RAiO

RA8873M

应用程序接口

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章节介绍

序言

在这份文件里，我们将为您介绍七种关于 RA8873M 的功能。有 MCU 数据写入与显示数据输入格式、几何图形绘图、DMA(Direct Memory Access)、BTE(Block Transfer Engine)、PIP(Picture in Picture)、文字以及 PWM(Pulse Width Modulation)功能…等等，并提供关于这些功能的应用程序接口。

在一开始，您需要在 Userdef.h 这个档案里面，搭配您的环境，选择您所使用的 **MCU 通讯接口协议**、**LCD Panel**、**MCU 数据写入与显示数据输入格式**、**集通字库**与 **PLL 设定值**(SDRAM CLK、Core CLK、Pixel CLK)。详细的说明与设定，如 PLL initialization、SDRAM initialization 或 LCD initialization，请参考附录 1/2/3 的说明。

MCU 通讯接口协议:RA8873M 提供了 Parallel 8080、Parallel 6800、SPI-3 wire、SPI-4 wire、IIC 等五种 MCU 通讯接口协议。

MCU 数据写入与显示数据输入格式:

8-bit MCU, 8bpp mode、8-bit MCU, 16bpp mode、8-bit MCU, 24bpp mode、16-bit MCU, 16bpp mode、16-bit MCU, 24bpp mode 1、16-bit MCU, 24bpp mode 2.

集通字库:RA8873M 可以经由外接集通字库，在显示上支持多种字体。

PLL 设定值(SDRAM CLK、Core CLK、Pixel CLK):SDRAM CLK(最大 166MHz)、Core CLK(最大 120MHz)、Pixel CLK(最大 80MHz)。

SDRAM CLK ≧ Core CLK

在 16 位色深情况下: Core CLK ≧ 1.5*Pixel CLK

在 24 位色深情况下: Core CLK ≧ 2 * Pixel CLK

第一章: 图层切换以及 MCU 数据写入与显示数据输入格式

概要:

图层切换介绍

RA8873M 提供六种模式给 MCU 对 SDRAM 做资料写入:

1.8-bit MCU 界面, 8bpp color depth mode (RGB 3:3:2)

2.8-bit MCU 界面, 16bpp color depth mode (RGB 5:6:5)

3.8-bit MCU 界面, 24bpp color depth mode (RGB 8:8:8)

4.16-bit MCU 界面, 16bpp color depth mode (RGB 5:6:5)

5.16-bit MCU 界面, 24bpp color depth mode 1 (RGB 8:8:8)

6.16-bit MCU 界面, 24bpp color depth mode 2 (RGB 8:8:8)

本章节将会帮助使用者简单的了解如何使用这六种模式

图层切换介绍:

RA8873M 总共提供三个图层，Layer1 address 为 1572864、Layer2 address 为 3670016、Layer3 address 为 5767168，我们这边提供了两组 API，让使用者可以直接选择要写入的图层，以及要显示的图层，程序以及说明如下:

```
void Write_Layer(unsigned char Layer)
{
unsigned long address;
        switch(Layer)
        {
         case 1:
                address = Layer1;       //Layer1 address define in userdef.h
                break;
         case 2:
                address = Layer2;       //Layer2 address define in userdef.h
                break;
         case 3:
               address = Layer3;       //Layer3 address define in userdef.h
                break;
        }
        Canvas_Image_Start_address(address);
        Goto_Pixel_XY(0,0);
}

void Show_Layer(unsigned char Layer)
{
unsigned long address;
        switch(Layer)
        {
         case 1:
                address = Layer1;       //Layer1 address define in userdef.h
                break;
         case 2:
                address = Layer2;       //Layer2 address define in userdef.h
                break;
         case 3:
               address = Layer3;       //Layer3 address define in userdef.h
                break;
        }
```

```
        Main_Image_Start_Address(address);
        Main_Window_Start_XY(0,0);
}
```

范例 1:

Write_Layer(1);

Show_Layer(1);

结果:目前写入位置为图层一，画面显示位置为图层一

范例 2:

Write_Layer(2);

Show_Layer(3);

结果:目前写入位置为图层二，画面显示位置为图层三

1.1.1:8-bit MCU 界面, 8bpp color depth mode (RGB 3:3:2)

Order	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
1	R_0^7	R_0^6	R_0^5	G_0^7	G_0^6	G_0^5	B_0^7	B_0^6
2	R_1^7	R_1^6	R_1^5	G_1^7	G_1^6	G_1^5	B_1^7	B_1^6
3	R_2^7	R_2^6	R_2^5	G_2^7	G_2^6	G_2^5	B_2^7	B_2^6
4	R_3^7	R_3^6	R_3^5	G_3^7	G_3^6	G_3^5	B_3^7	B_3^6
5	R_4^7	R_4^6	R_4^5	G_4^7	G_4^6	G_4^5	B_4^7	B_4^6
6	R_5^7	R_5^6	R_5^5	G_5^7	G_5^6	G_5^5	B_5^7	B_5^6

表 1：8-bit MCU, 8bpp mode 数据格式

API :

使用 8 bits MCU 接口以及 8bpp color depth. MCU 写资料到 SDRAM.

```
void MPU8_8bpp_Memory_Write
(
unsigned short x //x of coordinate
,unsigned short y // y of coordinate
,unsigned short w //width
,unsigned short h //height
,const unsigned char *data //8bit data
)
```

范例 ：

```
Write_Layer(1); //set memory read/write layer.Reference Page.5~6
Show_Layer(1);//set LCD display layer. Reference Page.5~6
MPU8_8bpp_Memory_Write(0,0,128,128 ,gImage_8);
MPU8_8bpp_Memory_Write(200,0,128,128 ,gImage_8);
MPU8_8bpp_Memory_Write(400,0,128,128 ,gImage_8);
```

gImage_8 是大小 128x128 的图资，格式为 MCU 8 位接口，色深 8 位时所使用。

LCD 实际画面(图层 1):

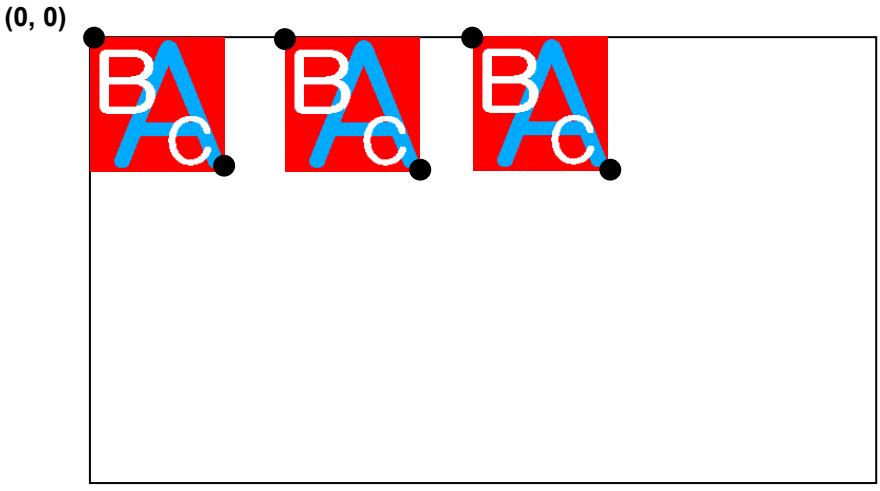


图 1.1： 使用 8 bits MCU 接口以及 8bpp color depth. MCU 写资料到图层一.

1.1.2:8-bit MCU 界面, 16bpp color depth mode (RGB 5:6:5)

Order	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
1	G_0^4	G_0^3	G_0^2	B_0^7	B_0^6	B_0^5	B_0^4	B_0^3
2	R_0^7	R_0^6	R_0^5	R_0^4	R_0^3	G_0^7	G_0^6	G_0^5
3	G_1^4	G_1^3	G_1^2	B_1^7	B_1^6	B_1^5	B_1^4	B_1^3
4	R_1^7	R_1^6	R_1^5	R_1^4	R_1^3	G_1^7	G_1^6	G_1^5
5	G_2^4	G_2^3	G_2^2	B_2^7	B_2^6	B_2^5	B_2^4	B_2^3
6	R_2^7	R_2^6	R_2^5	R_2^4	R_2^3	G_2^7	G_2^6	G_2^5

表 2 : 8-bit MCU, 16bpp mode 数据格式

API :

使用 8 bits MCU 接口以及 16bpp color depth. MCU 写资料到 SDRAM.

```
void MPU8_16bpp_Memory_Write
(
unsigned short x //x of coordinate
,unsigned short y // y of coordinate
,unsigned short w //width
,unsigned short h //height
,const unsigned char *data //8bit data
)
```

范例:

```
Write_Layer(1); //set memory read/write layer.Reference Page.5~6
Show_Layer(1);//set LCD display layer. Reference Page.5~6
MPU8_16bpp_Memory_Write (0,0,128,128,gImage_16);
MPU8_16bpp_Memory_Write (200,0,128,128,gImage_16);
MPU8_16bpp_Memory_Write (400,0,128,128,gImage_16);
```

gImage_16 是大小 128x128 的图资，格式为 MCU 8 位接口，色深 16 位时所使用。

LCD 实际画面(图层 1):

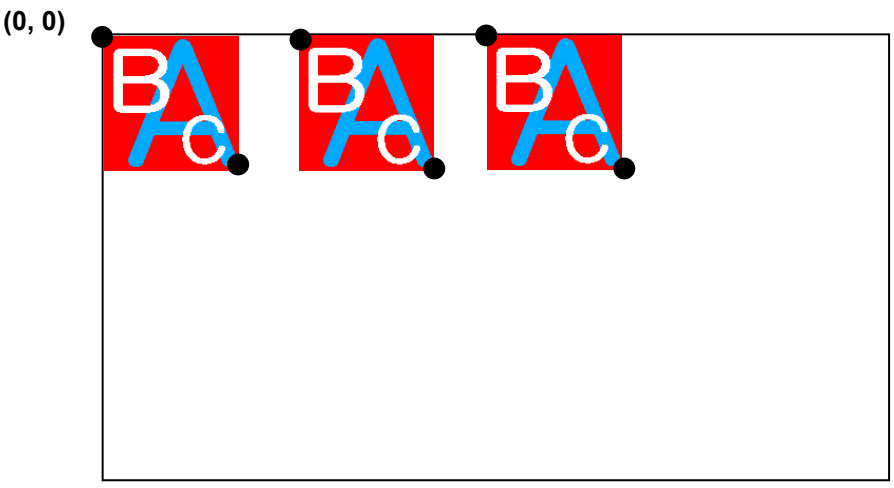


图 1.2 : 使用 8 bits MCU 接口以及 16bpp color depth. MCU 写资料到图层一.

1.1.3 :8-bit MCU 界面, 24bpp color depth mode (RGB 8:8:8)

Order	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
1	B_0^7	B_0^6	B_0^5	B_0^4	B_0^3	B_0^2	B_0^1	B_0^0
2	G_0^7	G_0^6	G_0^5	G_0^4	G_0^3	G_0^2	G_0^1	G_0^0
3	R_0^7	R_0^6	R_0^5	R_0^4	R_0^3	R_0^2	R_0^1	R_0^0
4	B_1^7	B_1^6	B_1^5	B_1^4	B_1^3	B_1^2	B_1^1	B_1^0
5	G_1^7	G_1^6	G_1^5	G_1^4	G_1^3	G_1^2	G_1^1	G_1^0
6	R_1^7	R_1^6	R_1^5	R_1^4	R_1^3	R_1^2	R_1^1	R_1^0

表 3 : 8-bit MCU, 24bpp mode 数据格式

API :

使用 8 bits MCU 接口以及 24bpp color depth. MCU 写资料到 SDRAM.

```
void MPU8_24bpp_Memory_Write
(
unsigned short x //x of coordinate
,unsigned short y // y of coordinate
,unsigned short w //width
,unsigned short h //height
,const unsigned char *data //8bit data
)
```

范例:

```
Write_Layer(1); //set memory read/write layer.Reference Page.5~6
Show_Layer(1);//set LCD display layer. Reference Page.5~6
MPU8_24bpp_Memory_Write (0,0,128,128 ,gImage_24);
MPU8_24bpp_Memory_Write (200,0,128,128,gImage_24);
MPU8_24bpp_Memory_Write (400,0,128,128,gImage_24);
```

gImage_24 是大小 128x128 的图资，格式为 MCU 8 位接口，色深 24 位时所使用。

LCD 实际画面(图层 1):

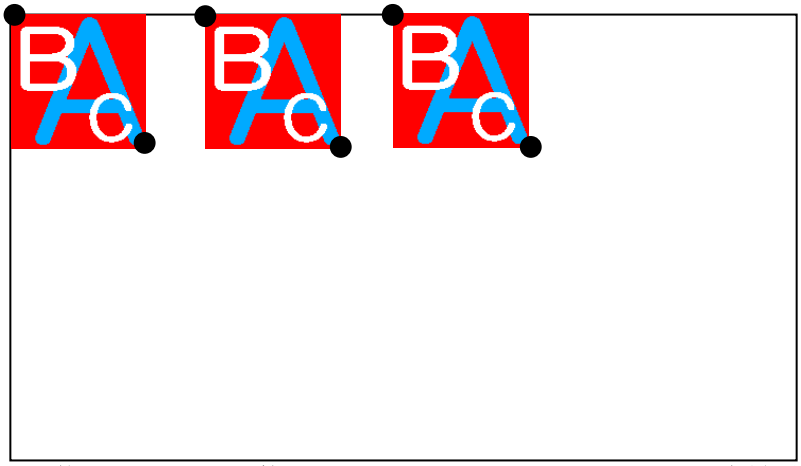


图 1.3 : 使用 8 bits MCU 接口以及 24bpp color depth. MCU 写资料到图层一.

1.1.4:16-bit MCU 界面, 16bpp color depth mode (RGB 5:6:5)

Order	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
1	R_0^7	R_0^6	R_0^5	R_0^4	R_0^3	G_0^7	G_0^6	G_0^5	G_0^4	G_0^3	G_0^2	B_0^7	B_0^6	B_0^5	B_0^4	B_0^3
2	R_1^7	R_1^6	R_1^5	R_1^4	R_1^3	G_1^7	G_1^6	G_1^5	G_1^4	G_1^3	G_1^2	B_1^7	B_1^6	B_1^5	B_1^4	B_1^3
3	R_2^7	R_2^6	R_2^5	R_2^4	R_2^3	G_2^7	G_2^6	G_2^5	G_2^4	G_2^3	G_2^2	B_2^7	B_2^6	B_2^5	B_2^4	B_2^3
4	R_3^7	R_3^6	R_3^5	R_3^4	R_3^3	G_3^7	G_3^6	G_3^5	G_3^4	G_3^3	G_3^2	B_3^7	B_3^6	B_3^5	B_3^4	B_3^3
5	R_4^7	R_4^6	R_4^5	R_4^4	R_4^3	G_4^7	G_4^6	G_4^5	G_4^4	G_4^3	G_4^2	B_4^7	B_4^6	B_4^5	B_4^4	B_4^3
6	R_5^7	R_5^6	R_5^5	R_5^4	R_5^3	G_5^7	G_5^6	G_5^5	G_5^4	G_5^3	G_5^2	B_5^7	B_5^6	B_5^5	B_5^4	B_5^3

表 4 : 16-bit MCU, 16bpp mode 数据格式

API :

使用 16 bits MCU 接口以及 16bpp color depth. MCU 写资料到 SDRAM.

```
void MPU16_16bpp_Memory_Write
(
unsigned short x //x of coordinate
,unsigned short y // y of coordinate
,unsigned short w //width
,unsigned short h //height
,const unsigned short *data //16-bit data
)
```

范例:

```
Write_Layer(1); //set memory read/write layer.Reference Page.5~6
Show_Layer(1);//set LCD display layer. Reference Page.5~6
MPU16_16bpp_Memory_Write (0,0,128,128,pic1616);
MPU16_16bpp_Memory_Write (200,0,128,128,pic1616);
MPU16_16bpp_Memory_Write (400,0,128,128,pic1616);
```

pic1616 是大小 128x128 的图资，格式为 MCU 16 位接口，色深 16 位时所使用。

LCD 实际画面(图层 1):

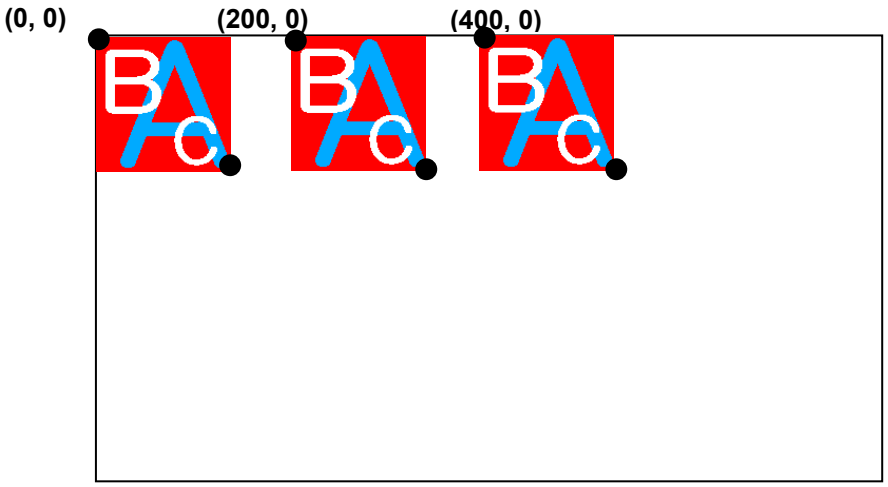


图 1.4 : 使用 16 bits MCU 接口以及 16bpp color depth. MCU 写资料到图层一.

1.1.5 :16-bit MCU 界面, 24bpp color depth mode 1 (RGB 8:8:8)

Order	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
1	G_0^7	G_0^6	G_0^5	G_0^4	G_0^3	G_0^2	G_0^1	G_0^0	B_0^7	B_0^6	B_0^5	B_0^4	B_0^3	B_0^2	B_0^1	B_0^0
2	B_1^7	B_1^6	B_1^5	B_1^4	B_1^3	B_1^2	B_1^1	B_1^0	R_0^7	R_0^6	R_0^5	R_0^4	R_0^3	R_0^2	R_0^1	R_0^0
3	R_1^7	R_1^6	R_1^5	R_1^4	R_1^3	R_1^2	R_1^1	R_1^0	G_1^7	G_1^6	G_1^5	G_1^4	G_1^3	G_1^2	G_1^1	G_1^0
4	G_2^7	G_2^6	G_2^5	G_2^4	G_2^3	G_2^2	G_2^1	G_2^0	B_2^7	B_2^6	B_2^5	B_2^4	B_2^3	B_2^2	B_2^1	B_2^0
5	B_3^7	B_3^6	B_3^5	B_3^4	B_3^3	B_3^2	B_3^1	B_3^0	R_2^7	R_2^6	R_2^5	R_2^4	R_2^3	R_2^2	R_2^1	R_2^0
6	R_3^7	R_3^6	R_3^5	R_3^4	R_3^3	R_3^2	R_3^1	R_3^0	G_3^7	G_3^6	G_3^5	G_3^4	G_3^3	G_3^2	G_3^1	G_3^0

表 5 : 16-bit MCU, 24bpp mode 1 数据格式

API :

使用 16 bits MCU 接口以及 24bpp color depth mode1. MCU 写资料到 SDRAM.

```
void MPU16_24bpp_Mode1_Memory_Write
(
unsigned short x //x of coordinate
,unsigned short y // y of coordinate
,unsigned short w //width
,unsigned short h //height
,const unsigned short *data //16-bit data
)
```

范例:

```
Write_Layer(1); //set memory read/write layer.Reference Page.5~6
Show_Layer(1);//set LCD display layer. Reference Page.5~6
MPU16_24bpp_Mode1_Memory_Write(0,0,128,128,pic16241);
MPU16_24bpp_Mode1_Memory_Write(200,0,128,128,pic16241);
MPU16_24bpp_Mode1_Memory_Write(400,0,128,128,pic16241);
```

pic16241 是大小 128x128 的图资，格式为 MCU 16 位接口，色深 24 位的 mode1 下所使用。

LCD 实际画面(图层 1):

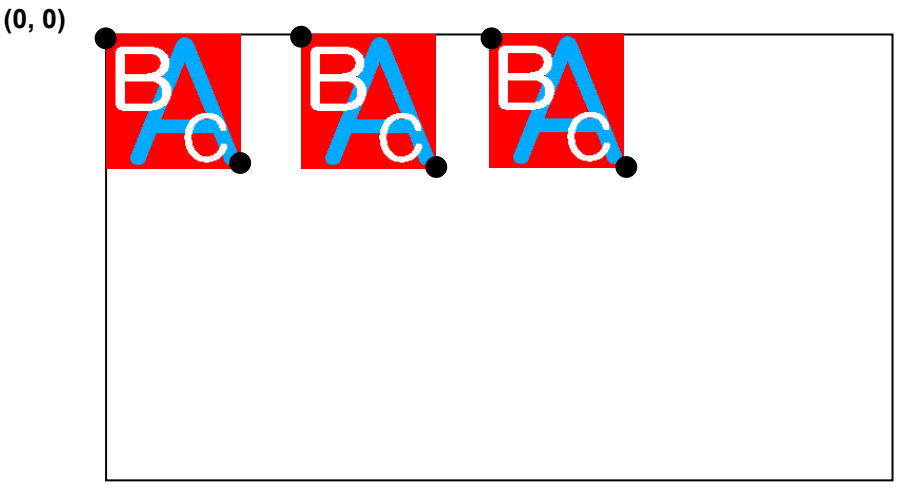


图 1.5 : 使用 16 bits MCU 接口以及 24bpp color depth mode1. MCU 写资料到图层一.

1.1.6:16-bit MCU 界面, 24bpp color depth mode 2 (RGB 8:8:8)

Order	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
1	G_0^7	G_0^6	G_0^5	G_0^4	G_0^3	G_0^2	G_0^1	G_0^0	B_0^7	B_0^6	B_0^5	B_0^4	B_0^3	B_0^2	B_0^1	B_0^0
2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	R_0^7	R_0^6	R_0^5	R_0^4	R_0^3	R_0^2	R_0^1	R_0^0
3	G_1^7	G_1^6	G_1^5	G_1^4	G_1^3	G_1^2	G_1^1	G_1^0	B_1^7	B_1^6	B_1^5	B_1^4	B_1^3	B_1^2	B_1^1	B_1^0
4	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	R_1^7	R_1^6	R_1^5	R_1^4	R_1^3	R_1^2	R_1^1	R_1^0
5	G_2^7	G_2^6	G_2^5	G_2^4	G_2^3	G_2^2	G_2^1	G_2^0	B_2^7	B_2^6	B_2^5	B_2^4	B_2^3	B_2^2	B_2^1	B_2^0
6	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	R_2^7	R_2^6	R_2^5	R_2^4	R_2^3	R_2^2	R_2^1	R_2^0

表 6 : 16-bit MCU, 24bpp mode 2 数据格式

API :

使用 16 bits MCU 接口以及 24bpp color depth mode2. MCU 写资料到 SDRAM.

```
void MPU16_24bpp_Mode2_Memory_Write
(
unsigned short x //x of coordinate
,unsigned short y // y of coordinate
,unsigned short w //width
,unsigned short h //height
,const unsigned short *data //16-bit data
)
```

范例:

```
Write_Layer(1); //set memory read/write layer.Reference Page.5~6
Show_Layer(1);//set LCD display layer. Reference Page.5~6
MPU16_24bpp_Mode2_Memory_Write(0,0,128,128,pic1624);
MPU16_24bpp_Mode2_Memory_Write(200,0,128,128,pic1624);
MPU16_24bpp_Mode2_Memory_Write(400,0,128,128,pic1624);
```

pic1624 是大小 128x128 的图资，格式为 MCU 16 位接口，色深 24 位的 mode2 下所使用。

LCD 实际画面(图层 1):

(0, 0)

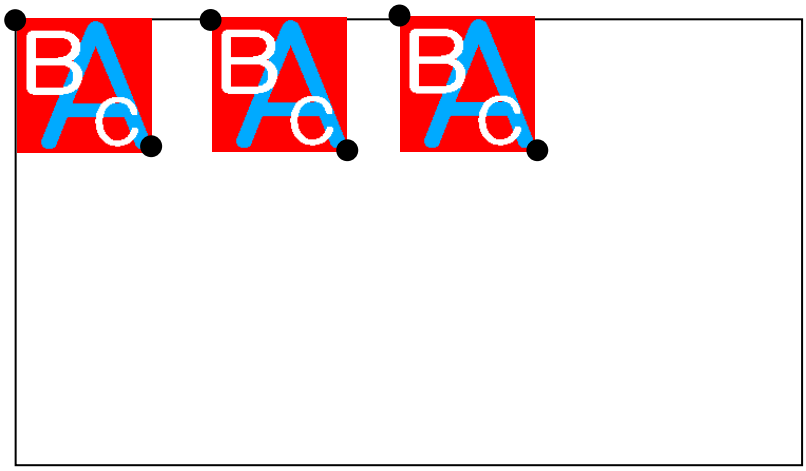


图 1.6 : 使用 16 bits MCU 接口以及 24bpp color depth mode2. MCU 写资料到图层一.

第二章 ： 几何图形绘图

概要:

在许多的人机界面应用中，时常需要去显示一些几何图形用来当作按键，感應器或者是其它的几何图形标志。当使用者想要透过 MCU 韧体来达到这个需求时，使用者会耗费很多的系统资源或心力，去做数学运算或者是图库编纂。

RA8873M 提供了几何绘图引擎，使用者只要下一些指令，就可以轻易的在 TFT-LCD 上达到几何图形显示。使用者仅需选择几何图形的颜色与它是不是应该被填满。这份应用说明将会帮助使用者去了解，如何使用 RA8873M 的几何图形绘图功能。

2.1: 椭圆/圆 输入

RA8873M 提供绘制椭圆/圆形绘图的功能，让使用者以简易或者低速的 MCU 就可以在 TFT LCD 模块上迅速做画圆的工作。首先，先设定椭圆/圆形的中心点 REG[7Bh~7Eh]，其次，设定椭圆的长轴与短轴或圆的半径 REG[77h~7Ah]，设定椭圆/圆的颜色 REG[D2h~D4h]，设定画椭圆/圆 REG[76h]Bit5=0 和 Bit4=0，然后启动绘图 REG[76h]Bit7 = 1，RA8873M 就会自动将椭圆/圆图形写入显示数据用的内存，此外，使用者可以经由设定 REG[76h]Bit6= 1，来画出实心椭圆/圆。

注意:椭圆/圆的中心必须要在 active windows 里面
写入程序请参照下图:

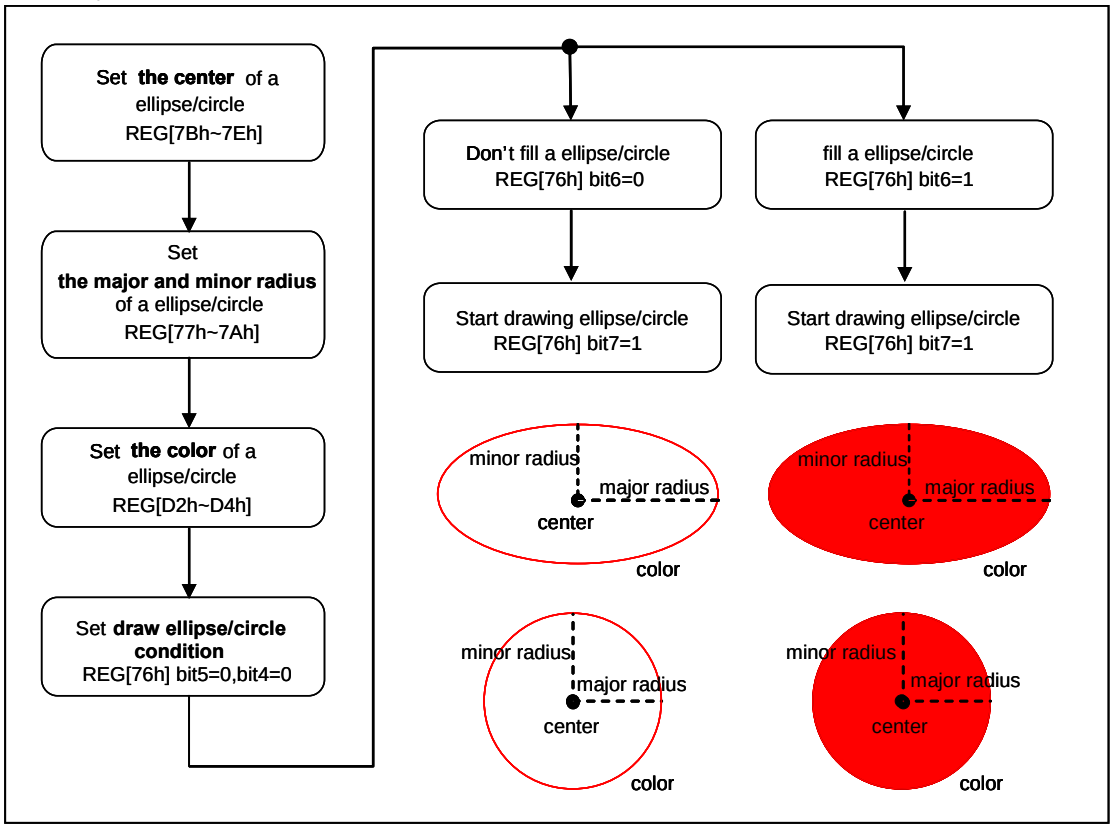


图 2.1 画圆形(填满)与椭圆形(填满)的程序流程图

画椭圆形或圆形的 **API :**

```
void Draw_Circle
(
unsigned long ForegroundColor //ForegroundColor: Set Draw Circle or Circle Fill color
/*ForegroundColor Color dataformat :
ColorDepth_8bpp : R3G3B2、ColorDepth_16bpp : R5G6B5、ColorDepth_24bpp : R8G8B8*/
,unsigned short XCenter //coordinate X of Center
,unsigned short YCenter //coordinate Y of Center
,unsigned short R //Circle Radius
)
void Draw_Circle_Fill
(
unsigned long ForegroundColor
/*ForegroundColor: Set Draw Circle or Circle Fill color
ForegroundColor Color dataformat :
ColorDepth_8bpp : R3G3B2、ColorDepth_16bpp : R5G6B5、ColorDepth_24bpp : R8G8B8*/
,unsigned short XCenter //coordinate X of Center
,unsigned short YCenter //coordinate Y of Center
,unsigned short R //Circle Radius
)

void Draw_Ellipse
(
unsigned long ForegroundColor //ForegroundColor : Set Draw Ellipse or Ellipse Fill color
/*ForegroundColor Color dataformat :
ColorDepth_8bpp : R3G3B2、ColorDepth_16bpp : R5G6B5、ColorDepth_24bpp : R8G8B8*/
,unsigned short XCenter //coordinate X of Center
,unsigned short YCenter //coordinate Y of Center
,unsigned short X_R // Radius Width of Ellipse
,unsigned short Y_R // Radius Length of Ellipse
)
void Draw_Ellipse_Fill
(
unsigned long ForegroundColor //ForegroundColor : Set Draw Ellipse or Ellipse Fill color
/*ForegroundColor Color dataformat :
ColorDepth_8bpp : R3G3B2、ColorDepth_16bpp : R5G6B5、ColorDepth_24bpp : R8G8B8*/
```

```
,unsigned short XCenter //coordinate X of Center
,unsigned short YCenter //coordinate Y of Center
,unsigned short X_R // Radius Width of Ellipse
,unsigned short Y_R // Radius Length of Ellipse
)
```

范例 1(画圆形):

```
Write_Layer(1); //set memory read/write layer.Reference Page.5~6
Show_Layer(1);//set LCD display layer. Reference Page.5~6
Active_Window_XY(0,0);
Active_Window_WH(Panel_width,Panel_length);   //set full LCD size can draw graph
+
//When color depth = 8bpp
Draw_Circle(0xfc,500,50,50);
Draw_Circle_Fill(0xfc,650,50,50);
Or
//When color depth = 16bpp
Draw_Circle(0xffe0,500,50,50);
Draw_Circle_Fill(0xffe0,650,50,50);
Or
//When color depth = 24bpp
Draw_Circle(0xffff00,500,50,50);
Draw_Circle_Fill(0xffff00,650,50,50);
```

LCD 实际画面(图层 1):

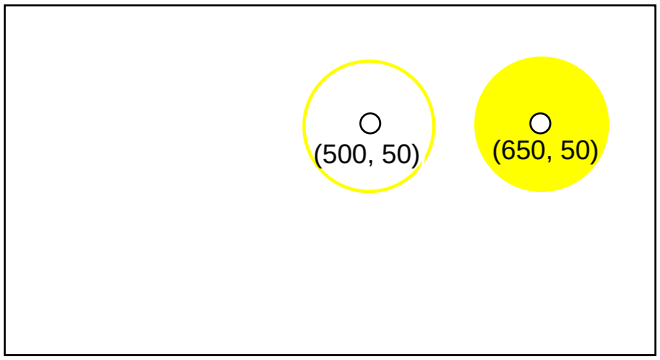


图 2.2：在图层一画一个颜色为黄色的圆，圆心位置(500,50)，半径 = 50，
和画一个被黄色填满的圆型，圆心位置(650,50)，半径 = 50。

范例 2(画椭圆形):

```
Write_Layer(1); //set memory read/write layer.Reference Page.5~6
Show_Layer(1);//set LCD display layer. Reference Page.5~6
Active_Window_XY(0,0);
Active_Window_WH(Panel_width,Panel_length);    //set full LCD size can draw graph
+
//When color depth = 8bpp
Draw_Ellipse(0x1f,100,200,100,50);
Draw_Ellipse_Fill(0x1f,350,200,100,50);
Or
//When color depth = 16bpp
Draw_Ellipse(0x07ff,100,200,100,50);
Draw_Ellipse_Fill(0x07ff,350,200,100,50);
Or
//When color depth = 24bpp
Draw_Ellipse(0x00ffff,100,200,100,50);
Draw_Ellipse_Fill(0x00ffff,350,200,100,50);
```

LCD 实际画面(图层 1):

