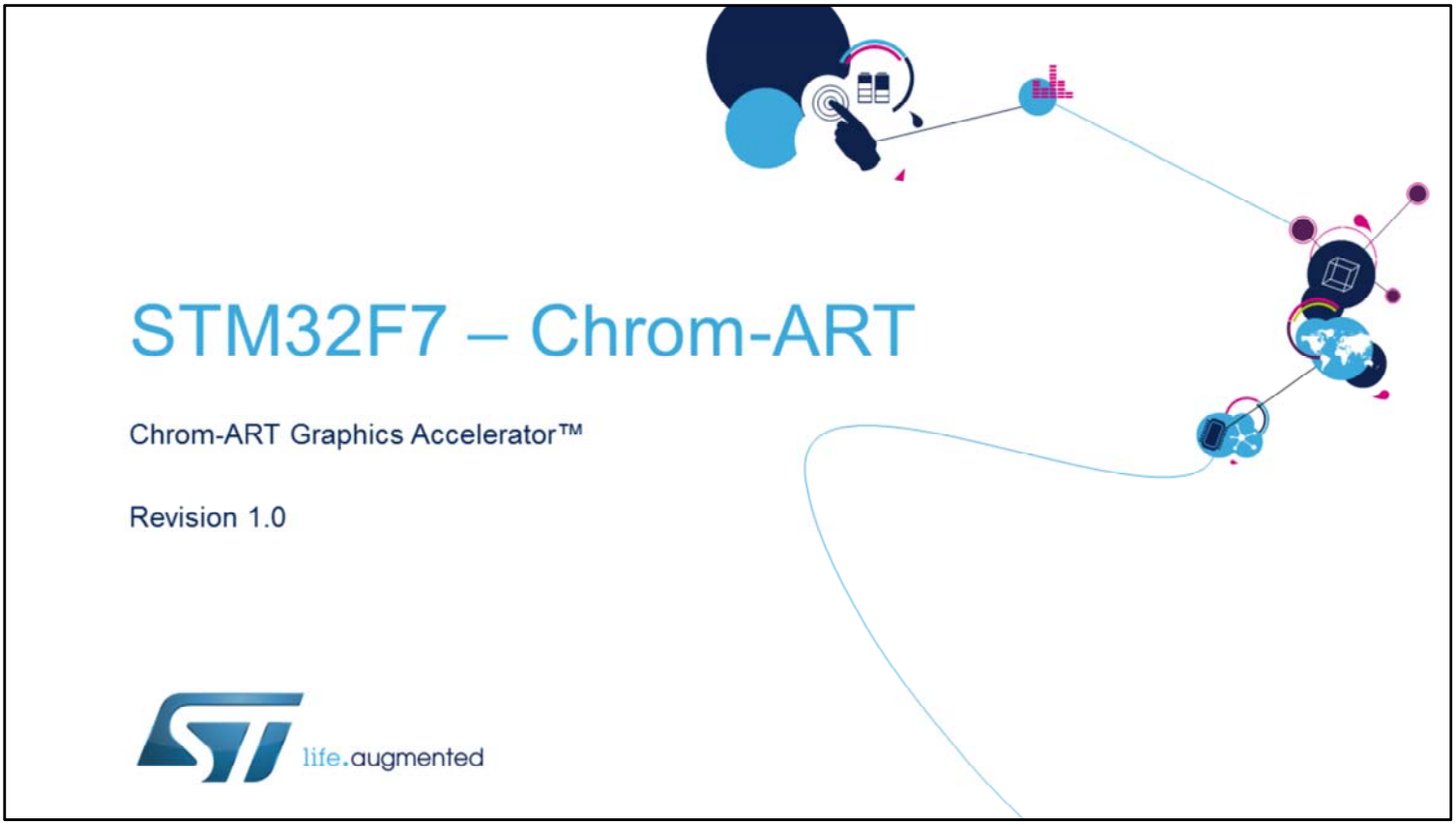
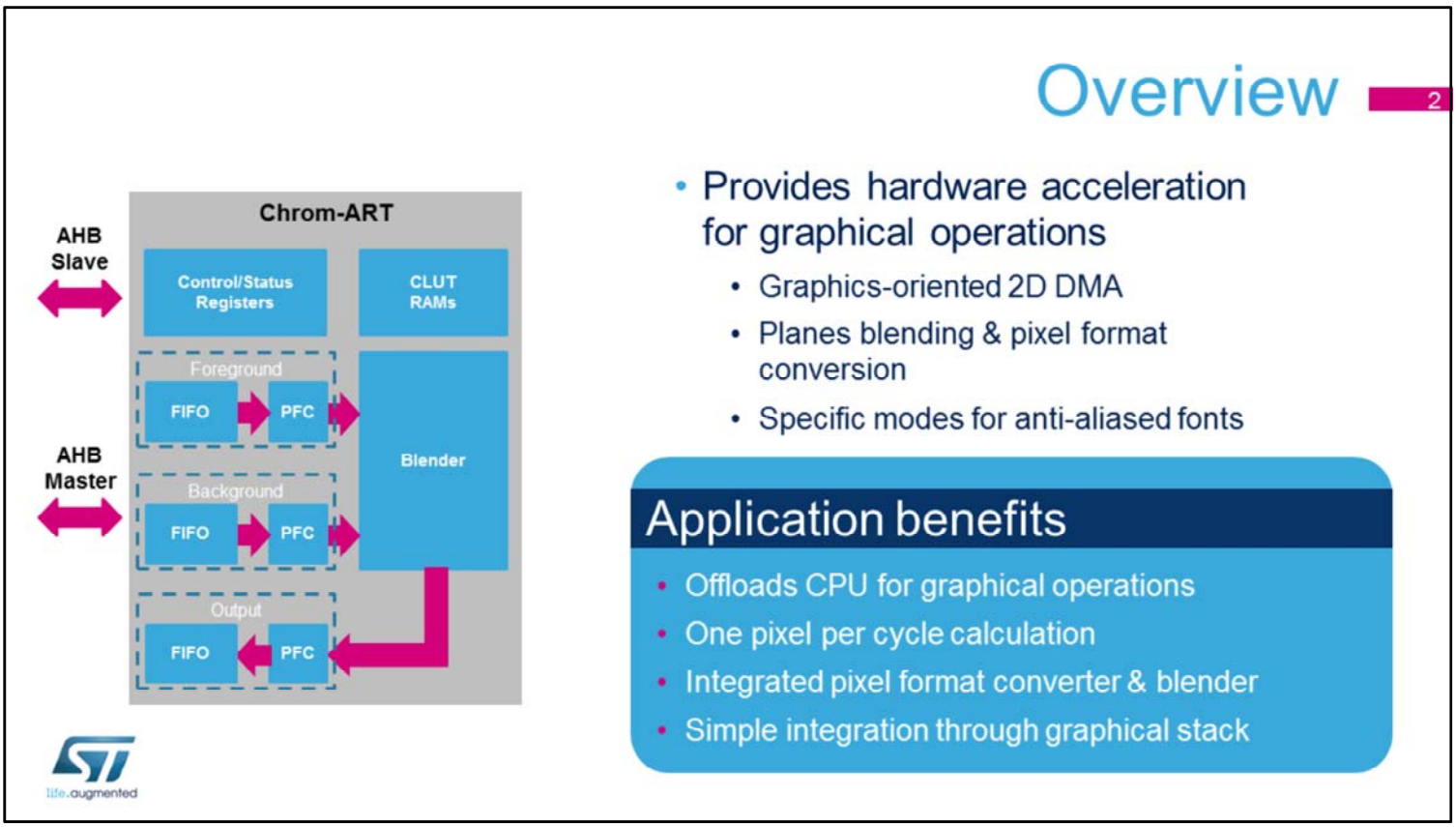
