ORSoC Graphics accelerator Specification

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WISHBONE
COMPATIBLE

Revision history

Rev.	Date	Author	Description
1.0	23/3/2012	Per Lenander	Initial draft and basic functionality
2.0	4/6/2012	Per Lenander	Advanced functionality (vector, 3D etc)

Contents

1 Introduction

The ORSoC Graphics accelerator allows the user to do advanced vector rendering and 2D blitting to a memory area. The core supports operations such as drawing textures, lines, curves and filling rectangular and triangular areas with color.

This IP Core is designed to integrate with the OpenRISC processor through a Wishbone bus interface. The core itself has no means of displaying the information rendered, for this purpose it can work alongside a display component, such as the enhanced VGA/LCD IP core found on OpenCores.

1.1 Features

- 32-bit Wishbone bus interface
- Integrates with enhanced VGA/LCD IP core
- Support for 16 bit color depth
- Support for variable resolution
- Acceleration of line operations
- Acceleration of rectangle and triangle rasterization
- Acceleration of memory copy operations
- Textures can be saved to video memory
- Vector transformation and rasterization
- Clipping/Scissoring
- Alpha blending and colorkeying
- Filled Bezier curves
- Bitmap Fonts
- Vector Fonts (ttf)
- Interpolation of colors
- UV-Mapping
- Transformation (scaling and rotation)
- 3D model support (.obj model files built using 3rd degree polygons)
- Z-Buffer (triangles drawn in depth order)
- Requires around 10000 Slice LUTs (Xilinx ISE 13.4)

1.2 IP Core directory structure

A overview of the contents of the IP core source folder can be found in figure 1.

2 Architecture

2.1 Overview

A topology of how the ORGFX is connected to the VGA driver and the OpenRISC core is shown in figure 2. The ORGFX has three wishbone interfaces: one read/write port that is used to communicate with the host CPU. One read port that reads depth/texture/alpha blending information from the RAM and one write port to write pixel information to the RAM.

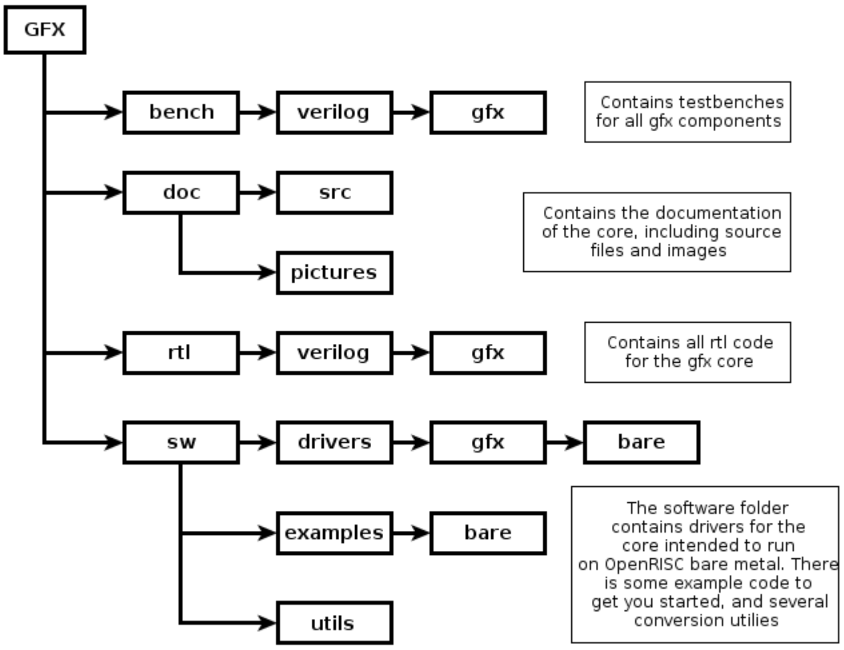

GFX
bench
verilog
gfx
Contains testbenches for all gfx components
doc
src
pictures
Contains the documentation of the core, including source files and images
rtl
verilog
gfx
Contains all rtl code for the gfx core
sw
drivers
gfx
bare
examples
bare
utils
The software folder contains drivers for the core intended to run on OpenRISC bare metal. There is some example code to get you started, and several conversion utilies

Figure 1: Directory structure of the ORSoC graphics accelerator.

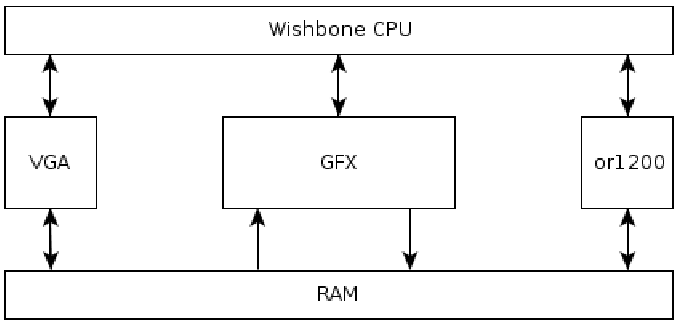


Figure 2: Overview of the ORPSoCv2's wishbone interconnection.

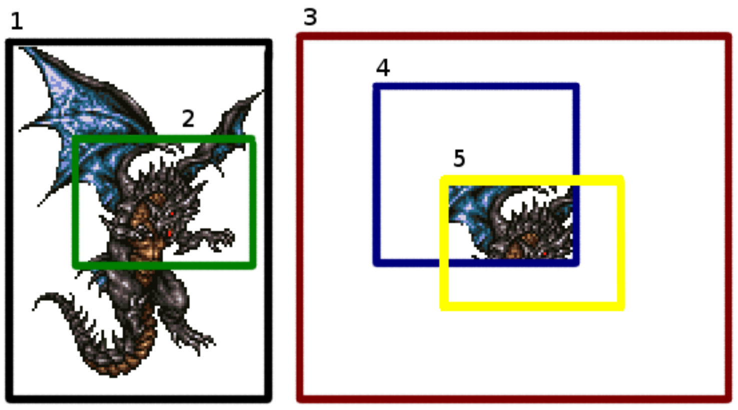


Figure 3: 1. Texture, 2. Source, 3. Render target, 4. Clip, 5. Destination

2.2 Concepts

This section describes a few basic terms used in this document.

Video memory – The ORGFX component writes pixels one by one to an external memory, usually a SDRAM or DDR RAM chip. The CPU should also have access to this memory space to be able to write pixels directly (the easiest way to load textures).

Render target – The render target, defined by the target base and size registers, describes the area to which all operations render pixels. It is possible to change the base address and size, enabling render-to-texture and double buffering.

Surface/Texture – Any memory area that can be rendered to, including the render target, is considered a surface. A surface is defined by it's base address and size. There are two main surfaces that the ORGFX device handles: the render target and the currently active texture. Swapping between different textures has to be done in software. The operation of setting the current render target or texture is referred to as *binding*.

Source, Destination and Clip rectangles – There are three sets of rectangles that affect rendering, each described by two points. The first point sets the beginning of the rectangle, while the second point sets the pixel after the end of the rectangle. This way, a rectangle exactly filling the screen would be (0,0,640,480) at 640x480 resolution. See figure 3;

Source rectangle – The source rectangle defines what pixels should be read from a texture during textured operations. The points are defined in the coordinates of the currently bound texture. This way sections of a texture can be drawn (good for tile maps or bitmap fonts).

