * 16,50 * 16) );
dl( VERTEX2F(100 * 16,62 * 16) );
dl( COLOR_RGB(255, 0, 0) );
dl( VERTEX2F(60 * 16,50 * 16) );
dl( VERTEX2F(80 * 16,62 * 16) );
dl( COLOR_MASK(0, 0, 0, 0) );
dl( TAG(1) );
dl( VERTEX2F(60 * 16,50 * 16) );
dl( VERTEX2F(100 * 16,62 * 16) );
cmd_track(60 * 16, 50 * 16, 40, 12, 1);

```

Vertical track of rectangle dimension 12x40 pixels and the present touch is at 50%:

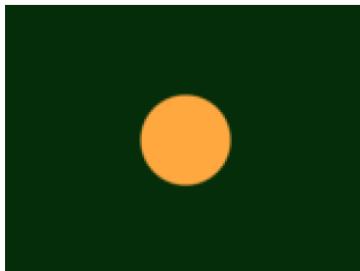


```

dl( CLEAR_COLOR_RGB(5, 45, 110) );
dl( COLOR_RGB(255, 168, 64) );
dl( CLEAR(1, 1, 1) );
dl( BEGIN(RECTS) );
dl( VERTEX2F(70 * 16, 40 * 16) );
dl( VERTEX2F(82 * 16, 80 * 16) );
dl( COLOR_RGB(255, 0, 0) );
dl( VERTEX2F(70 * 16, 40 * 16) );
dl( VERTEX2F(82 * 16, 60 * 16) );
dl( COLOR_MASK(0, 0, 0, 0) );
dl( TAG(1) );
dl( VERTEX2F(70 * 16, 40 * 16) );
dl( VERTEX2F(82 * 16, 80 * 16) );
cmd_track(70 * 16, 40 * 16, 12, 40, 1);

```

Circular track centered at (80,60) display location



```

dl( CLEAR_COLOR_RGB(5, 45, 110) );
dl( COLOR_RGB(255, 168, 64) );
dl( CLEAR(1, 1, 1) );
dl( TAG(1) );
dl( BEGIN(POINTS) );
dl( POINT_SIZE(20 * 16) );
dl( VERTEX2F(80 * 16, 60 * 16) );
cmd_track(80 * 16, 60 * 16, 1, 1, 1);

```

To draw a dial with tag 33 centered at (80, 60), adjustable by touch:



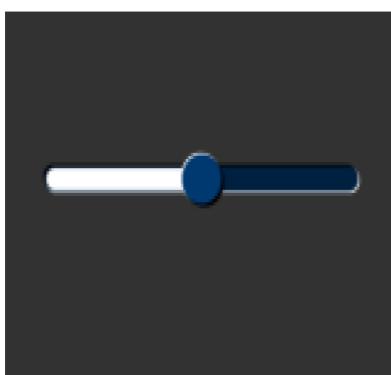
```

uint16_t angle = 0x8000;
cmd_track(80, 60, 1, 1, 33);
while (1) {
  cmd(TAG(33));
  cmd_dial(80, 60, 55, 0, angle);

  uint32_t tracker = rd32(REG_TRACKER);
  if ((tracker & 0xff) == 33)
    angle = tracker >> 16;
}

```

To make an adjustable slider with tag 34:



```

uint16_t val = 0x8000;
cmd_track(20, 50, 120, 8, 34);
while (1) {
  cmd(TAG(34));
  cmd_slider(20, 50, 120, 8, val, 65535);

  uint32_t tracker = rd32(REG_TRACKER);
  if ((tracker & 0xff) == 34)
    val = tracker >> 16;
}

```

## 5.72 CMD\_SNAPSHOT

This command causes the coprocessor engine to take a snapshot of the current screen, and write the result into **RAM\_G** as an **ARGB4** bitmap. The size of the bitmap is the size of the screen, given by the **REG\_HSIZE** and **REG\_VSIZE** registers.

During the snapshot process, the display should be disabled by setting **REG\_PCLK** to 0 to avoid display glitch. Since the coprocessor engine needs to write the result into the destination address, the destination address must never be used or referenced by the graphics engine.

### C prototype

```
void cmd_snapshot( uint32_t ptr );
```

### Parameters

#### ptr

Snapshot destination address, in **RAM\_G**

### Command layout

+0	<b>CMD_SNAPSHOT(0xFFFF FF1F)</b>
+4	ptr

### Examples

To take a snapshot of the current 160 x 120 screens, then use it as a bitmap in the new display list:

```
wr(REG_PCLK,0); //Turn off the PCLK
wr16(REG_HSIZE,120);
wr16(REG_WSIZE,160);

cmd_snapshot(0); //Taking snapshot.

wr(REG_PCLK,5); //Turn on the PCLK
wr16(REG_HSIZE,272);
wr16(REG_WSIZE,480);

cmd_dlstart();
cmd(CLEAR(1,1,1));
cmd(BITMAP_SOURCE(0));
cmd(BITMAP_LAYOUT(ARGB4, 2 * 160, 120));
cmd(BITMAP_SIZE(NEAREST, BORDER, BORDER, 160, 120));
cmd(BEGIN(BITMAPS));
cmd(VERTEX2II(10, 10, 0, 0));
```

## 5.73 CMD\_SNAPSHOT2

The snapshot command causes the coprocessor to take a snapshot of part of the current screen, and write it into graphics memory as a bitmap. The size, position and format of the bitmap may be specified. During the snapshot process, the display output process is suspended. LCD displays can easily tolerate variation in display timing, so there is no noticeable flicker.

### C prototype

```
void cmd_snapshot2( uint32_t fmt,
                    uint32_t ptr,
```

```
int16_t x,
int16_t y,
int16_t w,
int16_t h);
```

## Parameters

### fmt

Output bitmap format, one of **RGB565**, **ARGB4** or **0x20**. The value **0x20** produces an **ARGB8** format snapshot.

Refer to [BITMAP LAYOUT](#) for format List.

### ptr

Snapshot destination address, in **RAM\_G**

### x

x-coordinate of snapshot area top-left, in pixels

### y

y-coordinate of snapshot area top-left, in pixels

### w

width of snapshot area, in pixels. Note when *fmt* is **0x20**, i.e. in **ARGB8** format, the value of width shall be doubled.

### h

height of snapshot area, in pixels

## Command layout

+0	CMD_SNAPSHOT2(0xFFFF FF37)
+4	fmt
+8	ptr
+12	x
+14	y
+16	w
+18	h

## Examples

To take a 32x32 snapshot of the top-left of the screen, then use it as a bitmap in the new display list:

```
cmd_snapshot2(RGB565, 0, 0, 0, 32, 32);
cmd_dlstart();
cmd_setbitmap(0, RGB565, 32, 32);
cmd(CLEAR(1,1,1));
cmd(BEGIN(BITMAPS));
cmd(VERTEX2II(10, 10, 0, 0));
```

## Note: For ARGB8 format, pixel memory layout is as below:

ARGB8 Pixel Format					
31	24	23	16	15	8   0
Alpha Channel	Red Channel	Green Channel	Blue Channel		

## 5.74 CMD\_SETBITMAP

This command will generate the corresponding display list commands for given bitmap information, sparing the effort of writing display list manually. The display list commands to be generated candidates are as below:

- **BITMAP\_SOURCE**
- **BITMAP\_LAYOUT/ BITMAP\_LAYOUT\_H**
- **BITMAP\_SIZE/ BITMAP\_SIZE\_H**
- **BITMAP\_EXT\_FORMAT**

The parameters filter/wrapx/wrapy in **BITAMP\_SIZE** are always set to **NEAREST/BORDER/BORDER** value in the generated display list commands.

### C prototype

```
void cmd_setbitmap( uint32_t source,
                    uint16_t fmt,
                    uint16_t width,
                    uint16_t height );
```

### Parameters

#### source

Source address for bitmap, in **RAM\_G** or flash memory, as a **BITMAP\_SOURCE** parameter. it shall be in terms of block unit (each block is 32 bytes) when it is located in flash memory.

#### fmt

Bitmap format, see the definition in **BITMAP\_EXT\_FORMAT**.

#### width

bitmap width, in pixels. 2 bytes value.

#### height

bitmap height, in pixels. 2 bytes value.

### Command layout

+0	<b>CMD_SETBITMAP(0xFFFF FF43)</b>
+4	source
+8	fmt
+10	width
+12	height

### Examples

Display an ASTC image with width 35 and height 35 pixels residing in flash address 6016 ( 188 \* 32 ):

```
cmd_dlstart();
cmd_setbitmap(0x800000 | 188, COMPRESSED_RGBA_ASTC_5x5_KHR, 35, 35);
cmd(CLEAR(1,1,1));
cmd(BEGIN(BITMAPS));
cmd(VERTEX2II(10, 10, 0, 0));
```

**Note:**

Two bytes needs to be appended after last parameter for 4 bytes alignment.

When format is **PALETTED4444/PALETTED8/PALETTED565**, due to no display list commands **PALETTE\_SOURCE** is generated, user need write the **PALETTE\_SOURCE** command manually.

## 5.75 CMD\_LOGO



The logo command causes the coprocessor engine to play back a short animation of the Bridgetek logo. During logo playback the MCU shall not write or render any display list. After 2.5 seconds have elapsed, the coprocessor engine writes zero to **REG\_CMD\_READ** and **REG\_CMD\_WRITE**, and starts waiting for commands. After this command is complete, the MCU shall write the next command to the starting address of **RAM\_CMD**.

**C prototype**

```
void cmd_logo();
```

**Command layout**

+0	<b>CMD_LOGO(0xFFFF FF31)</b>
----	------------------------------

**Examples**

To play back the logo animation:

```
cmd_logo();
delay(3000); // Optional to wait
//Wait till both read & write pointer register are equal.
While(rd16(REG_CMD_WRITE) != rd16(REG_CMD_READ));
```

## 5.76 CMD\_FLASHERASE

This command erases the attached flash storage.

**C prototype**

```
void cmd_flasherase();
```

**Command layout**

+0	<b>CMD_FLASHERASE(0xFFFF FF44)</b>
----	------------------------------------

**Examples**

NA

## 5.77 CMD\_FLASHWRITE

This command writes the following inline data to flash storage. The storage should have been previously erased using **CMD\_FLASHERASE**.

### C prototype

```
void cmd_flashwrite( uint32_t ptr,  
                      uint32_t num );
```

#### Parameters

##### **ptr**

Destination address in flash memory. Must be 256-byte aligned. Start address of first block is from **zero**.

##### **num**

Number of bytes to write, must be multiple of 256

#### Command layout

<b>+0</b>	<b>CMD_FLASHWRTITE (0xFFFF FF45)</b>
+4	ptr
+8	num
+12...n	bytes <sub>1</sub> ...byte <sub>n</sub>

#### Examples

NA

## 5.78 CMD\_FLASHPROGRAM

This command writes the data to blank flash. It assumes that the flash is previously programmed to all-ones, which is the default state of flash chip by manufacturers.

### C prototype

```
void cmd_flashprogram( uint32_t dest,  
                       uint32_t src,  
                       uint32_t num );
```

#### Parameters

##### **dst**

destination address in flash memory. Must be 4096-byte aligned. Start address of first block is from **zero**.

##### **src**

source data in main memory. Must be 4-byte aligned

##### **num**

number of bytes to write, must be multiple of 4096

#### Command layout

<b>+0</b>	<b>CMD_FLASHPROGRAM (0xFFFF FF70)</b>
+4	dst
+8	src
+12	num

#### Examples

NA

## 5.79 CMD\_FLASHREAD

This command reads data from flash into main memory.

### C prototype

```
void cmd_flashread ( uint32_t dest,
                     uint32_t src,
                     uint32_t num );
```

### Parameters

#### dest

Destination address in **RAM\_G**. Must be 4-byte aligned.  
Start address of first block is from **zero**.

#### src

source address in flash memory. Must be 64-byte aligned.

#### num

number of bytes to write, must be multiple of 4

### Command layout

+0	<b>CMD_FLASHREAD(0xFFFF FF46)</b>
+4	dest
+8	src
+12	num

### Examples

```
// Read all of main RAM (1M bytes) from flash:  
cmd_flashread(0, 4096, 1048576);
```

## 5.80 CMD\_APPENDF

This command appends data from flash to the next available location in display list memory RAM\_DL, which was specified by REG\_CMD\_WRITE.

### C prototype