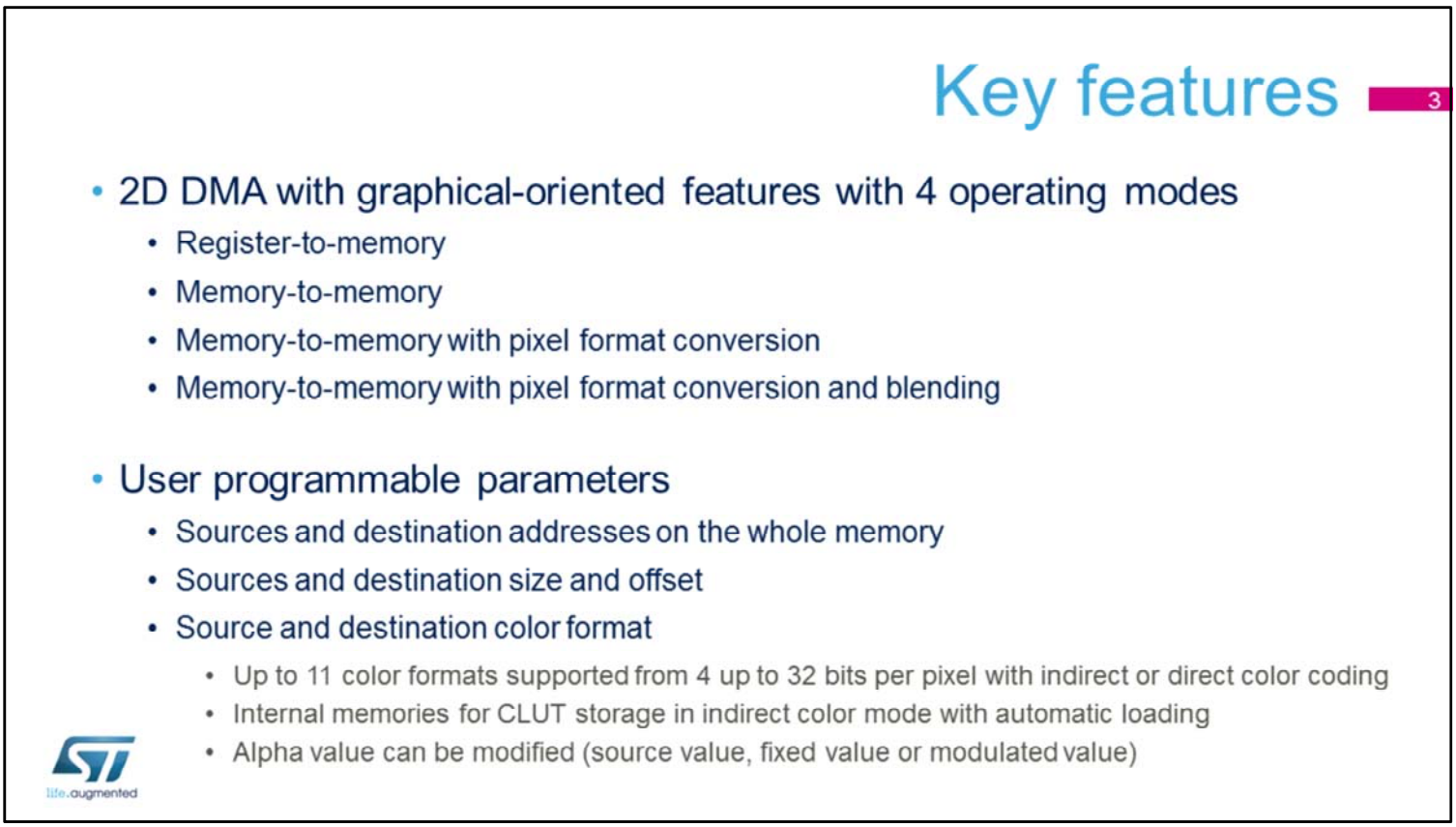