Destination rectangle – The destination rectangle defines where operations such as draw pixel and draw line will draw pixels, in the coordinates of the render target.

Clip rectangle – The clip rectangle defines an area within the current render target which is valid to draw to. Any pixels outside this rectangle are discarded in the rasterization step. Pixels outside of the render target are automatically discarded.

Z-buffer – The depth or Z-buffer is a surface containing z coordinate information. This can be used to draw graphics primitives in depth-correct order.

2.3 Coordinate precision

The ORGFX core supports variable coordinate precision through two parameters, **point_width** and **subpixel_width**. Both parameters defaults to 16 bits width.

Target size, clip and source rects are defined as **point_width** bit integers. Destination points are defined as fixed point numbers, with **point_width** bit integer precision and **subpixel_width** fractional precision. Internally many calculations are done with fixed point logic.

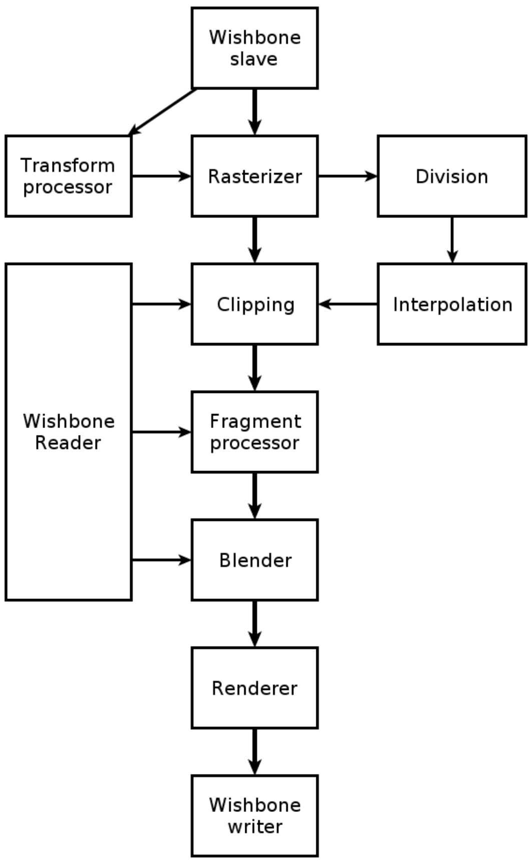


Figure 4: Picture of the ORGFX pipeline

2.4 Instruction FIFO

All wishbone writes sent to the slave interface will pass through an instruction fifo. If the device is in the busy state (when the pipeline is active) the instruction will be queued instead of being set immediately. This is important to take into account when reading from registers, since an operation that changes the register being read might be queued. To find out if the device is busy, poll the status register and check if the busy bit is high.

2.5 Pipeline

The ORGFX core uses a pipelined architecture to speed up operation. An overview of the pipeline can be seen in figure 4. Each module in the pipeline communicates with acknowledge and write signals. A module will not assert write to the next module unless it receives an ack first (or if the module was previously in a ready state, in which case the downstream pipeline is empty). All ack and write signals are always exactly one clock tick long, to prevent triggering multiple instances of the same instruction.

Each module in the pipeline may hold the upstream pipeline for several clock ticks. For example, the rasterizer will prevent incoming raster instructions until all the pixels for the current operation are generated. When the rasterizer is ready for new data, it will send an ack upstream.

2.6 Description of core modules

2.6.1 Wishbone slave

The wishbone slave handles all communication from the main OpenRISC processor (or other master CPU). This component holds all the registers, and the instruction FIFO that sets them. This component can be in one of two states: *busy* or *wait*. It enters the busy state when a pipeline operation is initialized, and returns to the wait state when the operation is finished. Operations can be initialized by writing to the control register (see section **??**).

2.6.2 Transformation processor

The transformation processor handles rotations and scaling.

2.6.3 Rasterizer

This rasterizer generates pixel coordinates from points for several different operations.

2.6.4 Clipper

Discard generated pixel if clipping is enabled and pixel is out of bounds. Always discard pixels outside of the target area.

2.6.5 Fragment processor

The fragment processor adds color to the pixel generated by the rasterizer. If texturing is disabled, a color supplied from the color register is used. If texturing is enabled on the other hand, the u v coordinates supplied by the rasterizer are used to fetch a pixel from the active texture. If colorkeying is enabled and the fetched color matches the color key, the current pixel is discarded.

2.6.6 Blender

The blender module performs alpha blending if this is enabled. The module fetches the color of the pixel that the current operation will write to, and the mixes the value of the target color and the color from the fragment processor using the following algorithm:

$$alpha = alpha_{global} * alpha_{pixel}$$
$$color_{out} = color_{in} * alpha + color_{target} * (1 - alpha)$$

Where alpha is a value between 0 (transparent) and 1 (opaque). If alpha blending is disabled the pixel is passed on unmodified. The alpha value can be interpolated over a triangle to create gradients. If this function is turned off (interpolation is disabled on triangle draws) then $alpha_{pixel}$ is set to 1.

2.6.7 Wishbone arbiter

Since two parts of the pipeline (fragment and blender) needs to access video memory, the arbiter makes certain only one of them can access the reader at once. The blender has the highest priority.

2.6.8 Wishbone master read

The wishbone reader handles all reads from video memory.

2.6.9 Renderer

The renderer calculates the memory address of the target pixel.

2.6.10 Wishbone master write

The wishbone master handles all writes to the video memory.

3 IO Ports

The Core has three wishbone interfaces:

- Wishbone slave – connects to the data bus of the OpenRISC processor. In the case of ORP-SoC, this bus is connected through an arbiter. Supports standard wishbone communications, not any burst modes.
- Wishbone master read-only – connects to a video memory port with read access. Used for fetching textures and during blending.
- Wishbone master write-only – connects to a video memory port with write access. Used for rendering pixels to the framebuffer.

There is an interrupt enabled that can be connected to the interrupt pins on the or1200 CPU (in the supplied orpsoc_top it is connected to or1200_pic_ints[9]). For this interrupt to trigger, the correct bits in the control register has to be set.