```
void cmd_appendf( uint32_t ptr,uint32_t num );
```

### Parameters

#### ptr

start of source commands in flash memory. Must be 64-byte aligned.  
Start address of first block is from **zero**.

#### num

number of bytes to copy. This must be a multiple of 4

### Command layout

+0	<b>CMD_APPENDF (0xFFFF FF59)</b>
+4	ptr
+8	num

## 5.81 CMD\_FLASHUPDATE

This command writes the given data to flash. If the data matches the existing contents of flash, nothing is done. Otherwise the flash is erased in 4K units, and the data is written.

### C prototype

```
void cmd_flashupdate( uint32_t dest,
                      uint32_t src,
                      uint32_t num );
```

### Parameters

#### dest

Destination address in flash memory. Must be 4096-byte aligned.  
Start address of first block is from **zero**.

#### src

source address in main memory **RAM\_G**. Must be 4-byte aligned.

#### num

number of bytes to write, must be multiple of 4096

### Command layout

+0	<b>CMD_FLASHUPDATE (0xFFFF FF47)</b>
+4	dest
+8	src
+12	num

### Example

```
// The pseudo code below shows how to program the blob file to first block of flash

// Assume the flash is in detach mode and now attach it
cmd_flashattach();

// Now check if the flash is in basic mode after attaching
while (FLASH_STATUS_BASIC != rd8(REG_FLASH_STATUS));

//Write the BLOB file into the first block of flash
//Assume the BLOB file is in RAM_G
cmd_flashupdate(0, RAM_G, 4096);

// To check if the blob is valid , try to switch to full mode
cmd_flashfast();

while (FLASH_STATUS_BASIC != rd8(REG_FLASH_FULL));
```

## 5.82 CMD\_FLASHDETACH

This command causes **EVE** to put the SPI device lines into hi-Z state. The only valid flash operations when detached are the low-level SPI access commands as following:

- **CMD\_FLASHSPIDESEL**
- **CMD\_FLASHSPITX**
- **CMD\_FLASHSPIRX**
- **CMD\_FLASHATTACH**

Refer to the section - Flash interface in BT817/8 datasheet.

### C prototype

```
void cmd_flashdetach( );
```

#### Command layout

+0	CMD_FLASHDETACH (0xFFFF FF48)
----	-------------------------------

## 5.83 CMD\_FLASHATTACH

This command causes **EVE** to re-connect to the attached SPI flash storage. After the command, register **REG\_FLASH\_STATE** should be **FLASH\_STATUS\_BASIC**. Refer to the section - Flash interface in BT817/8 datasheet.

#### C prototype

```
void cmd_flashattach( );
```

#### Command layout

+0	CMD_FLASHATTACH (0xFFFF FF49)
----	-------------------------------

## 5.84 CMD\_FLASHFAST

This command causes the BT81X chip to drive the attached flash in full-speed mode, if possible. Refer to the section - Flash interface in BT817/8 datasheet.

#### C prototype

```
void cmd_flashfast ( uint32_t result );
```

#### Parameters

##### result

Written with the result code. If the command succeeds, zero is written as a result.

Otherwise an error code is set as follows:

Error Code	Meaning
0xE001	flash is not supported
0xE002	no header detected in sector 0 – is flash blank?
0xE003	sector 0 data failed integrity check
0xE004	device/blob mismatch – was correct blob loaded?
0xE005	failed full-speed test – check board wiring

#### Command layout

+0	CMD_FLASHFAST (0xFFFF FF4A)
+4	result

**Note:** To access any data in flash by EVE, host needs send this command at least once to EVE in

order to drive flash in full-speed mode. In addition, the flash chip is assumed to have correct blob file programmed in its first block (4096 bytes). Otherwise, it will cause the failure of this command.

### Example

NA

## 5.85 CMD\_FLASHSPIDESEL

This command de-asserts the SPI CS signal. It is only valid when the flash has been detached, using **CMD\_FLASHDETACH**.

### C prototype

```
void cmd_flashspidesel();
```

### Command layout

+0	<b>CMD_FLASHSPIDESEL (0xFFFFF4B)</b>
----	--------------------------------------

### Parameters

NA

## 5.86 CMD\_FLASHSPITX

This command transmits the following bytes over the flash SPI interface. It is only valid when the flash has been detached, using **CMD\_FLASHDETACH**.

### C prototype

```
oid cmd_flashspitx ( uint32_t num );
```

### Parameters

#### num

number of bytes to transmit

### Command layout

+0	<b>CMD_FLASHSPITX (0xFFFF FF4C)</b>
+4	num
byte1...byten	the data to transmit

### Example

Transmit single-byte 06:

```
cmd_flashdetach();
cmd_flashspidesel();
cmd_flashspitx(1);
cmd(0x00000006);
```

## 5.87 CMD\_FLASHSPIRX

This command receives bytes from the flash SPI interface, and writes them to main memory. It is only valid when the flash has been detached, using **CMD\_FLASHDETACH**.

### C prototype

```
void cmd_flashpirx ( uint32_t ptr,
                      uint32_t num );
```

### Parameters

**ptr**

destination address in **RAM\_G**

**num**

number of bytes to receive

### Command layout

<b>+0</b>	<b>CMD_FLASHPIRX (0xFFFF FF4D)</b>
+4	ptr
+4	num

### Example

Read 3 bytes from SPI flash to main memory locations 100,101,102:

```
cmd_flashdetach();
cmd_flashspidesel();
cmd_flashpirx(100, 3);
```

## 5.88 CMD\_CLEARCACHE

This command clears the graphics engine's internal flash cache. It should be executed after modifying graphics data in flash by **CMD\_FLASHUPDATE** or **CMD\_FLASHWRITE**, otherwise bitmaps from flash may render "stale" data. It must be executed when the display list is empty, immediately after a **CMD\_DLSTART** command. Otherwise it generates a coprocessor fault ("display list must be empty") and sets **REG\_PCLK** to zero.

### C prototype

```
void cmd_clearcache ( );
```

### Command layout

<b>+0</b>	<b>CMD_CLEARCACHE (0xFFFF FF4F)</b>
-----------	-------------------------------------

### Example

```
//Flash is in Full mode and has the right content working with EVE
//Update the 4th block of flash chip with new bitmap data located at RAM_G+1024
cmd_flashupdate(4*4096, RAM_G+1024, 4*4096);