Hello, and welcome to this presentation of the STM32 Chrom-ART Accelerator™. It covers the features of this of this adaptive real-time accelerator block, which is widely used for graphic computing in the microcontroller.



The Chrom-ART accelerator offers true hardware acceleration for graphical operations.
The Chrom-ART accelerator is built around a 2D DMA engine for fast data copy with specific functions to support pixel format conversion as well as blending operations between two planes. It also provides specific modes for managing anti-aliased fonts.
The Chrom-ART accelerator will offload the CPU for most of the graphical operations with a one pixel per cycle throughput, integrated pixel format conversion and blending.
The Chrom-ART accelerator is fully integrated in graphical stacks making its software integration transparent to the user.

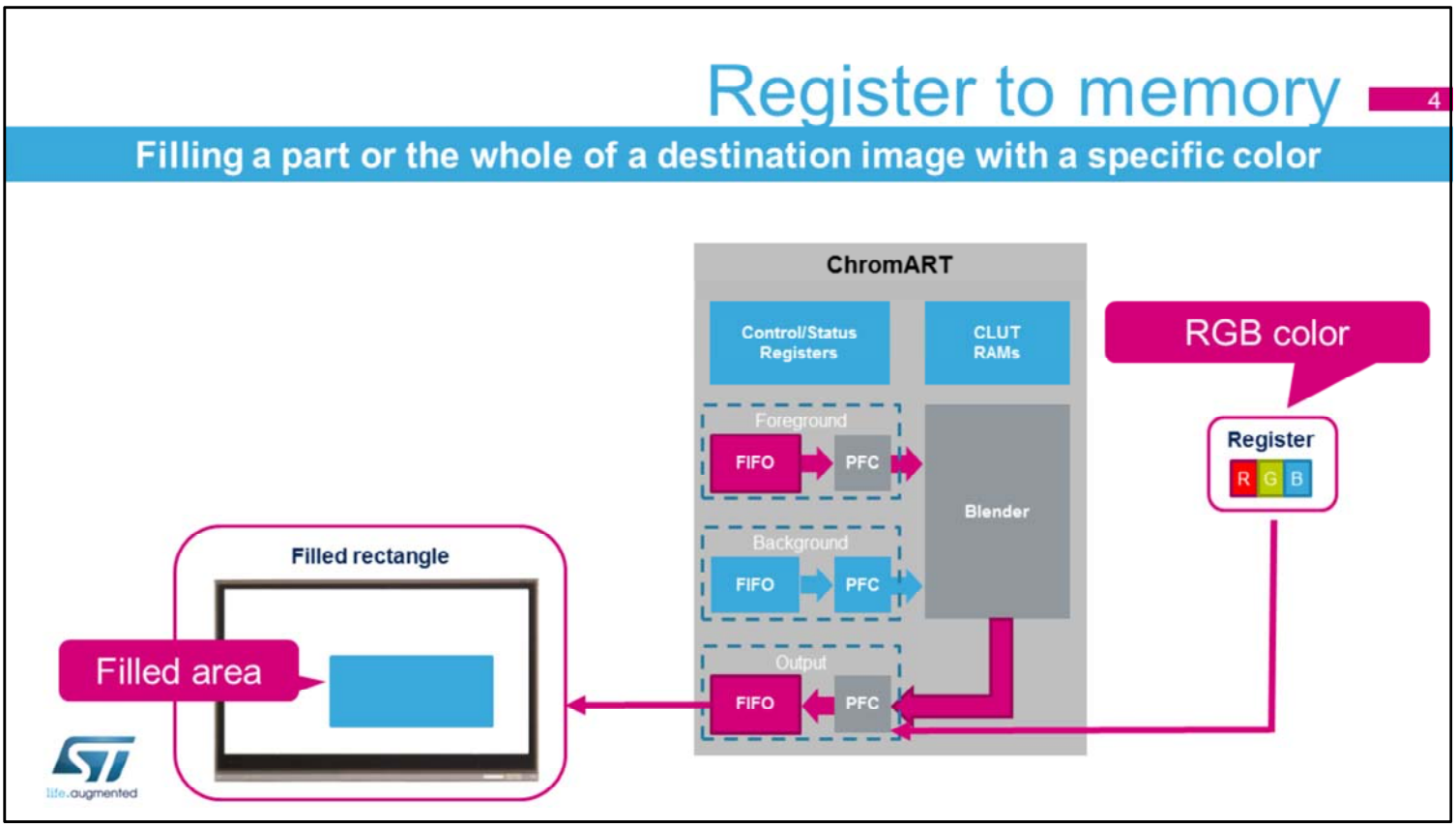


The Chrom-ART accelerator has four operating modes.

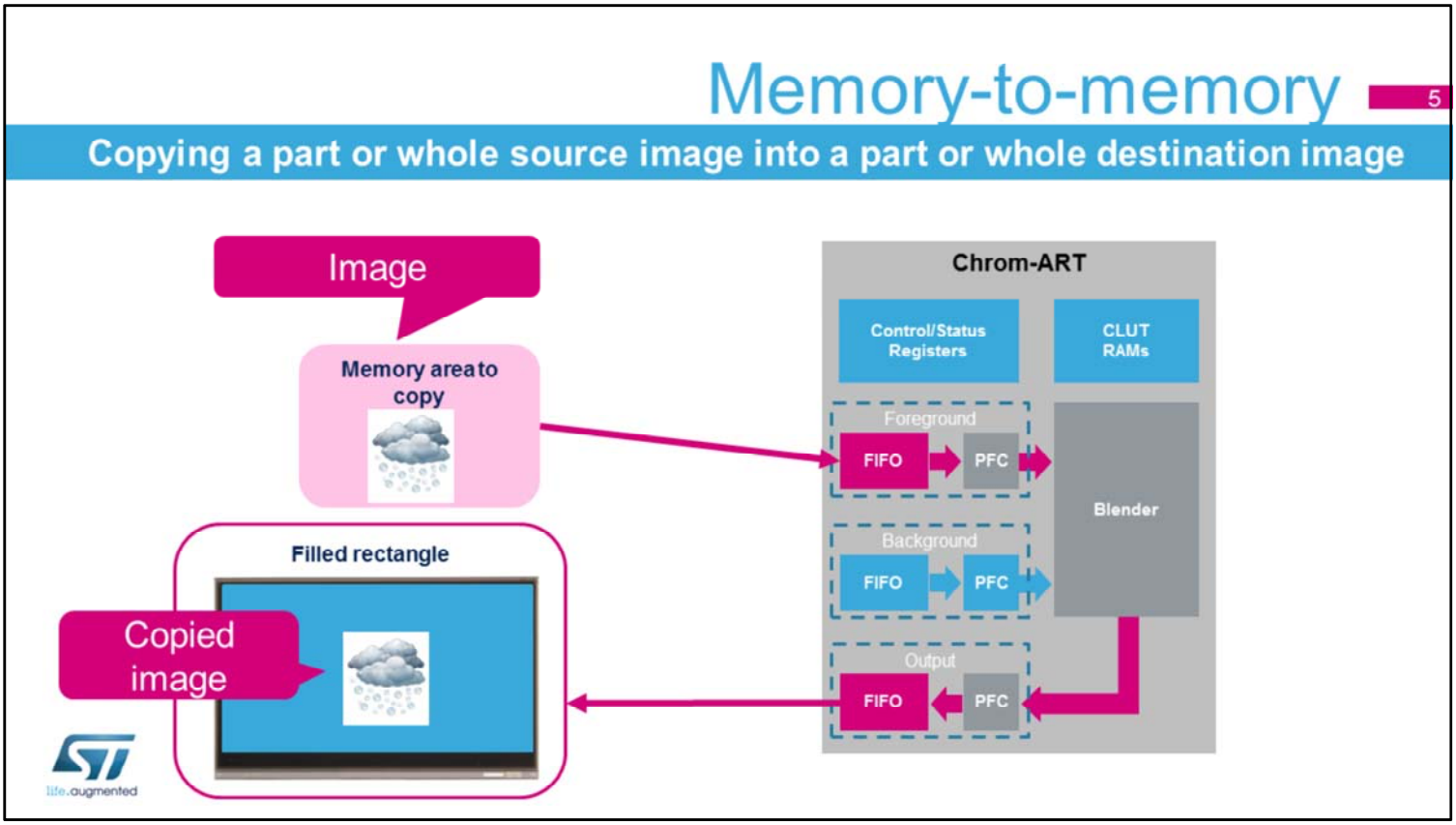
- Register-to-memory for rectangle filling operations,
- Memory-to-memory for 2D memory copy operations,
- Memory-to-memory with pixel format conversion for bitmap drawing with format conversion,
- Memory-to-memory with pixel format conversion and blending for bitmap or text drawing with transparency.