4 Registers

Name	**Addr**	**Width**	**Access**	**Description**
CONTROL	0x00	32	RW	Control register
STATUS	0x04	32	R	Status register
ALPHA	0x08	32	RW	Global alpha register
COLORKEY	0x0c	32	RW	Colorkey register
TARGET_BASE	0x10	32	RW	Render target base
TARGET_SIZE_X	0x14	32	RW	Render target width
TARGET_SIZE_Y	0x18	32	RW	Render target height
TEX0_BASE	0x1c	32	RW	Texture 0 base
TEX0_SIZE_X	0x20	32	RW	Texture 0 width
TEX0_SIZE_Y	0x24	32	RW	Texture 0 height
SRC_P0_X	0x28	32	RW	Source pixel 0 x
SRC_P0_Y	0x2c	32	RW	Source pixel 0 y
SRC_P1_X	0x30	32	RW	Source pixel 1 x
SRC_P1_Y	0x34	32	RW	Source pixel 1 y
DEST_X	0x38	32	RW	Destination pixel x
DEST_Y	0x3c	32	RW	Destination pixel y
DEST_Z	0x40	32	RW	Destination pixel z
AA	0x44	32	RW	Transformation matrix coefficient
AB	0x48	32	RW	Transformation matrix coefficient
AC	0x4c	32	RW	Transformation matrix coefficient
TX	0x50	32	RW	Transformation matrix coefficient
BA	0x54	32	RW	Transformation matrix coefficient
BB	0x58	32	RW	Transformation matrix coefficient
BC	0x5c	32	RW	Transformation matrix coefficient
TY	0x60	32	RW	Transformation matrix coefficient
CA	0x64	32	RW	Transformation matrix coefficient
CB	0x68	32	RW	Transformation matrix coefficient
CC	0x6c	32	RW	Transformation matrix coefficient
TZ	0x70	32	RW	Transformation matrix coefficient
CLIP_P0_X	0x74	32	RW	Clip pixel 0 x
CLIP_P0_Y	0x78	32	RW	Clip pixel 0 y
CLIP_P1_X	0x7c	32	RW	Clip pixel 1 x
CLIP_P1_Y	0x80	32	RW	Clip pixel 0 y
COLOR0	0x84	32	RW	Color 0
COLOR1	0x88	32	RW	Color 1
COLOR2	0x8c	32	RW	Color 2
U0	0x90	32	RW	Texture coordinate 0
V0	0x94	32	RW	Texture coordinate 0
U1	0x98	32	RW	Texture coordinate 1
V1	0x9c	32	RW	Texture coordinate 1
U2	0xa0	32	RW	Texture coordinate 2
V2	0xa4	32	RW	Texture coordinate 2
ZBUFFER_BASE	0xa8	32	RW	Depth buffer base address

Each register is described in detail in the following sections, with information about what the purpose of each bit in the register is. The default value provided for each register is set when the device receives a reset signal.

4.1 Control Register (CONTROL)

Bit #	**Access**	**Description**
[31:20]	-	Reserved
[19]	W	Transform point
[18]	W	Forward point
[17:16]	RW	Active point
[15:14]	-	Reserved
[13]	W	Bézier inside shape
[12]	W	Interpolation
[11]	W	Curve write
[10]	W	Triangle write
[9]	W	Line write
[8]	W	Rect write
[7]	-	Reserved
[6]	RW	Z-buffer enable
[5]	RW	Clipping enable
[4]	RW	Colorkey enable
[3]	RW	Blending enable
[2]	RW	Texture0 enable
[1:0]	RW	Color depth

Default value: 0x00

Color depth is defined as follows:

Mode	**Color depth**
00	8 bit
01	16 bit
10	24 bit (not supported)
11	32 bit

The active point is defined as follows:

Mode	**Point id**
00	p0
01	p1
10	p2
11	-

The operations **Forward point** and **Transform point** reads the current values of the active point and stores the x, y, z values in the correct register inside the device.

4.2 Status Register (STATUS)

Bit #	**Access**	**Description**
[31:16]	R	Current FIFO size
[15:1]	R	Reserved
[0]	R	Busy pin (high when busy)

Default value: –

4.3 Alpha (ALPHA)

Bit #	**Access**	**Description**
[31:24]	RW	Point 0 alpha
[23:16]	RW	Point 1 alpha
[15:8]	RW	Point 2 alpha
[7:0]	RW	Global alpha

Default value: 0xffffffff

The global alpha value is used in all rendering when alpha blending is enabled. **0xff** is full opacity, while **0x00** is full transparency (nothing rendered). When interpolation of triangles is activated, the point alpha values are used to find an interpolated alpha value for each pixel. This value is then multiplied with the global alpha before being used for blending.

4.4 Colorkey register (COLORKEY)

Bit #	Access	Description
[31:0]	RW	Colorkey

Default value: 0x00

By setting a colorkey certain pixels in a texture can be discarded in the fragment stage, providing a hard transparency. Depending on the color depth, a mask is applied to the color. Using 8 bit color, only the 8 least significant bits in the colorkey will be compared with the texture color during the check. The colorkey enable bit in the control register must be set to enable this functionality.

4.5 Target base address Register (TARGET_BASE)

Bit #	Access	Description
[31:2]	RW	Video Memory Address
[1:0]	-	Nothing

Default value: 0x00

4.6 Target size width Register (TARGET_SIZE_X)

Bit #	Access	Description
[31:0]	RW	Integer Width

Default value: 0x00

4.7 Target size y Register (TARGET_SIZE_Y)

Bit #	Access	Description
[31:0]	RW	Integer Height

Default value: 0x00

4.8 Texture 0 Base Register (TEX0_BASE)

Bit #	Access	Description
[31:2]	RW	Video Memory Address
[1:0]	-	Nothing

Default value: 0x00

4.9 Texture 0 size x Register (TEX0_SIZE_X)

Bit #	Access	Description
[31:0]	RW	Integer Width

Default value: 0x00

4.10 Texture 0 size y Register (TEX0_SIZE_Y)

Bit #	Access	Description
[31:0]	RW	Integer Height

Default value: 0x00

4.11 Source Pixel position 0 x Register (SRC_P0_X)

Bit #	Access	Description
[31:0]	RW	Integer x pos

Default value: 0x00

The source pixels are used to define a specific area in a texture to draw.

4.12 Source Pixel position 0 y Register (SRC_P0_Y)

Bit #	Access	Description
[31:0]	RW	Integer y pos

Default value: 0x00

4.13 Source Pixel position 1 Register (SRC_P1_X)

Bit #	Access	Description
[31:0]	RW	Integer x pos

Default value: 0x00

4.14 Source Pixel position 1 Register (SRC_P1_Y)

Bit #	Access	Description
[31:0]	RW	Integer y pos

Default value: 0x00

4.15 Destination Pixel position Register (DEST_X)

Bit #	Access	Description
[31:16]	RW	Signed Integer part
[15:0]	RW	Fractional part

Default value: 0x00

The control register flag active point decides the destination register inside the device. Points are pushed to the device by setting the forward or transform bit in the control register.

4.16 Destination Pixel position Register (DEST_Y)

Bit #	Access	Description
[31:16]	RW	Signed Integer part
[15:0]	RW	Fractional part

Default value: 0x00

4.17 Destination Pixel position Register (DEST_Z)

Bit #	Access	Description
[31:16]	RW	Signed Integer part
[15:0]	RW	Fractional part

Default value: 0x00

4.18 Matrix coefficient registers

The matrix coefficients are defined in the following way:

$$M = \begin{bmatrix} AA & AB & AC & TX \\ BA & BB & BC & TY \\ CA & CB & CC & TZ \end{bmatrix}$$

Each coefficient has a register, where the bits are defined as:

Bit #	Access	Description
[31:16]	RW	Signed Integer part
[15:0]	RW	Fractional part

The default matrix is set to no scaling, no rotation, no translation:

$$M_{default} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix}$$

4.19 Clip Pixel position 0 x Register (CLIP_P0_X)

Bit #	Access	Description
[31:0]	RW	Integer x

Default value: 0x00

4.20 Clip Pixel position 0 y Register (CLIP_P0_Y)

Bit #	Access	Description
[31:0]	RW	Integer y

Default value: 0x00

4.21 Clip Pixel position 1 x Register (CLIP_P1_X)

Bit #	Access	Description
[31:0]	RW	Integer x

Default value: 0x00

4.22 Clip Pixel position 1 y Register (CLIP_P1_Y)

Bit #	Access	Description
[31:0]	RW	Integer y

Default value: 0x00

4.23 Color Registers (COLOR0-2)

Bit #	Access	Description
[31:0]	RW	Color bits

Default value: 0x00

There are several color modes available (set in *control register*):

Mode	Format
32bpp	[31:24] is alpha channel. [23:16] is R, [15:8] is G and [7:0] is B
16bpp	[15:11] is R, [10:5] is B and [4:0] is G
8bpp gray	[7:0] sets both R, G and B values
8bpp palette	[7:0] sets the color index in the palette

Currently only 16 bit color depth is fully supported.