//To continue rendering the bitmap data in flash, need call cmd_clearcache
cmd_dlstart();
cmd_clearcache();
cmd_swap();
```

## 5.89 CMD\_FLASHSOURCE

This command specifies the source address for flash data loaded by the **CMD\_LOADIMAGE**, **CMD\_PLAYVIDEO**, **CMD\_VIDEOSTARTF** and **CMD\_INFLATE2** commands with the **OPT\_FLASH** option.

### C prototype

```
void cmd_flashsource ( uint32_t ptr );
```

### Parameters

#### ptr

flash address, must be 64-byte aligned. Start address of first block is from **zero**.

### Command layout

+0	<b>CMD_FLASHSOURCE (0xFFFF FF4E)</b>
+4	ptr

## 5.90 CMD\_VIDEOSTARTF

This command is used to initialize video frame decoder. The video data shall be present in flash memory, and its address previously set using **CMD\_FLASHSOURCE**. This command processes the video header information, and completes when it has consumed it.

### C prototype

```
void cmd_videostartf ( );
```

### Command layout

+0	<b>CMD_VIDEOSTARTF (0xFFFF FF5F)</b>
----	--------------------------------------

### Example

```
cmd_flashsource(LOGO_VIDEO_FLASH_ADDRESS);  
cmd_videostartf();  
cmd_videoframe(4, 0);
```

## 5.91 CMD\_ANIMSTART

This command is used to start an animation. If the channel was previously in use, the previous animation is replaced.

### C prototype

```
void cmd_animstart( int32_t ch,  
                    uint32_t aoptr,  
                    uint32_t loop );
```

### Parameters

#### ch

Animation channel, 0-31. If no channel is available, then an “out of channels” exception is raised.

**aoptr**

The address of the animation object in flash memory.

**loop**

Loop flags. ANIM\_ONCE plays the animation once, then cancel it. ANIM\_LOOP plays the animation in a loop. ANIM\_HOLD plays the animation once, then displays the final frame.

**Command layout**

<b>+0</b>	<b>CMD_ANIMSTART (0xFFFF FF53)</b>
+4	ch
+8	aoptr
+12	loop

**Example**

See [CMD\\_ANIMFRAME](#).

## 5.92 CMD\_ANIMSTARTRAM

This command is used to start an animation in RAM\_G. If the channel was previously in use, the previous animation is replaced. The animation object is in **RAM\_G**.

**C prototype**

```
void cmd_animstartram( int32_t ch,
                      uint32_t aoptr,
                      uint32_t loop );
```

**Parameters**

**ch**

Animation channel, 0-31. If no channel is available, then an “out of channels” exception is raised.

**aoptr**

Pointer to the animation object in RAM. Must be 64-byte aligned.

**loop**

Loop flags. ANIM\_ONCE plays the animation once, then cancels it. ANIM\_LOOP plays the animation in a loop. ANIM\_HOLD plays the animation once, then displays the final frame.

**Command layout**

<b>+0</b>	<b>CMD_ANIMSTARTRAM(0xFFFF FF6E)</b>
+4	ch
+8	aoptr
+12	loop

**Example**

See [CMD\\_ANIMFRAMERAM](#).

**Note:** BT817/8 specific command

## 5.93 CMD\_RUNANIM

This command is used to Play/run animations until complete. Playback ends when either a specified animation completes, or when host **MCU** writes to a control byte. Note that only animations started with **ANIM\_ONCE** complete. Pseudocode for **CMD\_RUNANIM** is:

```

do {
  if ((play != -1) && (*play != 0))
    break;
  CMD_DLSTART();
  Clear(1,1,1);
  CMD_ANIMDRAW(-1);
  CMD_SWAP();
} while ((waitmask & REG_ANIM_ACTIVE) == 0);

```

### C prototype

```
void cmd_runram( uint32_t waitmask,
                 uint32_t play );
```

### Parameters

#### waitmask

32-bit mask specifying which animation channels to wait for. Animation ends when the logical **AND** of this mask and **REG\_ANIM\_ACTIVE** is zero.

#### play

Address of play control byte. Animation stops when the byte at play is not zero. If this feature is not required, the special value of -1 (0xFFFF FFFF) means that there is no control byte.

### Command layout

+0	<b>CMD_RUNANIM(0xFFFF FF6F)</b>
+4	waitmask
+8	play

## Example

```
/*
play back several animations simultaneously
assume the animation is in flash
**/


/*
set up an channel for first animation
*/


cmd_animstart(1,4096, ANIM_ONCE);
cmd_animxy(400, 240); //The center of animation


/*
set up another channel for second animation
*/
cmd_animstart(2,4096 + 10*1024, ANIM_ONCE);
cmd_animxy(400, 240); //The center of animation
/*
set up another channel for second animation
*/
cmd_animstart(2,4096 + 10*1024, ANIM_ONCE);
cmd_animxy(400, 240); //The center of animation


/*
play back both animations and set up the control byte at 0xF0000 of RAM_G
*/
wr32(0xF0000, 1);
cmd_runanim(-1, 0xF0000); //The animation will be shown on display.

//......


/*
To stop the animation before it ends , write the contro byte to zero
*/
wr32(0xF0000, 0);
```

**Note:** BT817/8 specific command

## 5.94 CMD\_ANIMSTOP

This command stops one or more active animations.

### C prototype

```
void cmd_animstop( int32_t ch );
```

### Parameters

#### ch

Animation channel, 0-31. If ch is -1, then all animations are stopped.

### Command layout

+0	<b>CMD_ANIMSTOP (0xFFFF FF54)</b>
+4	ch

## 5.95 CMD\_ANIMXY

This command sets the coordinates of an animation.

### C prototype

```
void cmd_animxy ( int32_t ch,
                  int16_t x,
                  int16_t y );
```

### Parameters

#### ch

Animation channel, 0-31.

#### x

x screen coordinate for the animation center, in pixels

#### y

y screen coordinate for the animation center, in pixels

### Command layout

+0	<b>CMD_ANIMXY (0xFFFF FF55)</b>
+4	ch
+8	x
+10	y

**NOTE:** If the pixel precision is not set to 1/16 in current graphics context, a **VERTEX\_FOMART(4)** is mandatory to precede this command.

## 5.96 CMD\_ANIMDRAW

This command draws one or more active animations

### C prototype