The user can program independently all the parameters for the source and the destination:

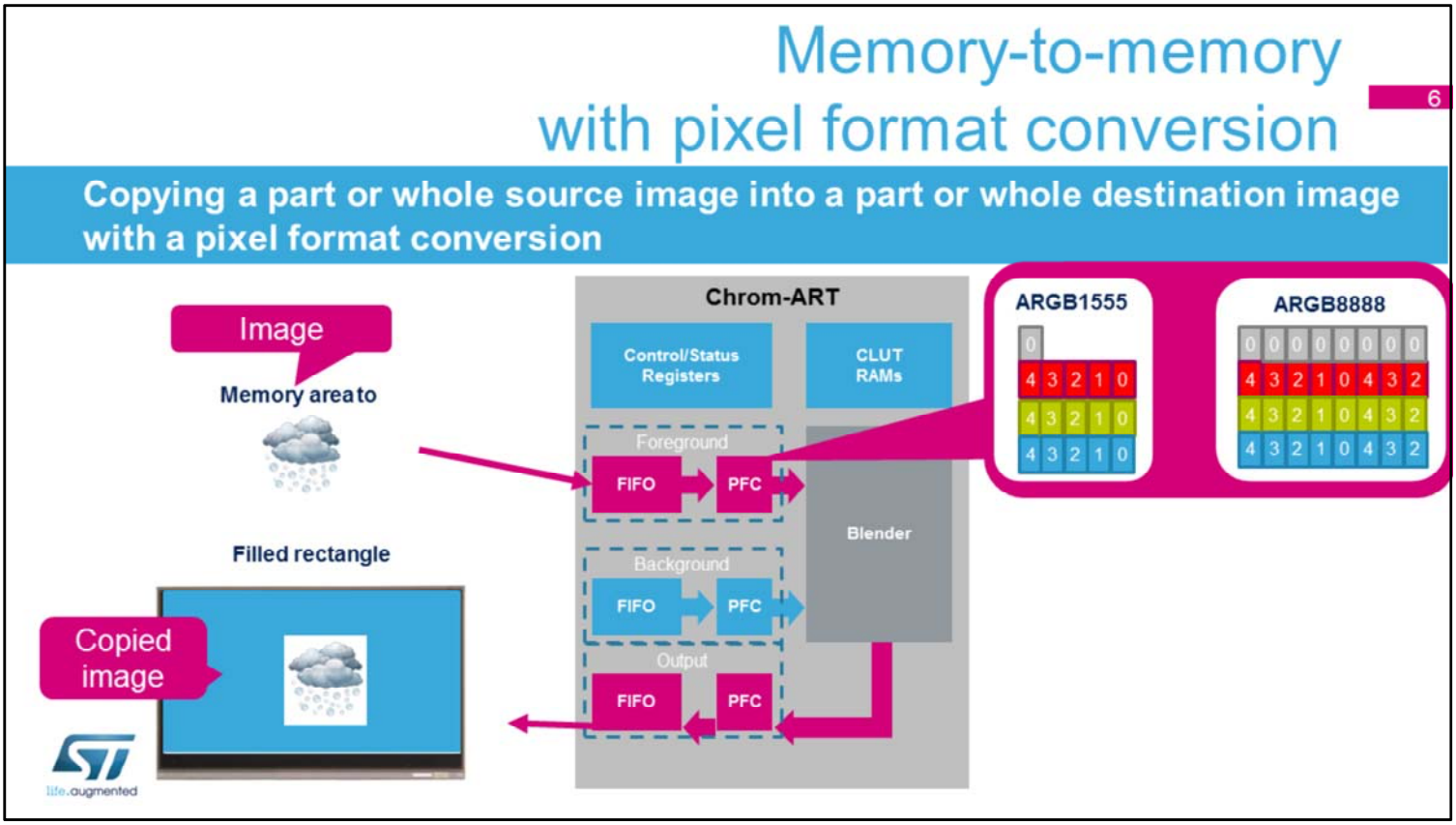
- The address of the layer including its size and position
- The color format
- The way transparency is managed.