4.24 Texture coordinate Registers (U0-2 and V0-2)

Bit #	Access	Description
[31:0]	RW	Coordinate bits (integer)

Default value: 0x00

4.25 Depth buffer Register (ZBUFFER_BASE)

Bit #	Access	Description
[31:2]	RW	32-bit word base address
[1:0]	-	Ignored

Default value: 0x00

This register holds the base address of the depth buffer. The depth buffer operations uses TARGET_SIZE_X and TARGET_SIZE_Y for the size of the depth buffer (it is assumed that the render target and the depth buffer are of the same size.

5 Operation

All hardware accelerated operations draw pixels to the currently active surface (defined by TADR_REG and TSZE_REG). These operations are all affected by clip_p0 and clip_p1. No pixels that fall outside the clipping rectangle will be rendered.

5.1 Draw pixel

Input needed: dest_p0, color0
ORGFX have no hardware-support for writing a single pixel to the video memory. However its possible to draw a line, rect or curve with the size of one pixel. The software API makes it possible to draw a pixel by writing directly to the memory (this is the most optimal way). Since the video memory can point to both the framebuffer and to textures, the same operation can be used to draw an arbitrary pixel to the screen and to load a texture into video memory.

5.2 Fill rect

Input needed: ctrl, dest_p0, dest_p1, color0, [src_p0, src_p1]
Fill rect will fill the area of a rectangle created between the pixel dest_p0 and dest_p1 with color. If texturing is enabled, color will be taken from the active texture in the area between src_p0 and src_p1. This operation is hardware accelerated, and is activated by setting the Rect write bit in the control register.

5.3 Line

Input needed: ctrl, dest_p0, dest_p1, color0
Line will draw a line between the pixels dest_p0 and dest_p1 with color. This operation is hardware accelerated.

5.4 Triangle

Input needed: ctrl, dest_p0, dest_p1, dest_p2, color0, [color1, color2, u0, v0, u1, v1, u2, v2]
Draw the pixels in the triangle created by dest_p0, dest_p1 and dest_p2. The triangle can be colored with either a flat color, a gradient or a texture. Gradient or textured coloring require the interpolation pin to be set in the control register.

5.5 Curve

Input needed: ctrl, dest_p0, dest_p1, dest_p2, color0, [color1, color2, u0, v0, u1, v1, u2, v2]
Draws a filled quadratic Bézier curve with dest_p0 as start, dest_p1 as control point and dest_p2 as end. For this operation to work, the interpolation pin must be set in the control register.

6 Clocks

The entire component uses the same clock domain.

7 Driver interface

The ORSoC graphics accelerator offers three different APIs to code against, two for bare metal when coding directly against the processor, and a Linux kernel module. The extended bare metal interface is a wrapper around the basic bare metal API, and makes coding easier by reducing the number of calls. The drawback is lesser control over the graphics card.

7.1 newlib

The basic library is provided in **orgfx.h** and **orgfx.c**.

The bare metal library declares a structure that can hold surfaces (both framebuffers and textures). Many functions take a pointer to one of these structures.

```
struct orgfx_surface
{
        unsigned int addr;
        unsigned int w;
        unsigned int h;
};
```

7.1.1 orgfx_init

Description: The orgfx_init must be called first to get other oc_gfx commands to work properly.

```
void orgfx_init(unsigned int memoryArea);
```

7.1.2 orgfx_vga_set_videomode

Description: Sets the video mode, width, height, bpp.

```
void orgfx_set_videomode(unsigned int width,
                         unsigned int height,
                         unsigned char bpp);
```

7.1.3 orgfx_vga_set_vbara

Description: Assign a memory address to "Video Base Address Register A".

```
void orgfx_vga_set_vbara(unsigned int addr);
```

7.1.4 orgfx_vga_set_vbarb

Description: Assign a memory address to "Video Base Address Register B".

```
void orgfx_vga_set_vbarb(unsigned int addr);
```

7.1.5 orgfx_vga_bank_switch

Description: Switches the framebuffer.

```
void orgfx_vga_bank_switch();
```

7.1.6 orgfx_init_surface

Description: Initialize a surface and return a control structure for it. This function increments an internal video memory stack pointer, so each surface will be allocated after the previous one in memory (starting at memoryArea set by orgfx_init). There is currently no memory management in place to recycle surface memory once it is no longer in use. The first surface initialized will point to the same memory that the video controller reads from, so it should be initialized with the width and height of the screen.

```
struct orgfx_surface
  orgfx_init_surface(unsigned int width,
                     unsigned int height);
```

7.1.7 orgfx_bind_rendertarget

Description: Binds a surface as the active render target. This function *must* be called before any drawing operations can be performed.

```
void orgfx_bind_rendertarget(struct orgfx_surface *surface);
```

7.1.8 orgfx_enable_cliprect

Description: Enables/disables clipping.

```
inline void orgfx_enable_cliprect(unsigned int enable);
```

7.1.9 orgfx_cliprect

Description: Sets the clipping rect. No pixels will be drawn outside of this rect (useful for restricting draws to a specific area of the render target). orgfx_bind_rendertarget will reset the clipping rect to the size of the surface.

```
inline void orgfx_cliprect(unsigned int x0,
                           unsigned int y0,
                           unsigned int x1,
                           unsigned int y1);
```

7.1.10 orgfx_srcrect

Description: Sets the source rectangle that will be used by texturing operations. This allows for only drawing a small part of a texture. orgfx_bind_tex0 will reset this to the size of the texture.

```
inline void orgfx_srcrect(unsigned int x0,
                          unsigned int y0,
                          unsigned int x1,
                          unsigned int y1);
```

7.1.11 orgfx_set_pixel

Description: Set a pixel on coordinate x,y to color. This is done in software by direct memory writes. This operation is not affected by the clipping rect!

```
inline void orgfx_set_pixel(int x,
                            int y,
                            unsigned int color);
```

7.1.12 orgfx_memcpy

Description: Copies memory from the processor to the video memory. Size is in 32-bit words. This function is intended to work with the output array of the sprite converter utility to load images into memory. Remember to bind a texture as the render target first!

```
void orgfx_memcpy(unsigned int mem[],
                  unsigned int size);
```

7.1.13 orgfx_set_color

Description: Sets the current drawing color (for flat coloring).

```
inline void orgfx_set_color(unsigned int color);
```

7.1.14 orgfx_set_colors

Description: Sets all the current drawing colors (for gradient coloring).

```
inline void orgfx_set_colors(unsigned int color0,
                             unsigned int color1,
                             unsigned int color2);
```

7.1.15 orgfx_rect

Description: Draws a rect from (x0,y0) to (x1,y1) and fills it with the current drawing color. If texturing is enabled, the current texture will be drawn instead.

```
inline void orgfx_rect(int x0,
                       int y0,
                       int x1,
                       int y1);
```