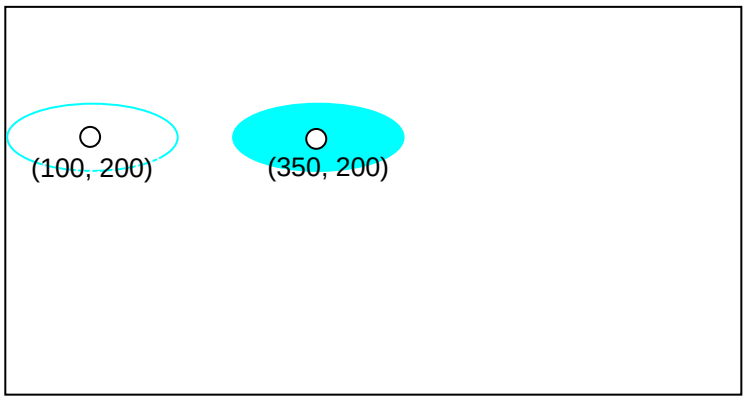


图 2.3：在图层 1 画一个青色的圆，圆心位置(100,200)、X 轴半径 = 100、Y 轴半径 = 50，和一个青色的实心圆，圆心位置(350,200)、X 轴半径 = 100、Y 轴半径 = 50。

2.2: 曲线输入

RA8873M 提供曲线绘图功能，让使用者以简易或低速的 MCU 就可以在 TFT 模块上画曲线。先设定曲线的中心点 REG[7Bh~7Dh]，曲线的长轴与短轴 REG[77h~7Ah]，曲线的颜色 REG[D2h~D4h]，曲线的相关参數为 REG[76h] Bit5=0 与 Bit4=1，REG[76h] Bit[1:0] 是椭圆的曲线部分，然后启动绘图设定 REG[76h] Bit7 = 1，RA8873M 就会自动将曲线的图形写入显示数据的内存。此外，使用者可以经由设定 REG[76h]Bit6 = 1 来画出实心曲线。

注意曲线的中心必须要在 active windows 里面
写入程序请参照下图:

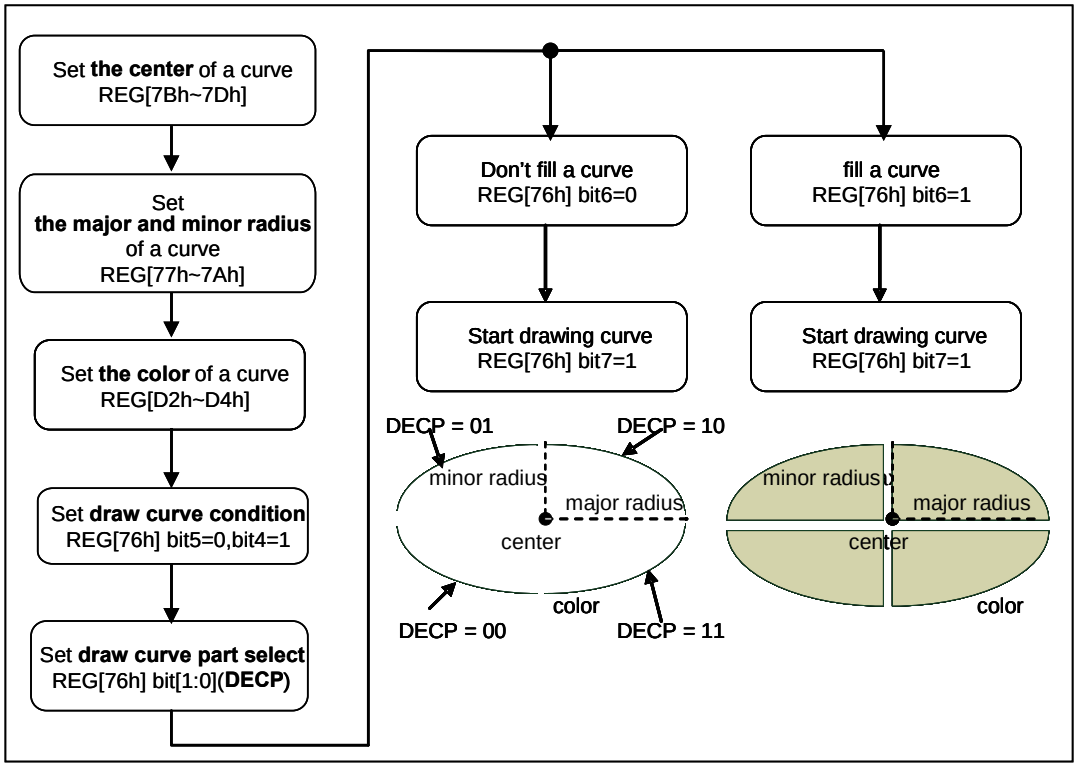


图 2-4 画圆弧与圆弧形填满的程序流程图

画圆弧与画圆弧填满功能的 **API：**

```
void Draw_Left_Up_Curve
(
unsigned long ForegroundColor //ForegroundColor: Set Curve or Curve Fill color
/*ForegroundColor Color dataformat :
ColorDepth_8bpp : R3G3B2、ColorDepth_16bpp : R5G6B5、ColorDepth_24bpp : R8G8B8*/
,unsigned short XCenter //coordinate X of Center
,unsigned short YCenter //coordinate Y of Center
,unsigned short X_R // Radius Width of Curve
,unsigned short Y_R // Radius Length of Curve
)

void Draw_Right_Down_Curve
(
unsigned long ForegroundColor //ForegroundColor: Set Curve or Curve Fill color
/*ForegroundColor Color dataformat :
ColorDepth_8bpp : R3G3B2、ColorDepth_16bpp : R5G6B5、ColorDepth_24bpp : R8G8B8*/
,unsigned short XCenter //coordinate X of Center
,unsigned short YCenter //coordinate Y of Center
,unsigned short X_R // Radius Width of Curve
,unsigned short Y_R // Radius Length of Curve
)

void Draw_Right_Up_Curve
(
unsigned long ForegroundColor //ForegroundColor: Set Curve or Curve Fill color
/*ForegroundColor Color dataformat :
ColorDepth_8bpp : R3G3B2、ColorDepth_16bpp : R5G6B5、ColorDepth_24bpp : R8G8B8*/
,unsigned short XCenter //coordinate X of Center
,unsigned short YCenter //coordinate Y of Center
,unsigned short X_R // Radius Width of Curve
,unsigned short Y_R // Radius Length of Curve
)
```

```
void Draw_Left_Down_Curve
(
unsigned long ForegroundColor //ForegroundColor: Set Curve or Curve Fill color
/*ForegroundColor Color dataformat :
ColorDepth_8bpp : R3G3B2、ColorDepth_16bpp : R5G6B5、ColorDepth_24bpp : R8G8B8*/
,unsigned short XCenter //coordinate X of Center
,unsigned short YCenter //coordinate Y of Center
,unsigned short X_R // Radius Width of Curve
,unsigned short Y_R // Radius Length of Curve
)

void Draw_Left_Up_Curve_Fill
(
unsigned long ForegroundColor //ForegroundColor: Set Curve or Curve Fill color
/*ForegroundColor Color dataformat :
ColorDepth_8bpp : R3G3B2、ColorDepth_16bpp : R5G6B5、ColorDepth_24bpp : R8G8B8*/
,unsigned short XCenter //coordinate X of Center
,unsigned short YCenter //coordinate Y of Center
,unsigned short X_R // Radius Width of Curve
,unsigned short Y_R // Radius Length of Curve
)

void Draw_Right_Down_Curve_Fill
(
unsigned long ForegroundColor //ForegroundColor: Set Curve or Curve Fill color
/*ForegroundColor Color dataformat :
ColorDepth_8bpp : R3G3B2、ColorDepth_16bpp : R5G6B5、ColorDepth_24bpp : R8G8B8*/
,unsigned short XCenter //coordinate X of Center
,unsigned short YCenter //coordinate Y of Center
,unsigned short X_R // Radius Width of Curve
,unsigned short Y_R // Radius Length of Curve
)
```

```
void Draw_Right_Up_Curve_Fill
(
unsigned long ForegroundColor //ForegroundColor: Set Curve or Curve Fill color
/*ForegroundColor Color dataformat :
ColorDepth_8bpp : R3G3B2、ColorDepth_16bpp : R5G6B5、ColorDepth_24bpp : R8G8B8*/
,unsigned short XCenter //coordinate X of Center
,unsigned short YCenter //coordinate Y of Center
,unsigned short X_R // Radius Width of Curve
,unsigned short Y_R // Radius Length of Curve
)

void Draw_Left_Down_Curve_Fill
(
unsigned long ForegroundColor //ForegroundColor: Set Curve or Curve Fill color
/*ForegroundColor Color dataformat :
ColorDepth_8bpp : R3G3B2、ColorDepth_16bpp : R5G6B5、ColorDepth_24bpp : R8G8B8*/
,unsigned short XCenter //coordinate X of Center
,unsigned short YCenter //coordinate Y of Center
,unsigned short X_R // Radius Width of Curve
,unsigned short Y_R // Radius Length of Curve
)
```

范例:

```
Write_Layer(1); //set memory read/write layer.Reference Page.5~6
Show_Layer(1);//set LCD display layer. Reference Page.5~6
Active_Window_XY(0,0);
Active_Window_WH(Panel_width,Panel_length);    //set full LCD size can draw graph
+
//When color deepth = 8bpp
Draw_Left_Up_Curve(0xe3,550,190,50,50);
Draw_Right_Down_Curve(0xff,560,200,50,50);
Draw_Right_Up_Curve(0xff,560,190,50,50);
Draw_Left_Down_Curve(0x1c,550,200,50,50);
Draw_Left_Up_Curve_Fill(0xe3,700,190,50,50);
Draw_Right_Down_Curve_Fill(0xff,710,200,50,50);
Draw_Right_Up_Curve_Fill(0xff,710,190,50,50);
Draw_Left_Down_Curve_Fill(0x1c,700,200,50,50);
Or
//When color deepth = 16bpp
Draw_Left_Up_Curve(0xf11f,550,190,50,50);
Draw_Right_Down_Curve(0xffff,560,200,50,50);
Draw_Right_Up_Curve(0xffff,560,190,50,50);
Draw_Left_Down_Curve(0x07e0,550,200,50,50);
Draw_Left_Up_Curve_Fill(0xf11f,700,190,50,50);
Draw_Right_Down_Curve_Fill(0xffff,710,200,50,50);
Draw_Right_Up_Curve_Fill(0xffff,710,190,50,50);
Draw_Left_Down_Curve_Fill(0x07e0,700,200,50,50);
Or
//When color deepth = 24bpp
Draw_Left_Up_Curve(0xff00ff,550,190,50,50);
Draw_Right_Down_Curve(0xffffff,560,200,50,50);
Draw_Right_Up_Curve(0xffffff,560,190,50,50);
Draw_Left_Down_Curve(0x00ff00,550,200,50,50);
Draw_Left_Up_Curve_Fill(0xff00ff,700,190,50,50);
Draw_Right_Down_Curve_Fill(0xffffff,710,200,50,50);
Draw_Right_Up_Curve_Fill(0xffffff,710,190,50,50);
Draw_Left_Down_Curve_Fill(0x00ff00,700,200,50,50);
```

本范例程序包含 8 个步骤:

1. Draw a pink upper left curve,Center(550,190), X_R = 50,Y_R=50
2. Draw a white lower right curve,Center(560,200), X_R = 50,Y_R=50
3. Draw a white upper right curve,Center(560,190), X_R = 50,Y_R=50
4. Draw a green lower left curve,Center(550,200), X_R = 50,Y_R=50
5. Draw a pink upper left curve fill,Center(700,190), X_R = 50,Y_R=50
6. Draw a white lower right curve fill,Center(710,200), X_R = 50,Y_R=50
7. Draw a white upper right curve fill,Center(710,190), X_R = 50,Y_R=50
8. Draw a green lower left curve fill,Center(700,200), X_R = 50,Y_R=50

LCD 实际画面(图层 1):

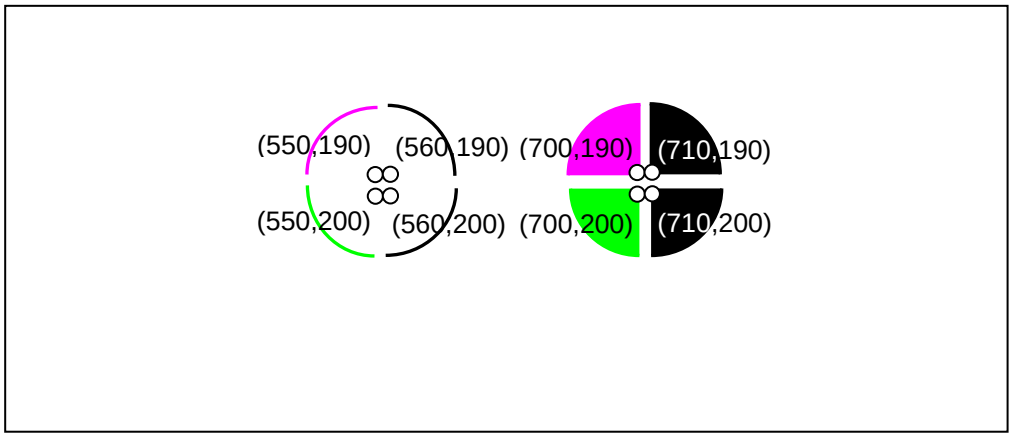


图 2.5：在图层 1 画圆弧与圆弧形填满的 LCD 显示示意图

2.3: 方形输入

RA8873M 提供方形绘图功能，让使用者以简易或低速的 MCU 就可以在 TFT 模块上画方形。先设定方形的起始点 REG[68h~6Bh]与结束点 REG[6Ch~6Fh]，方形的颜色 REG[D2h~D4h]，然后设定画方形设定 REG[76h]Bit5=1，Bit4=0 和启动绘图 REG[76h]Bit7 = 1，RA8873M 就会自动将方形的图形写入显示数据的内存，此外，使用者可以藉由设定 REG[76h]Bit6 = 1 来画出实心方形。

注意:方形的起始点与结束点必须要在 active windows 里面
写入程序请参照下图:

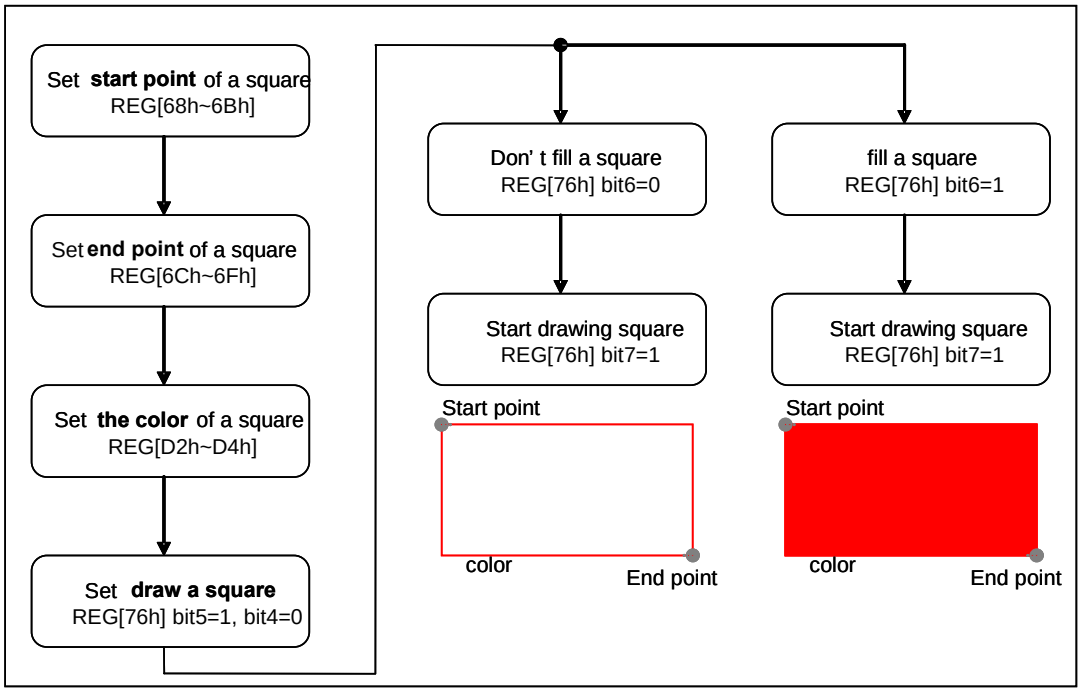


圖 2.6：画方形与方形填满的程序流程图

画方形的 **API:**

```
void Draw_Square
(
unsigned long ForegroundColor
/*ForegroundColor: Set Curve or Curve Fill color. ForegroundColor Color dataformat :
ColorDepth_8bpp : R3G3B2、ColorDepth_16bpp : R5G6B5、ColorDepth_24bpp : R8G8B8*/
,unsigned short X1 //X of point1 coordinate
,unsigned short Y1 //Y of point1 coordinate
,unsigned short X2 //X of point2 coordinate
,unsigned short Y2 //Y of point2 coordinate
)

void Draw_Square_Fill
(
unsigned long ForegroundColor
/*ForegroundColor: Set Curve or Curve Fill color. ForegroundColor Color dataformat :
ColorDepth_8bpp : R3G3B2、ColorDepth_16bpp : R5G6B5、ColorDepth_24bpp : R8G8B8*/
,unsigned short X1 //X of point1 coordinate
,unsigned short Y1 //Y of point1 coordinate
,unsigned short X2 //X of point2 coordinate
,unsigned short Y2 //Y of point2 coordinate
)
```

范例 ：

```
Write_Layer(1); //set memory read/write layer.Reference Page.5~6
Show_Layer(1);//set LCD display layer. Reference Page.5~6
Active_Window_XY(0,0);
Active_Window_WH(Panel_width,Panel_length);    //set full LCD size can draw graph
+
//when color depth = 8bpp
Draw_Square(0xe0,50,300,150,400);
Draw_Square_Fill(0xe0,200,300,300,400);
//Or
//When color deepth = 16bpp
Draw_Square(0xf800,50,300,150,400);
Draw_Square_Fill(0xf800,200,300,300,400);
//Or
//When color deepth = 24bpp
Draw_Square(0xff0000,50,300,150,400);
```

Draw_Square_Fill(0xff0000,200,300,300,400);

LCD 实际画面(图层 1):

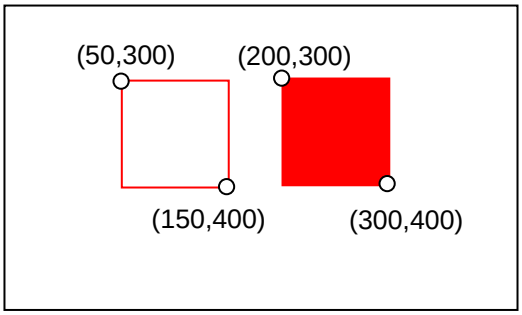


图 2.7：在图层 1 从点(50,300)到点(150,400)，画一个红色的正方形，以及从点(200,300)到点(300,400)，画一个红色被填满的方形。

2.4:画直线功能

RA8873M 支持画直线的绘图功能，让使用者以简易或低速的 MCU 就可以在 TFT 模块上画线，先设定起始点 REG[68h~6Bh]，结束点 REG[6Ch~6Fh]和线的颜色 REG[D2h~D4h]，然后设定画线参数 REG[67h]Bit1 = 0，和启动绘图 REG[67h]Bit7 = 1，RA8873M 就会自动将线的图形写入显示数据的内存。

注意: :线的起始点与结束点必须要在 active windows 里面
写入程序请参照下图:

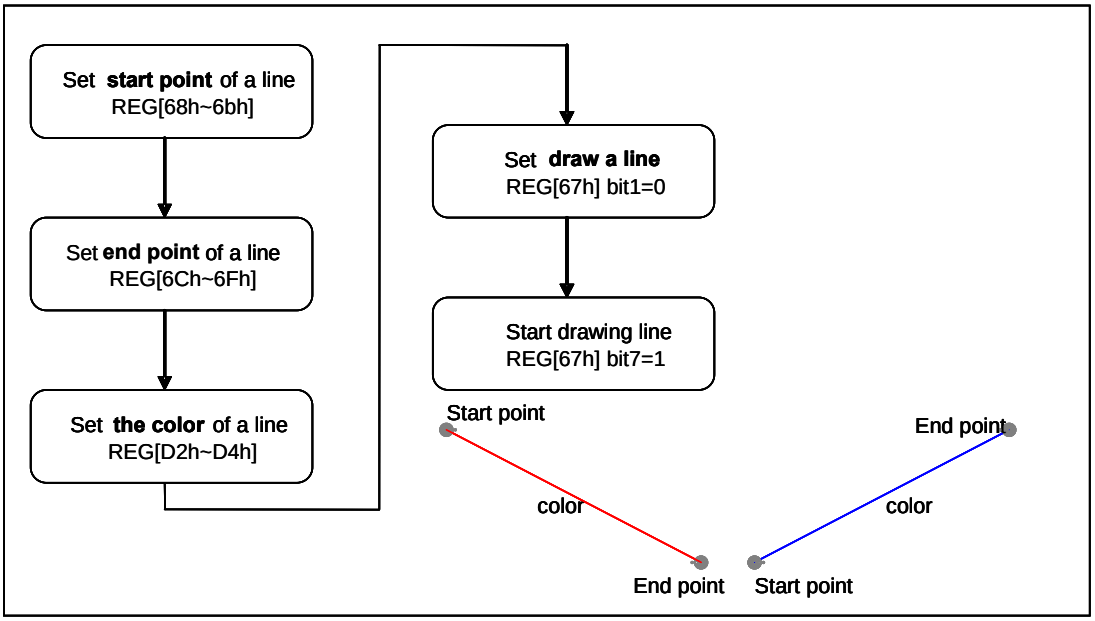


圖 2.8: 画直线的程序流程图

画直线的 **API:**

```
void Draw_Line
(
unsigned long LineColor
/*LineColor : Set Draw Line color. Line Color dataformat :
ColorDepth_8bpp : R3G3B2、ColorDepth_16bpp : R5G6B5、ColorDepth_24bpp : R8G8B8*/
,unsigned short X1 //X of point1 coordinate
,unsigned short Y1 //Y of point1 coordinate
,unsigned short X2 //X of point2 coordinate
,unsigned short Y2 // Y of point2 coordinate
)
```

范例 ：

```
Write_Layer(1); //set memory read/write layer.Reference Page.5~6
Show_Layer(1);//set LCD display layer. Reference Page.5~6
Active_Window_XY(0,0);
Active_Window_WH(Panel_width,Panel_length);   //set full LCD size can draw graph
+
//When color deepth = 8bpp
Draw_Line(0xe0,10,10,400,300);
Or
//When color deepth = 16bpp
Draw_Line(0xf800,10,10,400,300);
Or
//When color deepth = 24bpp
Draw_Line(0xff0000,10,10,400,300);
```

LCD 实际画面(图层 1):

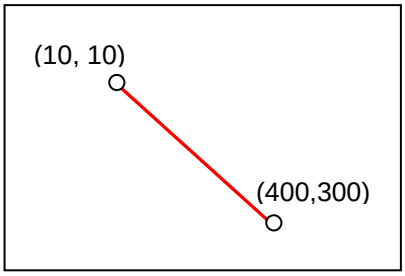


图 2.9：在图层 1 从点(10,10)到点(400,300)，画一条红色的直线。

2.5:画三角形的功能

RA8873M 支持三角形的绘图功能，让使用者以简易或低速的 MCU 就可以在 TFT 模块上画三角形。先设定三角的第 0 点 REG[68h~6Bh]、第 1 点 REG[6Ch~6Fh]、第 2 点 REG[70h~73h]和三角形的颜色 REG[D2h~D4h]，设定画三角形的参数 REG[67h] Bit1 = 1，然后启动绘图 REG[67h] Bit7 = 1，RA8873M 就会自动将三角形的图形写入显示数据的内存。此外，使用者可以透过设定 REG[67h] Bit5 = 1 来画出实心三角形。

注意:三角形的第 0 点第 1 点与第 2 点与结束点必须要在 active windows 里面
写入程序请参照下图:

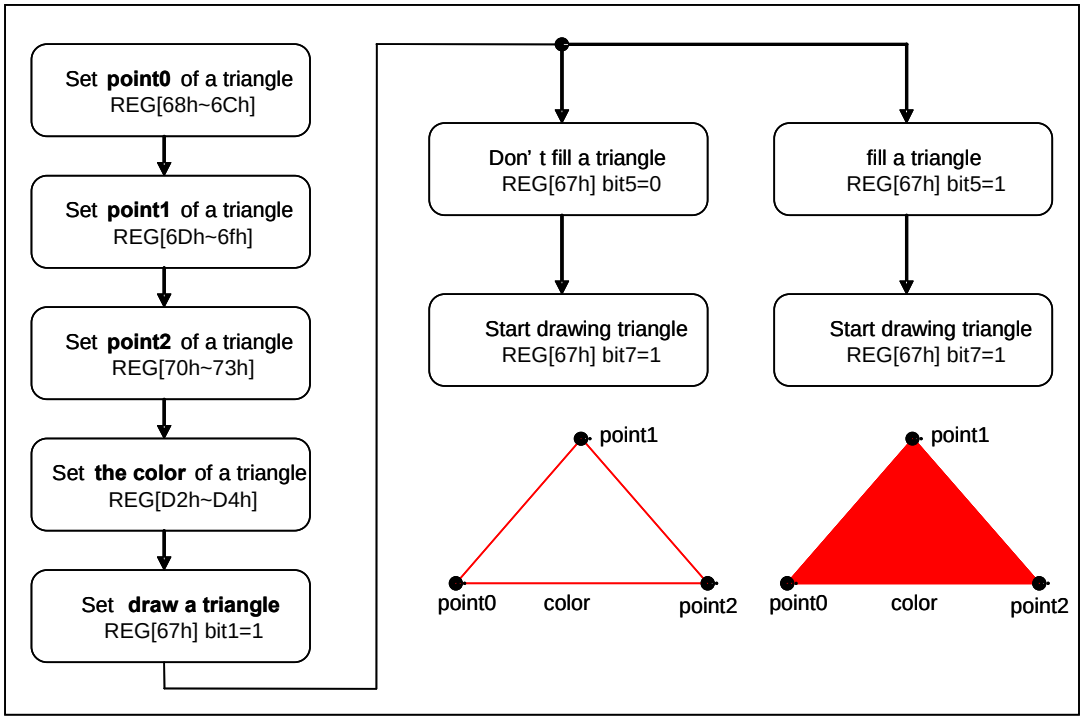


圖 2.10：画三角形与三角形填满的程序流程图

画三角形的 **API:**

```
void Draw_Triangle
(
unsigned long ForegroundColor
/*ForegroundColor: Set Draw Triangle color. ForegroundColor Color dataformat :
ColorDepth_8bpp : R3G3B2、ColorDepth_16bpp : R5G6B5、ColorDepth_24bpp : R8G8B8*/
,unsigned short X1 //X of point1 coordinate
,unsigned short Y1 //Y of point1 coordinate
,unsigned short X2 //X of point2 coordinate
,unsigned short Y2 //Y of point2 coordinate
,unsigned short X3 //X of point3 coordinate
,unsigned short Y3 //Y of point3 coordinate
)
void Draw_Triangle_Fill
(
unsigned long ForegroundColor
/*ForegroundColor: Set Draw Triangle color. ForegroundColor Color dataformat :
ColorDepth_8bpp : R3G3B2、ColorDepth_16bpp : R5G6B5、ColorDepth_24bpp : R8G8B8*/
,unsigned short X1 //X of point1 coordinate
,unsigned short Y1 //Y of point1 coordinate
,unsigned short X2 //X of point2 coordinate
,unsigned short Y2 //Y of point2 coordinate
,unsigned short X3 //X of point3 coordinate
,unsigned short Y3 //Y of point3 coordinate
)
```

范例:

```
Write_Layer(1); //set memory read/write layer.Reference Page.5~6
Show_Layer(1);//set LCD display layer. Reference Page.5~6
Active_Window_XY(0,0);
Active_Window_WH(Panel_width,Panel_length);    //set full LCD size can draw graph
+
//When color deepth = 8bpp
Draw_Triangle(0x07,150,0,150,100,250,100);
Draw_Triangle_Fill(0x03,300,0,300,100,400,100);
//Or
//When color deepth = 16bpp
Draw_Triangle(0x001f,150,0,150,100,250,100);
Draw_Triangle_Fill(0x001f,300,0,300,100,400,100);
//Or
//When color deepth = 24bpp
Draw_Triangle(0x0000ff,150,0,150,100,250,100);
Draw_Triangle_Fill(0x0000ff,300,0,300,100,400,100);
```

LCD 实际画面(图层 1):

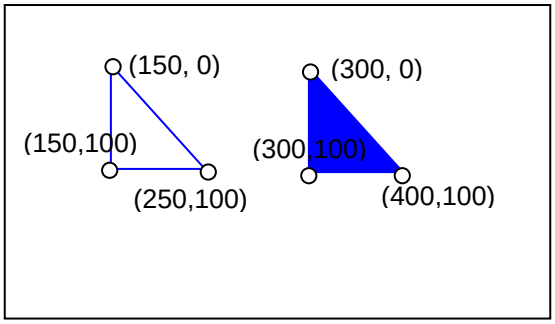


图 2.11：在图层 1 用(150,0)、(150,100)、(250,100)三点画一个蓝色的三角形，以及用(300,0) 、(300,100)、(400,100)三点画一个蓝色被填满的三角形。

2.6:画圆角方形的功能

RA8873M 支持圆角方形绘图功能，让使用者以简易或低速的 MCU 就可以在 TFT 模块上画方形。经由设定方形的起始点 REG[68h~6Bh]与结束点 REG[6Ch~6Fh]，圆角的长轴与短轴 REG[77h~7Ah]，圆角方形的颜色 REG[D2h~D4h]，然后设定画方形设定 REG[76h]Bit5=1，Bit4=1 和启动绘图 REG[76h]Bit7 = 1，RA8873M 就会自动将圆角方形的图形写入显示数据的内存，此外，使用者可以藉由设定 REG[76h]Bit6 = 1 来画出实心的圆角方形。

提醒 1：(结束点 X – 起始点 X) 必须要大于(2*长轴 + 1) 且 (结束点 Y – 起始点 Y) 必须要大于(2*短轴 + 1)

提醒 2：起始点与结束点需要在 active windows 内

写入程序请参照下图:

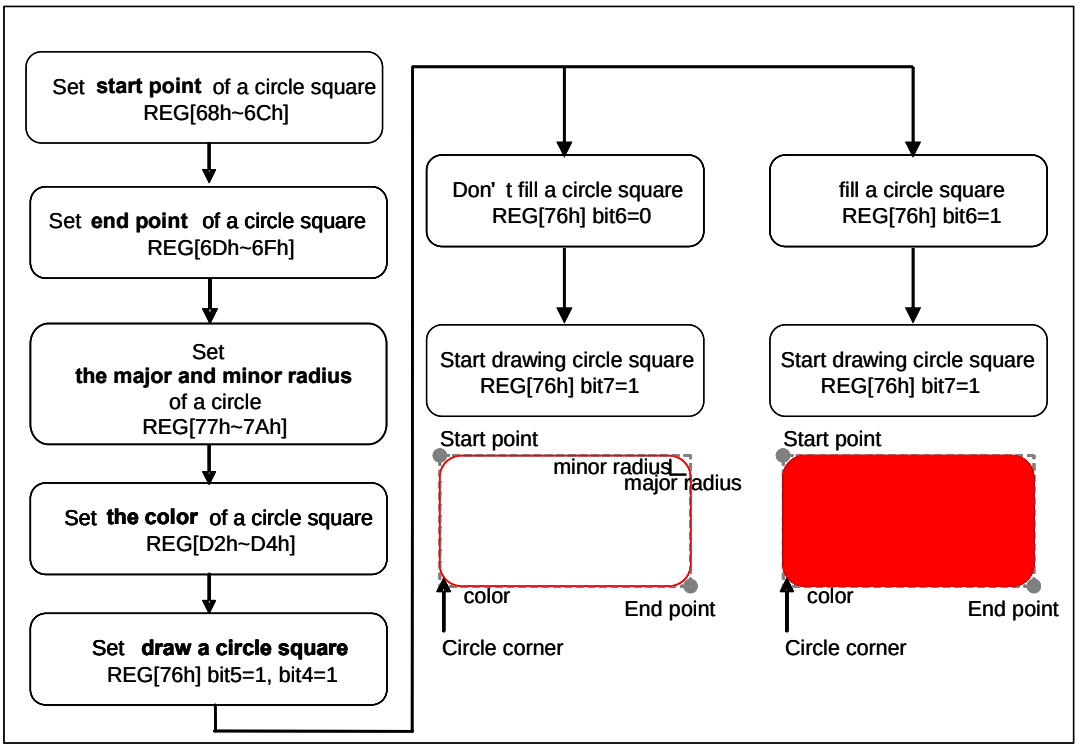


圖 2.12：画圆角方形与圆角方形填满的程序流程图

画圆角方形的 **API:**

```
void Draw_Circle_Square
(
unsigned long ForegroundColor
/*ForegroundColor : Set Circle Square color. ForegroundColor Color dataformat :
ColorDepth_8bpp : R3G3B2、ColorDepth_16bpp : R5G6B5、ColorDepth_24bpp : R8G8B8*/
,unsigned short X1 //X of point1 coordinate
,unsigned short Y1 //Y of point1 coordinate
,unsigned short X2 //X of point2 coordinate
,unsigned short Y2 //Y of point2 coordinate
,unsigned short X_R //Radius Width of Circle Square
,unsigned short Y_R //Radius Length of Circle Square
)

void Draw_Circle_Square_Fill
(
unsigned long ForegroundColor
/*ForegroundColor : Set Circle Square color. ForegroundColor Color dataformat :
ColorDepth_8bpp : R3G3B2、ColorDepth_16bpp : R5G6B5、ColorDepth_24bpp : R8G8B8*/
,unsigned short X1 //X of point1 coordinate
,unsigned short Y1 //Y of point1 coordinate
,unsigned short X2 //X of point2 coordinate
,unsigned short Y2 //Y of point2 coordinate
,unsigned short X_R //Radius Width of Circle Square
,unsigned short Y_R //Radius Length of Circle Square
)
```

范例:

```
Write_Layer(1); //set memory read/write layer.Reference Page.5~6
Show_Layer(1);//set LCD display layer. Reference Page.5~6
Active_Window_XY(0,0);
Active_Window_WH(Panel_width,Panel_length);    //set full LCD size can draw graph
+
//When color deepth = 8bpp
Draw_Circle_Square(0xe0, 100,100,200,200,20,30);
Draw_Circle_Square_Fill(0xe0, 250,100,350,200,20,30);
Or
//When color deepth = 16bpp
Draw_Circle_Square(0xf800, 100,100,200,200,20,30);
Draw_Circle_Square_Fill(0xf800, 250,100,350,200,20,30);
Or
//When color deepth = 24bpp
Draw_Circle_Square(0xff0000, 100,100,200,200,20,30);
Draw_Circle_Square_Fill(0xff0000 250,100,350,200,20,30);
```