```
void cmd_animdraw ( int32_t ch );
```

### Parameters

#### ch

Animation channel, 0-31. If ch is -1, then it draws all undrawn animations in ascending order.

### Command layout

+0	<b>CMD_ANIMDRAW(0xFFFF FF56)</b>
+4	ch

## 5.97 CMD\_ANIMFRAME

This command draws the specified frame of an animation

### C prototype

```
void cmd_animframe( int16_t x,
                    int16_t y,
                    uint32_t aoptr,
                    uint32_t frame );
```

#### Parameters

**x**

x screen coordinate for the animation center, in pixels.

**y**

y screen coordinate for the animation center, in pixels.

**aoptr**

The address of the animation object in flash memory.

**frame**

Frame number to draw, starting from zero.

#### Command layout

+0	<b>CMD_ANIMFRAME (0xFFFF FF5A)</b>
+4	x
+6	y
+8	aoptr
+12	frame

**NOTE:** If the pixel precision is not set to 1/16 in current graphics context, a **VERTEX\_FOMART(4)** is mandatory to precede this command.

#### Example

```
//Draw a frame located at the first available address of flash onto (0,400).
cmd_animframe(0, 400, 4096, 65);
```

## 5.98 CMD\_ANIMFRAMERAM

This command draws the specified frame of an animation in **RAM**.

### C prototype

```
void cmd_animframe( int16_t x,
                    int16_t y,
                    uint32_t aoptr,
                    uint32_t frame );
```

#### Parameters

**x**

x screen coordinate for the animation center, in pixels.

**y**

y screen coordinate for the animation center, in pixels.

**aoptr**

The address of the animation object in **RAM\_G**. Must be 64-byte aligned.

**frame**

Frame number to draw, starting from zero.

**Command layout**

<b>+0</b>	<b>CMD_ANIMFRAMERAM (0xFFFF FF6D)</b>
+4	x
+6	y
+8	aoptr
+12	frame

**Note:** If the pixel precision is not set to 1/16 in current graphics context, a **VERTEX\_FOMART(4)** is mandatory to precede this command.

**Example**

```
//Draw the 65th frame of the animation onto (400,240).The animation
object is in RAM_G+4096
cmd_animframeram(400, 240, 4096, 65);
```

**Note:** BT817/8 specific command

## 5.99 CMD\_SYNC

This command waits for the end of the video scan out period, then it returns immediately. It may be used to synchronize screen updates that are not part of a display list, and to accurately measure the time taken to render a frame.

**C prototype**

```
void cmd_sync( );
```

**Command layout**

<b>+0</b>	<b>CMD_SYNC(0xFFFF FF42)</b>
-----------	------------------------------

**Examples**

```
//To synchronize with a frame:
cmd_sync();

//To update REG_MACRO_0 at the end of scan out, to avoid tearing:
cmd_sync();
cmd_memwrite(REG_MACRO_0, 4);
cmd(value);

//To measure frame duration
cmd_sync();
cmd_memcpy(0, REG_CLOCK);
cmd_sync();
cmd_memcpy(4, REG_CLOCK);
//the difference between locations 4 and 0 give the frame interval
in clocks.
```

## 5.100 CMD\_BITMAP\_TRANSFORM

This command computes a bitmap transform and appends commands BITMAP\_TRANSFORM\_A – BITMAP\_TRANSFORM\_F to the display list. It computes the transform given three corresponding points in screen space and bitmap space. Using these three points, the command computes a matrix that transforms the bitmap coordinates into screen space, and appends the display list commands to set the bitmap matrix.

### C prototype

```
void cmd_bitmap_transform( int32_t x0,
                           int32_t y0,
                           int32_t x1,
                           int32_t y1,
                           int32_t x2,
                           int32_t y2,
                           int32_t tx0,
                           int32_t ty0,
                           int32_t tx1,
                           int32_t ty1,
                           int32_t tx2,
                           int32_t ty2,
                           uint16_t result )
```

### Command layout

<b>+0</b>	<b>CMD_BITMAP_TRANSFORM(0xFFFF FF21)</b>
+4	x <sub>0</sub>
+8	y <sub>0</sub>
+10	x <sub>1</sub>
+16	y <sub>1</sub>
+20	x <sub>2</sub>
+24	y <sub>2</sub>
+28	tx <sub>0</sub>
+32	ty <sub>0</sub>
+36	tx <sub>1</sub>
+40	ty <sub>1</sub>
+44	tx <sub>2</sub>
+48	ty <sub>2</sub>
+52	result

### Parameters

#### **x<sub>0</sub>,y<sub>0</sub>**

Point 0 screen coordinate, in pixels

#### **x<sub>1</sub>,y<sub>1</sub>**

Point 1 screen coordinate, in pixels

#### **x<sub>2</sub>,y<sub>2</sub>**

Point 2 screen coordinate, in pixels

#### **tx<sub>0</sub>,ty<sub>0</sub>**

Point 0 bitmap coordinate, in pixels

**tx<sub>1</sub>,ty<sub>1</sub>**

Point 1 bitmap coordinate, in pixels

**tx<sub>2</sub>,ty<sub>2</sub>**

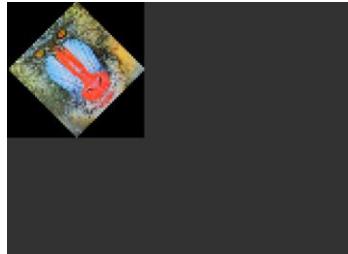
Point 2 bitmap coordinate, in pixels

**result**

result return. Set to -1 on success, or 0 if it is not possible to find the solution matrix.

## Examples

Transform a 64x64 bitmap:

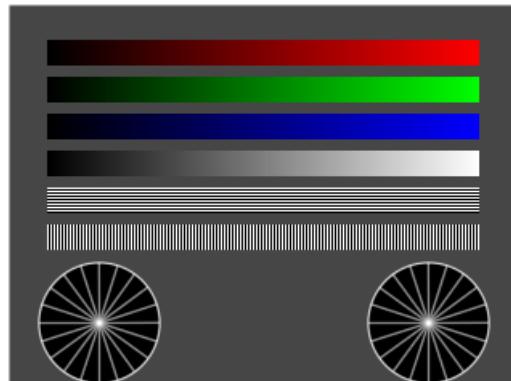