7.1.16 orgfx_line

Description: Draws a line from (x0,y0) to (x1,y1) with the current drawing color. If texturing is enabled, the first pixel of the current texture will be drawn instead.

```
inline void orgfx_line(int x0, int y0,
                       int x1, int y1);
```

7.1.17 orgfx_line3d

Description: Draws a line from (x0,y0,z0) to (x1,y1,z1) with the current drawing color. If texturing is enabled, the first pixel of the current texture will be drawn instead.

```
inline void orgfx_line3d(int x0, int y0, int z0,
                         int x1, int y1, int z1);
```

7.1.18 orgfx_triangle

Description: Draws a filled triangle of the space spanned by (x0,y0), (x1,y1) and (x2,y2). The order of the points is important, since triangles calculated to be counter clockwise will be discarded (backface culling). The interpolate flag indicates if flat coloring or interpolated coloring should be used. The interpolate flag *has* to be enabled for interpolated alpha, texture coordinates or depth is desired (flat coloring can be obtained by setting all three color registers to the same color).

```
inline void orgfx_triangle(int x0, int y0,
                           int x1, int y1,
                           int x2, int y2,
                           unsigned int interpolate);
```

7.1.19 orgfx_triangle3d

Description: This function works the same way as the triangle function, but the Z-values are set.

```
inline void orgfx_triangle3d(int x0, int y0, int z0,
                             int x1, int y1, int z1,
                             int x2, int y2, int z2,
                             unsigned int interpolate);
```

7.1.20 orgfx_curve

Description: Draws a Quadratic curve between the points (x0,y0) and (x2,y2) with the control points (x1,y1). The three points form a triangle. The *inside* flag determines if the inside or outside of the curve is filled inside the triangle.

```
inline void orgfx_curve(int x0, int y0,
                        int x1, int y1,
                        int x2, int y2,
                        unsigned int inside);
```

7.1.21 orgfx_uv

Description: Sets the three texture coordinates used in textured triangle renders.

```
inline void orgfx_uv(unsigned int u0, unsigned int v0,
                     unsigned int u1, unsigned int v1,
                     unsigned int u2, unsigned int v2);
```

7.1.22 orgfx_enable_tex0

Description: Enables or disables texturing.

```
void orgfx_enable_tex0(unsigned int enable);
```

7.1.23 orgfx_bind_tex0

Description: Binds a surface as the current texture. Will reset the source rect.

```
void orgfx_bind_tex0(struct orgfx_surface* surface);
```

7.1.24 orgfx_enable_zbuffer

Description: Enables or disables reads and writes to the depth buffer. Requires that a depth buffer is bound.

```
void orgfx_enable_zbuffer(unsigned int enable);
```

7.1.25 orgfx_bind_zbuffer

Description: Binds the depth buffer. This surface should have the same resolution as the render target.

```
void orgfx_bind_zbuffer(struct orgfx_surface *surface);
```

7.1.26 orgfx_clear_zbuffer

Description: Clears the depth buffer.

```
void orgfx_clear_zbuffer();
```

7.1.27 orgfx_enable_alpha

Description: Enables or disables alpha blending.

```
void orgfx_enable_alpha(unsigned int enable);
```

7.1.28 orgfx_set_alpha

Description: Sets the alpha blending value.

```
void orgfx_set_alpha(unsigned int alpha);
```

7.1.29 orgfx_enable_colorkey

Description: Enables or disables colorkey.

```
void orgfx_enable_colorkey(unsigned int enable);
```

7.1.30 orgfx_set_colorkey

Description: Sets the colorkey color.

```
void orgfx_set_colorkey(unsigned int colorkey);
```

7.1.31 orgfx_enable_transform

Description: Enables or disables hardware accelerated transformation of points.

```
void orgfx_enable_transform(unsigned int enable);
```

7.1.32 orgfx_set_transformation_matrix

Description: Sets the 3 by 4 transformation matrix used in hardware.

```
void orgfx_set_transformation_matrix(int aa, int ab, int ac, int tx,
                                     int ba, int bb, int bc, int ty,
                                     int ca, int cb, int cc, int tz);
```

7.2 Extended newlib

The extended library is provided in **orgfx_plus.h** and **orgfx_plus.c**, but **orgfx.c** also has to be compiled for it to work.

Instead of using surface structs directly, the extended API hides surface management by returning id tags for each surface. The screen surface (defined by id -1) is handled as a single surface, even when double buffering is enabled.

The driver defines the number of available surfaces (not counting the screen) with a static define. Change this if the default value is too low for your application.

There are no 3D functions in this API. For the more advanced 3D functionality (meshes, depth buffering etc.), see the advanced API.

7.2.1 orgfxplus_init

Description: Initializes the screen with the supplied video mode and returns an id for the screen. The only supported bpp is 16. Double buffering and depth buffering can be enabled (and the appropriate buffers will be allocated). The depth buffer is allocated with the same size as the screen. There is no support in the driver to allocate more than one depth buffer.

```
int orgfxplus_init(unsigned int width,
                   unsigned int height,
                   unsigned char bpp,
                   unsigned char doubleBuffering,
                   unsigned char zbuffer);
```

7.2.2 orgfxplus_init_surface

Description: Unlike the basic API, this function both initializes a surface and loads a prepared image to it in one function call. The return value is an id that can be used to bind the surface. It changes render target during operation, but switches back to the last render target on completion. Since the screen(s) are already initialized by a call to init, they do not need to be loaded using this function.

```
int orgfxplus_init_surface(unsigned int width,
                           unsigned int height,
                           unsigned int mem[]);
```

7.2.3 orgfxplus_bind_rendertarget

Description: Binds a surface as the current render target.

```
void orgfxplus_bind_rendertarget(int surface);
```

7.2.4 orgfxplus_bind_tex0

Description: Binds a surface as the current active texture.

```
void orgfxplus_bind_tex0(int surface);
```

7.2.5 orgfxplus_flip

Description: Swaps which buffer to draw on when using double buffering. Needs to be called once before anything shows up on screen!

```
void orgfxplus_flip();
```

7.2.6 orgfxplus_clip

Description: Sets the current clipping rect. This is reset to the size of the new render target when orgfxplus_bind_rendertarget is called.

```
inline void orgfxplus_clip(unsigned int x0,
                           unsigned int y0,
                           unsigned int x1,
                           unsigned int y1,
                           unsigned int enable);
```

7.2.7 orgfxplus_fill

Description: Draws a rectangle to the current render target with a flat color.

```
void orgfxplus_fill(int x0, int y0,
                    int x1, int y1,
                    unsigned int color);
```

7.2.8 orgfxplus_line

Description: Draws a line from (x0,y0) to (x1,y1) to the current render target with a flat color.

```
void orgfxplus_line(int x0, int y0,
                    int x1, int y1,
                    unsigned int color);
```

7.2.9 orgfxplus_triangle

Description: Draws a triangle between the points (x0,y0),(x1,y1) and (x2,y2) and fills it with a color.

```
void orgfxplus_triangle(int x0, int y0,
                        int x1, int y1,
                        int x2, int y2,
                        unsigned int color);
```

7.2.10 orgfxplus_curve

Description: Draws a quadratic Bézier curve from (x0,y0) to (x2,y2) with the control point (x1,y1). Uses flat coloring.

```
void orgfxplus_curve(int x0, int y0,
                     int x1, int y1,
                     int x2, int y2,
                     unsigned int inside,
                     unsigned int color);
```