LCD 实际画面(图层 1):

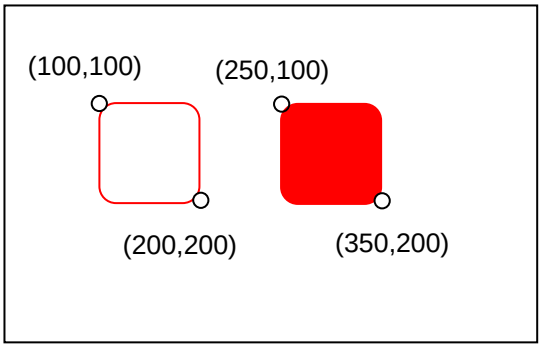


图 2.13：在图层 1，以长轴为 20，短轴为 30，从点(100,100)到点(200,200)，画一个红色的圆角方形，以及长轴为 20，短轴为 30，从点(250,100)到点(350,200)，画一个红色被填满的圆角方形

第三章 ：DMA In Block Mode

DMA block mode 是一个将图片从外部闪存搬(Serial Flash Memory)移到 RA8873M 用的显示内存(SDRAM)，DMA 功能的使用的单位是像素(pixel)。关于 DMA 功能的流程图，请参照以下的叙述。

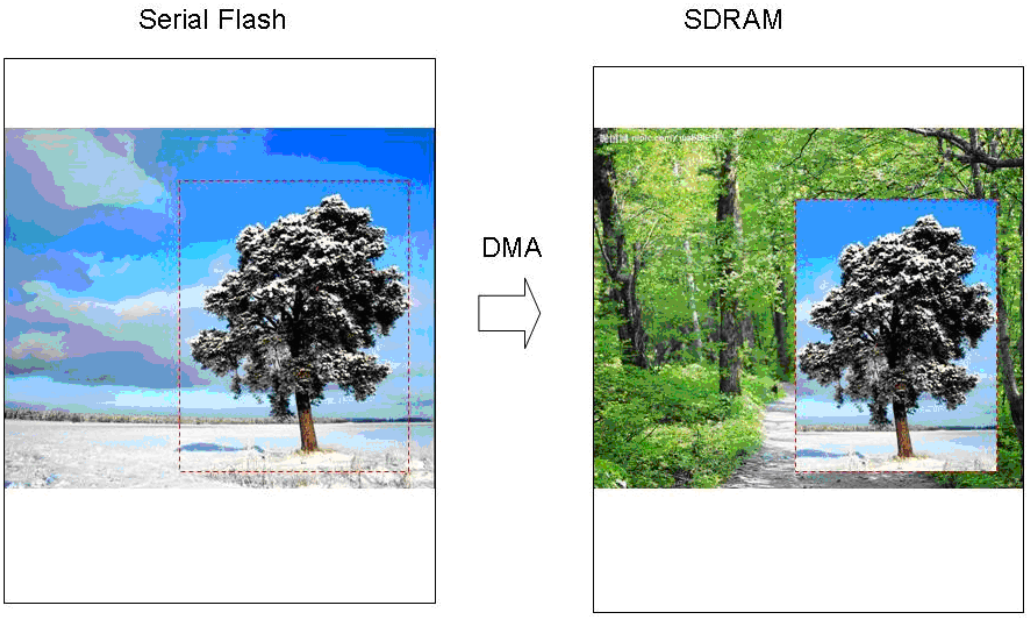


圖 3.1：DMA 功能

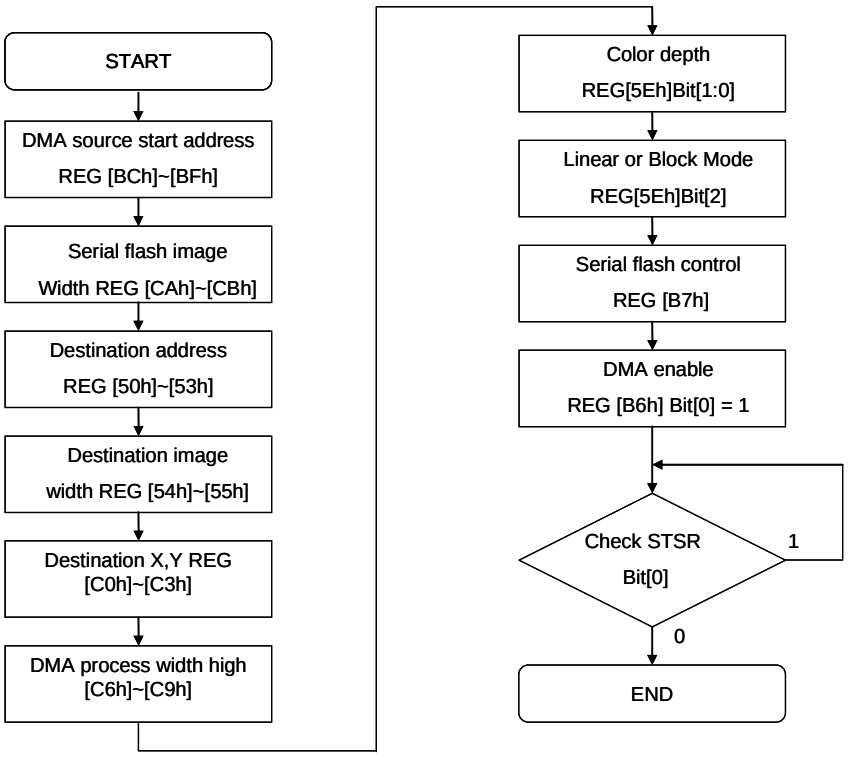


圖 3.21： 启动 DMA 功能的程序流程 – With Check Flag operation (STSR.0)

3-2.串列式 Flash/ROM 控制单元

RA8873M 建立了串列式 Flash/ROM 的接口，來支持下列的传输模式: 4-BUS 正常讀取(Normal Read)、5-BUS 快速讀取 (FAST Read)、双倍模式 0 (Dual mode 0)、双倍模式 1 (Dual mode 1)以及模式 0 (Mode 0) 与模式 3 (Mode 3)。

串列式 Flash/ROM 内存功能可用在文字模式 (FONT Mode)、DMA 模式(直接记忆存取模式)。文字模式意指外部串列式 Flash/ROM 内存被当成字体位图的來源。为了支持文字字体，RA8873M 可与专业的字体供货商— 上海集通公司的 FONT ROM 兼容。DMA 模式意指串列式 Flash/ROM 可当作 DMA (Direct Memory Access)的资料來源。使用者可以透过此模式，加快资料传送到显示内存(Display RAM) 的速度。

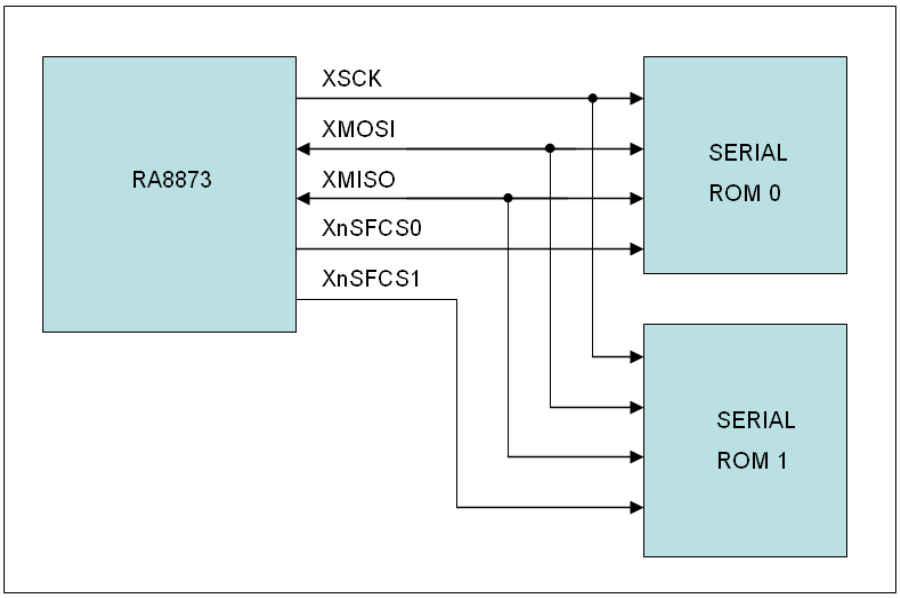


圖 3.3: RA8873M 串行式 Flash/ROM 系统

3.3. DMA 功能的 API 在 LCD 上的显示结果:

我们提供下列两组 API:

```
void DMA_24bit
(
unsigned char SCS //SCS : 0 = Use SCS0, 1 = Use SCS1
,unsigned char Clk //Clk : SPI Clock = System Clock /{(Clk+1)*2}
,unsigned short X1 //X of DMA Coordinate
,unsigned short Y1 //Y of DMA Coordinate
,unsigned short X_W //DMA Block width
,unsigned short Y_H //DMA Block height
,unsigned short P_W //DMA Picture width
,unsigned long Addr //DMA Source Start address
)

void DMA_32bit
(
unsigned char SCS //SCS : 0 = Use SCS0, 1 = Use SCS1
,unsigned char Clk //Clk : SPI Clock = System Clock /{(Clk+1)*2}
,unsigned short X1 //X of DMA Coordinate
,unsigned short Y1 //Y of DMA Coordinate
,unsigned short X_W //DMA Block width
,unsigned short Y_H //DMA Block height
,unsigned short P_W //DMA Picture width
,unsigned long Addr //DMA Source Start address
)
```

范例 :

```
Write_Layer(1); //set memory read/write layer.Reference Page.5~6
Show_Layer(1);//set LCD display layer. Reference Page.5~6
+
 (Flash = 128Mbit or under 128Mbit)
DMA_24bit(1,0,0,0,800,480,800,0);
Or
(Flash over 128Mbit, need open switch_24bits_to_32bits(1); in RA8873M_Initial();→
Set_Serial_Flash_IF();)
DMA_32bit(1,0,0,0,800,480,800,0);
```

条件 ：

SCS = 1 : Use SCS1.　Clk = 0 , SPI Clock = System Clock / {(0+1)*2} = System Clock.

(X1,Y1) = (0,0) : DMA Coordinate = (0,0).

X_W : DMA Block width = 800 . Y_H : DMA Block height = 480.

P_W : DMA Picture width =800 . Addr :DMA Source Start address = 0.

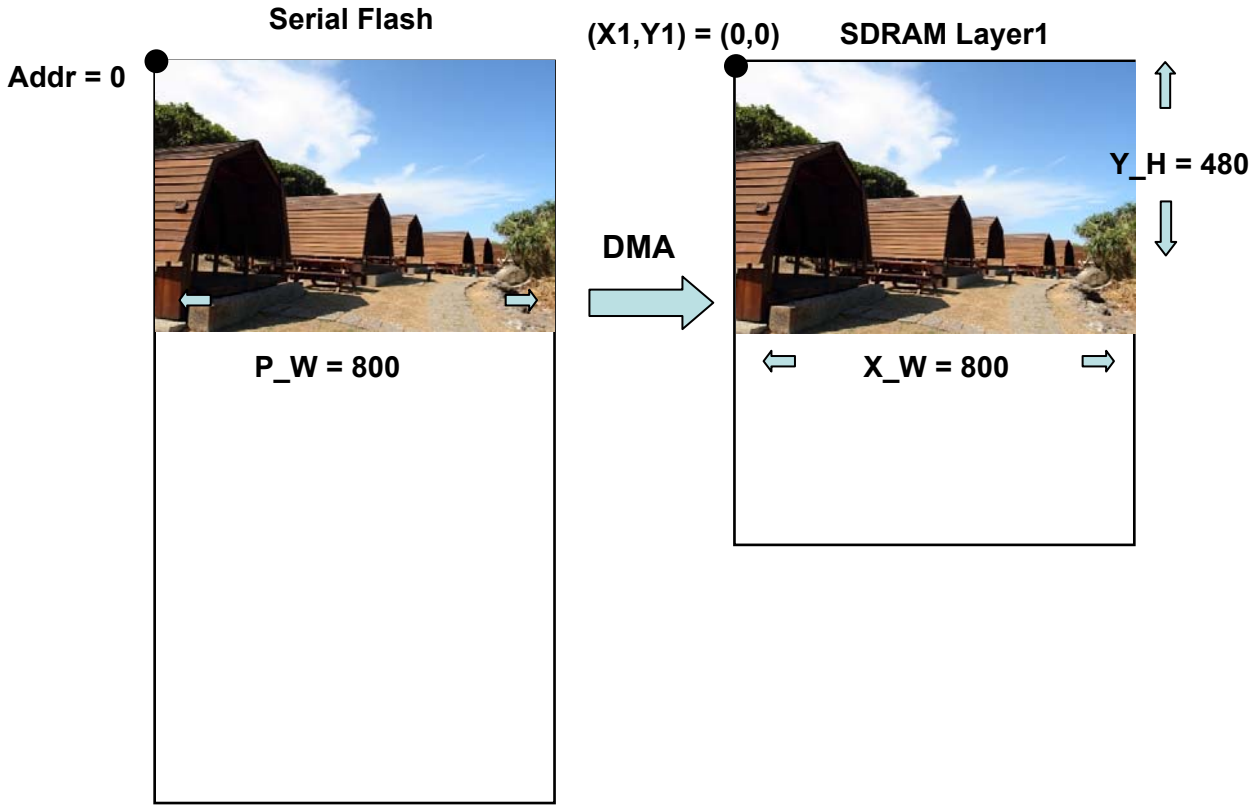


圖 3.4:　使用 DMA 功能将串行式 Flash 中的数据写到图层 1

第四章 ：Block Transfer Engine

概要:

RA8873M 内建了增加区域运算效能的区域运算引擎(BTE)，当有一个区块数据需要被搬移或是和某些特定数据做一些逻辑运算，RA8873M 可以经由 BTE 硬件加速来简化 MCU 的程序，这边我们将要来讨论 BTE 引擎的操作与功能。

在使用 BTE 功能之前，使用者必须选择相对应的 BTE 功能，RA8873M 支持 13 种 BTE 功能。关于功能描述，请参照表 4-1。每个 BTE 功能针对不同的应用最多支持 16 种光栅运算(ROP)。它们可以提供给光栅运算来源与光栅运算目的地不同的逻辑结合。通过结合 BTE 功能与光栅运算，使用者可以达到许多非常有用的应用操作。请参考章节后面的详细描述。这份应用说明集中在一些常用的 BTE 功能，如 **Solid Fill, Pattern Fill with ROP, Pattern Fill with Chroma key(w/o ROP),MCU Write with ROP, MCU Write with Chroma key(w/o ROP), Memory Copy with ROP, Memory Copy with chroma key(w/o ROP), MCU Write with Color Expansion, MCU Write with Color Expansion and chroma key, Memory copy with Alpha Blending.** "如果我们的客户需要其它 BTE 功能的解说，请洽询瑞佑科技业务部或代理商。

表 4-1：BTE 操作功能

BTE Operation REG[91h] Bits [3:0]	BTE Operation
0000b	MCU Write with ROP.
0010b	Memory copy with ROP.
0100b	MCU Write with Chroma key (w/o ROP)
0101b	Memory copy with Chroma key (w/o ROP)
0110b	Pattern Fill with ROP
0111b	Pattern Fill with Chroma key
1000b	MCU Write with Color Expansion
1001b	MCU Write with Color Expansion and Chroma key
1010b	Memory copy with Alpha blending
1011b	MCU Write with Alpha blending
1100b	Solid Fill
1110b	Memory copy with Color Expansion
1111b	Memory copy with Color Expansion and Chroma key
Other combinations	Reserved

表 4-2 : ROP Function

ROP Bits REG[91h] Bit[7:4]	Boolean Function Operation
0000b	0 (Blackness)
0001b	~S0・~S1 or ~ (S0+S1)
0010b	~S0・S1
0011b	~S0
0100b	S0・~S1
0101b	~S1
0110b	S0^S1
0111b	~S0+~S1 or ~ (S0・S1)
1000b	S0・S1
1001b	~ (S0^S1)
1010b	S1
1011b	~S0+S1
1100b	S0
1101b	S0+~S1
1110b	S0+S1
1111b	1 (Whiteness)

Note:

1. ROP 功能 S0: 来源 0 的资料, S1: 来源 1 的资料, D: 目的地的数据
2. 以 pattern fill 功能来说,目的地的资料是由来源来表示。

Example:

当 ROP 功能设定为 Ch (1100b), 目的地的数据 = 来源 0 的数据
当 ROP 功能设定为 Eh (1110b), 目的地的数据 = 来源 0 + 来源 1
当 ROP 功能设定为 2h (0010b), 目的地的资料 = ~来源 0・来源 1
当 ROP 功能设定为 Ah (1010b), 目的地的数据 = 来源 1 数据

BTE Access Memory Method

伴随着这些设定，BTE 的来源/目的地的数据被当作一个显示的区块，下面的例子解释了将来源 0/来源 1/目的地定义成区块的方法。

BTE Chroma Key (Transparency Color) Compare

当启用 BTE 通透色时，BTE 程序会比对来源 0 的数据和背景色缓存器的数据。数据相等的部分在目的地并不会有所改变，数据不相等的部分才会由来源 0 写入到目的地。

当来源色彩深度 = 256 色时，

来源 0 红色部分只比对 REG[D5h]Bit[7:5]

来源 0 绿色部分只比对 REG [D6h] Bit [7:5],

来源 0 蓝色部分只比对 REG [D7h] Bit [7:6]

当来源色彩深度 = 65k 色时，

来源 0 红色部分只比对 REG[D5h]Bit[7:3]

来源 0 绿色部分只比对 REG [D6h] Bit [7:2]

来源 0 蓝色部分只比对 REG [D7h] Bit [7:3]

当来源色彩深度 = 16.7M 色时，

来源 0 红色部分只比对 REG[D5h]Bit[7:0]

来源 0 绿色部分只比对 REG [D6h] Bit [7:0]

来源 0 蓝色部分只比对 REG [D7h] Bit [7:0]

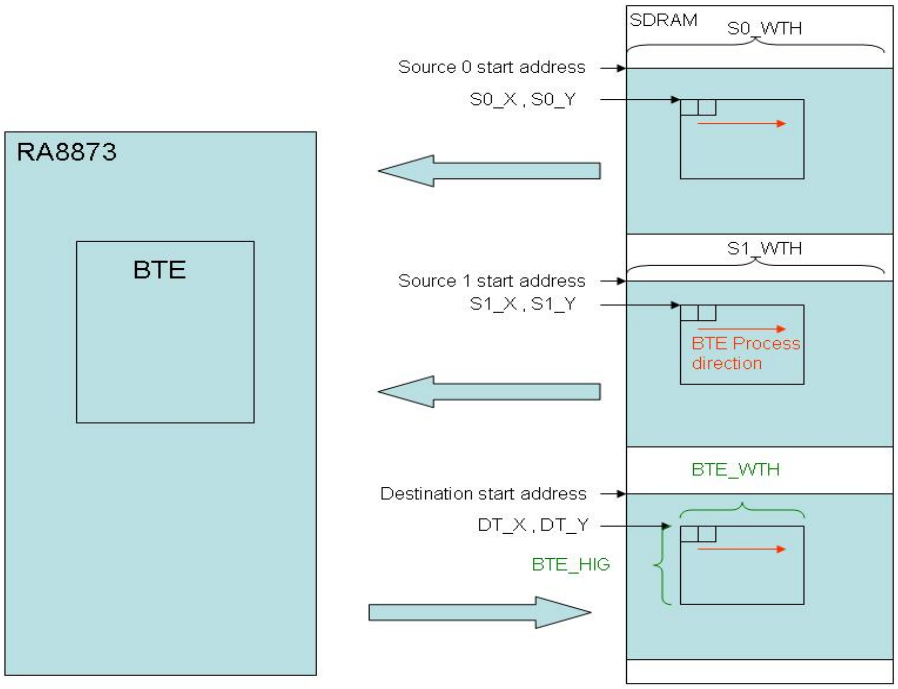


圖 4-1 : Memory Access of BTE Function

4.1.1: Solid Fill

Solid Fill BTE 功能提供使用者可将特定的区域 (BTE 來源区域) 以特定颜色来填满。这个功能用在将 SDRAM 里的一个大区块填满为同样的一个颜色，它的颜色是经由 BTE 前景色来设定。

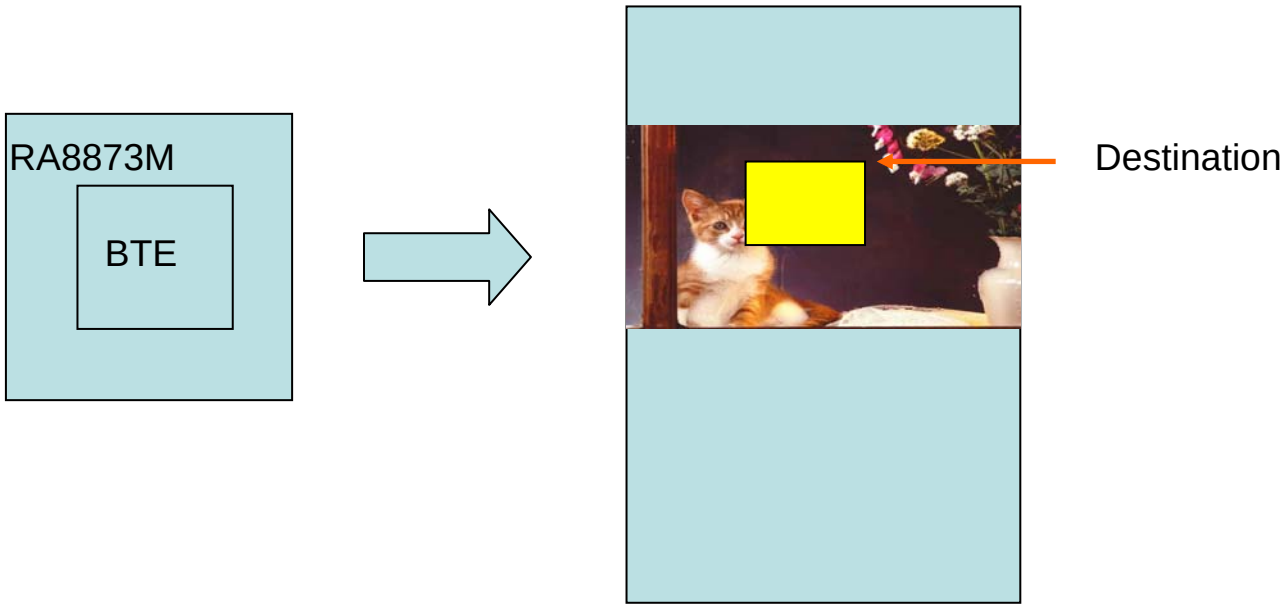


圖 4-2 : Hardware Data Flow

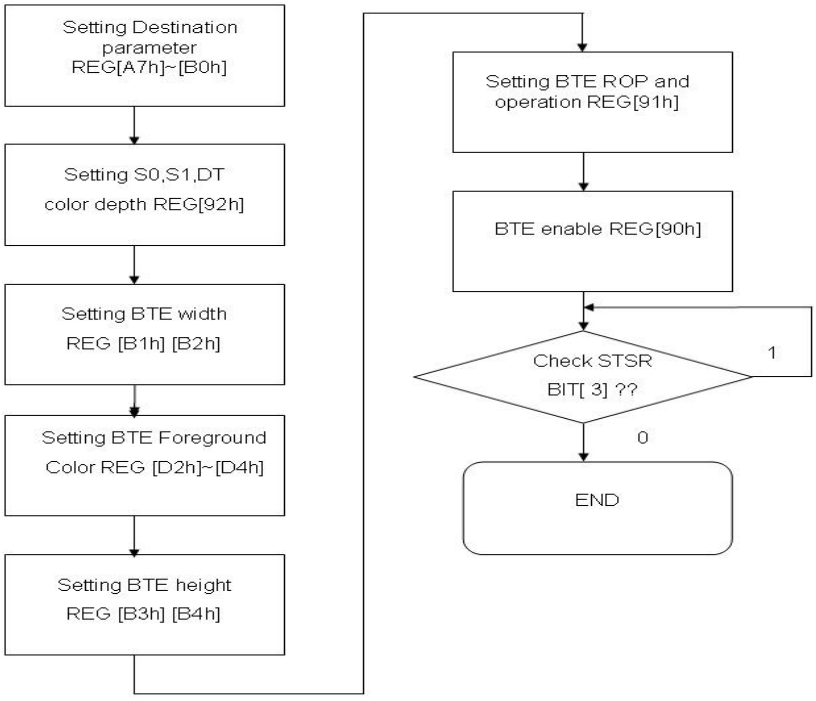


圖 4-3 : 流程图

4.1.2. BTE 的 Solid Fill 功能在 LCD 上的显示结果:

以下为 API 程序与范例说明，图 4-4 为使用 Solid Fill 功能填满一个红色的方形区块。

```
void BTE_Solid_Fill
(
unsigned long Des_Addr //start address of destination
,unsigned short Des_W // image width of destination (recommend = canvas image width)
, unsigned short XDes //coordinate X of destination
,unsigned short YDes //coordinate Y of destination
,unsigned long Foreground_color //Solid Fill color
,unsigned short X_W //Width of BTE Window
,unsigned short Y_H //Length of BTE Window
)
```

范例:

```
Write_Layer(1); //set memory read/write layer.Reference Page.5~6
Show_Layer(1);//set LCD display layer. Reference Page.5~6
+
BTE_Solid_Fill(Layer1,Panel_width,0,0,0xe0,200,200); //When color depth = 8bpp
or
BTE_Solid_Fill(Layer1,Panel_width,0,0,0xf800,200,200); //When color depth = 16bpp
or
BTE_Solid_Fill(Layer1,Panel_width,0,0,0xFF0000,200,200); //When color depth = 24bpp
```

条件:

start address of destination = Layer1, ImageWidth = Panel_width(define in userdef.h) , coordinate of destination = (0,0)
Foreground Color: 0xe0 (8bpp) (R3G3B2)、0xf800(16bpp)(R5G6B5)、0xFF0000(24bpp)(R8G8B8)
BTE Window Size = 200x200

LCD 实际画面(图层 1):

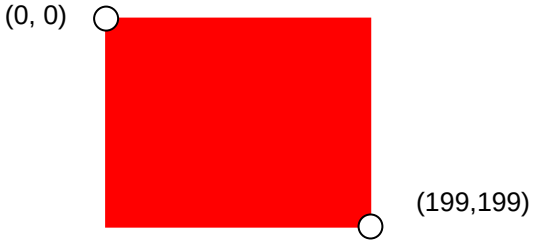


圖 4-4 :使用 Solid Fill 功能，将图层 1 的[(0, 0) 到(199,199)]用红色填满

4.2.1:Pattern Fill with ROP

“Pattern Fill with ROP” 功能可设定一个在 SDRAM 中的特定方形记忆区块，并填入重复的特定图形样板。图形样板是 8x8/16x16 的像素图形，存放在 SDRAM 中的非显示区的特定位置，图形样板并且可以配合 16 种光栅运算和目的地资料做邏辑运算。此操作可以用來加速某些需要在特定区域重复貼入某一种图形，像是背景图案等应用。

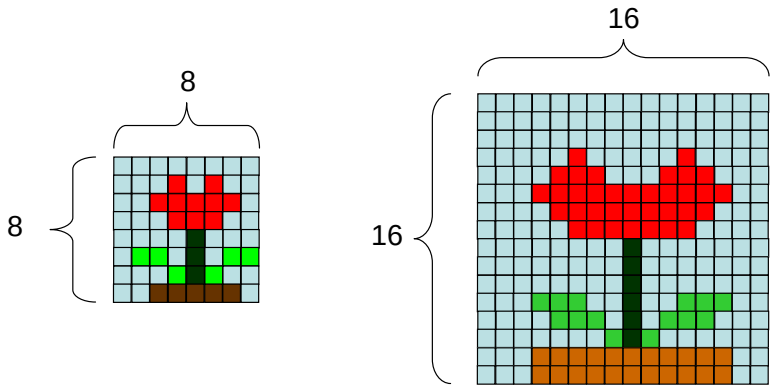


圖 4-5 : Pattern Format

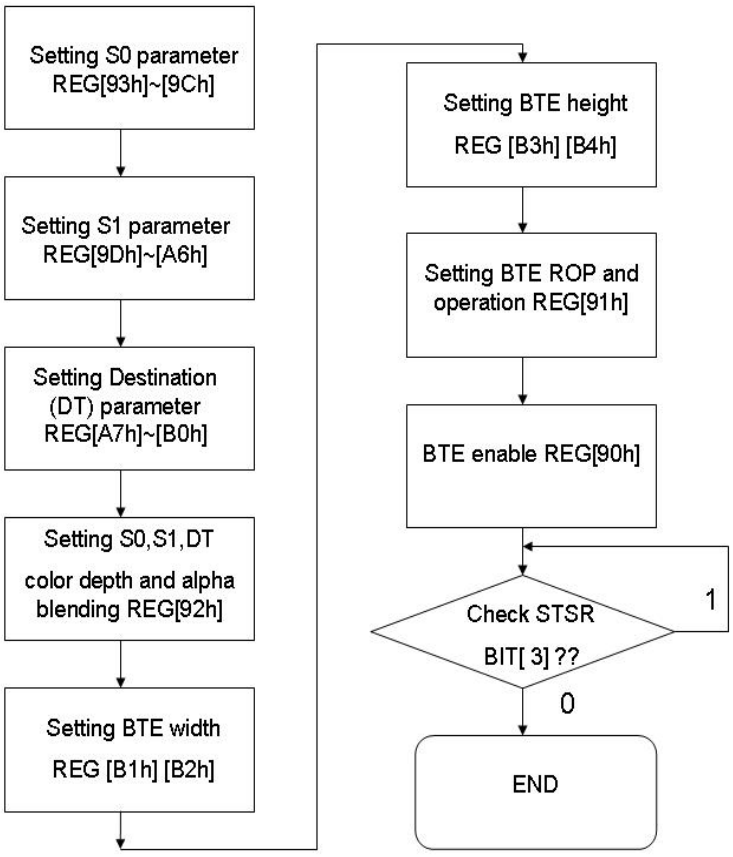


圖 4-6： 流程图

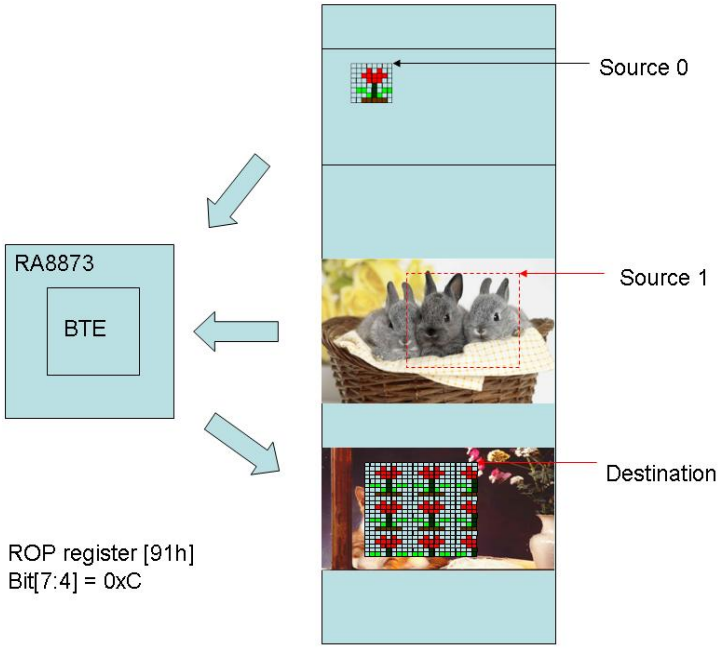

Source 0
Source 1
Destination
RA8873
BTE
ROP register [91h]
Bit[7:4] = 0xC

圖 4-72：硬件数据流

4.2.2. BTE 的 Pattern Fill with ROP 功能在 LCD 上的执行显示结果:

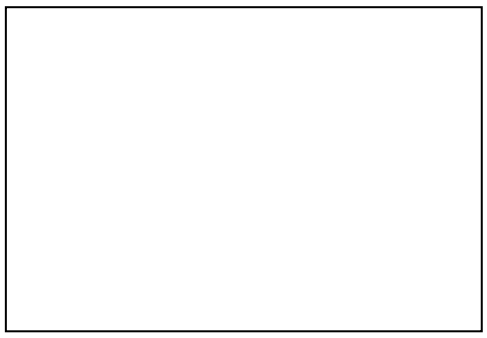


图 4-8: 在这个范例中，SDRAM 目前的资料

图 4-9 (16x16) 图形样版

API for pattern fill with ROP:

```
void BTE_Pattern_Fill
(
unsigned char P_8x8_or_16x16 //0 : use 8x8 Icon , 1 : use 16x16 Icon.
,unsigned long S0_Addr //Start address of Source 0
,unsigned short S0_W //image width of Source 0 (recommend = canvas image width)
,unsigned short XS0 // coordinate X of Source 0
,unsigned short YS0 // coordinate Y of Source 0
,unsigned long S1_Addr //Start address of Source 1
,unsigned short S1_W //image width of Source 1 (recommend = canvas image width)
,unsigned short XS1 //coordinate X of Source 1
,unsigned short YS1 //coordinate Y of Source 1
,unsigned long Des_Addr // start address of Destination
,unsigned short Des_W //image width of Destination (recommend = canvas image width)
, unsigned short XDes //coordinate X of Destination
,unsigned short YDes //coordinate Y of Destination
,unsigned int ROP_Code
/*ROP_Code :
    0000b       0(Blackness)
    0001b       ~S0!E~S1 or ~(S0+S1)
    0010b       ~S0!ES1
    0011b       ~S0
    0100b       S0!E~S1
    0101b       ~S1
    0110b       S0^S1
    0111b       ~S0 + ~S1 or ~(S0 + S1)
    1000b       S0!ES1
    1001b       ~(S0^S1)
```

```
    1010b       S1
    1011b       ~S0+S1
    1100b       S0
    1101b       S0+~S1
    1110b       S0+S1
    1111b       1(whiteness)*/
,unsigned short X_W //Width of BTE Winodw
,unsigned short Y_H //Length of BTE Winodw
)
```