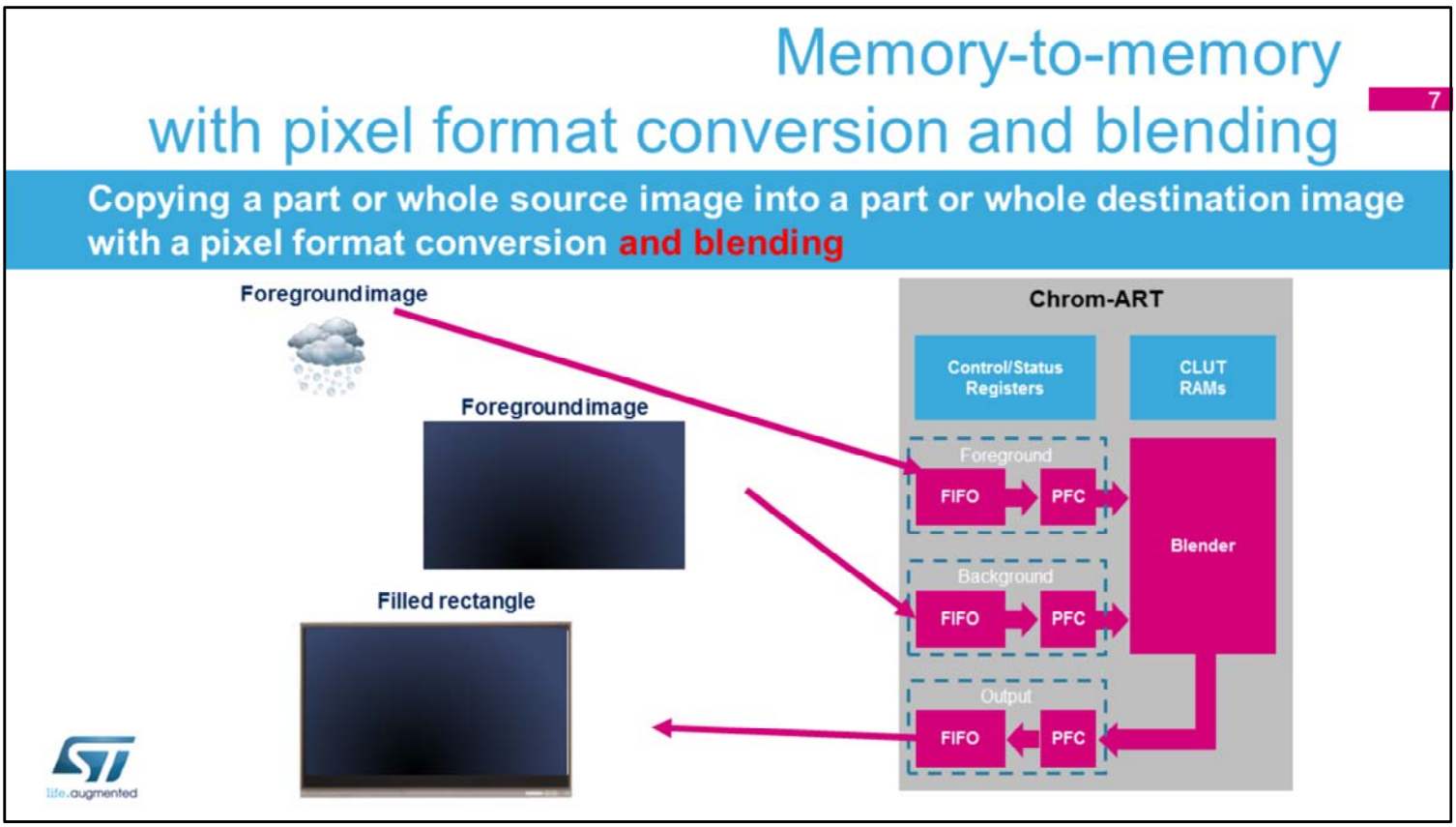
Register-to-memory mode is used to fill a part or whole destination image with a specific color.
The color value is set in a register of the output PFC.



Memory-to-memory mode is used to copy a part or whole source image into a part or whole destination image without changing the color format.



Memory-to-memory mode with pixel format conversion is used to do the same type of copy as Memory-to memory mode but with a pixel format conversion. It can copy an RGB565 image into an RGB888 image without having to use the CPU.



Memory-to-memory mode with pixel format conversion and blending is used to blend a part or whole source image with a part or whole destination image with a different pixel format. This is widely used to draw bitmap icons having transparency or fonts.