7.2.11 orgfxplus_draw_surface

Description: Draws a texture to the current render target.

```
void orgfxplus_draw_surface(int x0, int y0,
                            unsigned int surface);
```

7.2.12 orgfxplus_draw_surface_section

Description: Draws a section of a texture defined by src0, src1 to the current render target.

```
void orgfxplus_draw_surface_section(int x0, int y0,
                                    unsigned int srcx0,
                                    unsigned int srcy0,
                                    unsigned int srcx1,
                                    unsigned int srcy1,
                                    unsigned int surface);
```

7.2.13 orgfxplus_colorkey

Description: Sets the colorkey color and enables or disables the use of the colorkey.

```
void orgfxplus_colorkey(unsigned int colorkey,
                        unsigned int enable);
```

7.2.14 orgfxplus_alpha

Description: Sets the alpha value and enables or disables the use of the alpha blending.

```
void orgfxplus_alpha(unsigned int alpha,
                     unsigned int enable);
```

7.3 Bitmap Fonts

Note that bitmap fonts can be generated with the bitfontmaker utility. This utility generates an initialization function that calls the **orgfx_make_bitmap_font** function and returns a valid font.

7.3.1 orgfx_make_bitmap_font

Creates a orgfx_bitmap_font from a image. *glyphSpacing* is the space in pixels between two glyphs in the string, and *spaceWidth* is the size of the space character.

```
orgfx_bitmap_font orgfx_make_bitmap_font(orgfx_tileset* glyphs,
                                         unsigned int glyphSpacing,
                                         unsigned int spaceWidth);
```

7.3.2 orgfx_put_text

Puts the text "str" on the screen with the specified "font" on position x0,y0.

```
void orgfx_put_text(orgfx_font* font,
                    int x0, int y0,
                    const wchar_t *str);
```

Note the use of wide strings (which enables the use of special characters such as åäö). Example usage:

```
orgfx_put_text(&font, x0, y0,
               L"Some example text");
```

7.4 Vector Fonts

Note that vector fonts can be generated with the fonter utility. This utility generates an initialization function that calls the **orgfx_make_vector_font** and **orgfx_init_vector_font** functions and returns a valid font.

7.4.1 orgfx_make_vector_font

Creates a orgfx_vector_font from a series of glyphs.

```
orgfx_vector_font orgfx_make_vector_font(Glyph *glyphlist,
                                         int size,
                                         Glyph **glyphindexlist,
                                         int glyphindexlistsize)
```

7.4.2 orgfx_init_vector_font

Initializes the font for use. Needs to be called to set the index list.

```
int  orgfx_init_vector_font(orgfx_vector_font font);
```

7.4.3 orgfx_put_vector_text

CURRENTLY UNDER REVISION

7.5 3D API

There are two major parts of the 3D API, one is the transformation matrix interface and the other is the 3D mesh interface.

7.5.1 Transformations

By setting the transformation matrix the ORGFX core can perform hardware accelerated transformations for every point sent to it, causing significantly less overhead than if this was done in software.

The relevant functions are listed below:

```
orgfx_matrix orgfx3d_identity(void);
orgfx_matrix orgfx3d_rotateX(orgfx_matrix mat, float rad);
orgfx_matrix orgfx3d_rotateY(orgfx_matrix mat, float rad);
orgfx_matrix orgfx3d_rotateZ(orgfx_matrix mat, float rad);
orgfx_matrix orgfx3d_scale(orgfx_matrix mat, orgfx_point3 s);
orgfx_matrix orgfx3d_translate(orgfx_matrix mat, orgfx_point3 t);

inline void orgfx3d_set_matrix(orgfx_matrix mat);
```

7.5.2 orgfx3d_make_mesh

Initializes a mesh with the necessary arrays generated by the meshmaker utility.

```
orgfx_mesh orgfx3d_make_mesh(orgfx_face* faces,
                             unsigned int nFaces,
                             orgfx_point3* verts,
                             unsigned int nVerts,
                             orgfx_point2* uvs,
                             unsigned int nUvs);
```

7.5.3 orgfx3d_mesh_texture_size

This should be called *only once* for each mesh that will be using texture coordinates. Since the ORGFX device uses pixel coordinates the UV coordinates must be updated with the size of the used texture.

```
void orgfx3d_mesh_texture_size(orgfx_mesh* mesh,
                               unsigned int width,
                               unsigned int height);
```

7.5.4 orgfx3d_draw_mesh

This function draws the mesh to screen, using the *translation*, *rotation* and *scale* vectors stored in the mesh structure. If *filled* is set to zero, the mesh will be drawn as a colored wireframe. If *filled* is set to one and *textured* to zero, the mesh will be drawn with interpolated colors (the mesh format currently does not support materials). If *filled* is set to one and *textured* is also set to one, the mesh will be textured using interpolated uv texture coordinates.

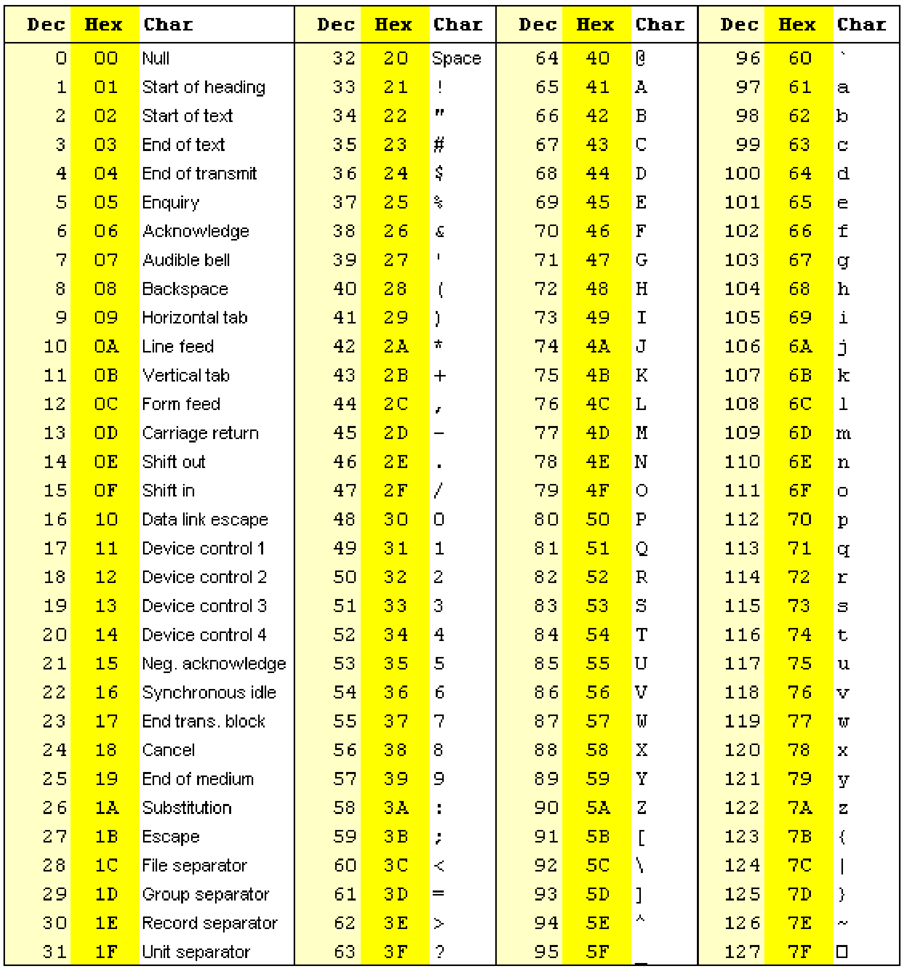
```
void orgfx3d_draw_mesh(orgfx_mesh* mesh,
                       int filled, int textured);
```

7.6 Linux

The current version of the core does not have a Linux driver.