范例:

```
Write_Layer(1); //set memory read/write layer.Reference Page.5~6
Show_Layer(1);//set LCD display layer. Reference Page.5~6
+
MCU_8bit_ColorDepth_8bpp
DMA_24bit (1,0,0,0,800,480,800,0);
MPU8_8bpp_Memory_Write(0,0,16,16,Icon_8bit_8bpp);
or
MCU_8bit_ColorDepth_16bpp
DMA_24bit (1,0,0,0,800,480,800,0);
MPU8_16bpp_Memory_Write(0,0,16,16,Icon_8bit_16bpp);
or
MCU_8bit_ColorDepth_24bpp
DMA_24bit (1,0,0,0,800,480,800,0);
MPU8_24bpp_Memory_Write(0,0,16,16,Icon_8bit_24bpp);
or
MCU_16bit_ColorDepth_16bpp
DMA_24bit (1,0,0,0,800,480,800,0);
MPU16_16bpp_Memory_Write(0,0,16,16,Icon_16bit_16bpp);
or
MCU_16bit_ColorDepth_24bpp_Mode_1
DMA_24bit (1,0,0,0,800,480,800,0);
MPU16_24bpp_Mode1_Memory_Write(0,0,16,16,Icon_16bit_24bpp_mode1);
or
MCU_16bit_ColorDepth_24bpp_Mode_2
DMA_24bit (1,0,0,0,800,480,800,0);
MPU16_24bpp_Mode2_Memory_Write(0,0,16,16,Icon_16bit_24bpp_mode2);
+
BTE_Pattern_Fill(1,Layer1,Panel_width,0,0,Layer1,Panel_width,0,0,Layer1,Panel_width,500,200,12
```

,100,100);

条件:

P_8x8_or_16x16 = 1 , Pattern size = 16x16
Source 0 : Start Address = Layer1, Image Width = Panel_width , coordinate (0,0)
Source 1 : Start Address = Layer1, Image Width = Panel_width , coordinate (0,0)
Destination : Start Address = Layer1, Image Width = Panel_width , coordinate (500,200)
ROP_Code = 12 : Destination data = Source 0 data. BTE Window Size = 100x100

步骤 1： 使用 DMA 功能将外部 Flash Memory 中的图档写到 DDRAM 内 (SDRAM)

图 4-10: 使用 DMA 功能将外部 Flash Memory 中的图档写到 DDRAM 内 (SDRAM)

步骤 2： 写入一个 16x16 的图形样版到 SDRAM 内

图 4-11:写入一个 16x16 的图形样版到 SDRAM 内

步骤 3：执行 Pattern fill 的功能

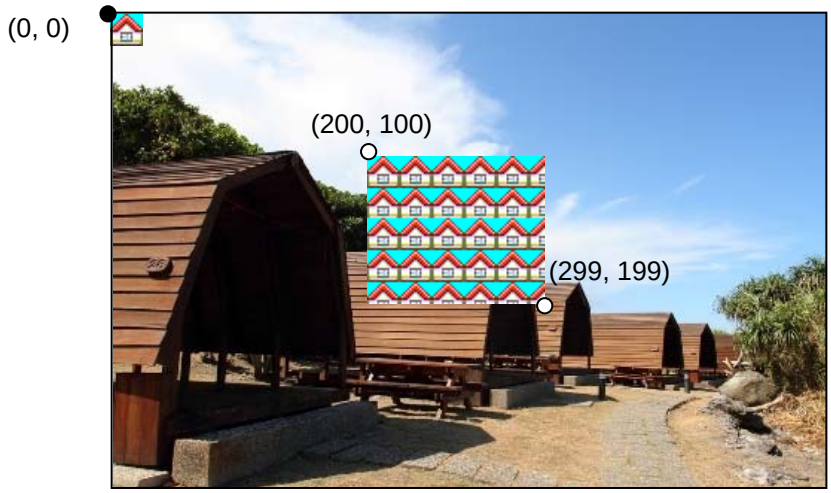


图 4-12:来源范围从图层 1 的(0,0)到(15,15)且目的地显示范围从图层 1 的(500,200)到(599,299)，使用了 pattern fill function 后的情况。

4.2.3:Pattern Fill with Chroma Key(w/o ROP)

“Pattern Fill with Chroma Key” 功能可设定在一个 DDRAM 中的特定方形内存，并填入重复的特定图形样板，此功能与「Pattern Fill with ROP」功能有相同的功能，不同的是，加入通透性的功能。也就是对于特定的「通透色」，此 BTE 功能会予以忽略。通透色是在 REG[D5h]~[D7h]中被设定，当图形样板中的颜色与通透色一致时，那部份的“***目的地数据***”将不会改变。

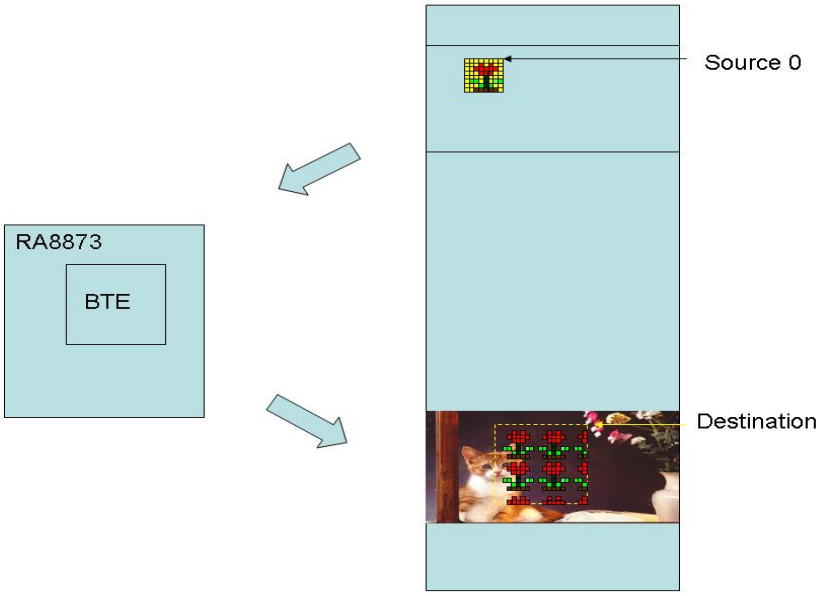


圖 4-10：硬件数据流

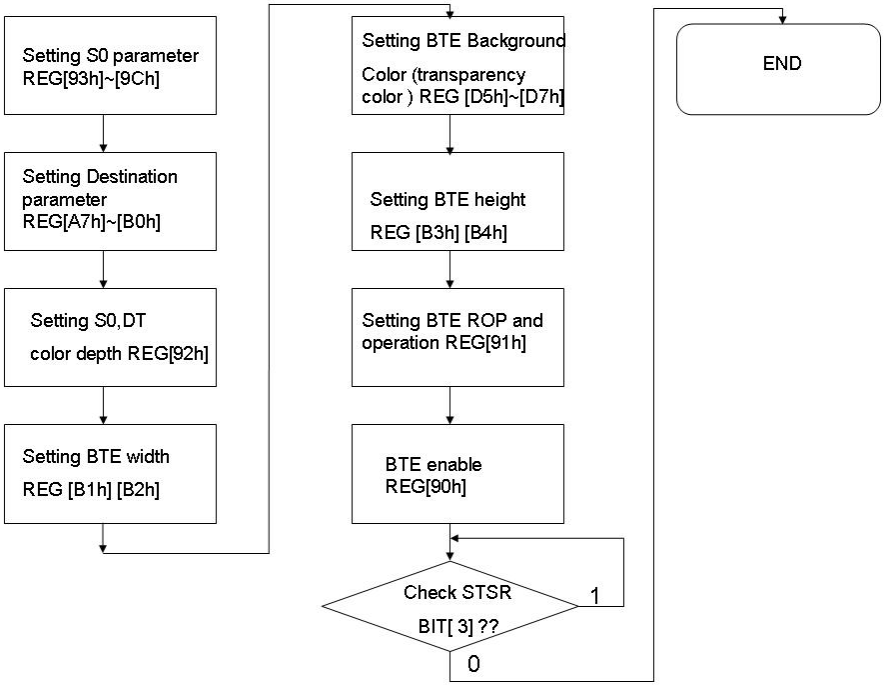


圖 4-11：流程图

4.2.4: BTE Pattern Fill with Chroma key(w/o ROP)功能在 LCD 上的显示结果:

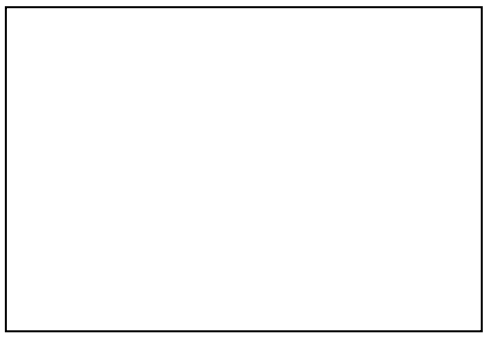


图 4-12: 在这个范例中，SDRAM 目前的资料

图 4-13 (16x16) 图形样版

API:

```
void BTE_Pattern_Fill_With_Chroma_key
(
unsigned char P_8x8_or_16x16 //0 : use 8x8 Icon , 1 : use 16x16 Icon.
,unsigned long S0_Addr //Start address of Source 0
,unsigned short S0_W //image width of Source 0 (recommend = canvas image width)
,unsigned short XS0 //coordinate X of Source 0
,unsigned short YS0 //coordinate Y of Source 0
,unsigned long S1_Addr //Start address of Source 1
,unsigned short S1_W //image width of Source 1 (recommend = canvas image width)
,unsigned short XS1 //coordinate X of Source 1
,unsigned short YS1 //coordinate Y of Source 1
,unsigned long Des_Addr //Des_Addr : start address of Destination
,unsigned short Des_W //Des_W : image width of Destination (recommend = canvas image width)
,unsigned short XDes //coordinate X of Destination
,unsigned short YDes //coordinate Y of Destination
,unsigned int ROP_Code
/*ROP_Code :
    0000b       0(Blackness)
    0001b       ~S0!E~S1 or ~(S0+S1)
    0010b       ~S0!ES1
    0011b       ~S0
    0100b       S0!E~S1
    0101b       ~S1
    0110b       S0^S1
    0111b       ~S0 + ~S1 or ~(S0 + S1)
    1000b       S0!ES1
    1001b       ~(S0^S1)
```

```
    1010b       S1
    1011b       ~S0+S1
    1100b       S0
    1101b       S0+~S1
    1110b       S0+S1
    1111b       1(whiteness)*/
,unsigned long Background_color //Transparent color
,unsigned short X_W //Width of BTE Window
,unsigned short Y_H //Length of BTE Window
)
```

范例:

```
Write_Layer(1); //set memory read/write layer.Reference Page.5~6
Show_Layer(1);//set LCD display layer. Reference Page.5~6
+
//MCU_8bit_ColorDepth_8bpp
DMA_24bit (1,0,0,0,800,480,800,0);
MPU8_8bpp_Memory_Write(0,0,16,16,Icon_8bit_8bpp);
BTE_Pattern_Fill_With_Chroma_key(1,Layer1,Panel_width,0,0,Layer1,Panel_width,0,0,Layer1,
Panel_width,500,200,12,0x1f,100,100);
or
//MCU_8bit_ColorDepth_16bpp
DMA_24bit (1,0,0,0,800,480,800,0);
MPU8_16bpp_Memory_Write(0,0,16,16,Icon_8bit_16bpp);
BTE_Pattern_Fill_With_Chroma_key(1,Layer1,Panel_width,0,0,Layer1,Panel_width,0,0,Layer1,
Panel_width,500,200,12,0x07ff,100,100);
or
//MCU_8bit_ColorDepth_24bpp
DMA_24bit (1,0,0,0,800,480,800,0);
MPU8_24bpp_Memory_Write(0,0,16,16,Icon_8bit_24bpp);
BTE_Pattern_Fill_With_Chroma_key(1,Layer1,Panel_width,0,0,Layer1,Panel_width,0,0,Layer1,
Panel_width,500,200,12,0x00ffff,100,100);
or
//MCU_16bit_ColorDepth_16bpp
DMA_24bit (1,0,0,0,800,480,800,0);
MPU16_16bpp_Memory_Write(0,0,16,16,Icon_16bit_16bpp);
BTE_Pattern_Fill_With_Chroma_key(1,Layer1,Panel_width,0,0,Layer1,Panel_width,0,0,Layer1,
Panel_width,500,200,12,0x07ff,100,100);
or
```

```
//MCU_16bit_ColorDepth_24bpp_Mode_1
DMA_24bit (1,0,0,0,800,480,800,0);
MPU16_24bpp_Mode1_Memory_Write(0,0,16,16,Icon_16bit_24bpp_mode1);
BTE_Pattern_Fill_With_Chroma_key(1,Layer1,Panel_width,0,0,Layer1,Panel_width,0,0,Layer1,
Panel_width,500,200,12,0x00ffff,100,100);
or
//MCU_16bit_ColorDepth_24bpp_Mode_2
DMA_24bit (1,0,0,0,800,480,800,0);
MPU16_24bpp_Mode2_Memory_Write(0,0,16,16,Icon_16bit_24bpp_mode2);
BTE_Pattern_Fill_With_Chroma_key(1,Layer1,Panel_width,0,0,Layer1,Panel_width,0,0,Layer1,
Panel_width,500,200,12,0x00ffff,100,100);
```

条件:

P_8x8_or_16x16 = 1 , Pattern size = 16x16
Source 0 : Start Address = Layer1, Image Width = Panel_width,Coordinate = (0,0)
Source 1 : Start Address = Layer1, Image Width = Panel_width, Coordinate = (0,0)
Destination : Start Address = Layer1, Image Width = Panel_width, Coordinate = (500,200)
ROP_Code = 12 : Destination data = Source 0 data. BTE Window Size = 200x200
Background_color = Transparency color = 0x1f(8bpp) , 0x07ff(16bpp) ,0x00ffff(24bpp)(blue-green)

步骤 1： 运用 DMA 功能从外部串行式闪存写入一张图片到 SDRAM 中

图 4-14: 使用 DMA 功能将外部 Flash Memory 中的图档写到 DDRAM 内 (SDRAM)

步骤 2： 写一个 16x16 的图形样版到 DDRAM 内 (SDRAM)

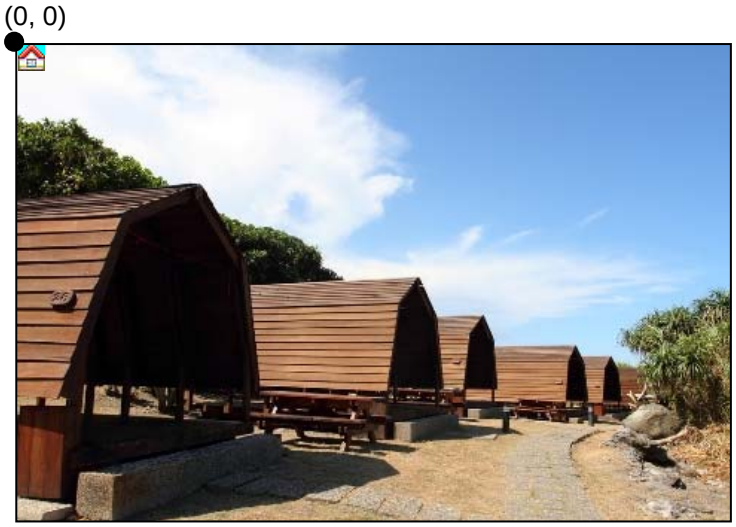


图 4-15:写入一个 16x16 的图形样版到 SDRAM 中

步骤 3： 执行 Pattern fill with chroma key(w/o ROP)的功能

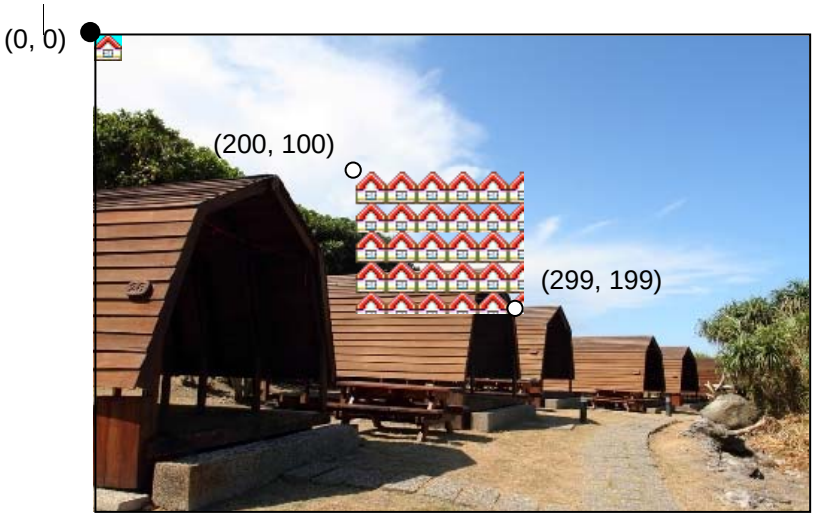


图 4-16: 执行“pattern fill with chroma key(w/o ROP)”功能，图案样版的来源是从图层 1 的(0, 0) 到 (15, 15)，而目的地的范围是从图层 1 的(500,200) to (599,299)。

4.3.1: MCU Write with ROP

MCU Write with ROP 的 BTE 功能，增加了 MCU 介面寫入 SDRAM 的資料傳送速度。透過 MCU，Write BTE 搭配光柵運算將資料填入特定的 SDRAM 區域，Write BTE 功能支援全部 16 種光柵運算。Write BTE 功能需要 MCU 端提供資料。

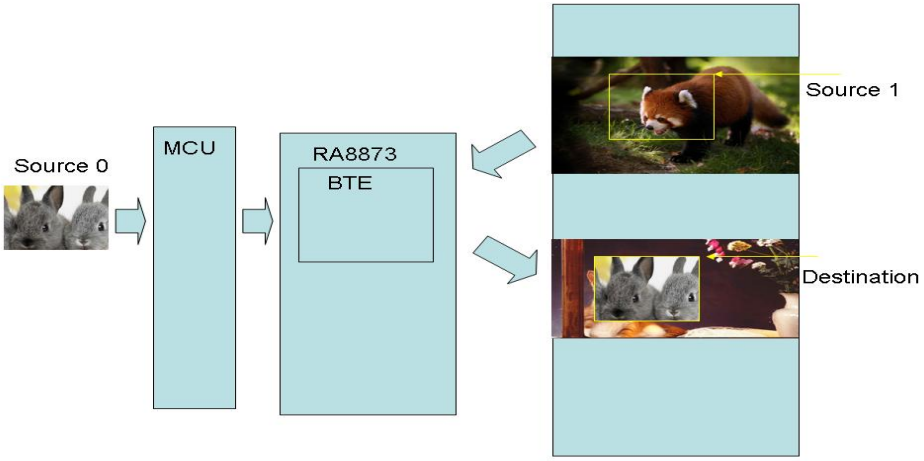


圖 4-17：硬件数据流

以下是建议的程序流程以及缓存器设定：

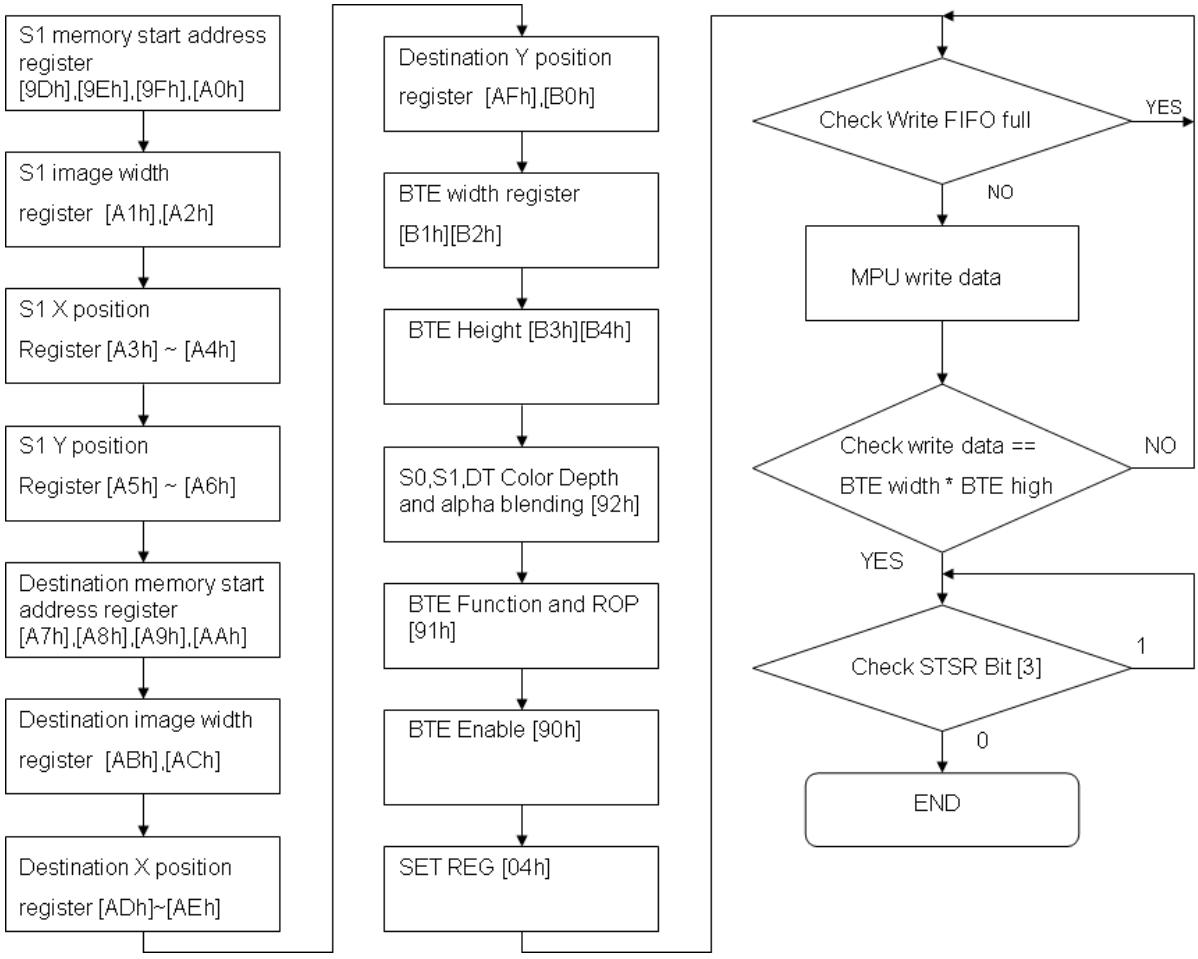


圖 4-18：流程图

4.3.2: BTE MCU Write with ROP 功能在 LCD 上的显示结果

在 BTE MCU Write with ROP 中，我们针对 MCU 8bit 和 16bit 各提供一组 API 供使用者使用，图 4-19 为 SDRAM 的数据，图 4-20 为 MCU 端的图资，使用 BTE MCU Write with ROP 功能，搭配上 ROP 参数，可以将 MCU 端输入的图资做逻辑运算后写入 SDRAM。以下为 API 程序与范例解说:

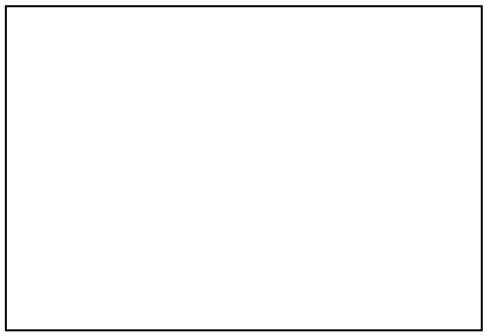


图 4-19: 在这个范例中，SDRAM 目前的资料

图 4-20：MCU 写入的资料(128x128)

```
void BTE_MCU_Write_MCU_8bit
(
unsigned long S1_Addr //Start address of Source 1
,unsigned short S1_W //image width of Source 1 (recommend = canvas image width)
,unsigned short XS1 //coordinate X of Source 1
,unsigned short YS1 //coordinate Y of Source 1
,unsigned long Des_Addr //start address of Destination
,unsigned short Des_W //image width of Destination (recommend = canvas image width)
,unsigned short XDes //coordinate X of Destination
,unsigned short YDes //coordinate Y of Destination
,unsigned int ROP_Code
/*ROP_Code :
    0000b       0(Blackness)
    0001b       ~S0!E~S1 or ~(S0+S1)
    0010b       ~S0!ES1
    0011b       ~S0
    0100b       S0!E~S1
    0101b       ~S1
    0110b       S0^S1
    0111b       ~S0 + ~S1 or ~(S0 + S1)
    1000b       S0!ES1
    1001b       ~(S0^S1)
    1010b       S1
    1011b       ~S0+S1
    1100b       S0
```

```
    1101b       S0+~S1
    1110b       S0+S1
    1111b       1(whiteness)*/
,unsigned short X_W // Width of BTE Window
,unsigned short Y_H // Length of BTE Window
,const unsigned char *data // 8-bit data
)


void BTE_MCU_Write_MCU_16bit
(
unsigned long S1_Addr //Start address of Source 1
,unsigned short S1_W //image width of Source 1 (recommend = canvas image width)
,unsigned short XS1 //coordinate X of Source 1
,unsigned short YS1 //coordinate Y of Source 1
,unsigned long Des_Addr //start address of Destination
,unsigned short Des_W //image width of Destination (recommend = canvas image width)
,unsigned short XDes //coordinate X of Destination
,unsigned short YDes //coordinate Y of Destination
,unsigned int ROP_Code
/*ROP_Code :
    0000b       0(Blackness)
    0001b       ~S0!E~S1 or ~(S0+S1)
    0010b       ~S0!ES1
    0011b       ~S0
    0100b       S0!E~S1
    0101b       ~S1
    0110b       S0^S1
    0111b       ~S0 + ~S1 or ~(S0 + S1)
    1000b       S0!ES1
    1001b       ~(S0^S1)
    1010b       S1
    1011b       ~S0+S1
    1100b       S0
    1101b       S0+~S1
    1110b       S0+S1
    1111b       1(whiteness)*/
,unsigned short X_W // Width of BTE Window
```

```
,unsigned short Y_H // Length of BTE Window
,const unsigned short *data // 16-bit data
)
```

范例:

```
Write_Layer(1); //set memory read/write layer.Reference Page.5~6
Show_Layer(1);//set LCD display layer. Reference Page.5~6
+
//Use 8bit MCU, 8bpp color depth
BTE_MCU_Write_MCU_8bit(Layer1,Panel_width,0,0,Layer1,Panel_width,100,100,12,128,128
,gImage_8);
or
//Use 8bit MCU, 16bpp color depth
BTE_MCU_Write_MCU_8bit(Layer1,Panel_width,0,0,Layer1,Panel_width,100,100,12,128,128
,gImage_16);
or
//Use 8bit MCU, 24bpp color depth
BTE_MCU_Write_MCU_8bit(Layer1,Panel_width,0,0,Layer1,Panel_width,100,100,12,128,128
,gImage_24);
or
//Use 16bit MCU, 16bpp color depth
BTE_MCU_Write_MCU_16bit(Layer1,Panel_width,0,0,Layer1,Panel_width,100,100,12,128,128
,pic1616);
or
//Use 16bit MCU, 24bpp color depth and data format use mode 1
BTE_MCU_Write_MCU_16bit(Layer1,Panel_width,0,0,Layer1,Panel_width,100,100,12,128,128
,pic16241);
or
//Use 16bit MCU, 24bpp color depth and data format use mode 2
BTE_MCU_Write_MCU_16bit(Layer1,Panel_width,0,0,Layer1,Panel_width,100,100,12,128,128
,pic1624);
```

条件:

Source 0 from MCU.

Source 1 : Start Address = Layer1, Image Width = Panel_width, Coordinate = (0,0) .

Destination: Start Address = Layer1, Image Width = Panel_width, Coordinate = (100,100) .

ROP Code = 12 → Destination data= Source 0 data, Don't care Source 1.

BTE Window Size = 128x128 .

实际画面:

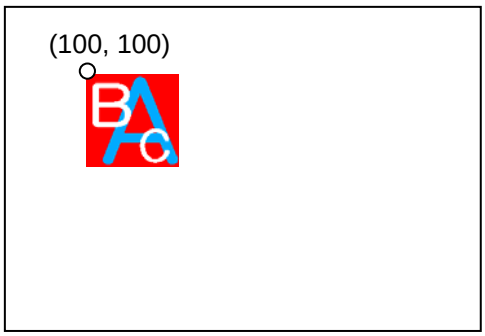


图 4-21: 用 BTE MCU Write 将图片写入 SDRAM 中，目的地位置从图层 1 的(100,100)到(227,227)

4.3.3:MCU Write With Chroma Key (w/o ROP)

BTE 通透性写入功能（MCU Write With Chroma Key），可以加增加 MCU 端写入显示数据至 SDRAM 的传送速度，一旦 BTE 通透性写入功能开始，BTE 引擎会持续动作直到所有的像素都被写入为止。

BTE 通透性写入功能可用來更新一个 SDRAM 的特定区域，而由 MCU 提供显示资料來源，不同于前面章节提到的 MCU Write with ROP 的 BTE 功能，BTE 通透性写入功能会忽略某些特定颜色的操作，此特定的通透色可由使用者设定，在 RA8873M 中，此特定通透色设定于缓存器中的「BTE 背景色」中，当讀到來源资料的颜色，为符合通透色设定时，RA8873M 便会忽略这部份的显示数据，不执行写入的功能。此功能在处理将一张图片的部分图形复制到 SDRAM 时很有帮助，不需被复制的地方，在來源图片中便以「通透色」來处理，在 BTE 通透性写入功能执行时，便不会进入被写入 SDRAM。利用此功能可以很快的在任意背景图上，写入一个前景图案。如图 4-22 为例，來源图案为一个红色的背景搭配黄色的饼图案，借着设定红色为「通透色」，并且执行 BTE 通透性写入功能，就相当于将一个黄色的饼图案，贴到目的地位置的功能。BTE 通透性写入功能在來源和目的资料设定皆支持“线性”和“区块”寻址模式。

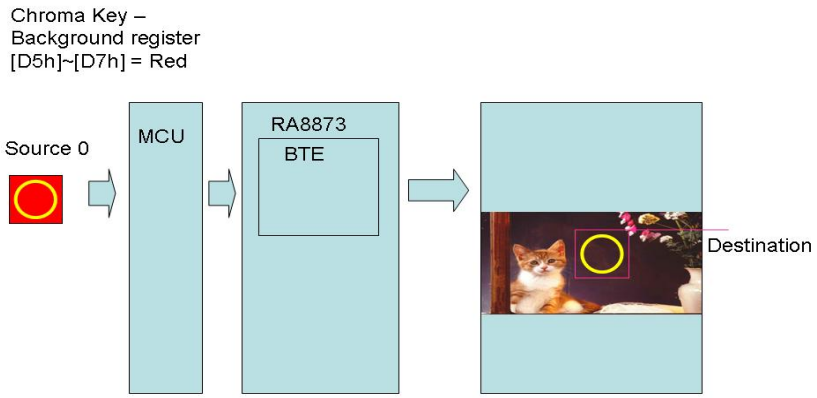


圖 4-22：硬件数据流

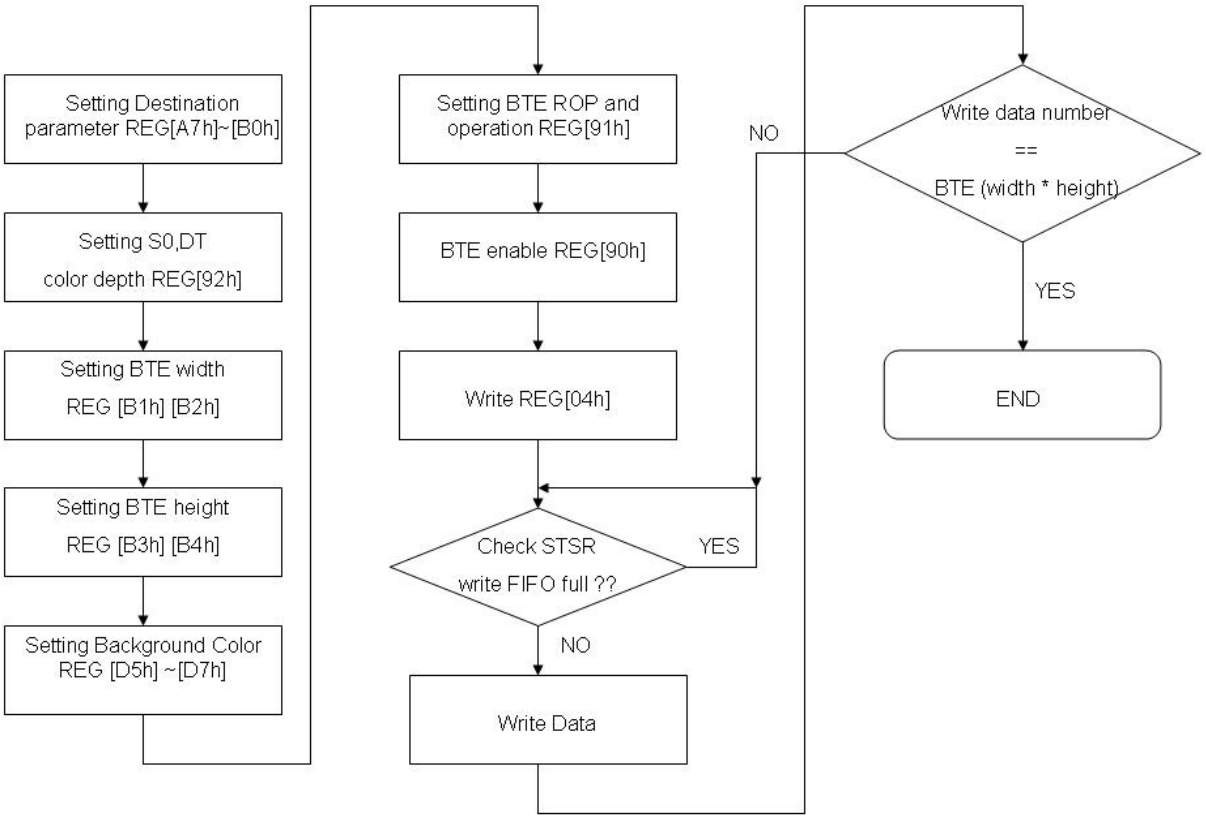

Setting Destination parameter REG[A7h]~[B0h]
Setting S0,DT color depth REG[92h]
Setting BTE width REG [B1h] [B2h]
Setting BTE height REG [B3h] [B4h]
Setting Background Color REG [D5h] ~[D7h]
Setting BTE ROP and operation REG[91h]
BTE enable REG[90h]
Write REG[04h]
Check STSR write FIFO full ??
YES
NO
Write Data
Write data number == BTE (width * height)
NO
YES
END

圖 4-23：流程图

4.3.4:BTE MCU Write With Chroma Key 功能在 LCD 上的显示结果:

BTE 通透性写入功能，可以增加 MCU 端写入显示数据至 SDRAM 的传送速度，一旦 BTE 通透性寫入功能開始，BTE 引擎會持續動作直到所有的像素都被寫入為止。

不同于前面章节提到的 MCU Write with ROP 的 BTE 功能，MCU Write with chroma key 将忽略 MCU 设定的通透色，此特定通透色設定於暫存器中的「BTE 背景色」中，當讀到來源資料的顏色為被设定的通透色時，RA8873M 便會忽略這部份的顯示資料，不執行寫入的功能。举例来说，如图 4-25，来源图片有一个蓝色字母 A 与两个白色字母 B 与 C 在搭配上红色背景。经由设定红色为通透色，然后使用 MCU Write with chroma key 功能，就会将背景红色滤掉，只剩下蓝、白色字母的数据。

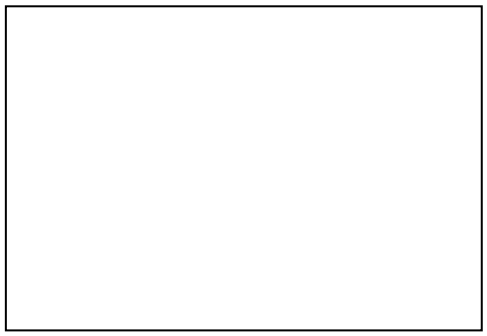


图 4-24: 在这个范例中，SDRAM 目前的资料

图 4-25 :MCU 写入的资料(128x128)

API:

```
void BTE_MCU_Write_Chroma_key_MCU_8bit
(
unsigned long Des_Addr //start address of Destination
,unsigned short Des_W //image width of Destination (recommend = canvas image width)
,unsigned short XDes //coordinate X of Destination
,unsigned short YDes //coordinate Y of Destination
,unsigned long Background_color //transparency color
,unsigned short X_W //Width of BTE Window
,unsigned short Y_H //Length of BTE Window
,const unsigned char *data // 8-bit data
)


void BTE_MCU_Write_Chroma_key_MCU_16bit
(
unsigned long Des_Addr //start address of Destination
,unsigned short Des_W //image width of Destination (recommend = canvas image width)
,unsigned short XDes //coordinate X of Destination
,unsigned short YDes //coordinate Y of Destination
,unsigned long Background_color //transparency color
```

```
,unsigned short X_W //Width of BTE Window
,unsigned short Y_H //Length of BTE Window
,const unsigned short *data // 16-bit data
)
```

范例:

```
Write_Layer(1); //set memory read/write layer.Reference Page.5~6
Show_Layer(1);//set LCD display layer. Reference Page.5~6
+
//Use 8bit MCU , 8bpp color depth
BTE_MCU_Write_Chroma_key_MCU_8bit(Layer1,Panel_width,100,100,0xe0,128,128,gImage_8);
or
//Use 8bit MCU , 16bpp color depth
BTE_MCU_Write_Chroma_key_MCU_8bit(Layer1,Panel_width,100,100,0xf800,128,128,gImage_16);
or
//Use 8bit MCU , 24bpp color depth
BTE_MCU_Write_Chroma_key_MCU_8bit(Layer1,Panel_width,100,100,0xff0000,128,128,
gImage_24);
or
//Use 16bit MCU , 16bpp color depth
BTE_MCU_Write_Chroma_key_MCU_16bit(Layer1,Panel_width,100,100,0xf800,128,128,pic1616);
or
//Use 16bit MCU , 24bpp color depth and data format use mode 1
BTE_MCU_Write_Chroma_key_MCU_16bit(Layer1,Panel_width,100,100,0xff0000,128,128
,pic16241);
or
//Use 16bit MCU , 24bpp color depth and data format use mode 2
BTE_MCU_Write_Chroma_key_MCU_16bit(Layer1,Panel_width,100,100,0xff0000,128,128,pic1624);
```

条件:

Source 0 from MCU,

Destination: Start Address = Layer1, Image Width = Panel_width, Coordinate = (100,100) .