Input pixel format conversion

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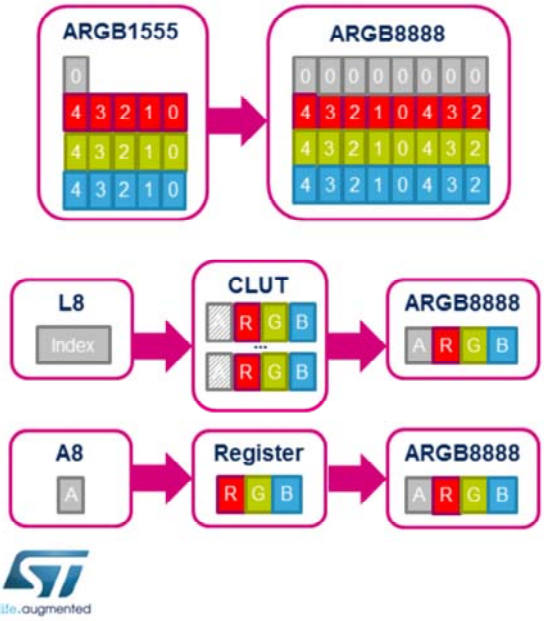
Independently supports different input color depths



- Direct mode
  - ARGB8888, ARGB444444 or ARGB1555
  - RGB888 or RGB565 (with alpha in register)
  - Alpha can be replaced or modulated
- **Indirect mode**
  - L8 or L4 and a Color Look-up Table (**CLUT**)
  - A8 or A4 and a color register (for fonts)
  - Mixed AL88 or AL44
- **Internal operations are done in ARGB8888**

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For each foreground and background layer, the format can be programmed independently.
Direct mode fetches the RGB or ARGB content directly from the memory.
Indirect mode uses an intermediate color look-up table to determine the color to be used during the copy or blending operation.
All the input color modes are transformed internally into ARGB8888 format to perform the blending operation.

Font special modes

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Efficient support for anti aliased bitmap fonts

- Using A8 or A4 coding
  - Only the Alpha channel is stored in the memory
  - The Chrom-ART accelerator adds a programmed color

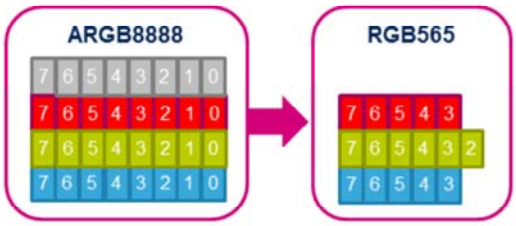
Aliased Anti-aliased

Specific modes can be used to efficiently manage texts and fonts.
Only the transparency value is stored in memory for rendering anti-aliased fonts.
The color is added during the pixel format conversion process and can be programmed by the user.
These modes are very efficient for storing high-quality bitmap fonts.

Output pixel format conversion

Support several output color depth

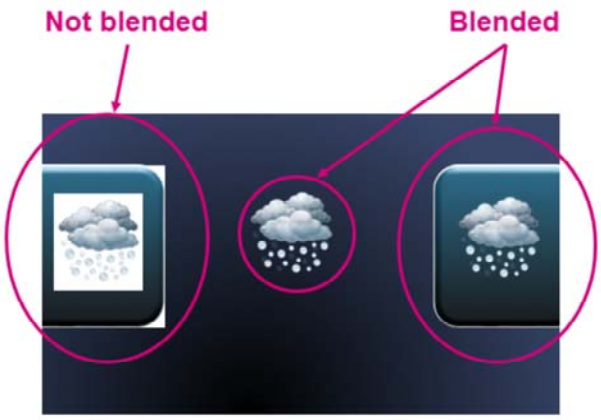
- Direct mode
  - ARGB8888, ARGB444444 or ARGB1555
  - RGB888 or RGB565
- Memory-to-memory without Pixel Format Conversion (PFC) is agnostic of the pixel format



The output pixel format converter generates the color for the destination independently from the source.
There is no indirect mode in output as this would imply to calculate a color look-up table (CLUT).
Nevertheless, memory-to-memory operations without Pixel Format Conversion (PFC) can copy data independently of their formats.

Blending

Fully hardware blending process



- Hardware Blending
  - Blend Foreground & Background pixels
  - 1 pixel generated per cycle
  - Native ARGB8888 operation
  - Input data are converted into ARGB8888 by their respective PFC
  - Output data has also its own PFC

The fully hardware blender allows to blend a foreground image and a background image with transparency.
This can be used to draw bitmap images of any shape with a perfect rendering.
1 pixel is generated per cycle making this complex operation much more efficient than if it was done by the CPU.
The resulting pixel can be coded independently from the source thanks to the output pixel format converter.