7.7 Software emulation

The entire device has a software implementation to make it easier to write applications for the device. The **orgfx_sw.c** file replaces the **orgfx.c** and **orgfx_plus.c** files, and renders pixels as they would be rendered by the graphics accelerator, but on a PC. The software implementation uses SDL as the backend.



Dec	Hex	Char	Dec	Hex	Char	Dec	Hex	Char	Dec	Hex	Char
0	00	Null	32	20	Space	64	40	@	96	60	`
1	01	Start of heading	33	21	!	65	41	A	97	61	a
2	02	Start of text	34	22	"	66	42	B	98	62	b
3	03	End of text	35	23	#	67	43	C	99	63	c
4	04	End of transmit	36	24	$	68	44	D	100	64	d
5	05	Enquiry	37	25	%	69	45	E	101	65	e
6	06	Acknowledge	38	26	&	70	46	F	102	66	f
7	07	Audible bell	39	27	'	71	47	G	103	67	g
8	08	Backspace	40	28	(	72	48	H	104	68	h
9	09	Horizontal tab	41	29	)	73	49	I	105	69	i
10	0A	Line feed	42	2A	*	74	4A	J	106	6A	j
11	0B	Vertical tab	43	2B	+	75	4B	K	107	6B	k
12	0C	Form feed	44	2C	,	76	4C	L	108	6C	l
13	0D	Carriage return	45	2D	-	77	4D	M	109	6D	m
14	0E	Shift out	46	2E	.	78	4E	N	110	6E	n
15	0F	Shift in	47	2F	/	79	4F	O	111	6F	o
16	10	Data link escape	48	30	0	80	50	P	112	70	p
17	11	Device control 1	49	31	1	81	51	Q	113	71	q
18	12	Device control 2	50	32	2	82	52	R	114	72	r
19	13	Device control 3	51	33	3	83	53	S	115	73	s
20	14	Device control 4	52	34	4	84	54	T	116	74	t
21	15	Neg. acknowledge	53	35	5	85	55	U	117	75	u
22	16	Synchronous idle	54	36	6	86	56	V	118	76	v
23	17	End trans. block	55	37	7	87	57	W	119	77	w
24	18	Cancel	56	38	8	88	58	X	120	78	x
25	19	End of medium	57	39	9	89	59	Y	121	79	y
26	1A	Substitution	58	3A	:	90	5A	Z	122	7A	z
27	1B	Escape	59	3B	;	91	5B	[	123	7B	{
28	1C	File separator	60	3C	<	92	5C	\	124	7C	|
29	1D	Group separator	61	3D	=	93	5D	]	125	7D	}
30	1E	Record separator	62	3E	>	94	5E	^	126	7E	~
31	1F	Unit separator	63	3F	?	95	5F	_	127	7F	□

Figure 5: The ASCII table. Each number from 0 to 127 refers to a character. The numbers 0 to 31 cannot be printed.

7.8 Utilities

7.8.1 Sprite maker utility

A small application that converts an image into a header file that can be included in the project when compiled. The application generates an array of color values that can be loaded as a sprite.

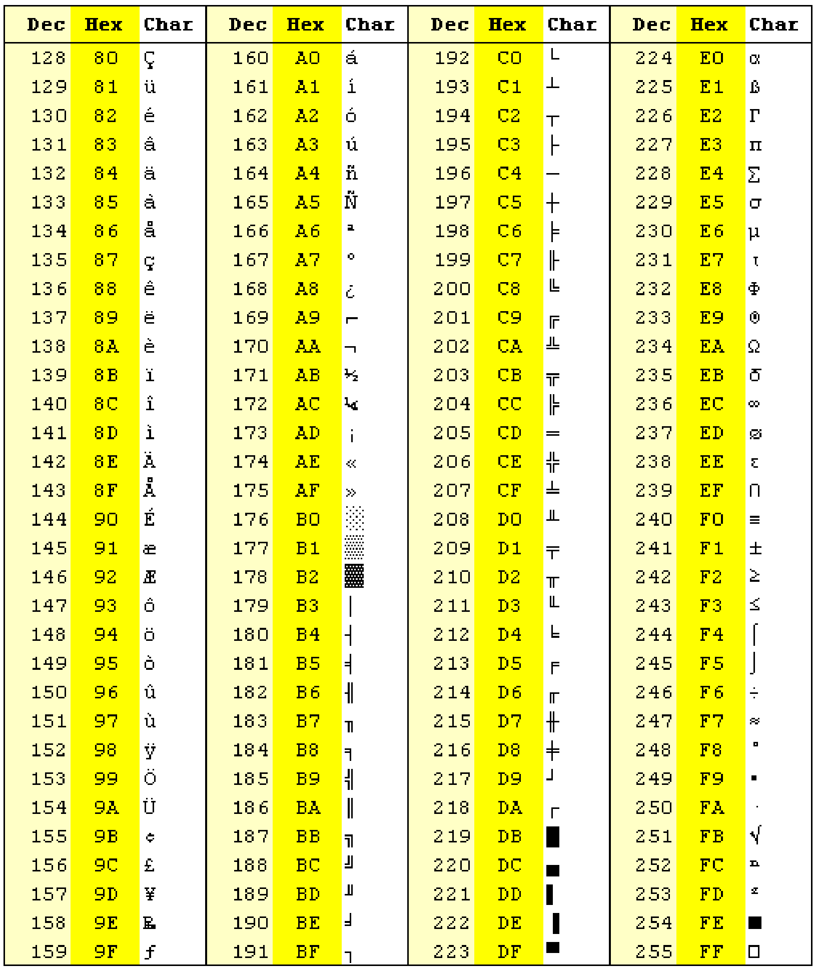
The application has support for reading common image file formats such as bmp, png and jpg (for a full list, see the supported file formats of the SDL_image libaray). 8- 16- and 32-bit output is supported, and can be changed by passing a command line argument to the program (by default, the output is adjusted for 16 bit color mode).

The resulting output header file, which is named after the input, can be included in a program using the extended bare metal driver. The easiest way to use the sprite is to use the generated initialize function defined in the header file.

7.8.2 Bitmap font maker utility

Another application generates the data structures necessary to load bitmap fonts with very little effort. It takes an image and a grid spacing as input, and automatically generates offsets for all the glyphs in the font. The font generated by the program has 256 characters arranged according to the ASCII charset, as seen in figure **??** and **??**.