BTE Window Size = 128x128 .

Transparency color = 0xe0 , 0xf800 ,0xff0000 (Red)

In BTE Chroma Key (Transparency color) function Enable, BTE process compare source 0 data and background color register data.

实际画面:

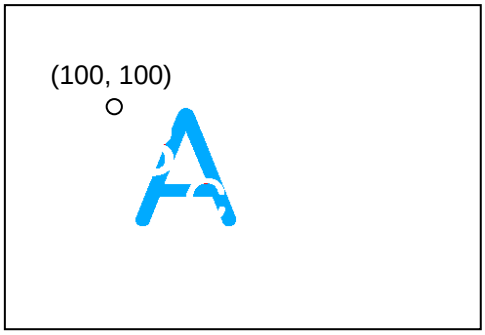


图 4-26: BTE MCU Write With Choma Key，通透色为红色，目的地位置从图层 1 的(100,100)到(227,227)。

4.4.1: Memory Copy with ROP

Memory Copy (move) with ROP 的 BTE 功能，是将 SDRAM 的一个特定区块的数据，搬移到另外一个区块。这个功能可以加速一个区块的数据复制，而且能省下很多 MCU 端的执行时间以及负担。

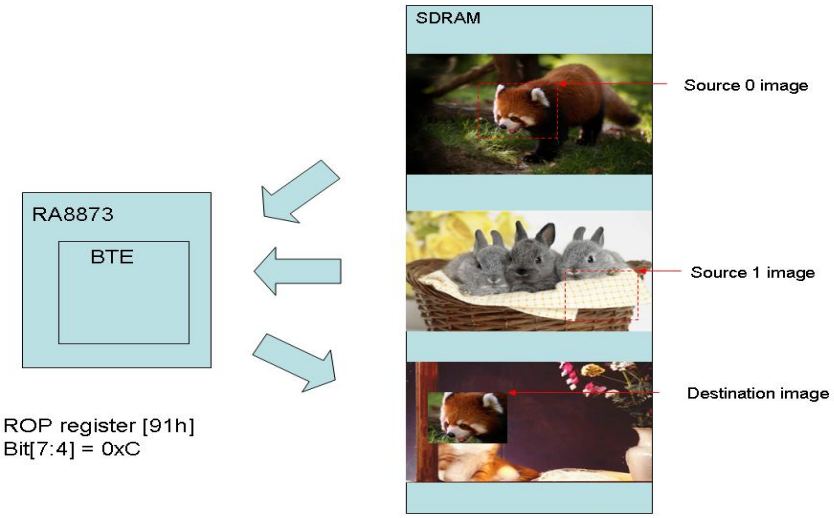


圖 4-27： 硬件数据流

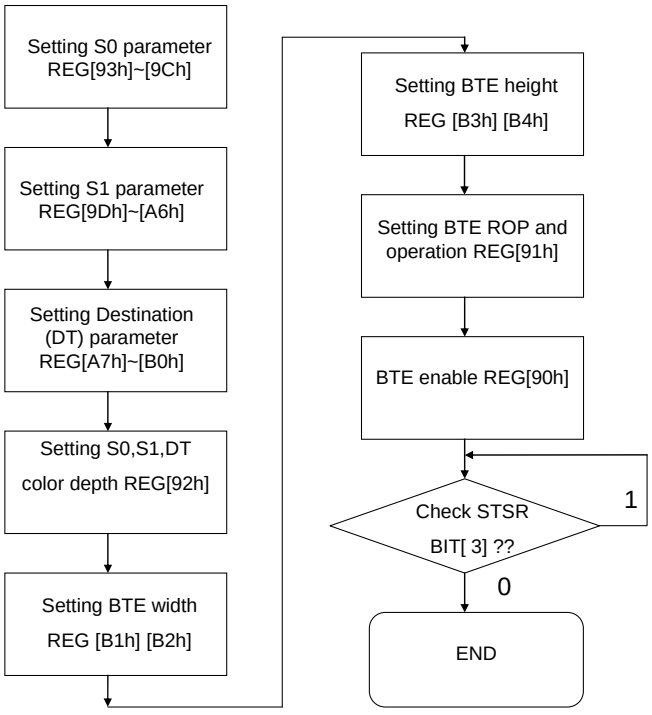


圖 4-28： 流程图

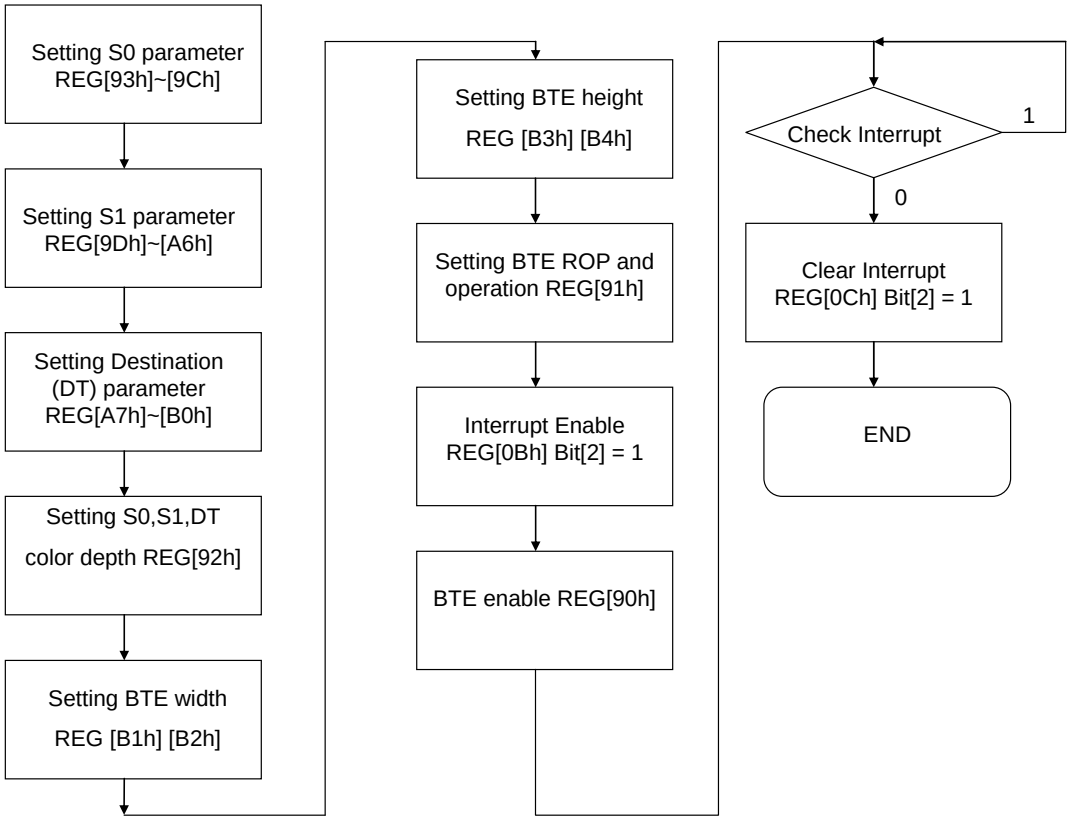


圖 4-29： 流程图 – Check Int

4.4.2: BTE Memory Copy 功能在 LCD 上的显示结果:

以下为 BTE Memory Copy API 功能的解说与范例，先利用了 BTE Solid Fill 功能画出一块填满红色的方形，以及用画圆功能画出一个黄色的实心圆(如图 4-30)，再透过 BTE Memory Copy 复制一个一样的图案(如图 4-31)。

```
void BTE_Memory_Copy
(
unsigned long S0_Addr //Start address of Source 0
,unsigned short S0_W //image width of Source 0 (recommend = canvas image width)
,unsigned short XS0 //coordinate X of Source 0
,unsigned short YS0 //coordinate Y of Source 0
,unsigned long S1_Addr //Start address of Source 1
,unsigned short S1_W //image width of Source 1 (recommend = canvas image width)
,unsigned short XS1 //coordinate X of Source 1
,unsigned short YS1 //coordinate Y of Source 1
,unsigned long Des_Addr //start address of Destination
,unsigned short Des_W //image width of Destination (recommend = canvas image width)
,unsigned short XDes //coordinate X of Destination
,unsigned short YDes //coordinate Y of Destination
,unsigned int ROP_Code
/*ROP_Code :
    0000b       0(Blackness)
    0001b       ~S0!E~S1 or ~(S0+S1)
    0010b       ~S0!ES1
    0011b       ~S0
    0100b       S0!E~S1
    0101b       ~S1
    0110b       S0^S1
    0111b       ~S0 + ~S1 or ~(S0 + S1)
    1000b       S0!ES1
    1001b       ~(S0^S1)
    1010b       S1
    1011b       ~S0+S1
    1100b       S0
    1101b       S0+~S1
    1110b       S0+S1
    1111b       1(whiteness)*/
,unsigned short X_W //X_W : Width of BTE Window
```

```
,unsigned short Y_H //Y_H : Length of BTE Window
)
```

范例:

```
/*Source 0 : Start Address = Layer1, Image Width = Panel_width, Coordinate = (0,0) .
Source 1 : Start Address = Layer1, Image Width = Panel_width, Coordinate = (0,0)
Destination: Start Address = Layer1, Image Width = Panel_width, Coordinate = (500,200) .
ROP Code = 12  →Destination = Source 0 , Don't care Source 1.
BTE Window Size = 128x128 .*/

 Write_Layer(1); //set memory read/write layer.Reference Page.5~6
 Show_Layer(1);//set LCD display layer. Reference Page.5~6
+
BTE_Solid_Fill(Layer1,Panel_width,0,0,0xe0,200,200); //8bpp color depth
Draw_Circle_Fill(0xfc,100,100,50); //8bpp color depth
or
BTE_Solid_Fill(Layer1,Panel_width,0,0,0xf800,200,200); //16bpp color depth
Draw_Circle_Fill(0xffe0,100,100,50); //16bpp color depth
or
BTE_Solid_Fill(Layer1,Panel_width,0,0,0xFF0000,200,200); //24bpp color depth
Draw_Circle_Fill(0xffff00,100,100,50); //24bpp color depth
+
BTE_Memory_Copy(Layer1,Panel_width,0,0,Layer1,Panel_width,0,0,Layer1,Panel_width,500
,200,12,200,200);
```

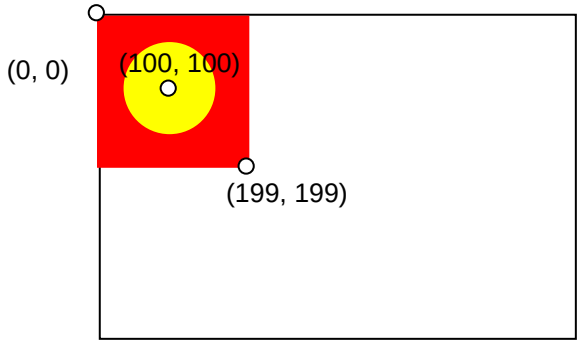


图 4-30: 在图层 1 绘一黄色的实心圆与红色实心矩形

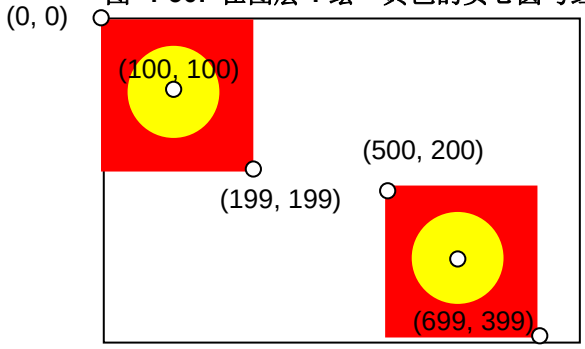


图 4-31：在图层 1 使用 BTE Memory Copy with ROP 功能复制一个一样的图案。

4.4.3:Memory Copy With Chroma Key (w/o ROP)

Memory Copy With Chroma Key (w/o ROP)的 BTE 功能，是将 SDRAM 的一个特定区块的数据，搬移到另外一个区块，而且滤掉特定的通透色。而通透色设定是在背景色缓存器。当通透色与被复制的资料是一致时，RA8873M 便会忽略这部份的显示数据，不执行写入的功能，故该目的地的区块数据不会有所改变。在这个功能下，来源 0、来源 1 以及目的地的数据区块都是在 DDRAM 里面。

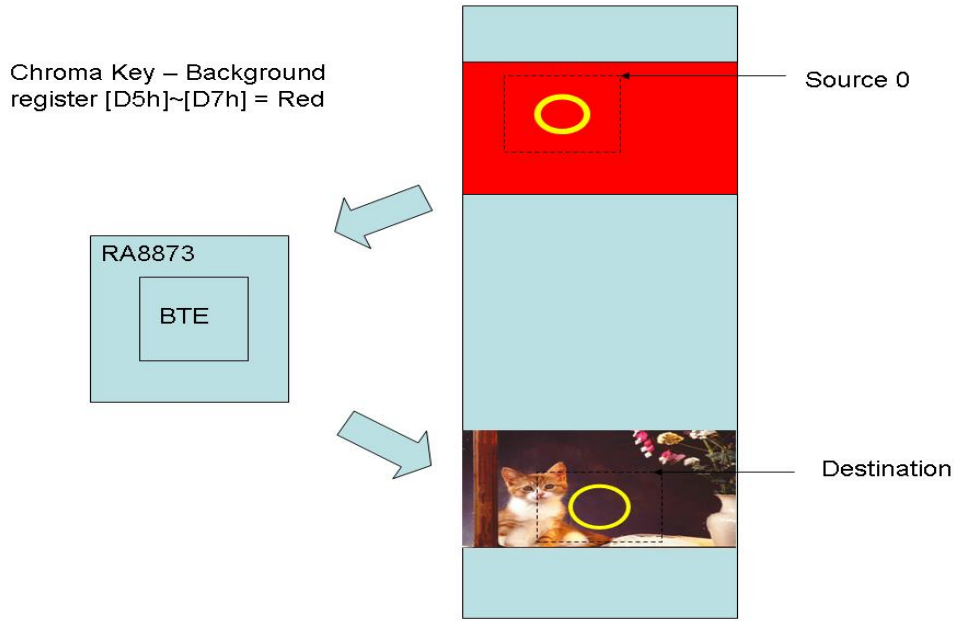


圖 4-32：硬件数据流

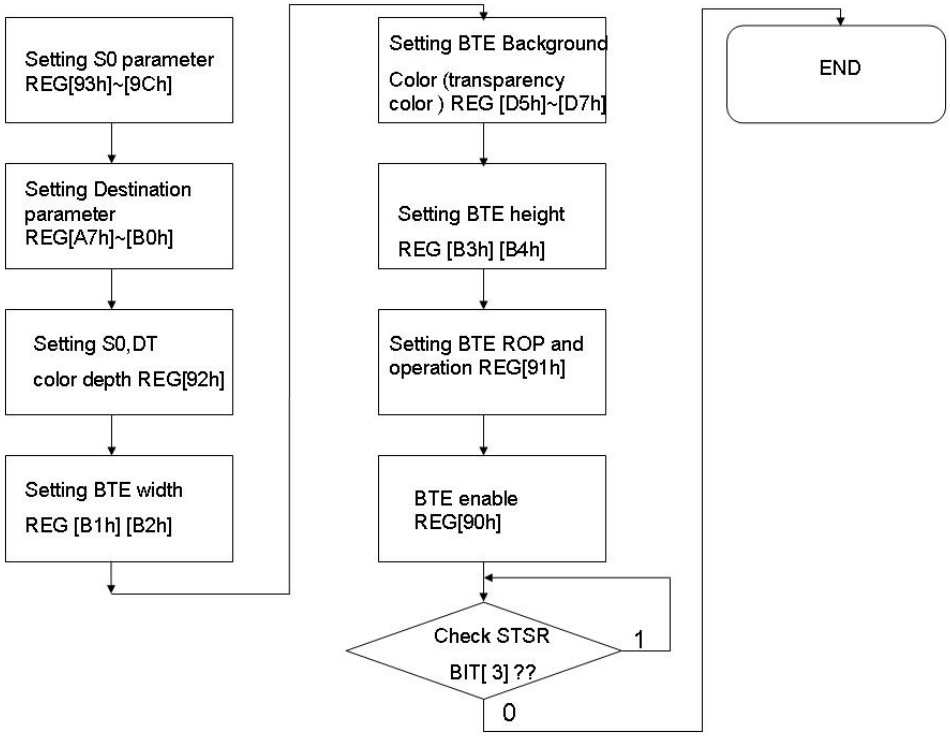


圖 4-33：流程图

4.4.4 : BTE Memory Copy with Chroma key(w/o ROP)在 LCD 上的显示说明:

以下为 BTE Memory Copy with Chroma key(w/o ROP) API 功能的解说与范例，先利用了 BTE Solid Fill 功能画出一块填满红色的方形，以及用画圆功能画出一个黄色的实心圆(如图 4-34)，再透过 BTE Memory Copy with Chroma key(w/o ROP)复制一个将红色部分滤掉的图案(如图 4-35)。

```
void BTE_Memory_Copy_Chroma_key
(
unsigned long S0_Addr //Start address of Source 0
,unsigned short S0_W //image width of Source 0 (recommend = canvas image width)
,unsigned short XS0 //coordinate X of Source 0
,unsigned short YS0 //coordinate Y of Source 0
,unsigned long Des_Addr //start address of Destination
,unsigned short Des_W //image width of Destination (recommend = canvas image width)
,unsigned short XDes //coordinate X of Destination
,unsigned short YDes //coordinate Y of Destination
,unsigned long Background_color // transparent color
,unsigned short X_W //Width of BTE Window
,unsigned short Y_H //Length of BTE Window
)
```

范例:

```
/*Source 0 : Start Address = Layer1, Image Width = Panel_width, coordinate = (0,0) .
Source 1 : Start Address = Layer1, Image Width = Panel_width, coordinate = (0,0)
Destination: Start Address = Layer1, Image Width = Panel_width, coordinate = (500,200) .
BTE Window Size = 200x200
Transparency color = 0xe0, 0xf800, 0xff0000 (Red)
In BTE Chroma Key (Transparency color) function Enable, BTE process compare source 0 data
and background color register data.*/

 Write_Layer(1); //set memory read/write layer.Reference Page.5~6
 Show_Layer(1);//set LCD display layer. Reference Page.5~6
+
//8bpp color depth
BTE_Solid_Fill(Layer1,Panel_width,0,0,0xe0,200,200);
Draw_Circle_Fill(0xfc,100,100,50);
BTE_Memory_Copy_Chroma_key(Layer1,Panel_width,0,0,Layer1,Panel_width,500,200,0xe0
,200,200);
Or
//16bpp color depth
```

```
BTE_Solid_Fill(Layer1,Panel_width,0,0,0xf800,200,200);
Draw_Circle_Fill(0xffe0,100,100,50);
BTE_Memory_Copy_Chroma_key(Layer1,Panel_width,0,0,Layer1,Panel_width,500,200,0xf800
,200,200);
or
//24bpp color depth
BTE_Solid_Fill(Layer1,Panel_width,0,0,0xFF0000,200,200);
Draw_Circle_Fill(0xffff00,100,100,50);
BTE_Memory_Copy_Chroma_key(Layer1,Panel_width,0,0,Layer1,Panel_width,500,200,0xff0000
,200,200);
```

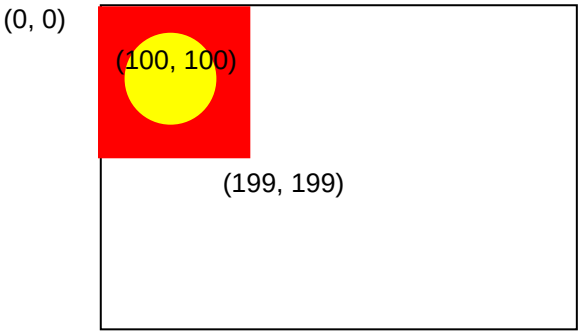


图 **4-34:** 在图层 **1** 绘一黄色的实心圆与红色实心矩形

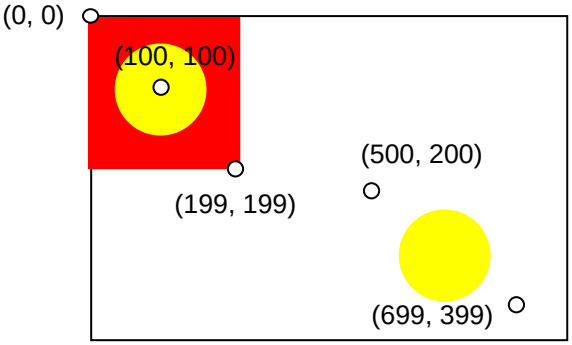


图 **4-35:** 在图层 **1** 使用 **BTE Memory Copy with chroma key** 功能复制黄色的实心圆，并过滤掉红色实心矩形的部分。

4.5.1: MCU Write With Color Expansion

MCU Write with Color Expansion 是一个很有用的功能，用來处理 MCU 的单色图形资料转换为彩色图形资料，并写入 SDRAM 中。此功能的來源资料为 MCU 提供的单色图形资料 (Monochromes Bitmap)。而每一个位根据内容被转换为 BTE 前景色或背景色。若单色数据來源为”1” 则会被转换为 BTE 前景色，若为”0” 则会转换为 BTE 背景色。此功能可以大大降低将单色系统资料转换为彩色系统资料的成本。颜色扩充功能会根据 MCU 的资料汇流排宽度，持续讀入 16 位或 8 位的资料做转换，并且可以位为单位，设定每一行的第一笔单色图形资料的起始转换位，并且在每一行的最后一笔资料讀入后，超过范围的位也会被忽略而不写入，而下一行则从下一笔资料开始执行同样的操作。这样以位为单位的运算大大增加此功能的弹性。另外，每一笔资料的处理方向是从最高位 (MBS) 至最低位 (LSB)。

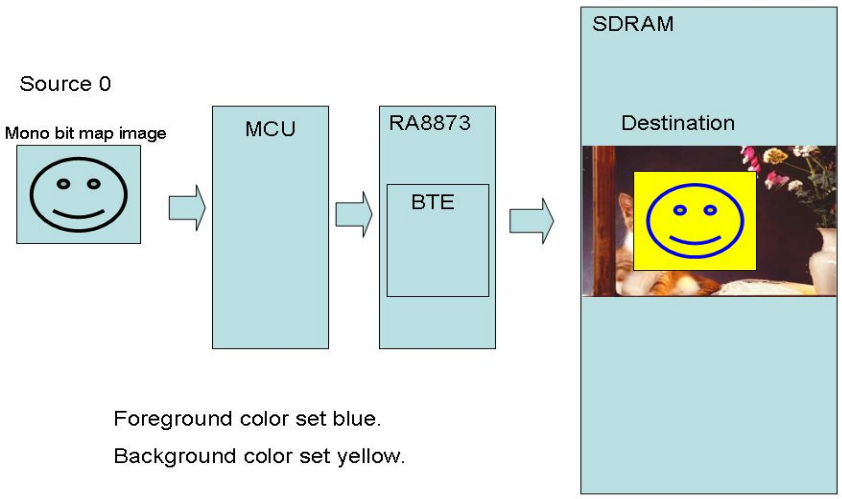


圖 4-36： 硬件数据流

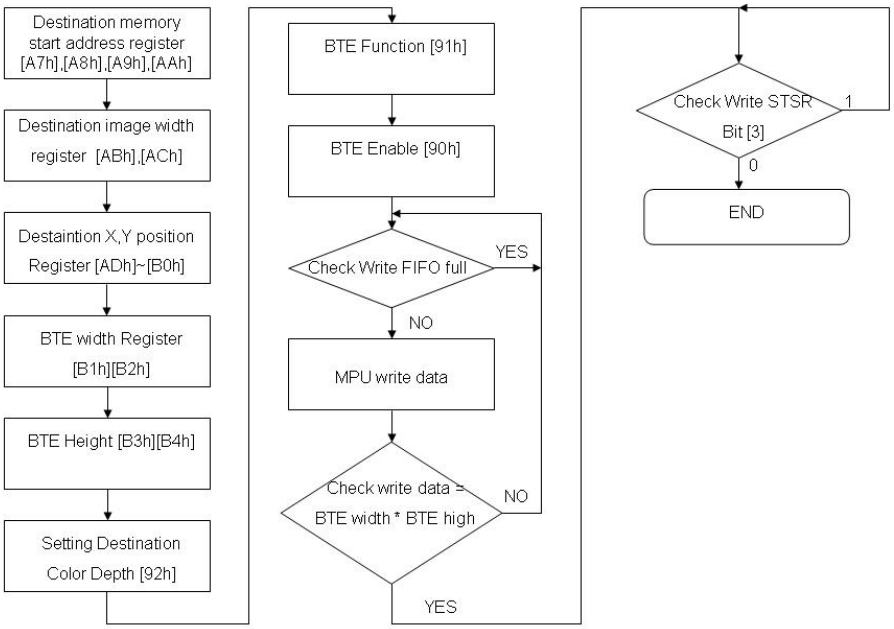


图 4-37：流程图

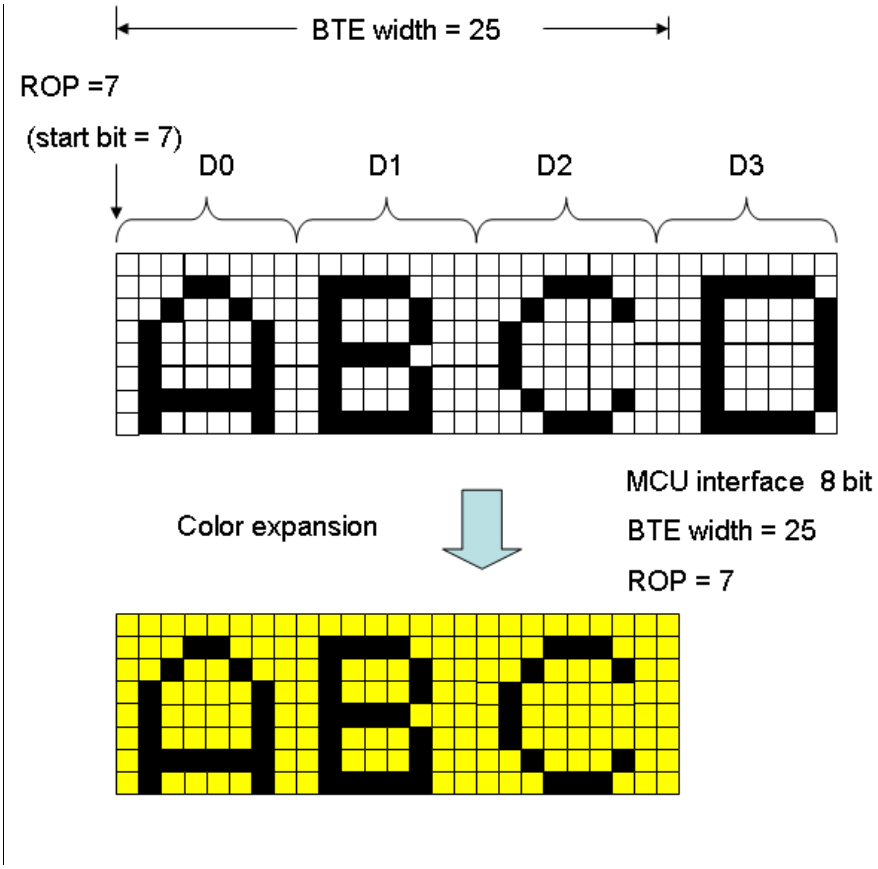


圖 4-38：起始位范例一

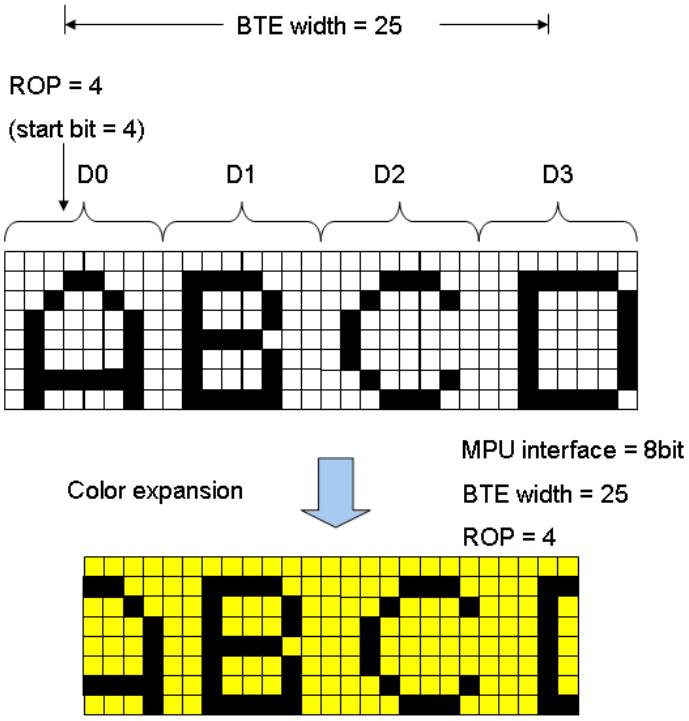


圖 4-39：起始位范例二

Note:

1. Calculate sent data numbers per row = ((BTE Width size REG – (MCU interface bits – (start bit + 1))) / MCU interface bits) + ((start bit + 1) % (MCU interface))

2. Total data number = (sent data numbers per row) x BTE Vertical REG setting

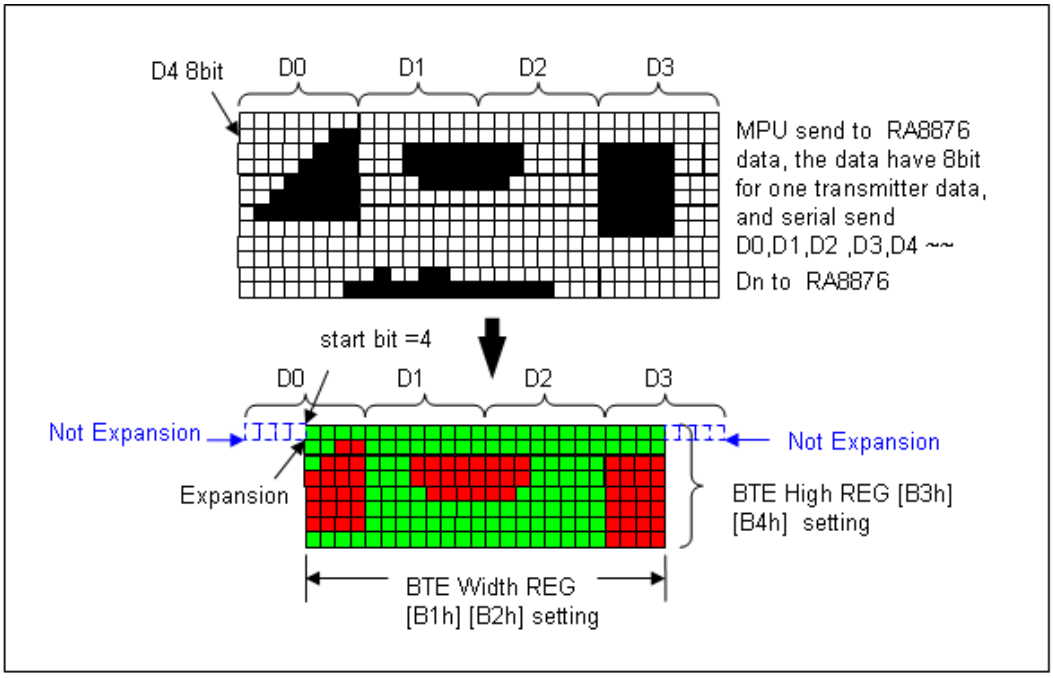


圖 4□40：Color Expansion 资料图

4.5.2: BTE MCU Write with Color Expansion 在 LCD 上的显示说明:

图 4-41 为 128x128 的单色黑白图像，假设前景色设定为绿色，背景色设定为蓝色，使用了 BTE MCU Write with Color Expansion 功能后，就会转出像图 4-42 的图案一样。以下我们针对 MCU 8bit 与 16bit 各提供一组 API 以及说明与范例供使用者参考。

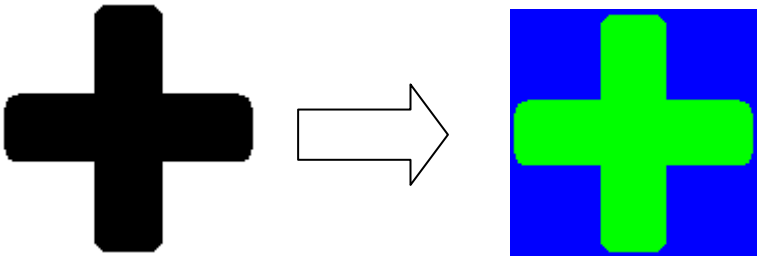


图 4-41 :
128x128 黑白单色图资

图 4-42 :
BTE with color expansion

BTE MCU Write with Color Expansion API:

```
void BTE_MCU_Write_ColorExpansion_MCU_8bit
(
unsigned long Des_Addr //start address of Destination
,unsigned short Des_W //image width of Destination (recommend = canvas image width)
,unsigned short XDes //coordinate X of Destination
,unsigned short YDes //coordinate Y of Destination
,unsigned short X_W //Width of BTE Window
,unsigned short Y_H //Length of BTE Window
,unsigned long Foreground_color
/*Foreground_color : The source (1bit map picture) map data 1 translate to Foreground color by color expansion*/
,unsigned long Background_color
/*Background_color : The source (1bit map picture) map data 0 translate to Foreground color by color expansion*/
,const unsigned char *data // 8-bit data
)
```

```
void BTE_MCU_Write_ColorExpansion_MCU_16bit
(
unsigned long Des_Addr //start address of Destination
,unsigned short Des_W //image width of Destination (recommend = canvas image width)
,unsigned short XDes //coordinate X of Destination
,unsigned short YDes //coordinate Y of Destination
,unsigned short X_W //Width of BTE Window
,unsigned short Y_H //Length of BTE Window
,unsigned long Foreground_color
/*Foreground_color : The source (1bit map picture) map data 1 translate to Foreground color by color expansion*/
,unsigned long Background_color
/*Background_color : The source (1bit map picture) map data 0 translate to Background color by color expansion*/
,const unsigned short *data //16-bit data
)
```

范例:

```
/*Des_Addr : start address of Destination = Layer1
Des_W : image width of Destination (recommend = canvas image width) = Panel_width
XDes : coordinate X of Destination = 0
YDes : coordinate Y of Destination =0
X_W : Width of BTE Window =128
Y_H : Length of BTE Window =128
Foreground_color : The source (1bit map picture) map data 1 translate to Background color by color expansion = 0x03(8bpp)、0x001f(16bpp)、0x0000ff(24bpp) (Blue)
Background_color : The source (1bit map picture) map data 0 translate to Foreground color by color expansion = 0x1c(8bpp)、0x07e0(16bpp)、0x00ff00(24bpp) (Green)
When ColorDepth =8bpp */

Write_Layer(1); //set memory read/write layer.Reference Page.5~6
Show_Layer(1);//set LCD display layer. Reference Page.5~6
+
//MCU_8bit_ColorDepth_8bpp                    //setting in UserDef.h
BTE_MCU_Write_ColorExpansion_MCU_8bit(Layer1,Panel_width,0,0,128,128,0x03,0x1c,gImage_1);
or
//MCU_8bit_ColorDepth_16bpp                    //setting in UserDef.h
BTE_MCU_Write_ColorExpansion_MCU_8bit(Layer1,Panel_width,0,0,128,128,0x001f,0x07e0,gImage_1);
```

```
or
//MCU_8bit_ColorDepth_24bpp                    //setting in UserDef.h
BTE_MCU_Write_ColorExpansion_MCU_8bit(Layer1,Panel_width,0,0,128,128,0x0000ff,0x00ff00
,gImage_1);
or
//MCU_16bit_ColorDepth_16bpp                   //setting in UserDef.h
BTE_MCU_Write_ColorExpansion_MCU_16bit(Layer1,Panel_width,0,0,128,128,0x001f,0x07e0,Test);
or
//MCU_16bit_ColorDepth_24bpp_Mode_1            //setting in UserDef.h
BTE_MCU_Write_ColorExpansion_MCU_16bit(Layer1,Panel_width,0,0,128,128,0x0000ff,0x00ff00,Test);
or
//MCU_16bit_ColorDepth_24bpp_Mode_2            //setting in UserDef.h
BTE_MCU_Write_ColorExpansion_MCU_16bit(Layer1,Panel_width,0,0,128,128,0x0000ff,0x00ff00,Test);
```

LCD 上的显示画面:

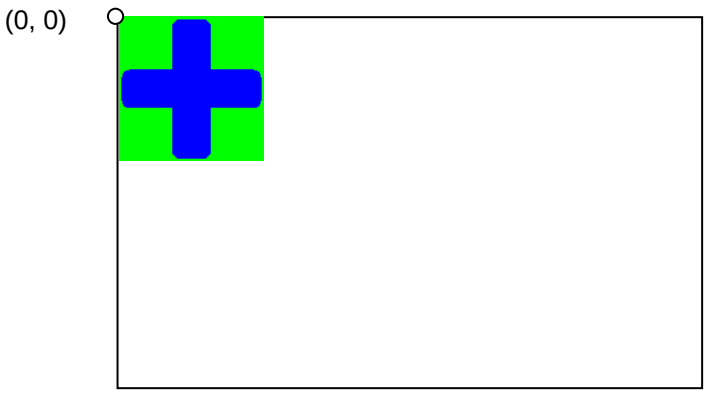


图 4-43：在图层 1 使用 BTE MCU Write with Color Expansion

4.5.3: MCU Write with Color Expansion and Chroma key

除了将 BTE 的背景色忽略，用来当作通透色，此 BTE 功能与 BTE MCU Write with Color Expansion 功能几乎是相同的。就是所有输入单色数据值为”1” 的位将会被转换为 BTE 的前景色并且写入目的位置，所有输入单色数据值为”0” 的位将不被转换，而保持原來的目的资料颜色值。

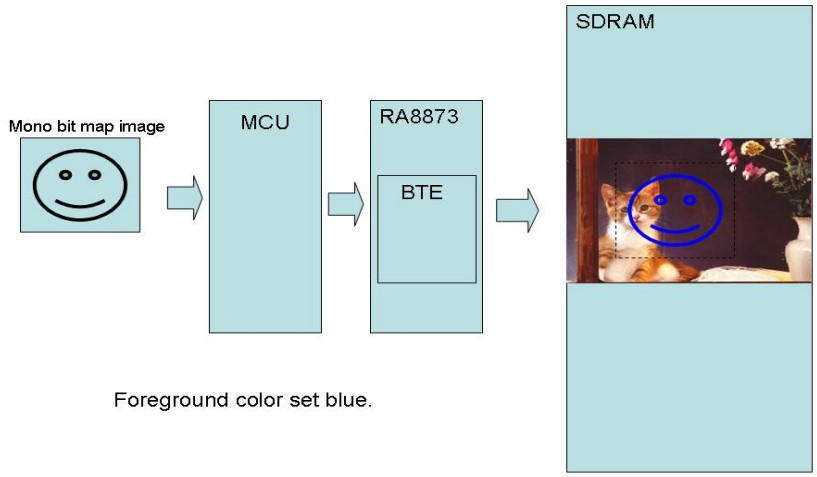


圖 4-44：硬件数据流

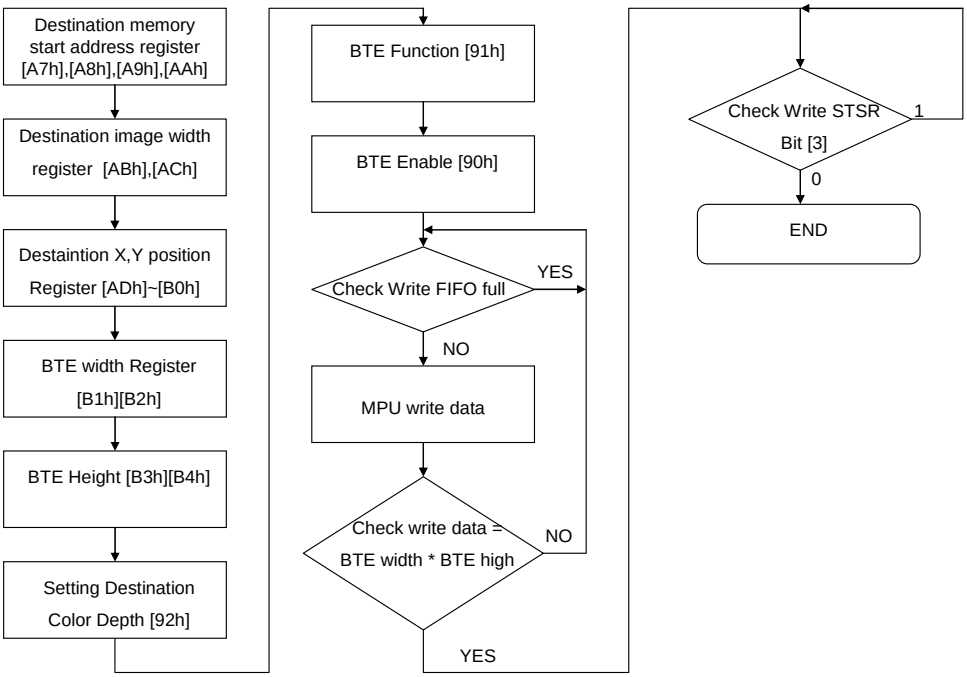


圖 4-45：流程图

4.5.4: BTE MCU Write With Color Expansion and Chroma key 的 API 在 LCD 上的显示说明:

图 4-46 为范例所用到的 128x128 黑白的单色图，透过 BTE MCU Write With Color Expansion and Chroma key 功能，可以转换成其它颜色的图案，图 4-47 就是将图 4-46 使用了此功能后将原本的图转换成绿色。以下我们也分别针对 MCU8bit 与 16bit 提供了两组 API 以及范例说明。

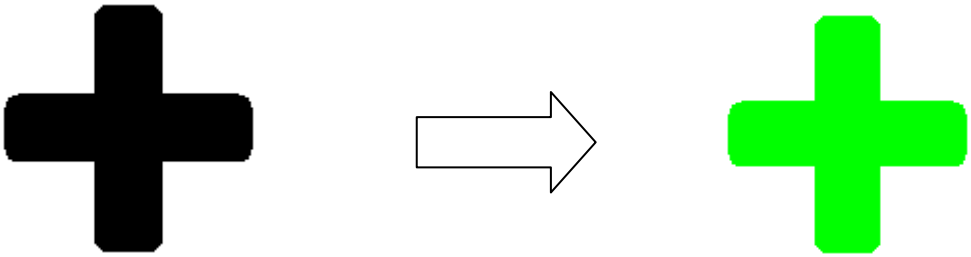


图 4-46 :
128x128 黑白单色图资

图 4-47 :
BTE with color expansion and Chroma key

API:

```
void BTE_MCU_Write_ColorExpansion_Chroma_key_MCU_8bit
(
unsigned long Des_Addr //start address of Destination
,unsigned short Des_W //image width of Destination (recommend = canvas image width)
,unsigned short XDes //coordinate X of Destination
,unsigned short YDes //coordinate Y of Destination
,unsigned short X_W //Width of BTE Window
,unsigned short Y_H //Length of BTE Window
,unsigned long Foreground_color
/*Foreground_color : The source (1bit map picture) map data 1 translate to Foreground color by color expansion*/
,const unsigned char *data //8-bit data
)

void BTE_MCU_Write_ColorExpansion_Chroma_key_MCU_16bit
(
unsigned long Des_Addr //start address of Destination
,unsigned short Des_W //image width of Destination (recommend = canvas image width)
,unsigned short XDes //coordinate X of Destination
,unsigned short YDes //coordinate Y of Destination
,unsigned short X_W //Width of BTE Window
,unsigned short Y_H //Length of BTE Window
,unsigned long Foreground_color
```

```
/*Foreground_color : The source (1bit map picture) map data 1 translate to Foreground color by color expansion*/
,const unsigned short *data //16-bit data
)
```

范例:

```
/*Des_Addr : start address of Destination = Layer1
Des_W : image width of Destination (recommend = canvas image width) = Panel_width
XDes : coordinate X of Destination = 0
YDes : coordinate Y of Destination =0
X_W : Width of BTE Window =128
Y_H : Length of BTE Window =128
Foreground_color : The source (1bit map picture) map data 1 translate to Foreground color by color expansion = 0xe0 (8bpp)、0xf800 (16bpp)、0xff0000 (24bpp) (Red)*/
Write_Layer(1); //set memory read/write layer.Reference Page.5~6
Show_Layer(1);//set LCD display layer. Reference Page.5~6
+
//MCU_8bit_ColorDepth_8bpp                          //setting in UserDef.h
BTE_MCU_Write_ColorExpansion_Chroma_key_MCU_8bit(Layer1,Panel_width,0,0,128,128,0xe0
,gImage_1);
or
//MCU_8bit_ColorDepth_16bpp                         //setting in UserDef.h
BTE_MCU_Write_ColorExpansion_Chroma_key_MCU_8bit(Layer1,Panel_width,0,0,128,128,0xf800
,gImage_1);
or
//MCU_8bit_ColorDepth_24bpp                         //setting in UserDef.h
BTE_MCU_Write_ColorExpansion_Chroma_key_MCU_8bit(Layer1,Panel_width,0,0,128,128,0xff0000
,gImage_1);
or
//MCU_16bit_ColorDepth_16bpp                        //setting in UserDef.h
BTE_MCU_Write_ColorExpansion_Chroma_key_MCU_16bit(Layer1,Panel_width,0,0,128,128,0xf800
,Test);
or
//MCU_16bit_ColorDepth_24bpp_Mode_1                 //setting in UserDef.h
BTE_MCU_Write_ColorExpansion_Chroma_key_MCU_16bit(Layer1,Panel_width,0,0,128,128,0xff0000
,Test);
or
//MCU_16bit_ColorDepth_24bpp_Mode_2                 //setting in UserDef.h
```

BTE_MCU_Write_ColorExpansion_Chroma_key_MCU_16bit(Layer1,Panel_width,0,0,128,128,0xff0000 ,Test);

LCD 实际画面:

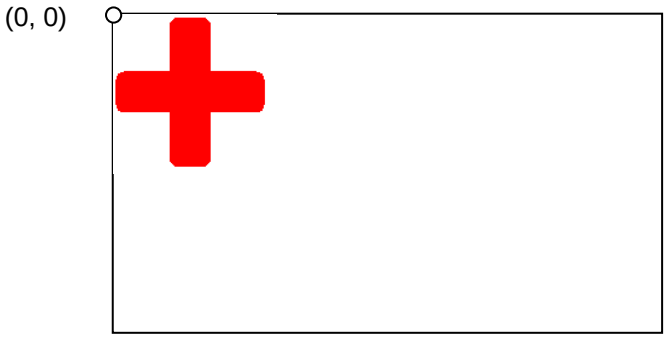


图 4-48 : BTE MCU Write With Color Expansion and Chroma key (w/o ROP)

4.6 :BTE Alpha Blending

概要:

在许多显示功能中，alpha blending 是一张图像与其它层的显示数据在画面上做出半透明的效果。RA8873M 也提供了硬件做 Alpha Blending 的功能，使用者不用花费很多的系统资源，就可以得到更绚丽的显示效果。这份应用说明书将帮助我们的使用者，去了解并使用 RA8873M 的 Alpha Blending 功能。

4.6.1: Memory Copy with Alpha Blending

“Memory Copy with Alpha blending”这个功能可以混合来源 0 与来源 1 的显示数据，并将合并的结果显示在目的地的显示区块。这个功能有两种模式 – Picture mode 与 Pixel mode，Picture mode 可以操作在 8bpp/16bpp/24bpp 模式下。Pixel mode 只能操作在 8bpp/16bpp 模式下。在 16bpp 的 pixel mode 下，来源 1 资料的 bit[15:12]为 alpha level，其它的位是色彩数据，在 8 bpp 的 pixel mode 下，来源 1 资料的 bit[7:6]为 alpha level。Bit[5:0]用来指定调色盘上的色彩数据。

Picture mode 的目的地资料 = (来源 0* (1- alpha Level)l) + (来源 1 * alpha Level)

Pixel mode 16bpp 下的目的地资料 = (来源 0 * (1 - alpha Level)) + (来源 1 [11:0] * alpha Level)

Pixel mode 8bpp 下的目的地数据 = (来源 0 * (1 - alpha Level)) + (调色盘索引 (Source 1[5:0]) * alpha Level)

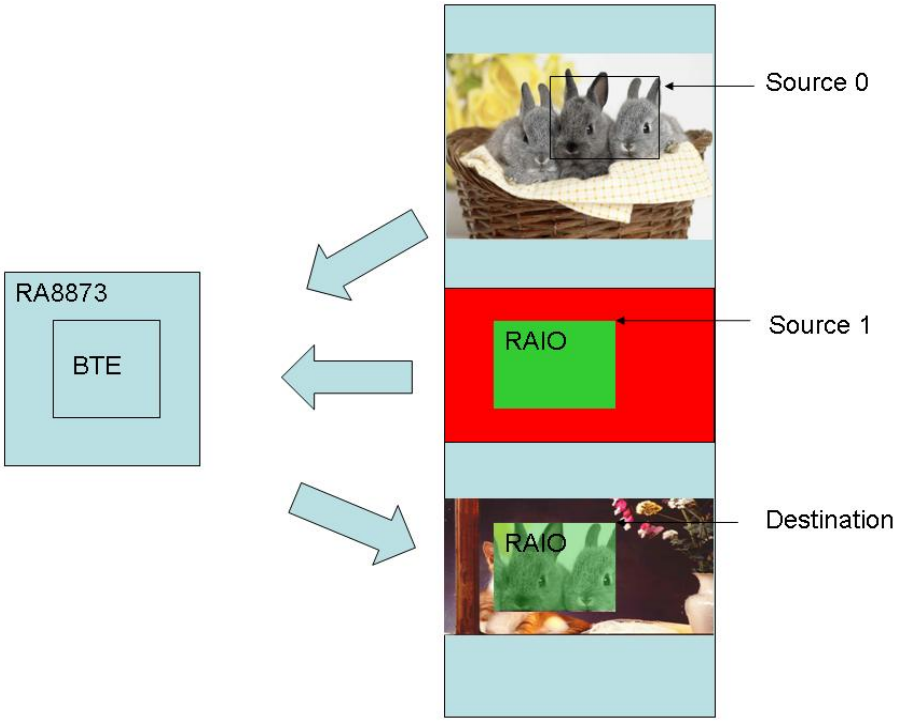


圖 4-49 : Picture Mode 硬件数据流

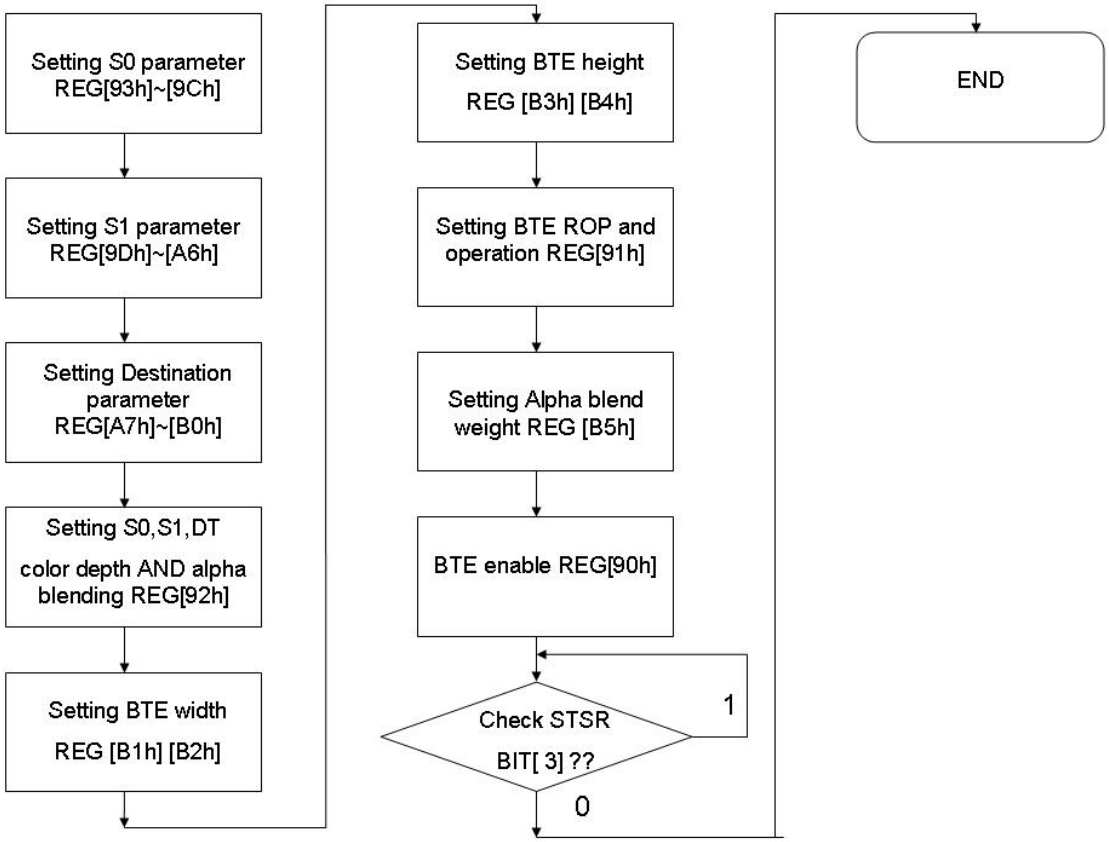


圖 4-50 : Picture Mode 流程图

4.6.2: BTE Memory Copy with Alpha Blending in Picture mode 在 LCD 上的显示说明:

“Memory Copy with Alpha blending”这个功能可以混合来源 0 与来源 1 的数据，然后显示在目的地的显示区块。

这个功能有两种模式 – Picture mode 与 Pixel mode，在这边，我们使用 picture mode 做说明。

Picture mode 目的地资料 = (来源 0 * (1- alpha Level)l) + (来源 1 * alpha Level)

```
void BTE_Alpha_Blending
(
unsigned long S0_Addr //Start address of Source 0
,unsigned short S0_W //image width of Source 0 (recommend = canvas image width)
,unsigned short XS0 //coordinate X of Source 0
,unsigned short YS0 //coordinate Y of Source 0
,unsigned long S1_Addr //Start address of Source 1
,unsigned short S1_W //image width of Source 1 (recommend = canvas image width)
,unsigned short XS1 //coordinate X of Source 1
,unsigned short YS1 //coordinate Y of Source 1
,unsigned long Des_Addr //start address of Destination
,unsigned short Des_W //image width of Destination (recommend = canvas image width)
,unsigned short XDes //coordinate Y of Destination
,unsigned short YDes //coordinate Y of Destination
,unsigned short X_W //Width BTE Window
,unsigned short Y_H //Length BTE Window
,unsigned char alpha
//alpha : Alpha Blending effect 0 ~ 32, Destination data = (Source 0 * (1- alpha)) + (Source 1 * alpha)
)
```

范例:

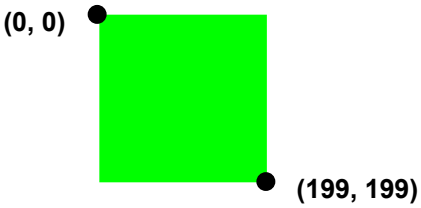
```
/*Source 0 : Start Address = Layer1, Image Width = Panel_width, coordinate = (0,0) .
Source 1 : Start Address = Layer2, Image Width = Panel_width, coordinate = (0,0) .
Destination: Start Address = Layer1, Image Width = Panel_width, coordinate = (0,0) .
BTE Window Size = 200x200 , alpha = 16 .*/
Write_Layer(1); //set memory read/write layer.Reference Page.5~6
Show_Layer(1);//set LCD display layer. Reference Page.5~6
+
//When Color Depth = 8bpp
DMA_24bit(1,0,0,0,800,480,800,0);
BTE_Solid_Fill(Layer2,Panel_width,0,0,0x1c,200,200);
or
//When Color Depth = 16bpp
DMA_24bit(1,0,0,0,800,480,800,0);
BTE_Solid_Fill(Layer2,Panel_width,0,0,0x07e0,200,200);
```

or

```
//When Color Depth = 24bpp
DMA_24bit(1,0,0,0,800,480,800,0);
BTE_Solid_Fill(Layer2,Panel_width,0,0,0x00FF00,200,200);
+
BTE_Alpha_Blending(Layer1,Panel_width,0,0,Layer2,Panel_width,0,0,Layer1,Panel_width,0,0,200,200
,16);
```

图层 1 资料:

图层 2 资料:



LCD 实际画面:

图 4-51: 来源 0 从图层 1 的(0,0)到(199,199) ,来源 1 从图层 2(0,0)到(199,199)，在 alpha 值为 16 下，使用 alpha blending 并且显示在目的地，图层 1 的[(0,0)到(199,199]。

目的地:

alpha = 0　alpha = 8　alpha = 16　alpha = 24　alpha = 32

图 4-52: 在不同 alpha level 下的目的地数据。

Picture mode - Destination data = (Source 0 * (1- alpha Level)) + (Source 1 * alpha Level);

第 5 章 ：Picture In Picture Function

5.1:PIP Window

RA8873M 在主要显示窗口里，支持使用者可以使用两个 PIP 窗口。PIP 窗口不支持通透功能，它仅提供使用者开启或关闭将图片数据覆盖在主显示画面上。当 PIP1 与 PIP2 画面重迭时，PIP1 会覆盖在 PIP2 之上。PIP 窗口的位置与大小由 REG[2Ah]到 REG[3Bh]与 REG[11h]来设定，PIP1 与 PIP2 共享设定缓存器，而且根据 REG[10h] 的 Bit[4]，去选择 REG[2Ah~3Bh]是 PIP1 或是 PIP2 窗口的参数。而相关的 PIP window 功能可经由若干功能位做设置。PIP 窗口大小与起始位置水平方向是 4 个像素为一个单位，垂直则为一个像素。

5.2:PIP Windows Settings

一个 PIP 窗口的位置与大小是由 PIP 图像起始地址、PIP 图像宽度、PIP 显示 X/Y 坐标、PIP 图像 X/Y 座标、PIP 窗口的色彩深度、PIP 窗口的宽度与高度等等的缓存器来界定。PIP1 与 PIP2 共享设定缓存器，然后根据 REG[10h]Bit[4]来选择 REG[2Ah~3Bh]是 PIP1 或 PIP2 窗口的参数设定。

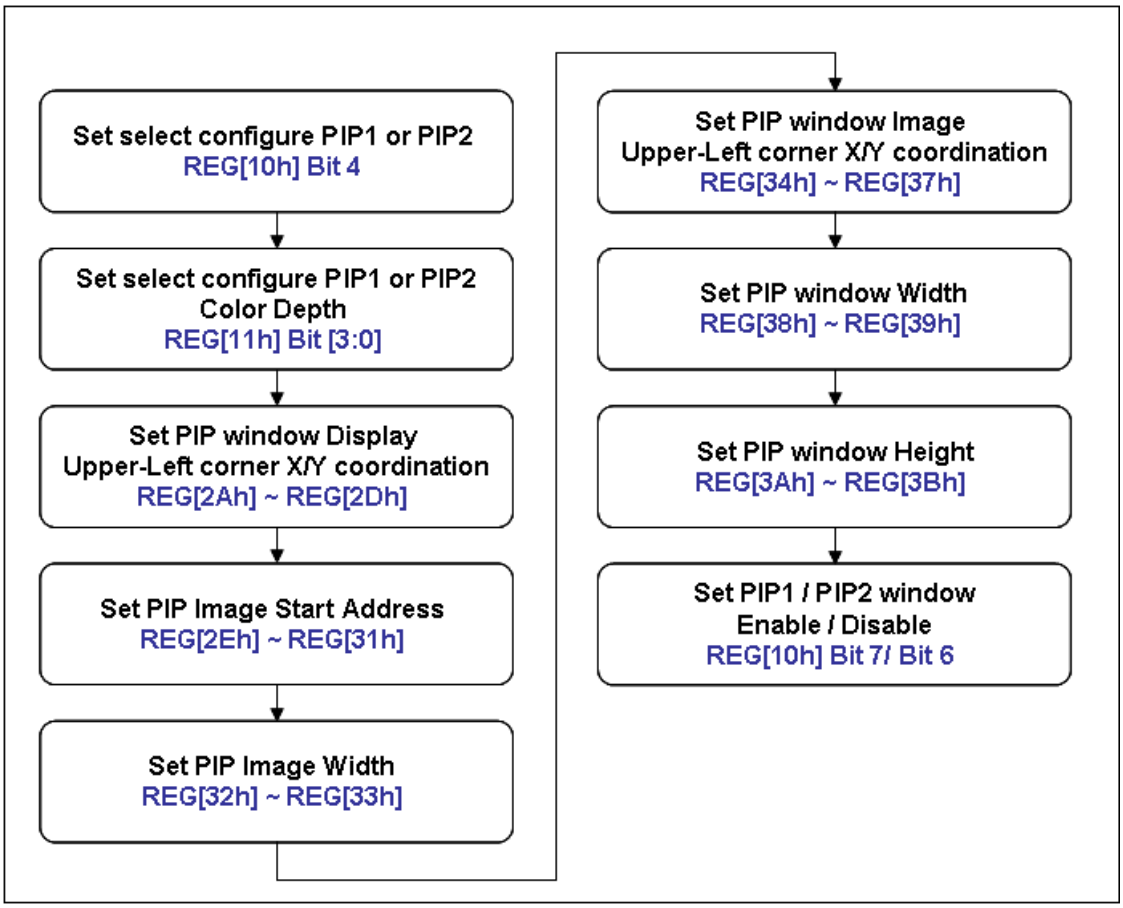


圖 5-1： 流程图

5.3: PIP 功能图解:

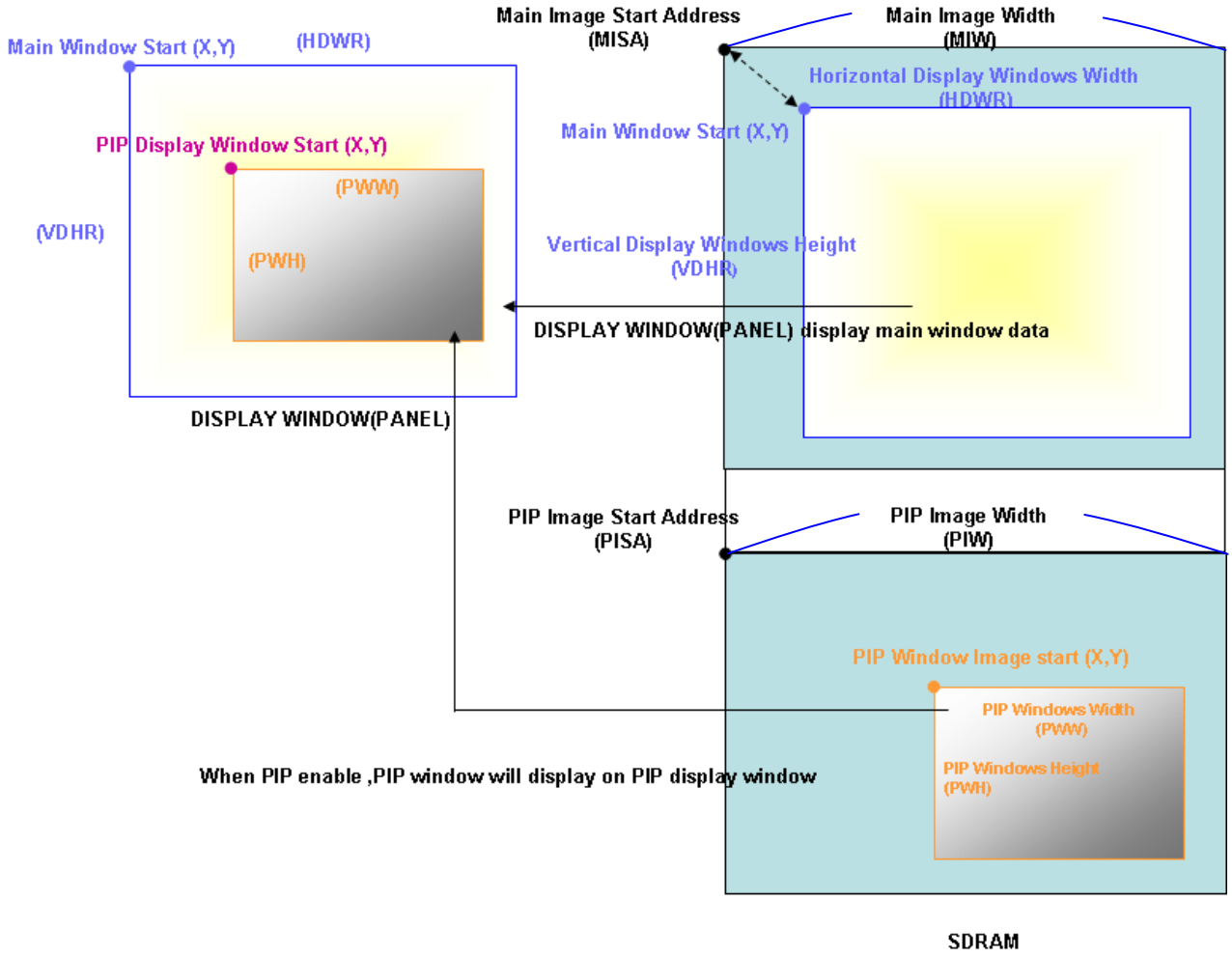


图 5-2

5.4:PIP 功能在 LCD 上的显示说明:

RA8873M 支持使用者可以使用两个 PIP 窗口。PIP 窗口不支持通透功能，它仅提供使用者开启或关闭将图片数据覆盖在主显示画面上。当 PIP1 与 PIP2 画面重迭时，PIP1 会覆盖在 PIP2 之上。这个应用程序接口将会帮助使用者容易的去使用 PIP 这个功能。

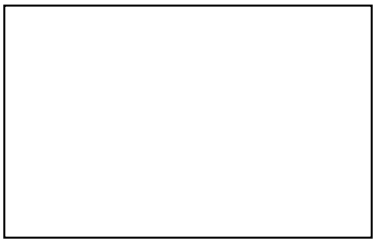
```
void PIP
(
unsigned char On_Off // 0 : disable PIP, 1 : enable PIP, 2 : To maintain the original state
,unsigned char Select_PIP // 1 : use PIP1 , 2 : use PIP2
,unsigned long PAddr //start address of PIP
,unsigned short XP //coordinate X of PIP Window, It must be divided by 4.
,unsigned short YP //coordinate Y of PIP Window, It must be divided by 4.
,unsigned long ImageWidth //Image Width of PIP (recommend = canvas image width)
,unsigned short X_Dis //coordinate X of Display Window
,unsigned short Y_Dis //coordinate Y of Display Window
,unsigned short X_W //width of PIP and Display Window, It must be divided by 4.
,unsigned short Y_H //height of PIP and Display Window , It must be divided by 4.
)
```

范例: (DMA 功能部分请参考第三章)

```
Write_Layer(2);//set memory read/write layer.Reference Page.5~6
Show_Layer(1); //set LCD display layer. Reference Page.5~6
+
//When color depth
DMA_24bit(1,0,0,0,800,480,800,5376000);//write 800x480 picture to layer 2
Write_Layer(3); //set memory read/write layer.Reference Page.5~6
DMA_24bit(1,0,0,0,800,480,800,5760000); //write 800x480 picture to layer 3
Or
//When color depth = 16bpp
DMA_24bit(1,0,0,0,800,480,800,3225600); //write 800x480 picture to layer 2
Write_Layer(3); //set memory read/write layer.Reference Page.5~6
DMA_24bit(1,0,0,0,800,480,800,3993600); //write 800x480 picture to layer 3
Or
//When color depth = 24bpp (just support to 640x480)
DMA_24bit(1,0,0,0,640,480,640,0); //write 640x480 picture to layer 2
Write_Layer(3); //set memory read/write layer.Reference Page.5~6
DMA_24bit(1,0,0,0,640,480,640,1152000); //write 640x480 picture to layer 3
+
PIP(1,1,Layer2,0,0,Panel_width,0,0,400,480);
PIP(1,2,Layer3,0,0,Panel_width,400,0,400,480);
```

步骤 1： 利用 DMA 功能将欲显示图片数据写入 RA8873M 的 SDRAM 中

Layer 1 data:



800x480 fill white color

Layer 2 data:

800x480 picture

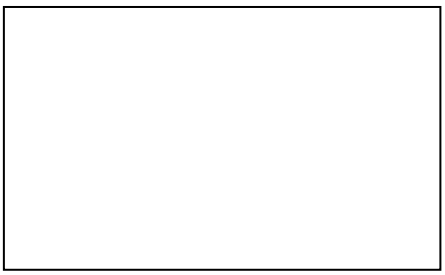
Layer 3 data:

800x480 picture

步骤 2：

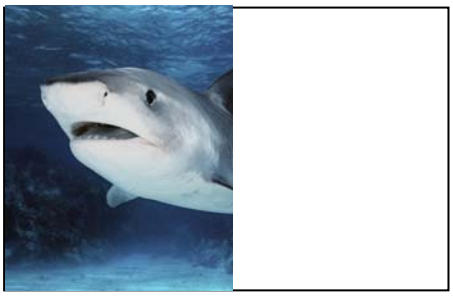
打开 PIP window 显示，PIP 1 窗口为 Layer 2 的(0,0)到(399,479)，显示位置为 Layer 1 的(0,0)到(399,479)。PIP 2 窗口为 Layer 3 的(0,0)到(399,479)，显示位置为 Layer 1 的(400,0)到(799,479)，LCD 画面显示 Layer 1 数据。

当 PIP 1 与 PIP2 关闭时 LCD 显示画面:

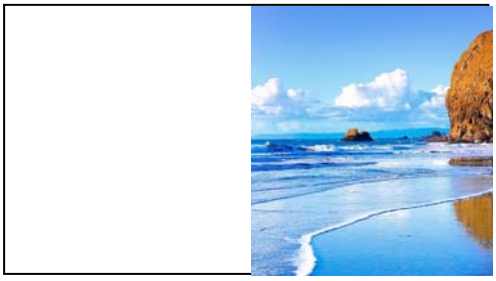


当 PIP 1 与 PIP2 同时开启时 LCD 显示画面:

当 PIP 1 开启、PIP2 关闭时 LCD 显示画面:



当 PIP 1 关闭、PIP2 开启时 LCD 显示画面:



第六章 ： 文字

RA8873M 可支持两种字库来源，分为内建字库与外部字库，内建字库支持 ISO/IEC 8859-1/2/4/5 等字型。外部字库搭配上海集通公司 (Genitop Inc) 的部分串列字型 ROM，可支持多国字库或字型标准的显示，如 ASIC, GB12345, GB18030 , GB2312 Special, BIG5, UNI-jpn, JIS0208, Latin, Greek, Cyrillic, Arabic, UNICODE, Hebrew, Thai, ISO-8859 以及 GB2312 Extension 等等

RA8873M 的文字输入可分为两种来源:

1. 内建字 .
2. 外部字型 ROM .

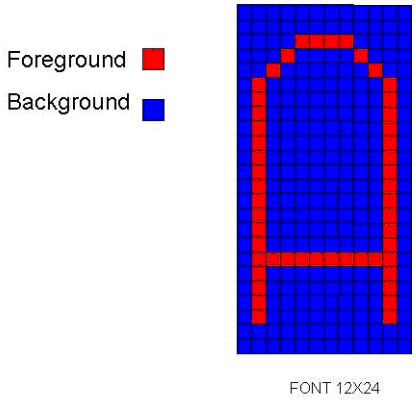


圖 6-1： 范例

文字有一些参数设定，在 REG[CCh]~REG[DEh]，当你需要改变任何的字型参数，你可以参考下面的流程图。

字型的颜色设定在前景色与背景色的缓存器 REG[D2h]~[D7h]。

例如：我们写 font1 与 font2 两笔字符串，各别有 64 笔字库的资料。

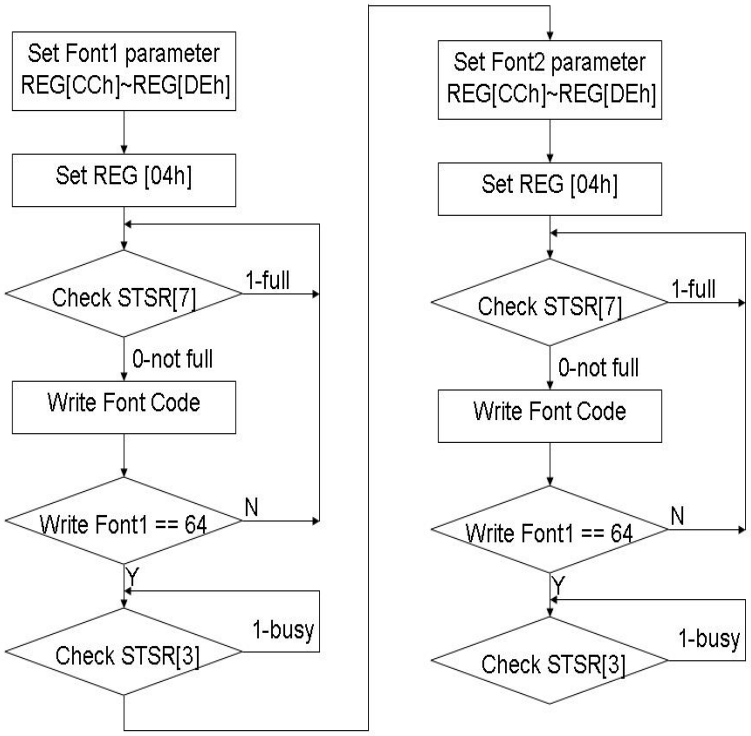


圖 6-2：文字显示流程图

内建字

RA8873M 内建 8x16,12x24,16x32 点的 ASCII 字型 ROM，提供使用者更方便的方式，用特定编码 (Code) 输入文字。内建的字集支持 ISO/IEC 8859-1/2/4/5 编码标准，此外，使用者可以透过 REG[D2h~D4h] 选择文字前景颜色，以及透过 REG[D5h~D7h] 选择背景颜色，文字写入的程序请参考下图:

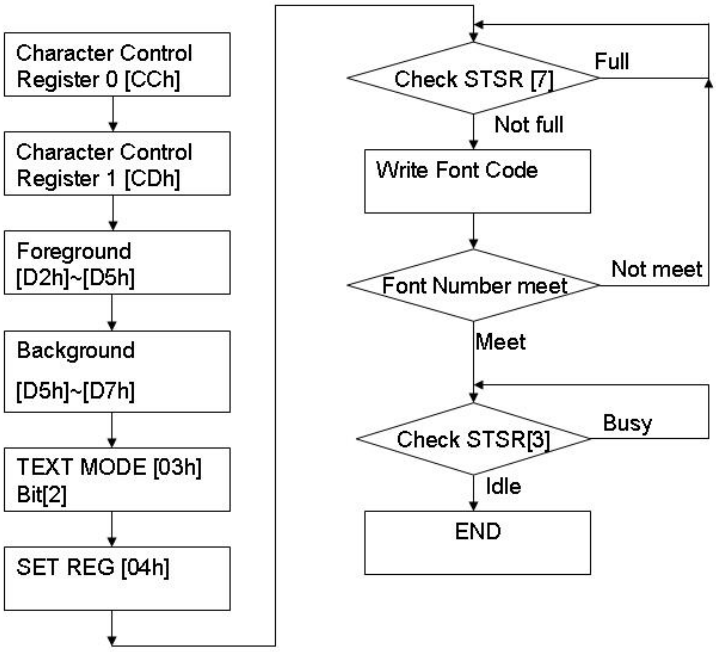


圖 6-3：內部 ASCII 字库使用流程

表 6-1 内含 ISO/IEC 8859-1 标准的字集。ISO 是国际标准化组织的简称，ISO/IEC 8859-1 又称 ”Latin-1” 或「西欧语言」，是国际标准化组织内 ISO/IEC 8859 的第一个发展的 8 位字集。以 ASCII 为基础，包含了 0xA0 到 0xFF 的范围内 192 个拉丁字母及符号。此字集编码使用遍及西欧，包括阿尔巴尼亚语、巴斯克语、布列塔尼语、加泰羅尼亚语、丹麦语、荷蘭语、法羅语、弗裡斯语 (Frisian)、加利西亚语、德语、格陵蘭语、冰岛语、爱尔蘭盖尔语、义大利语、义大利语、拉丁语、盧森堡语、挪威语、葡萄牙语、里托羅曼斯语、苏格蘭盖尔语、西班牙语及瑞典语。

英语虽然没有重音字母，但仍会标明为 ISO 8859-1 编码，欧洲以外的部份语言，如南非荷蘭语、斯瓦希里 语、印度尼西亚语及马來语、菲律宾他加洛语 (Tagalong) 也可使用 ISO8859-1 编码。

表 6-1 : ASCII Block 1(ISO/IEC 8859-1)

L\H	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0		☺	☻	♥	♦	♣	♠	•	◘	○	◙	♂	♀	♪	♫	☼
1	►	◄	↕	‼	¶	§	▬	↨	↑	↓	→	←	∟	↔	▲	▼
2		!	”	#	$	%	&	’	(	)	*	+	,	—	.	/
3	0	1	2	3	4	5	6	7	8	9	:	;	<	=	>	?
4	@	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
5	P	Q	R	S	T	U	V	W	X	Y	Z	[	\	]	^	_
6	`	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o
7	p	q	r	s	t	u	v	w	x	y	z	{	|	}	~	
8	€		‚	ƒ	„	…	†	‡	ˆ	‰	Š	<	Œ		Ž	
9		‘	’	“	”	•	–	—	˜	™	š	>	œ		ž	Ÿ
A		¡	¢	£	¤	¥	¦	§	¨	©	ª	«	¬	-	®	¯
B	°	±	2	3	´	µ	¶	·	¸	1	0	»	¼	½	¾	¿
C	À	Á	Â	Ã	Ä	Å	Æ	Ç	È	É	Ê	Ë	Ì	Í	Î	Ï
D	Ð	Ñ	Ò	Ó	Ô	Õ	Ö	×	Ø	Ù	Ú	Û	Ü	Ý	Þ	ß
E	à	á	â	ã	ä	å	æ	ç	è	é	ê	ë	ì	í	î	ï
F	ð	ñ	ò	ó	ô	õ	ö	÷	ø	ù	ú	û	ü	ý	þ	ÿ

表 6-2 内为 ISO/IEC 8859-2 的标准字集，又称 Latin-2 或「中欧语言」，是国际标准化组织内 ISO/IEC 8859 的第二个 8 位字符集。此字符集主要支持以下文字：克羅埃西亚语、捷克语、匈牙利语、波蘭语、斯洛伐克语、斯洛维尼亚语、索布语。而阿尔巴尼亚语、英语、德语、拉丁语也可用此字符集显示。芬蘭语中只有外來语才有 å 字符，若不考虑此字符，ISO/IEC8859-2 也可用于瑞士及芬蘭语。

表 6-2: ASCII Block 2 (ISO/IEC 8859-2)

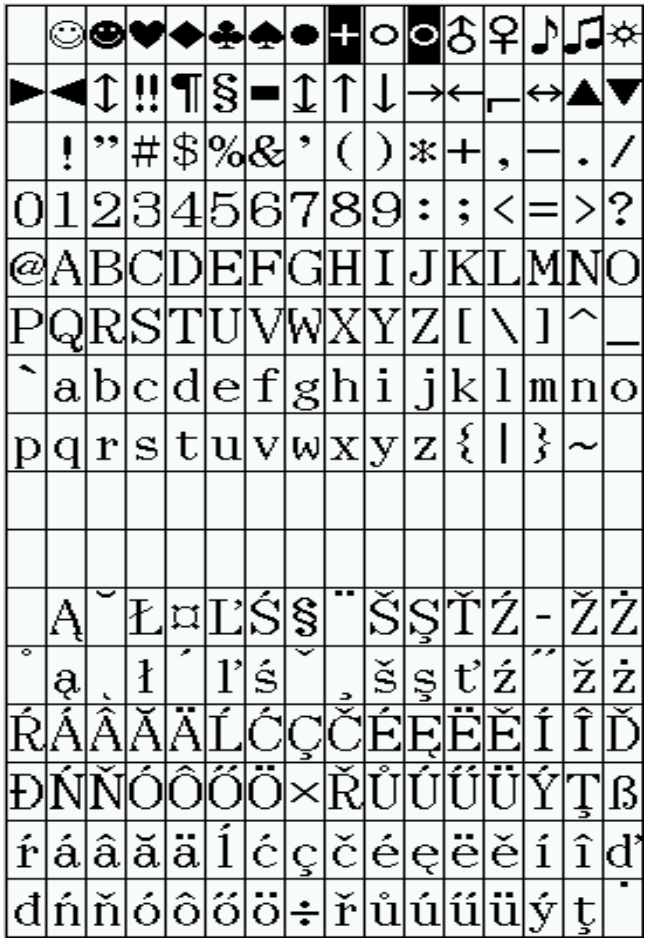


表 6-3 内为 ISO/IEC 8859-4 之标准字集，又称 Latin-4 或「北欧语言」，是国际标准化组织内 ISO/IEC 8859 的第四个 8 位字符集，它设计來表示爱沙尼亚语、格陵蘭语、拉脱维雅语、立陶宛语及部分萨米语 (Sami) 文字，此字符集同时能支持以下文字：丹麦语、英语、芬蘭语、德语、拉丁语、挪威语、斯洛维尼亚语及瑞典语。

表 6-3: ASCII Block 3 (ISO/IEC 8859-4)

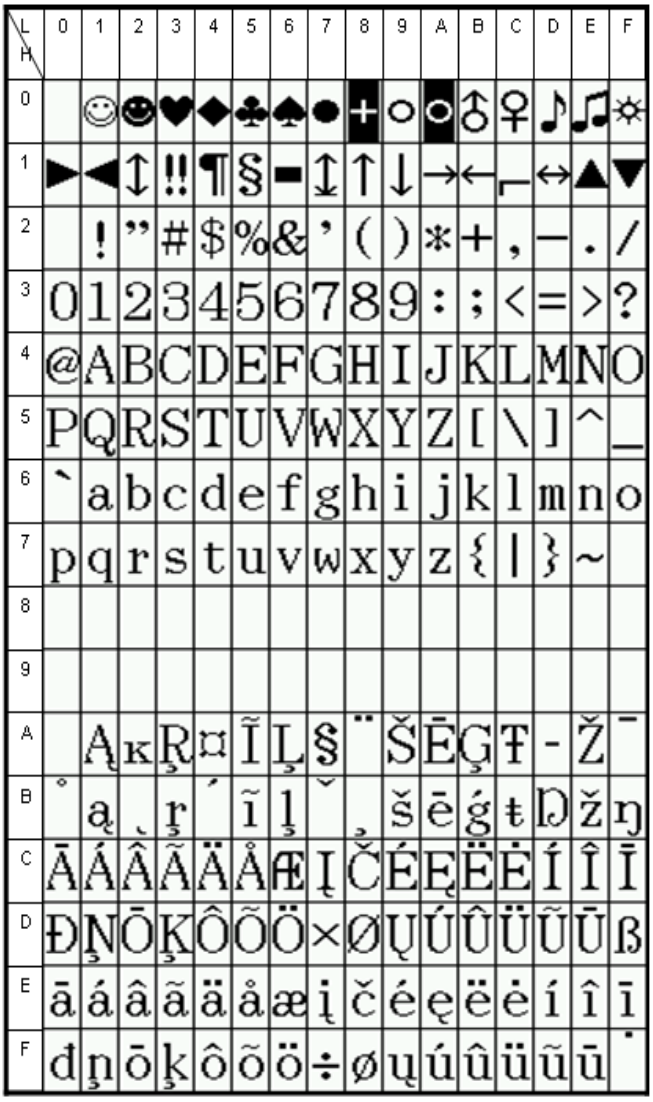


表 6-4 内为 ISO/IEC 8859-5 之标准字集，是国际标准化组织内 ISO/IEC 8859 的第五个 8 位字符集，它设计來表示保加利亞語、俄語、塞爾維亞語与馬其頓人語。

表 6-4 : ASCII Block 4 (ISO/IEC 8859-5)

外部字型 ROM

RA8873M 的外部串行 ROM 接口针对不同应用提供了许多种字体。此接口兼容于集通公司 (Genitop Inc) 的部分串列字型 ROM，支持产品编号包含: GT21L16T1W、GT30L16U2W、GT30L24T3Y、GT30L24M1Z、GT30L32S4W、GT23L24F6Y、GT23L24S1W。根据不同的产品，它提供了不同的大小，其中包含 16x16、24x24、32x32 以及各种不同宽度的字体大小。'详细的说明如下表列：

6.1.1:GT21L16T1W

- Reg[CEh][7:5]: 000b
- Character height: x16

Allowed character sets & width:

	GB12345 GB18030	BIG5	ASCII	UNI-jpn	JIS0208
Normal	V	V	V	V	V
Arial			V		
Roman			V		
Bold			V		

	Latin	Greek	Cyrillic	Arabic
Normal	V	V	V	
Arial	V	V	V	V
Roman				V
Bold				

*Arial & Roman is variable width.

6.1.2:GT30L16U2W

- Reg[CEh][7:5]: 001b
- Character height: x16

Allowed character sets & width:

	UNICODE	ASCII	Latin	Greek	Cyrillic	Arabic	GB2312 Special
Normal	V	V	V	V	V		V
Arial		V	V	V	V	V	
Roman		V				V	
Bold							

*Arial & Roman is variable width.

6.1.3:GT30L24T3Y

- Reg[CEh][7:5]: 010b
- Character height: x16

Allowed character sets & width:

	GB2312	GB12345/ GB18030	BIG5	UNICODE	ASCII
Normal	V	V	V	V	V
Arial					V
Roman					
Bold					

*Arial & Roman is variable width.

- Character height: x24

Allowed character sets & width:

	GB2312	GB12345/ GB18030	BIG5	UNICODE	ASCII
Normal	V	V	V	V	
Arial					V
Roman					
Bold					

*Arial & Roman is variable width.

6.1.4:GT30L24M1Z

- Reg[CEh][7:5]: 011b
- Character height: x24

Allowed character sets & width:

	GB2312 Extension	GB12345/ GB18030	ASCII
Normal	V	V	V
Arial			V
Roman			V
Bold			

*Arial & Roman is variable width.

6.1.5:GT30L32S4W

- Reg[CEh][7:5]: 100b
- Character height: x16

Allowed character sets & width:

	GB2312	GB2312 Extension	ASCII
Normal	V	V	V
Arial			V
Roman			V
Bold			

*Arial & Roman is variable width.

- Character height: x24

Allowed character sets & width:

	GB2312	GB2312 Extension	ASCII
Normal	V	V	V
Arial			V
Roman			V
Bold			

*Arial & Roman is variable width.

- Character height: x32

Allowed character sets & width:

	GB2312	GB2312 Extension	ASCII
Normal	V	V	V
Arial			V
Roman			V
Bold			

*Arial & Roman is variable width.

6.1.6:GT20L24F6Y

- Reg[CEh][7:5]: 101b
- Character height: x16

Allowed character sets & width:

	ASCII	Latin	Greek	Cyrillic
Normal	V	V	V	V
Arial	V	V	V	V
Roman	V			
Bold	V			

	Arabic	Hebrew	Thai	ISO-8859
Normal		V	V	V
Arial	V			
Roman				
Bold				

*Arial & Roman is variable width.

- Character height: x24

Allowed character sets & width:

	ASCII	Latin	Greek	Cyrillic	Arabic
Normal		V	V	V	
Arial	V				V
Roman					
Bold					

*Arial & Roman is variable width.

6.1.7:GT21L24S1W

- Reg[CEh][7:5]: 110b
- Character height: x24

Allowed character sets & width:

	GB2312	GB2312 Extension	ASCII
Normal	V	V	V
Arial			V
Roman			
Bold			

*Arial & Roman is variable width.

6.2:在 LCD 显示字

6.2.1:内建字 ：

RA8873M内建8x16,12x24,16x32点的ASCII字形ROM提供使用者更方便的方式用特定编码 (Code) 输入文字。内建字库支持了ISO//IEC 8859-1/2/4/5的标准字集。

```
void Select_Font_Height_WxN_HxN_ChromaKey_Alignment
(
unsigned char Font_Height
/*Font_Height:
16 : Font = 8x16 、16x16
24 : Font = 12x24、24x24
32 : Font = 16x32、32x32*/
,unsigned char XxN // Font size Width it could be set from x 1 to x 4
,unsigned char YxN // Font size Height it could be set from x 1 to x 4
,unsigned char ChromaKey
/*ChromaKey :
0 : Font Background color with no transparency
1 : Set Font Background color with transparency*/
,unsigned char Alignment //0 : no alignment , 1 : Set font alignment
)

void Print_Internal_Font_String
(
unsigned short x //coordinate x for print string
,unsigned short y //coordinate x for print string
,unsigned short X_W //active window width
,unsigned short Y_H //active window height
,unsigned long FontColor //FontColor : Set Font Color
,unsigned long BackGroundColor
/*BackGroundColor : Set Font BackGround Color.Font Color and BackGround Color dataformat :
ColorDepth_8bpp : R3G3B2
ColorDepth_16bpp : R5G6B5
ColorDepth_24bpp : R8G8B8*/
,char tmp2[] //tmp2 : Font String which you want print on LCD
)
```

范例 ：

```
/*Font_Height = 24 : Font   = 12x24、24x24 、XxN = 4 :Font Width x4、YxN = 4 :Font Height x 4、
ChromaKey = 0 : Font Background color with no transparency、
Alignment = 0 : no alignment
x : coordinate x for print string = 0
y : coordinate y for print string = 0
X_W : active window width = Panel_width
Y_H : active window height = Panel_length
FontColor : Set Font Color = 0xe0(8bpp)、0xf800(16bpp)、0xff0000(24bpp)
BackGroundColor : Set Font BackGround Color = 0x1c(8bpp)、0x07e0(16bpp)、0x00ff00(24bpp)*/

Write_Layer(1); //set memory read/write layer.Reference Page.5~6
Show_Layer(1);//set LCD display layer. Reference Page.5~6
+
Select_Font_Height_WxN_HxN_ChromaKey_Alignment(24,2,2,0,0);
+
//When Color Depth = 8bpp
Print_Internal_Font_String(0,0, Panel_width,Panel_length,0xe0,0x1c, "adfsdfdgfhhgfh");
Or
//When Color Depth = 16bpp
Print_Internal_Font_String(0,0, Panel_width,Panel_length,0xf800,0x07e0, "adfsdfdgfhhgfh");
or
//When Color Depth = 24bpp
Print_Internal_Font_String(0,0, Panel_width,Panel_length,0xff0000,0x00ff00, "adfsdfdgfhhgfh");
```

实际的显示画面 ：

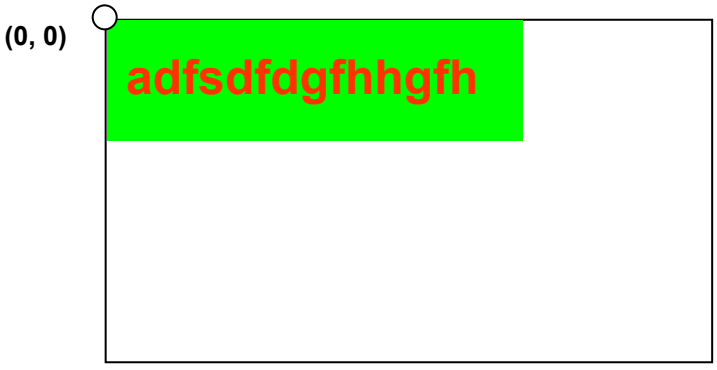


图 6-4 在图层 1 写入内建字

6.2.2:透过外部字库写入 Big5 字符串

RA8873M 的外部串行 ROM 接口针对不同应用提供了许多种字体。此接口兼容于集通公司 (Genitop Inc) 的部分串列字型 ROM，支持产品编号包含：GT21L16T1W、GT30L16U2W、GT30L24T3Y、GT30L24M1Z、GT30L32S4W、GT23L24F6Y、GT23L24S1W。根据不同的产品，它提供了不同的大小，其中包含 16x16、24x24、32x32 以及各种不同宽度的字体大小。

这个应用程序接口是使用了 RA8873M 外部串行字库来打印出 Big5 的字符串。

```
void Select_Font_Height_WxN_HxN_ChromaKey_Alignment
(
unsigned char Font_Height
/*Font_Height:
16 : Font = 8x16 、16x16
24 : Font = 12x24、24x24
32 : Font = 16x32、32x32*/
,unsigned char XxN // Font size Width it could be set from x 1 to x 4
,unsigned char YxN // Font size Height it could be set from x 1 to x 4
,unsigned char ChromaKey
/*ChromaKey :
0 : Font Background color with no transparency
1 : Set Font Background color with transparency*/
,unsigned char Alignment //0 : no alignment , 1 : Set font alignment
)

void Print_BIG5String
(
unsigned char Clk //SPI CLK = System Clock / 2*(Clk+1)
,unsigned char SCS //0 : use CS0 , 1 : use CS1
,unsigned short x //coordinate x for print string
,unsigned short y //coordinate y for print string
,unsigned short X_W //active window width
,unsigned short Y_H //active window height
,unsigned long FontColor //Set Font Color
,unsigned long BackGroundColor //Set Font BackGround Color
/*Font Color and BackGround Color dataformat :
ColorDepth_8bpp : R3G3B2
ColorDepth_16bpp : R5G6B5
ColorDepth_24bpp : R8G8B8*/
,char *tmp2 //tmp2 : BIG5 Font String which you want print on LCD
```

)

范例:

```
/*Font_Height = 24 : Font   = 12x24、24x24 、XxN = 4 :Font Width x4、YxN = 4 :Font Height x 4、
ChromaKey = 0 : Font Background color with no transparency、
Alignment = 0 : no alignment
x : coordinate x for print string = 0
y : coordinate y for print string = 0
X_W : active window width = Panel_width
Y_H : active window height = Panel_length
FontColor : Set Font Color = 0xe0(8bpp)、0xf800(16bpp)、0xff0000(24bpp)
BackGroundColor : Set Font BackGround Color = 0x1c(8bpp)、0x07e0(16bpp)、0x00ff00(24bpp)
Print 瑞佑科技 123456*/

Write_Layer(1); //set memory read/write layer.Reference Page.5~6
Show_Layer(1);//set LCD display layer. Reference Page.5~6
+
//When Color Depth = 8bpp
Select_Font_Height_WxN_HxN_ChromaKey_Alignment(24,2,2,0,0);
+
Print_BIG5String(3,0,0,0, Panel_width,Panel_length,0xe0,0x1c,"瑞佑科技 123456");
Or
//When Color Depth = 16bpp
Print_BIG5String(3,0,0,0, Panel_width,Panel_length,0xf800,0x07e0,"瑞佑科技 123456");
Or
//When Color Depth = 24bpp
Print_BIG5String(3,0,0,0 Panel_width,Panel_length,0xff0000,0x00ff00,"瑞佑科技 123456");
```

图 6-5 透过外部字库在图层 1 写入 Big5 字符串

6.2.3:透过外部字库写入 GB2312 字符串:

RA8873M 的外部串行 ROM 接口针对不同应用提供了许多种字体。此接口兼容于集通公司 (Genitop Inc) 的部分串列字型 ROM，支持产品编号包含：GT21L16T1W、GT30L16U2W、GT30L24T3Y、GT30L24M1Z、GT30L32S4W、GT23L24F6Y、GT23L24S1W。根据不同的产品，它提供了不同的大小，其中包含 16x16、24x24、32x32 以及各种不同宽度的字体大小。

这个应用程序接口是使用了 RA8873M 外部串行字库来打印出 GB2312 的字符串。

```
void Select_Font_Height_WxN_HxN_ChromaKey_Alignment
(
unsigned char Font_Height
/*Font_Height:
16 : Font = 8x16 、16x16
24 : Font = 12x24、24x24
32 : Font = 16x32、32x32*/
,unsigned char XxN // Font size Width it could be set from x 1 to x 4
,unsigned char YxN // Font size Height it could be set from x 1 to x 4
,unsigned char ChromaKey
/*ChromaKey :
0 : Font Background color with no transparency
1 : Set Font Background color with transparency*/
,unsigned char Alignment // 0 : no alignment, 1 : Set font alignment
)

void Print_GB2312String
(
unsigned char Clk //Clk : SPI CLK = System Clock / 2*(Clk+1)
,unsigned char SCS //SCS : 0 = CS0 , 1 = CS1
,unsigned short x //coordinate x for print string
,unsigned short y //coordinate y for print string
,unsigned short X_W //active window width
,unsigned short Y_H //active window height
,unsigned long FontColor //Set Font Color
,unsigned long BackGroundColor //Set Font BackGround Color
/*Font Color and BackGround Color dataformat :
ColorDepth_8bpp : R3G3B2
ColorDepth_16bpp : R5G6B5
ColorDepth_24bpp : R8G8B8*/
```

```
,char tmp2[] //tmp2 : GB2312 Font String which you want print on LCD
)
```

范例 ：

```
/*Font_Height = 24 : Font   = 12x24、24x24 、XxN = 4 :Font Width x4、YxN = 4 :Font Height x 4、
ChromaKey = 0 : Font Background color with no transparency、
Alignment = 0 : no alignment
x : coordinate x for print string = 0
y : coordinate y for print string = 0
X_W : active window width = Panel_width
Y_H : active window height = Panel_length
FontColor : Set Font Color = 0xe0(8bpp)、0xf800(16bpp)、0xff0000(24bpp)
BackGroundColor : Set Font BackGround Color = 0x1c(8bpp)、0x07e0(16bpp)、0x00ff00(24bpp)
Print 瑞佑科技 123456*/

Write_Layer(1); //set memory read/write layer.Reference Page.5~6
Show_Layer(1);//set LCD display layer. Reference Page.5~6
+
Select_Font_Height_WxN_HxN_ChromaKey_Alignment(24,2,2,0,0);
+
//When Color Depth = 8bpp
Print_GB2312String(3,0,0,0,Panel_width,Panel_length,0xe0,0x03," 瑞佑科技 123456");
Or
//When Color Depth = 16bpp
Print_GB2312String(3,0,0,0,Panel_width,Panel_length, 0xf800,0x001f," 瑞佑科技 123456");
or
//When Color Depth = 24bpp
Print_GB2312String(3,0,0,0,Panel_width,Panel_length, 0xff0000,0x0000ff," 瑞佑科技 123456");
```

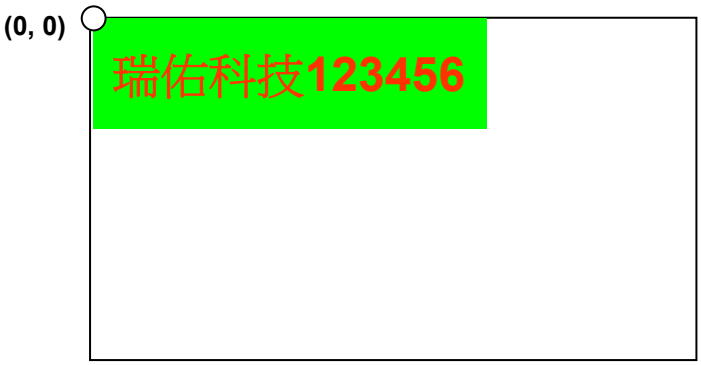


图 6-6: 透过外部字库在图层 1 写入 GB2312 字符串

6.3.4: 透过外部字库写入 GB12345 字符串

RA8873M 的外部串行 ROM 接口针对不同应用提供了许多种字体。此接口兼容于集通公司 (Genitop Inc) 的部分串列字型 ROM，支持产品编号包含：GT21L16T1W、GT30L16U2W、GT30L24T3Y、GT30L24M1Z、GT30L32S4W、GT23L24F6Y、GT23L24S1W。根据不同的产品，它提供了不同的大小，其中包含 16x16、24x24、32x32 以及各种不同宽度的字体大小。