```
cmd(BLEND_FUNC(ONE, ZERO));
cmd_bitmap_transform(32,0, 64,32, 32,64,0,0,
0,64, 64,64, 0);
cmd(BEGIN(BITMAPS));
cmd(VERTEX2II(0, 0, 0, 0));
```

## 5.101 CMD\_TESTCARD

The testcard command loads a display list with a testcard graphic, and executes **CM\_SWAP** - swap the current display list to display it. The graphic is automatically scaled for the current display size, taking into account **REG\_HSIZE**, **REG\_VSIZE**, and **REG\_ROTATE**. Features of the testcard are:

- white border at the extents to confirm screen edges and clock stability
- red, green, blue and white gradients to confirm color bit depth
- horizontal and vertical checker patterns to confirm signal integrity
- circle graphics to confirm aspect ratio
- radial line pattern to confirm antialias performance



### C prototype

```
void cmd_testcard ( )
```

### Command layout

+0	<b>CMD_TESTCARD(0xFFFF FF61)</b>
----	----------------------------------

### Parameters

NA

## Examples

```
//To display a test card, call the command:  
cmd_testcard();
```

**Note:** BT817/8 specific command

## 5.102 CMD\_WAIT

This command waits for a specified number of microseconds. Delays of more than 1s (1000000 µs) are not supported.

### C prototype

```
void cmd_wait ( uint32_t us )
```

### Command layout

+0	CMD_WAIT(0xFFFF FF65)
+4	us

### Parameters

#### us

Delay time, in microseconds

## Examples

```
//To delay for 16.7 ms:  
cmd_wait(16700);
```

**Note:** BT817/8 specific command

## 5.103 CMD\_NEWTLIST

This command starts the compilation of a command list into **RAM\_G**. Instead of being executed, the following commands are appended to the list, until the following **CMD\_ENDLIST**. The list can then be called with **CMD\_CALLIST**. The following commands are not supported in command lists. Their behavior is undefined:

- **CMD\_FLASHSPITX**
- **CMD\_FLASHWRITE**
- **CMD\_INFLATE**
- **CMD\_NEWTLIST**

The following commands are supported only when using **OPT\_MEDIAFIFO**:

- **CMD\_INFLATE2**
- **CMD\_LOADIMAGE**
- **CMD\_PLAYVIDEO**

### C prototype

```
void cmd_newlist ( uint32_t a )
```

### Command layout

+0	CMD_NEWTIST(0xFFFF FF68)
+4	a

### Parameters

**a**

memory address of start of command list

### Examples

```
/*
Create a command list at RAM_G address 0xF0000 by
sending the following commands to command buffer
*/
cmd_newlist(RAM_G + 0xF0000);
cmd(COLOR_RGB(255, 100, 0));
cmd_button(20, 20, 60, 60, 30, 0, "OK!");
cmd_endlist();

//.....

/*
Invoke the command list
*/
cmd_dlstart();
cmd(COLOR_RGB(255, 255, 255));
cmd(CLEAR(1,1,1));
cmd_calllist(RAM_G + 0xF0000);
cmd(DISPLAY());
cmd_swap();
```

**Note:** BT817/8 specific command

## 5.104 CMD\_ENDLIST

This command terminates the compilation of a command list into **RAM\_G**. **CMD\_GETPTR** can be used to find the first unused memory address following the command list..

### C prototype

```
void cmd_endlist()
```

### Command layout

+0	CMD_ENDLIST(0xFFFF FF69)
----	--------------------------

### Examples

See [CMD\\_NEWTIST](#).

**Note:** BT817/8 specific command

## 5.105 CMD\_CALLLIST

This command calls a command list. After this command, all the commands compiled into the command list between **CMD\_NEWTIST** and **CMD\_ENDLIST** are executed, as if they were executed at the point of the **CMD\_CALLLIST**. The command list itself may contain **CMD\_CALLLIST** commands, up to a depth of 4 levels.

### C prototype

```
void cmd_calllist ( uint32_t a )
```

### Command layout

+0	<b>CMD_CALLLIST(0xFFFF FF67)</b>
+4	a

### Parameters

**a**  
 memory address of the command list

### Examples

See [CMD\\_NEWTIST](#).

**Note:** BT817/8 specific command

## 5.106 CMD\_RETURN

This command ends a command list. Normally it is not needed by the user, because **CMD\_ENDLIST** appends **CMD\_RETURN** to the command list. However it may be used in situations where the user is constructing command lists offline.

### C prototype

```
void cmd_return ( )
```

### Command layout

+0	<b>CMD_RETURN(0xFFFF FF66)</b>
----	--------------------------------

### Examples

```
/*
Construct a command list in RAM_G to show a button
*/
wr32(RAM_G + 0 * 4, SAVE_CONTEXT());
wr32(RAM_G + 1 * 4, COLOR_RGB(125, 125, 128));
wr32(RAM_G + 2 * 4, CMD_BUTTON);

wr16(RAM_G + 3 * 4, 160);      //x coordinate of button
wr16(RAM_G + 3 * 4 + 2, 160); //y coordinate of button
wr16(RAM_G + 4 * 4, 123);    //w
wr16(RAM_G + 4 * 4 + 2, 234); //h
wr16(RAM_G + 5 * 4, 31);     //Font handle
wr16(RAM_G + 5 * 4 + 2, 0);   //option parameter of cmd_button
wr8(RAM_G + 6 * 4, 'T');
```

```

wr8(RAM_G + 6 * 4 + 1, 'E');
wr8(RAM_G + 6 * 4 + 2, 'S');
wr8(RAM_G + 6 * 4 + 3, 'T');

wr8(RAM_G + 7 * 4, '\0');      //the null terminators for string "TEST"

//Append extra 3 bytes for alignment purpose
wr8(RAM_G + 7 * 4 + 1, '\0');
wr8(RAM_G + 7 * 4 + 2, '\0');
wr8(RAM_G + 7 * 4 + 3, '\0');

wr32(phost, RAM_G + 8 * 4, RESTORE_CONTEXT());
wr32(phost, RAM_G + 9 * 4, CMD_RETURN); //Indicate the end of command list

//.....
****

Invoke the command list in RAM_G to render the button
****/
cmd_dlstart();
cmd(COLOR_RGB(255, 255, 255));
cmd(CLEAR(1,1,1));
cmd_calllist(RAM_G);
cmd(DISPLAY());
cmd_swap();

```

**Note:** BT817/8 specific command

## 5.107 CMD\_FONTCACHE

This command enables the font cache, which loads all the bitmaps (glyph) used by a flash-based font into a **RAM\_G** area. This eliminates flash bitmap rendering, at the expense of using some **RAM\_G**. The area must be sized to hold all the bitmaps used in **two** consecutive frames. It applies to **ASTC** based custom font only.

### C prototype