The application has support for reading common image file formats such as bmp, png and jpg (for a full list, see the supported file formats of the SDL_image libaray). 8- 16- and 32-bit output is



Dec	Hex	Char	Dec	Hex	Char	Dec	Hex	Char	Dec	Hex	Char
128	80	Ç	160	A0	á	192	C0	└	224	E0	α
129	81	ü	161	A1	í	193	C1	┴	225	E1	ß
130	82	é	162	A2	ó	194	C2	┬	226	E2	Γ
131	83	â	163	A3	ú	195	C3	├	227	E3	π
132	84	ä	164	A4	ñ	196	C4	─	228	E4	Σ
133	85	à	165	A5	Ñ	197	C5	┼	229	E5	σ
134	86	å	166	A6	ª	198	C6	╞	230	E6	µ
135	87	ç	167	A7	º	199	C7	╟	231	E7	τ
136	88	ê	168	A8	¿	200	C8	╚	232	E8	Φ
137	89	ë	169	A9	⌐	201	C9	╔	233	E9	Θ
138	8A	è	170	AA	¬	202	CA	╩	234	EA	Ω
139	8B	ï	171	AB	½	203	CB	╦	235	EB	δ
140	8C	î	172	AC	¼	204	CC	╠	236	EC	∞
141	8D	ì	173	AD	¡	205	CD	═	237	ED	φ
142	8E	Ä	174	AE	«	206	CE	╬	238	EE	ε
143	8F	Å	175	AF	»	207	CF	╧	239	EF	∩
144	90	É	176	B0	░	208	D0	╨	240	F0	≡
145	91	æ	177	B1	▒	209	D1	╤	241	F1	±
146	92	Æ	178	B2	▓	210	D2	╥	242	F2	≥
147	93	ô	179	B3	│	211	D3	╙	243	F3	≤
148	94	ö	180	B4	┤	212	D4	╘	244	F4	⌠
149	95	ò	181	B5	╡	213	D5	╒	245	F5	⌡
150	96	û	182	B6	╢	214	D6	╓	246	F6	÷
151	97	ù	183	B7	╖	215	D7	╫	247	F7	≈
152	98	ÿ	184	B8	╕	216	D8	╪	248	F8	°
153	99	Ö	185	B9	╣	217	D9	┘	249	F9	∙
154	9A	Ü	186	BA	║	218	DA	┌	250	FA	·
155	9B	¢	187	BB	╗	219	DB	█	251	FB	√
156	9C	£	188	BC	╝	220	DC	▄	252	FC	ⁿ
157	9D	¥	189	BD	╜	221	DD	▌	253	FD	²
158	9E	₧	190	BE	╛	222	DE	▐	254	FE	■
159	9F	ƒ	191	BF	┐	223	DF	▀	255	FF	□

Figure 6: The extended ASCII table. Each number from 128 to 255 refers to a character, mostly special characters not included in the basic table.

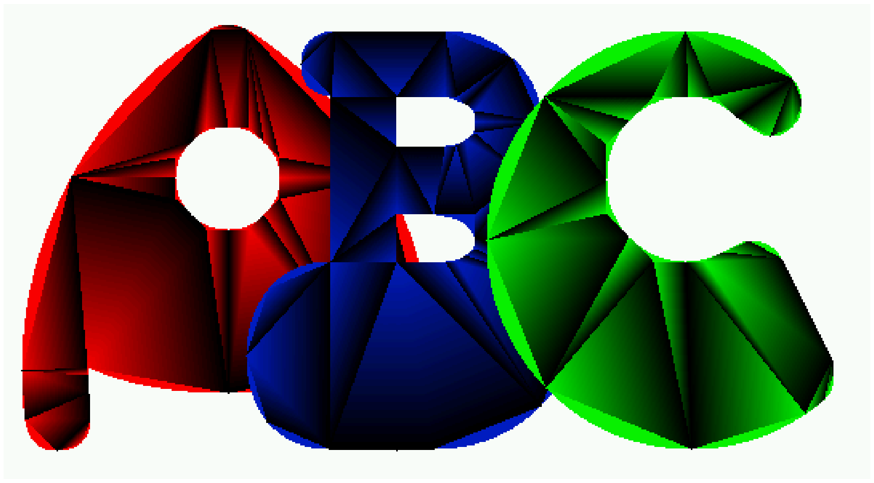


Figure 7: A font rendered by the software implementation of the ORGFX. Bézier curves are single colored while the triangles are interpolated between current color and black

supported, and can be changed by passing a command line argument to the program (by default, the output is adjusted for 16 bit color mode). Both vertical and horizontal grid spacing are set to 32 pixels by default, but this can be changed through command line arguments.

The resulting output header file, which is named after the input, can be included in a program using the bare metal and font driver. The easiest way to use the bitmap font is to use the generated initialize function defined in the header file.

7.8.3 Mesh maker utility

The mesh maker utility loads 3D objects and generates a header file that can be used by the advanced 3D API. Currently the utility only supports Wavefront .obj files which only contains 3rd order polygons. Any higher order polygons will be discarded, so all polygons in the model must be converted to triangles prior to running the utility.

The application supports loading texture coordinates for each vertex, allowing for textured meshes.

The resulting output header file, which is named after the input, can be included in a program using the bare metal 3D API. The easiest way to use the mesh is to use the generated initialize function defined in the header file.

7.8.4 Vector font maker utility

The Font maker is a application that can convert a .ttf file to a format that the graphics card can handle. The Font maker outputs a .h file that can be included in a project to enable the graphics accelerators vector font capabilities. The converter finds all explicit vector points in a ttf file and then calculates the implicit points. At the same time it checks where the glyphs contours ends, the points is then sent to a Delaunay triangulation function based on the work of V. Domiter and B. Zalik and implemented by M. Green and T. Åhlén [1]. The generated .h file consists of two fields for each glyph, one field for Bézier writes and one for triangle writes. The generated header file will contain two lists for each glyph, one to store Bézier writes and one to store triangle writes. The rendered result can be seen in figure **??**.

7.8.5 Regger

The regger is a application that keeps track of what register addresses is set in the RTL code and in the drivers.

[1]http://code.google.com/p/poly2tri/

8 Programming examples

The following piece of code shows how to use the extended interface for a bare metal implementation on the ORPSoCv2 platform. Bahamut_cc.png.h is a 186 by 248 pixel image with a pinkish background (rgb code ff00ff, or f81f in 16 bit). The header file is generated by the sprite maker utility at 16 bit color depth.

```
#include "orgfx_plus.h"

#include "Bahamut_cc.png.h"

int main(void)
{
    int i;

    // Initialize screen to 640x480-16@60
    // No double buffering
    int screen = orgfxplus_init(640, 480, 16, 0);

    // Initialize dragon sprite
    int bahamut_sprite =
        orgfxplus_init_surface(186, 248, Bahamut_cc);

    // Activate colorkeying
    orgfxplus_colorkey(0xf81f, 1);

    // Clear screen, white color
    orgfxplus_fill(0,0,640,480,0xffff);
    // Draw a few lines with different colors
    orgfxplus_line(200,100,10,10,0xf000);
    orgfxplus_line(200,100,351,31,0x0ff0);
    orgfxplus_line(200,100,121,231,0x00f0);
    orgfxplus_line(200,100,321,231,0xf00f);

    // Draw the dragon at different alpha settings
    orgfxplus_alpha(64,1);
    orgfxplus_draw_surface(100, 100, bahamut_sprite);
    orgfxplus_alpha(128,1);
    orgfxplus_draw_surface(120, 102, bahamut_sprite);
    orgfxplus_alpha(255,1);
    orgfxplus_draw_surface(140, 104, bahamut_sprite);

    while(1);
}
```

More example programs are supplied with the implementation in the **sw/examples** directory.