Output configuration

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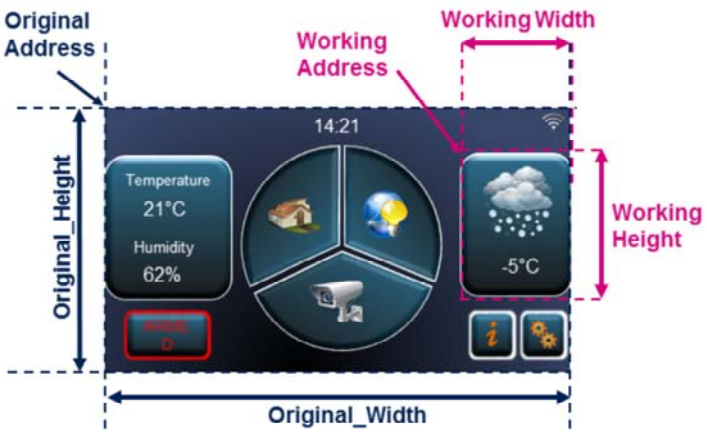
Output configuration defines the area of work & output color coding



- Area of work
  - Width
  - Height
- Output configuration
  - Address
  - LineOffset
  - Color Format (BPP)

Working_Address = Original_Address + (X + Original_Width * Y) * BPP

LineOffset = Original_Width – Working_Width

The output configuration defines the working area for the Chrom-ART operation.

The address and the line offset parameters are used to select which sub-area of the output is concerned.

FG & BG configuration

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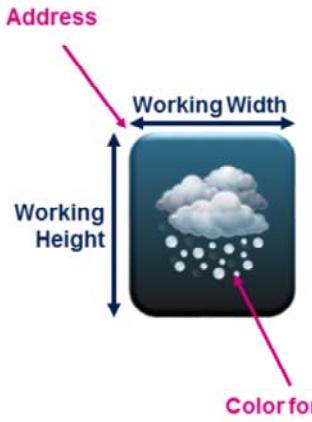
FG & BG configuration define address and color coding

- Foreground parameters
  - Address
  - LineOffset (as per output)
  - Color format
- Background parameters
  - Address (as per output)
  - LineOffset (as per output)
  - Color format



Most of the time, background and output have the same parameters

The background and foreground layers have their own configuration for address, line offset and color format.
This defines which area of the foreground and background layers are targeted by the Chrom-ART operations.

Interrupts

Interrupt event	Description
Configuration error	Error of configuration detected when starting the Chrom-ART (not allowed or wrong configuration)
CLUT transfer complete	CLUT copy from a system memory area to the internal Chrom-ART memory is complete
CLUT access error	CPU accesses the CLUT while the CLUT is being automatically copied from a system memory to the internal Chrom-ART memory
Transfer watermark	Indicates the last pixel of the watermarked line has been transferred
Transfer complete	Chrom-ART transfer operation is complete
Transfer error	An error occurred during Chrom-ART transfer

The Chrom-ART accelerator has 6 interrupt sources to signal:

- Configuration errors
- CLUT transfer complete
- CLUT access error
- Watermark reached during a transfer
- Transfer complete
- Transfer error

No DMA trigger is used as the Chrom-ART accelerator embeds its own DMA.

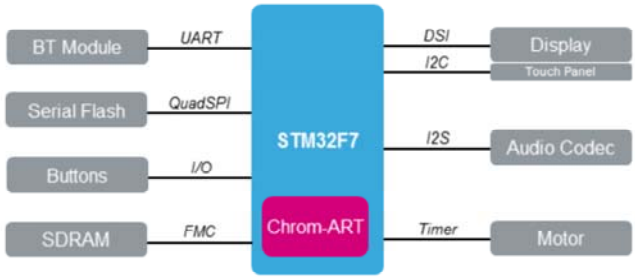
Low-power modes

Mode	Description
Run	Active.
Sleep	Active. Peripheral interrupts cause the device to exit Sleep mode.
Stop	Frozen. Peripheral registers content is kept.
Standby	Powered-down. The peripheral must be reinitialized after exiting Standby mode.

The Chrom-ART accelerator is active in Run and Sleep modes. A Chrom-ART interrupt can cause the device to exit Sleep mode. In Stop mode, the Chrom-ART accelerator is frozen and its registers content is kept. In Standby mode, the Chrom-ART accelerator is powered-down and it must be reinitialized afterwards.

Application examples

- Home appliances including connectivity and HMI:



- Chrom-ART can handle HMI building
  - Composition of the scene with transparency and animations
  - Text management

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The Chrom-ART accelerator is widely used in any graphical application to compute the frame buffer without any CPU load and with a very efficient throughput.
It can compose the whole scene with transparency and facilitate the management of animations.
Text rendering is also accelerated, making it easy and efficient to manage anti-aliased fonts.

Related peripherals

- Refer to these trainings related to this peripheral:
  - RCC (Chrom-ART clock control, Chrom-ART enable/reset)
  - Interrupts (Chrom-ART interrupt mapping)

You can refer to the trainings related to the RCC and interrupts for additional information.