```
void cmd_fontcache( uint32_t font,
                     int32_t ptr,
                     uint32_t num );
```

### Command layout

<b>+0</b>	<b>CMD_FONTCACHE(0xFFFF FF6B)</b>
+4	font
+8	ptr
+12	num

### Parameters

#### **font**

font handle to cache. Must be an extended format font. If 255, then the font cache is disabled.

#### **ptr**

Start of cache area, 64-byte aligned.

#### **num**

Size of cache area in bytes, 4 byte aligned. Must be at least 16 Kbytes.

## Examples

To cache font 13 with a 64 Kbyte font cache at the top of memory:

```
cmd_fontache(13, 0xf0000, 0x10000);
```

**Note:** BT817/8 specific command

## 5.108 CMD\_FONTCACHEQUERY

This command queries the capacity and utilization of the font cache.

### C prototype

```
void cmd_fontcachequery( uint32_t total,
                        int32_t used );
```

### Command layout

+0	<b>CMD_FONTCACHEQUERY(0xFFFF FF6C)</b>
+4	total
+8	used

### Parameters

#### **total**

Output parameter; Total number of available bitmaps in the cache, in bytes.

#### **used**

Output parameter; Number of used bitmaps in the cache, in bytes

## Examples

```
uint32_t total, used;
uint16_t ram_fifo_offset = rd16(REG_CMD_WRITE);
cmd_fontcachequery(total, used);

total = rd32(RAM_CMD + (ram_fifo_offset + 4) % 4096);
used = rd32(RAM_CMD + (ram_fifo_offset + 8) % 4096);

printf("Font cache usage: %d / %d", used, total);
```

**Note:** BT817/8 specific command

## 5.109 CMD\_GETIMAGE

This command returns all the attributes of the bitmap made by the previous CMD\_LOADIMAGE, CMD\_PLAYVIDEO, CMD\_VIDEOSTART or CMD\_VIDEOSTARTF.

### C prototype

```
void cmd_getimage( uint32_t source,
                   uint32_t fmt,
                   uint32_t w,
                   uint32_t h,
                   uint32_t palette );
```

## Command layout

+0	<b>CMD_GETIMAGE (0xFFFF FF64)</b>
+4	source
+8	fmt
+12	w
+16	h
+20	palette

## Parameters

### source

Output parameter; source address of bitmap.

### fmt

Output parameter; format of the bitmap

### w

Width of bitmap, in pixels

### h

Height of bitmap, in pixels

### palette

Palette data of the bitmap if fmt is PALETTED565 or PALETTED4444. Otherwise zero.

## Examples

```
//To find the base address and dimensions of the previously loaded image
uint32_t source, fmt, w, h, palette;
uint16_t ram_fifo_offset = rd16(REG_CMD_WRITE);

cmd_getimage(src, fmt, w, h, palette);

src = rd32(RAM_CMD + (ram_fifo_offset) + 4 % 4096);
fmt = rd32(RAM_CMD + (ram_fifo_offset) + 8 % 4096);
w = rd32(RAM_CMD + (ram_fifo_offset) + 12 % 4096);
h = rd32(RAM_CMD + (ram_fifo_offset) + 16 % 4096);
palette = rd32(RAM_CMD + (ram_fifo_offset + 20) % 4096);

cmd_setbitmap(src, fmt, w, h);
if (palette != 0) PaletteSource(palette);
```

**Note:** BT817/8 specific command

## 5.110 CMD\_HSF

### C prototype

```
void cmd_hsf( uint32_t w );
```

## Command layout

+0	<b>CMD_HSF (0xFFFF FF62)</b>
+4	w

## Parameters

**w**

Output pixel width, which must be less than REG\_HSIZE. 0 disables HSF.

## Examples

A popular panel format is 800×480. This gives a logical aspect ratio of

$$800/480 = 1.6667$$

However the physical size of the panel is 153.84 × 85.63mm, giving an aspect ratio of 1.796. This difference means that the panel has non-square pixels. So we can compute the logical width of the panel, keeping the height constant:

$$480 \times (153.84/85.63) = 862.3$$

So by rendering all graphics at 862×480 then resizing to 800×480, all drawing can assume square pixels. To configure this panel, set REG\_HSIZE to 862, then issue this command:

cmd\_hsf(800);

To disable the HSF, do:

cmd\_hsf(0);

**Note:** BT817/8 specific command

## 5.111 CMD\_PCLKFREQ

This command sets **REG\_PCLK\_FREQ** to generate the closest possible frequency to the one requested. If no suitable frequency can be found, the result field is zero and **REG\_PCLK\_FREQ** is unchanged.

### C prototype

```
void cmd_pclkfreq( uint32_t ftarget,
                    int32_t rounding,
                    uint32_t factual );
```

### Command layout

+0	<b>CMD_PCLKFREQ (0xFFFF FF6A)</b>
+4	ftarget
+8	rounding
+12	factual

## Parameters

**ftarget**

Target frequency, in Hz.

**rounding**

Approximation mode. Valid values are 0, -1, 1:

0 is nearest,

-1 is highest frequency less than or equal to target,

1 is lowest frequency greater than or equal to target.

**factual**

Output parameter; Actual frequency achieved. If no frequency was found, it is zero.

**Examples**

```
//To set the output PCLK as close to 9 MHz as possible:  
cmd_pclkfreq(9000000, 0, 0);
```

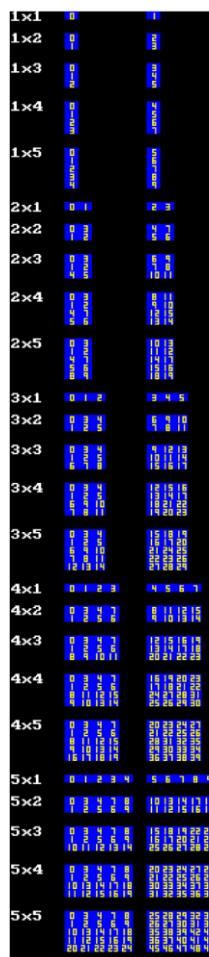
**Note:** BT817/8 specific command

## 6 ASTC

**ASTC** stands for **Adaptive Scalable Texture Compression**, an open standard developed by **ARM®** for use in mobile GPUs. **ASTC** is a block-based lossy compression format. The compressed image is divided into a number of blocks of uniform size, which makes it possible to quickly determine which block a given texel resides in. Each block has a fixed memory footprint of 128 bits, but these bits can represent varying numbers of texels (the block footprint). Block footprint sizes are not confined to powers-of-two, and are also not confined to be square. For 2D formats the block dimensions range from 4 to 12 texels. Using ASTC for the large ROM fonts can save considerable space. Encoding the four largest fonts in ASTC format gives no noticeable loss in quality and reduces the ROM size from 1M Byte to about 640K Kbytes.

**BT81X** series empowers animation features and **Unicode** support based on **ASTC** format. Through ASTC format, BT81X Series is able to show images directly from flash memory without taking the precious **RAM\_G** space. With enough ASTC images in flash memory or **RAM\_G**, it is possible for user to construct an image-rich **GUI** application.

### 6.1 ASTC RAM Layout



**ASTC** blocks represent between 4x4 to 12x12 pixels. Each block is 16 bytes in memory. Please see the Table 13 – BITMAP\_LAYOUT Format List for more details. In a nutshell, 4x4 stands for lowest compression rate but best quality while 12x12 means for highest compression rate but worst quality. Users may need evaluate the image quality of various **ASTC blocks** on hardware in order to achieve the trade-off.

ASTC bitmaps in main memory must be 16-byte aligned.

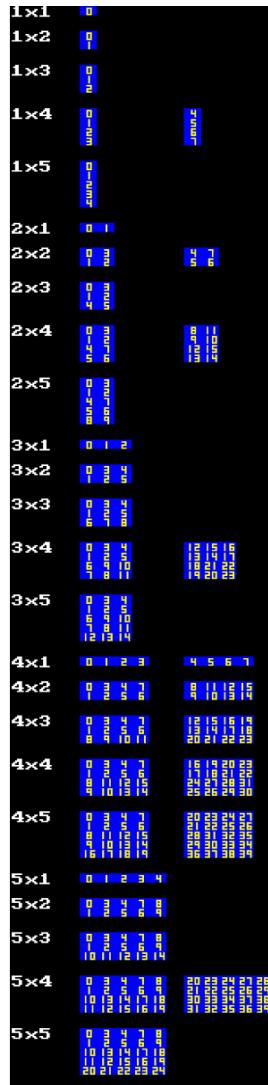
The mapping from bitmap coordinates to memory locations is not always linear. Instead blocks are grouped into 2x2 tiles. Within the tile the order is:

0	3
1	2

When there is an odd number of blocks on a line, the final two blocks are packed into a 1x2. When there is an odd number of rows, then the final row of blocks is linear.

The above diagram shows the same piece of memory loaded with ASTC blocks drawn with ascending memory addresses. The first column shows the addresses used by cell 0, the second column cell 1.

## 6.2 ASTC Flash Layout



ASTC bitmaps in flash must be 64-byte aligned. This means that multi-celled bitmaps must have a size which is a multiple of 4 blocks. In particular fonts in flash must use a multiple of four blocks per character. Note that only bitmaps with multiple-of-four size have cell 1 shown.

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## Appendix A – References

### Document References

[BT815/6 Datasheet](#)

[BT817/8 Datasheet](#)

[OpenGL 4.5 Reference Pages](#)

### Acronyms and Abbreviations

Terms	Description
ADC	Analog-to-digital
API	Application Programming Interface
AVI	Audio Video Interactive
ASTC	Adaptive Scalable Texture Compression
ASCII	American Standard Code for Information Interchange
CTPM	Capacitive Touch Panel Module
CTSE	Capacitive Touch Screen Engine
EVE	Embedded Video Engine
FIFO	First In First Out buffer
I <sup>2</sup> C	Inter-Integrated Circuit
JPEG	Joint Photographic Experts Group
LCD	Liquid Crystal Display
MCU	Micro controller unit
MPU	Microprocessor Unit
PCB	Printed Circuit Board
PCM	Pulse-Code Modulation
PNG	Portable Network Graphics
PWM	Pulse Width Modulation
RAM	Random Access Memory
RTE	Resistive Touch Engine
ROM	Read Only Memory
SPI	Serial Peripheral Interface

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## Appendix C – Revision History

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Revision	Changes	Date (DD-MM-YYYY)
Version 1.0	Initial release	14-08-2018
Version 1.1	<p>Corrected the reset value of Bitmap_transform_A/B/D/E;</p> <p>Added the limitation of cmd_loadimage for PNG image : top 42K bytes of RAM_G is overwritten;</p> <p>Fixed the typo of cmd_flashfast; Added the flash driver information; Fixed the typo in cmd_track example; Added more explanation for cmd_interrupt</p> <p>Added the missing definition of OPT_FILL</p> <p>Removed GL_FORMAT in extended font format,</p> <p>Added the exception of bitmap format in font metrics block.</p> <p>Fixed the broken reference.</p> <p>Updated the ASTC RAM layout image.</p>	03-07-2019
Version 1.2	Updated statement in CMD_VIDEOFRAME	30-03-2020
Version 2.0	<p>Added description for BT817/8</p> <p>Enhanced the register tables and command example code format (CMD_GETPTR &amp; CMD_CLEARCACHE)</p> <p>Example added for CMD_CLEARCACHE</p> <p>The -1 definition of channel number for animation playback removed</p> <p>Updated Table 28 (Added Parameter option - OPT_DITHER)</p>	07-07-2020
Version 2.1	Updated the Table of Flash Interface; Updated the Sample code to cover the RAM_CMD wrapup use case; Updated the Section 5.4 to reflect CMD_KEYS does not support UTFB characters; Deleted the obsolete CMD_SKETCH; Fixed the mute sound value in the code snippet "Avoid Pop Sound"	07-06-2021
Version 2.2	Fixed multiple minor format and typo issues; Used lower case for commands parameters; Updated the conversion specifier 'c' and 's' in string format section from upper case to lower case; Corrected the bit per pixel value for ASTC 8x8,10x5,10x6 in table 12: Bitmap formats and bits per pixel; Added the missing member in xfont structure	24-09-2021