这个应用程序接口是使用了 RA8873M 外部串行字库来打印出 GB12345 的字符串。

```
void Select_Font_Height_WxN_HxN_ChromaKey_Alignment
(
unsigned char Font_Height
/*Font_Height:
16 : Font = 8x16 、16x16
24 : Font = 12x24、24x24
32 : Font = 16x32、32x32*/
,unsigned char XxN // Font size Width it could be set from x 1 to x 4
,unsigned char YxN // Font size Height it could be set from x 1 to x 4
,unsigned char ChromaKey
/*ChromaKey :
0 : Font Background color with no transparency
1 : Set Font Background color with transparency*/
,unsigned char Alignment // 0 : no alignment, 1 : Set font alignment
)

void Print_GB12345String(
unsigned char Clk //Clk : SPI CLK = System Clock / 2*(Clk+1)
,unsigned char SCS //SCS : 0 = CS0 , 1 = CS1
,unsigned short x //Print font start coordinate of X
,unsigned short y //Print font start coordinate of Y
,unsigned short X_W //active window width
,unsigned short Y_H //active window height
,unsigned long FontColor //Set Font Color
,unsigned long BackGroundColor //Set Font BackGround Color
/*Font Color and BackGround Color dataformat :
ColorDepth_8bpp : R3G3B2
ColorDepth_16bpp : R5G6B5
ColorDepth_24bpp : R8G8B8*/
,char *tmp2 //tmp2 : GB12345 Font String you want print
```

)

范例 ：

```
Write_Layer(1); //set memory read/write layer.Reference Page.5~6
Show_Layer(1);//set LCD display layer. Reference Page.5~6
+
Select_Font_Height_WxN_HxN_ChromaKey_Alignment(24,2,2,0,0);
+
//When Color Depth = 8bpp
Print_GB2312String(3,0,0,0,Panel_width,Panel_length,0xe0,0x03," 瑞佑科技 123456");
Or
//When Color Depth = 16bpp
Print_GB2312String(3,0,0,0,Panel_width,Panel_length, 0xf800,0x001f," 瑞佑科技 123456");
or
//When Color Depth = 24bpp
Print_GB2312String(3,0,0,0,Panel_width,Panel_length, 0xff0000,0x0000ff," 瑞佑科技 123456");
```

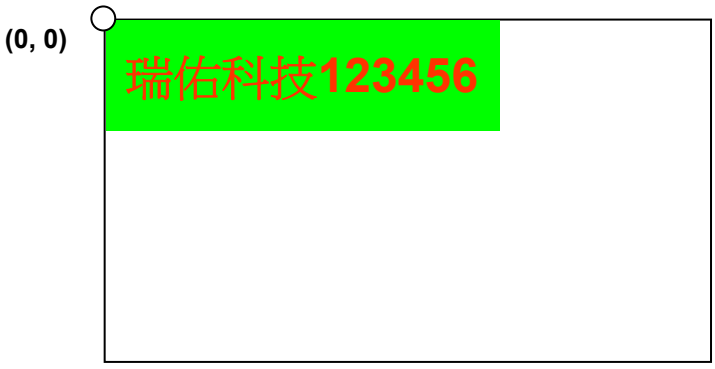


图 6-7: 透过外部字库在图层 1 写入 GB12345 字符串

6.3.5: 透过外部字库写入 Unicode 字符串

RA8873M 的外部串行 ROM 接口针对不同应用提供了许多种字体。此接口兼容于集通公司 (Genitop Inc) 的部分串列字型 ROM，支持产品编号包含：GT21L16T1W、GT30L16U2W、GT30L24T3Y、GT30L24M1Z、GT30L32S4W、GT23L24F6Y、GT23L24S1W。根据不同的产品，它提供了不同的大小，其中包含 16x16、24x24、32x32 以及各种不同宽度的字体大小。

这个应用程序接口是使用了 RA8873M 外部串行字库来打印出 Unicode 的字符串。

```
void Select_Font_Height_WxN_HxN_ChromaKey_Alignment
(
unsigned char Font_Height
/*Font_Height:
16 : Font = 8x16 、16x16
24 : Font = 12x24、24x24
32 : Font = 16x32、32x32 */
,unsigned char XxN //XxN :Font Width x 1~4
,unsigned char YxN //YxN :Font Height x 1~4
,unsigned char ChromaKey
/*ChromaKey :
0 : Font Background color not transparency
1 : Set Font Background color transparency*/
,unsigned char Alignment // 0 : no alignment, 1 : Set font alignment
)

void Print_UnicodeString
(
unsigned char Clk //SPI CLK = System Clock / 2*(Clk+1)
,unsigned char SCS //SCS : 0 = CS0 , 1 = CS1
,unsigned short x //Print font start coordinate of X
,unsigned short y //Print font start coordinate of Y
,unsigned short X_W //active window width
,unsigned short Y_H //active window height
,unsigned long FontColor //Set Font Color
,unsigned long BackGroundColor //Set Font BackGround Color
/*Font Color and BackGround Color dataformat :
ColorDepth_8bpp : R3G3B2
ColorDepth_16bpp : R5G6B5
ColorDepth_24bpp : R8G8B8*/
```

,unsigned short *tmp2 /*tmp2 : Unicode Font String which you want print on LCD (L"string" in keil c is Unicode string)*/
)

范例 ：

```
Write_Layer(1); //set memory read/write layer.Reference Page.5~6
Show_Layer(1);//set LCD display layer. Reference Page.5~6
+
Select_Font_Height_WxN_HxN_ChromaKey_Alignment(24,2,2,0,0);
+
//When Color Depth = 8bpp
Print_UnicodeString(3,0,0,0,Panel_width,Panel_length,0xe0,0x1c,L"新竹縣竹北市台元一街 8 號 6 樓之 5");
Or
//When Color Depth = 16bpp
Print_UnicodeString(3,0,0,0,Panel_width,Panel_length,0xf800,0x07e0,L"新竹縣竹北市台元一街 8 號 6 樓之 5");
Or
//When Color Depth = 24bpp
Print_UnicodeString(3,0,0,0,Panel_width,Panel_length,0xff0000,0x00ff00,L"新竹縣竹北市台元一街 8 號 6 樓之 5");
```

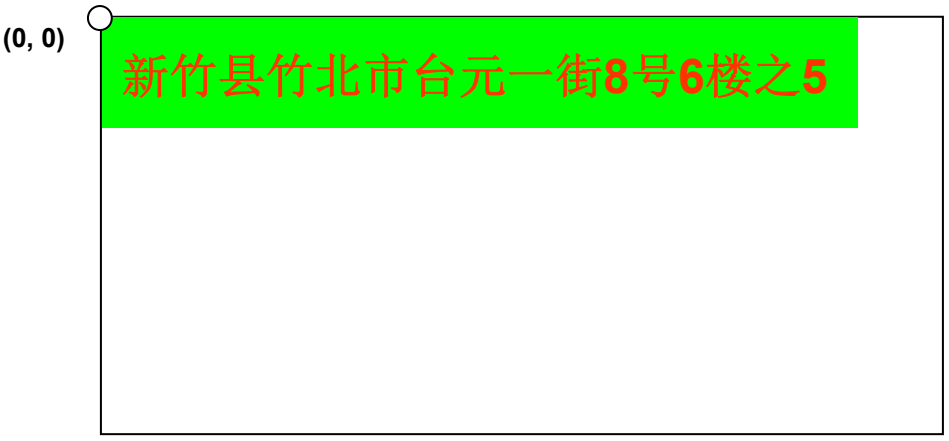


图 6-8: 透过外部字库在图层 1 写入 Unicode 字符串

第 7 章 ：PWM (Pulse Width Modulation)

RA8873M有2组16位定時器。定時器0和1具有脈衝寬度調製（PWM）功能。定時器0具有一個死區生成器，其用於以大電流的設備。

定時器0和1有一个共享的8位元的預分频器(prescalar)。每個定時器还有一個時脉除頻器，從而產生4個不同的除頻信號（1，1/2，1/4和1/8）。

最后透过timer count buffer (TCNTBn)用来调整PWM输出的周期时间以及利用timer compare buffer (TCMPBn)的值來進行脈衝寬度調製（PWM），产生一个稳定的脉波。详细公式与图解如下列说明:

PWM CLK = (Core CLK / Prescalar) /2$^{\text{clock divided}}$

PWM output period = (Count Buffer + 1) x PWM CLK time

PWM output high level time = (Compare Buffer + 1) x PWM CLK time

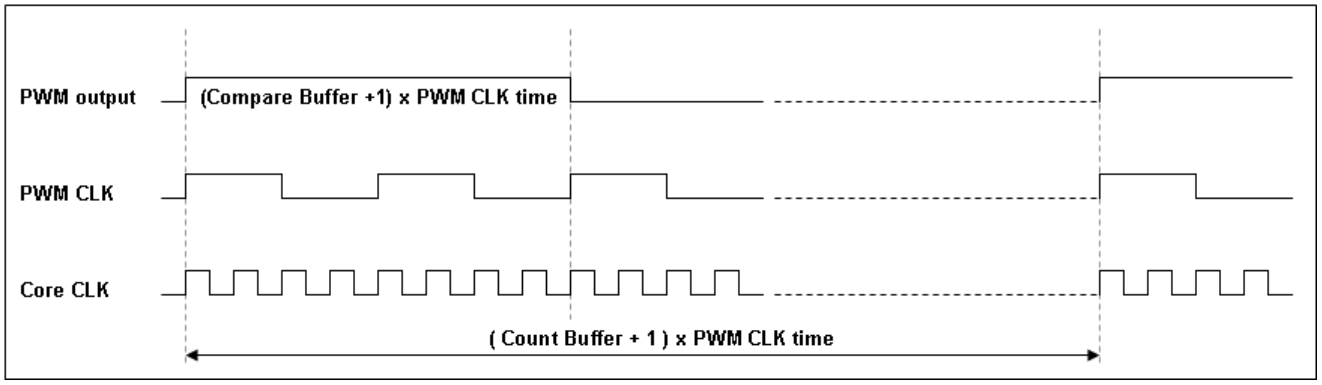


图 7-1 : PWM 时序图

PWM 功能 API:

```
void PWM0
(
unsigned char on_off //on_off = 1 ,enable PWM, on_off = 0 , disable PWM.
, unsigned char Clock_Divided // divided PWM clock, only 0~3(1,1/2,1/4,1/8)
, unsigned char Prescalar //Prescaler : only 1~256
, unsigned short Count_Buffer //Count_Buffer : set PWM output period time
,unsigned short Compare_Buffer //Compare_Buffer : set PWM output high level time(Duty cycle)
/*Such as the following formula :
PWM CLK = (Core CLK / Prescalar ) /2^ divided clock
PWM output period = (Count Buffer + 1) x PWM CLK time
PWM output high level time = (Compare Buffer + 1) x PWM CLK time */
)

void PWM1
(
unsigned char on_off //on_off = 1 ,enable PWM, on_off = 0 , disable PWM.
, unsigned char Clock_Divided // divided PWM clock, only 0~3(1,1/2,1/4,1/8)
, unsigned char Prescalar //Prescaler : only 1~256
, unsigned short Count_Buffer //Count_Buffer : set PWM output period time
,unsigned short Compare_Buffer //Compare_Buffer : set PWM output high level time(Duty cycle)
/*Such as the following formula :
PWM CLK = (Core CLK / Prescalar ) /2^ divided clock
PWM output period = (Count Buffer + 1) x PWM CLK time
PWM output high level time = (Compare Buffer + 1) x PWM CLK time */
)
```

范例:

当 Core CLK = 60MHz

```
PWM0(1,3,100,1,0);
PWM1(1,3,100,4,3);
```

PWM0 输出:

/*On_off = 1, PWM Enable.

Clock Divided = 3, Prescalar = 100, Count_Buffer = 1, Compare_Buffer = 0.

PWM CLK = (Core CLK / Prescaler) /$2^{clock\ divided}$ = (60M / 100) / 2^3 = 75KHz

PWM output period = (Count Buffer + 1) x PWM CLK time = (1+1) x (1 / 75K) ≒ 26.67us

PWM output high level time = (Compare Buffer + 1) x PWM CLK time = (0+1) x (1 / 75K) ≒ 13.33us*/

示波器波形:

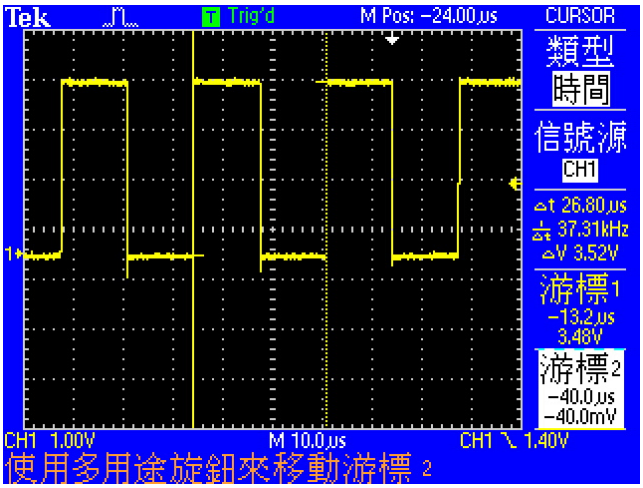


图 7-2：PWM0 输出波形周期

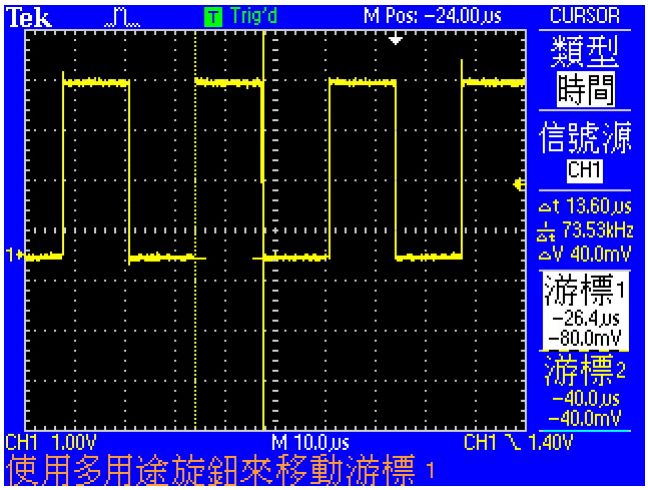


图 7-3：PWM0 输出高电位的时间

PWM1 输出:

/*On_off = 1, PWM Enable.

Clock Divided = 3, Prescalar = 100, Count_Buffer = 4, Compare_Buffer = 3.

PWM CLK = (Core CLK / Prescaler) /$2^{clock\ divided}$ = (60M / 100) / 2^3 = 75KHz

PWM output period = (Count Buffer + 1) x PWM CLK time = (4+1) x (1 / 75K) ≒ 66.67us

PWM output high level time = (Compare Buffer + 1) x PWM CLK time = (3+1) x (1 / 75K) ≒ 53.33us*/

示波器波形:

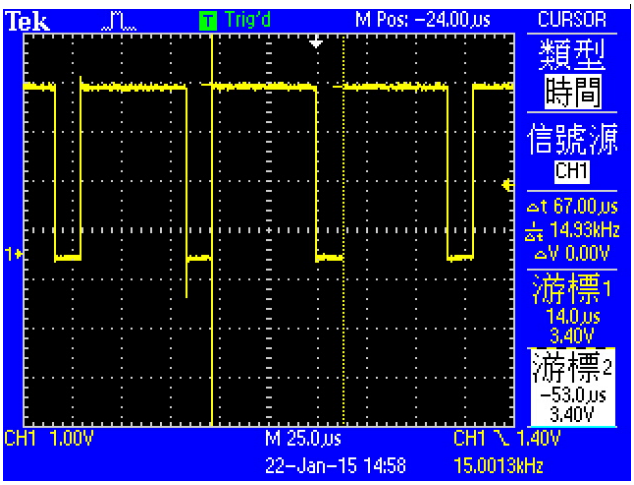


图 7-4：PWM1 输出波形周期

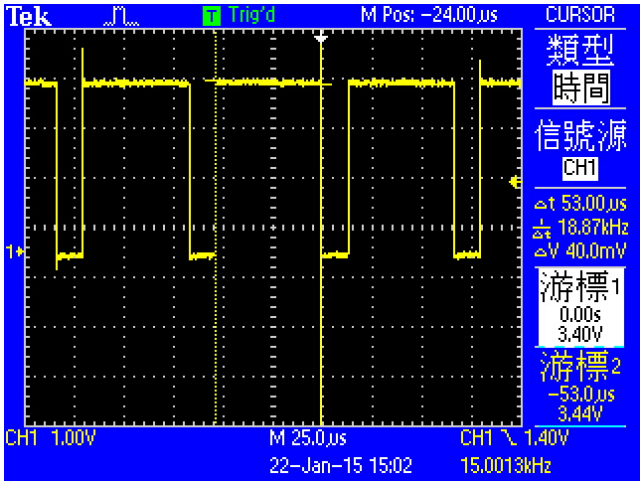


图 7-5：PWM1 输出高电位的时间

第 8 章 ： 键盘扫描

键盘扫描会扫描并读取键盘状态，而键盘矩阵会由硬件来切换扫描线。这个功能可以提供键盘应用，圖 8-3 显示的是基本的键盘应用电路。RA8873M 为因应外部电路需求，已经在 KIN[4:0] 内建上拉电阻。

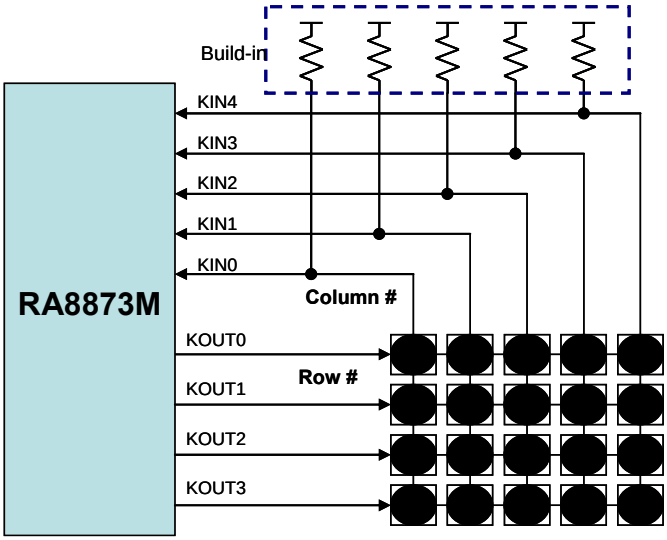


圖 8-3 : Key-Pad Application

8.1 键盘扫描操作方式

RA8873M 键盘扫描控制器的特点如下:

1. 最多支持 5x5 键盘矩阵
2. Key-Scan 具有可程序化的扫描频率与取样时间。
3. 可调整的长按键时间
4. 支持多键同时按
   注意: 可同时按 2 个按键或是要按 3 个按键 (但是 3 按键组成不能是 90°排列)
5. 可使用按键来唤醒系统

KSCR 是键盘扫描的状态缓存器，这个缓存器被使用在了解键盘扫描的操作状态，如取样时间、取样频率、致能长按键。而若是有按键按下，使用者也可以透过中断得知。在 KSCR2 bit1~0 纪录目前按下的按键数目。然后使用者可以透过读取 KSDR 得到按键码。

注：“Normal key” 是在以取样时间为基础上有被认知为合格的按下按键行为。“Long Key” 则是在长按键取样周期下有被认知为合格的按下按键行为。先产生 "Normal Key" 才会产生 “Long Key” ，有时在某些应用上需要分开使用。

表 8-1 是在 ”Nnomal Key” 下键码与键盘矩阵的对应，按下的按键键码会被存在 KSDR0~2。如果是长时间按下按键，则表现出的会是 ”Long Key”，而相关键码在表 8-2。

表 8-1: Key Code Mapping 表 (Normal Key)

	Kin0	Kin1	Kin2	Kin3	Kin4

Kout0	00h	01h	02h	03h	04h
Kout1	10h	11h	12h	13h	14h
Kout2	20h	21h	22h	23h	24h
Kout3	30h	31h	32h	33h	34h
Kout4	40h	41h	42h	43h	44h

表 8-2: Key Code Mapping 表 (Long Key)

	Kin0	Kin1	Kin2	Kin3	Kin4
Kout0	80h	81h	82h	83h	84h
Kout1	90h	91h	92h	93h	94h
Kout2	A0h	A1h	A2h	A3h	A4h
Kout3	B0h	B1h	B2h	B3h	B4h
Kout4	C0h	C1h	C2h	C3h	C4h

当按下多键时，最多有三个按键会被存在 KSDR0，KSDR1 与 KSDR2 三个缓存器中。注意键码储存的方式与按键位置有关或者说与键码有关，而与按键顺序无关，请参下列例子:

在相同时间按下键码 0x34, 0x00 and 0x22，在 KSDR0~2 储存方式如下:

KSDR0 = 0x00
KSDR1 = 0x22
KSDR2 = 0x34

以上所提的键盘扫描设定介绍如下:

表 8-3 : Key-Scan Relative Registers

Reg.	Bit_Num	Description	Reference
KSCR1	Bit 6	Long Key Enable bit	REG[FBh]
	Bit [5:4]	Key-Scan sampling times setting	
	Bit [2:0]	Key-Scan scan frequency setting	
KSCR2	Bit [7]	Key-Scan Wakeup Function Enable Bit	REG[FCh]
	Bit [3:2]	long key timing adjustment	
	Bit [1:0]	The number of key hit	
KSDR0 KSDR1 KSDR2	Bit [7:0]	Key code for pressed key	REG[FDh ~ FFh]
CCR	Bit 5	Key-Scan enable bit	REG[01h]
INTR	Bit 4	Key-Scan interrupt enable	REG[0Bh]
INTC2	Bit 4	Key-Scan Interrupt Status bit	REG[0Ch]

致能键盘扫描功能(Key-Scan)，使用者可以使用下列方法检查按键状态:

1) Software check method: 检查 Key-scan 的状态值 (status)，来得知是否被按下。

2) Hardware check method: 由中断来得知是否有按键被按下。

若是设定中断致能 (INTEN bit[3]) 为 1，那么有键盘有被按下时就会产生中断。而当中断产生时，Key-scan 中断状态旗标 (bit[3] of INTF) 将永远为 1，无论使用何种方法，使用者在读取键码后必须清除中断状态旗标，否则以后就不会再产生中断。

此外，RA8873M 在省电模式下支持“Key-stroke wakeup ”，经由设定完成后，任何按键触发都可以将 RA8873M 由睡眠模式中唤醒。为了检知唤醒事件，MPU 可以透过软件程序去轮询 RA8873M 的中断是否产生。

以上应用的缓存器程序设定流程图如下:

1. 软件方法

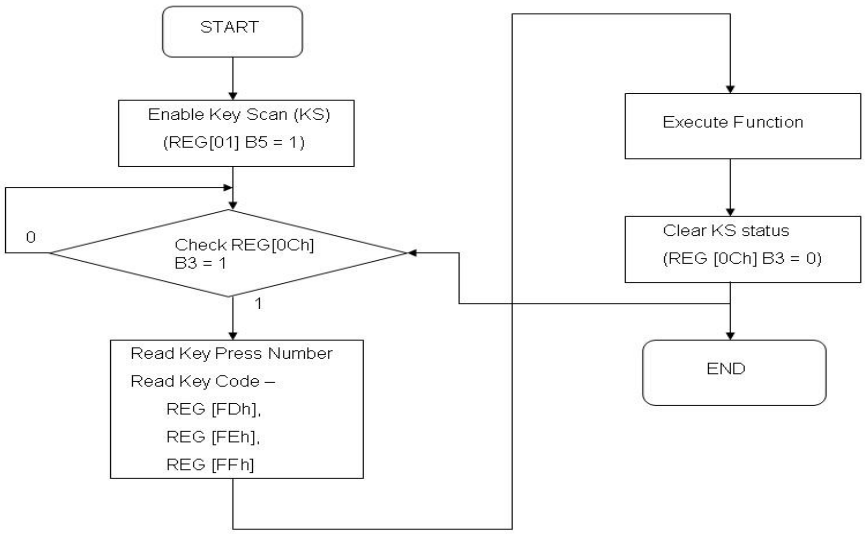


圖 8-4 : Key-Scan Flowchart for Software Polling

2. 硬件方法

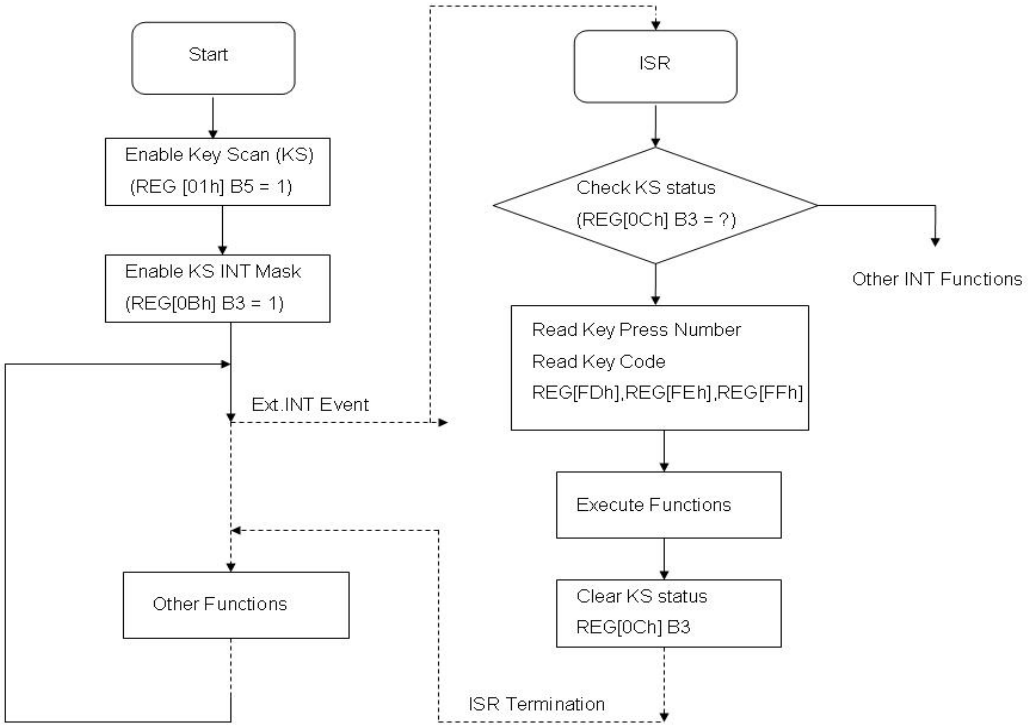


圖 8-5 : Key-Scan for Hardware Interrupt

KEY SCAN 功能 API:

void API_Print_key_code(unsigned short x,unsigned short y,unsigned long FontColor,unsigned long BackGroundColor)

執行

Write_Layer(1); //set memory read/write layer.Reference Page.5~6

Show_Layer(1);//set LCD display layer. Reference Page.5~6

+

API_Print_key_code(0,0,0x00,0xff); //8bbp color depth

Or

API_Print_key_code(0,0,0x0000,0xffff); //16bbp color depth

Or

API_Print_key_code(0,0,0x000000,0xffffff); //24bbp color depth

条件:

x:显示 Key Code 的 X 座标 = 0

y:显示 Key Code 的 Y 座标 = 0

FontColor:显示 Keycode 的颜色 = 黑色

BackGroundColor:显示 Keycode 的背景色 = 白色

Example:

如按下下列三个按键

	Kin0	Kin1	Kin2	Kin3	Kin4
Kout0	00h	01h	02h	03h	04h
Kout1	10h	11h	12h	13h	14h
Kout2	20h	21h	22h	23h	24h
Kout3	30h	31h	32h	33h	34h
Kout4	40h	41h	42h	43h	44h

LCD 显示画面:

001123

附录 1：PLL initialization

$$xCLK = \frac{\left(Fin / (xPLLDIVM + 1)\right) \times (xPLLDIVN + 1)}{2^{xPLLDIVK}}$$

The input OSC frequency (F_{IN}) must greater & PLLDIVM has following restriction:

$$10MHz \le Fin \le 15MHz \quad \& \quad 10MHz \le \frac{Fin}{PLLDIVM} \le 40MHz$$

The internal multiplied clock frequency $Fvco = \frac{Fin}{PLLDIVM + 1} \times (PLLDIVN + 1)$ must be equal to or greater than 250 MHz and small than 500 MHz. i.e, $250MHz \le Fvco \le 500MHz$

If F_{IN} = 10Mhz

```
 void RA8873_PLL(void)
{
//SCLK Setting :
LCD_RegisterWrite(0x05,0x16);      //PLL Divided by 16
LCD_RegisterWrite(0x06,0x2f);
/* SCLK = {(10MHz/(0+1)) * (0x2f+1) } / 2^4 = 30Mhz
REG[05h] SCLK PLL Control Register 1
Bit[5:3] SCLK extra divider
xx1b: divided by 1.
000b: divided by 1.
010b: divided by 2.
100b: divided by 4.
110b: divided by 8.
Bit[2:1] SCLK PLLDIVK[1:0]
SCLK PLL Output divider
00b: divided by 1.
01b: divided by 2.
10b: divided by 4.
11b: divided by 8.
Bit[0] SCLK PLLDIVM
SCLK PLL Pre-driver parameter.
0b: divided by 1.
1b: divided by 2.
REG[06h] SCLK PLL Control Register 2
SCLK PLLDIVN[5:0]
SCLK PLL input parameter, the value should be 1~63. (i.e. value 0 is forbidden).
*/
```

//MCLK Setting :

```
LCD_RegisterWrite(0x07,0x04);      //PLL Divided by 4
LCD_RegisterWrite(0x08,0x1b);
/* MCLK = {(10MHz/(0+1)) * (0x1b+1) } / 2^2 = 70MHz
REG[07h] MCLK PLL Control Register 1
 Bit[2:1]MCLK PLLDIVK
 MCLK PLL Output divider
 00b: divided by 1.
 01b: divided by 2.
 10b: divided by 4.
 11b: divided by 8.
Bit[0]MCLK PLLDIVM
MCLK PLL Pre-driver parameter.
0b: divided by 1.
1b: divided by 2.
REG[08h] MCLK PLL Control Register 2
MCLK PLLDIVN[5:0]
MCLK PLL input parameter, the value should be 1~63. (i.e. value 0 is forbidden).
*/
```

//CCLK Setting :

```
LCD_RegisterWrite(0x09,0x04);      //PLL Divided by 4
LCD_RegisterWrite(0x0A,0x1b);
/* CCLK = {(10MHz/(0+1)) * (0x1b+1) } / 2^2 = 70MHz
REG[09h] CCLK PLL Control Register 1
Bit[2:1]CCLK PLLDIVK
CCLK PLL Output divider
00b: divided by 1.
01b: divided by 2.
10b: divided by 4.
11b: divided by 8.
Bit[0]CCLK PLLDIVM
CCLK PLL Pre-driver parameter.
0b: divided by 1.
1b: divided by 2.
REG[0Ah] CCLK PLL Control Register 2
CCLK PLLDIVN[5:0]
CCLK PLL input parameter, the value should be 1~63. (i.e. value 0 is forbidden).
*/
LCD_RegisterWrite(0x01,0x80);                    // PLL Enable
Delay_ms(100);
}
```

附录 2：SDRAM initialization

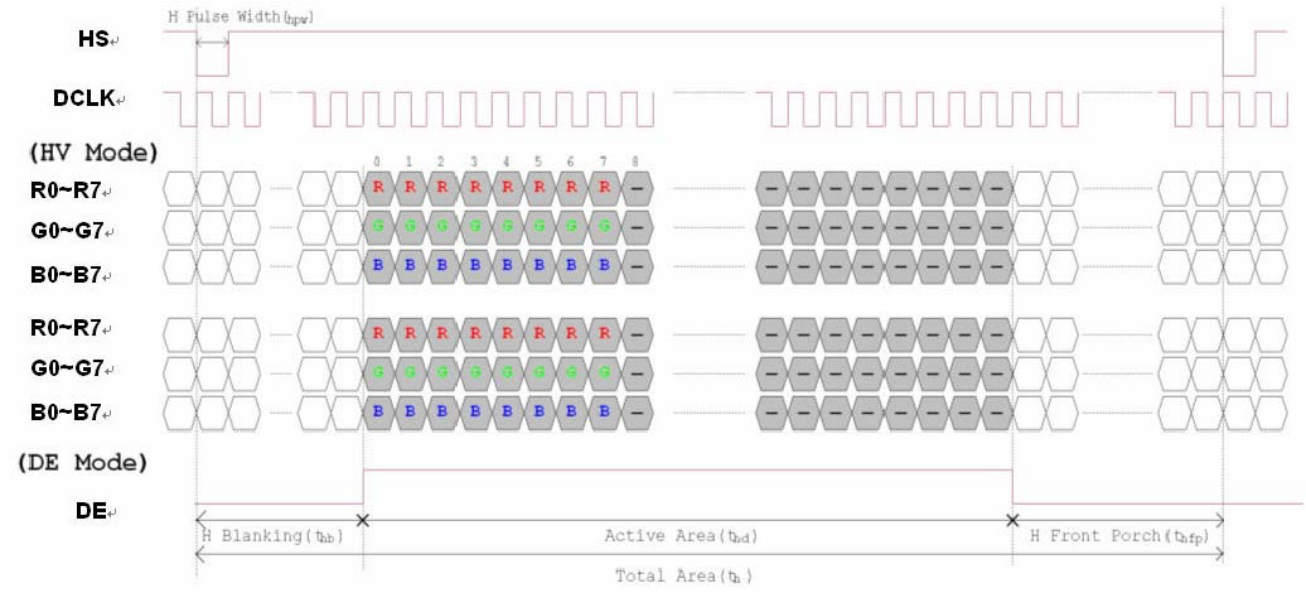
```
void RA8873_SDRAM_initial(void)
{
unsigned short       Auto_Refresh;
Auto_Refresh=(64*DRAM_FREQ*1000)/(4096) - 2;
LCD_RegisterWrite(0xe0,0x28);
LCD_RegisterWrite(0xe1,0x02);
LCD_RegisterWrite(0xe2,Auto_Refresh);
LCD_RegisterWrite(0xe3,Auto_Refresh>>8);
LCD_RegisterWrite(0xe4,0x01);
Check_SDRAM_Ready();
}
```

附录 3 LCD initialization:

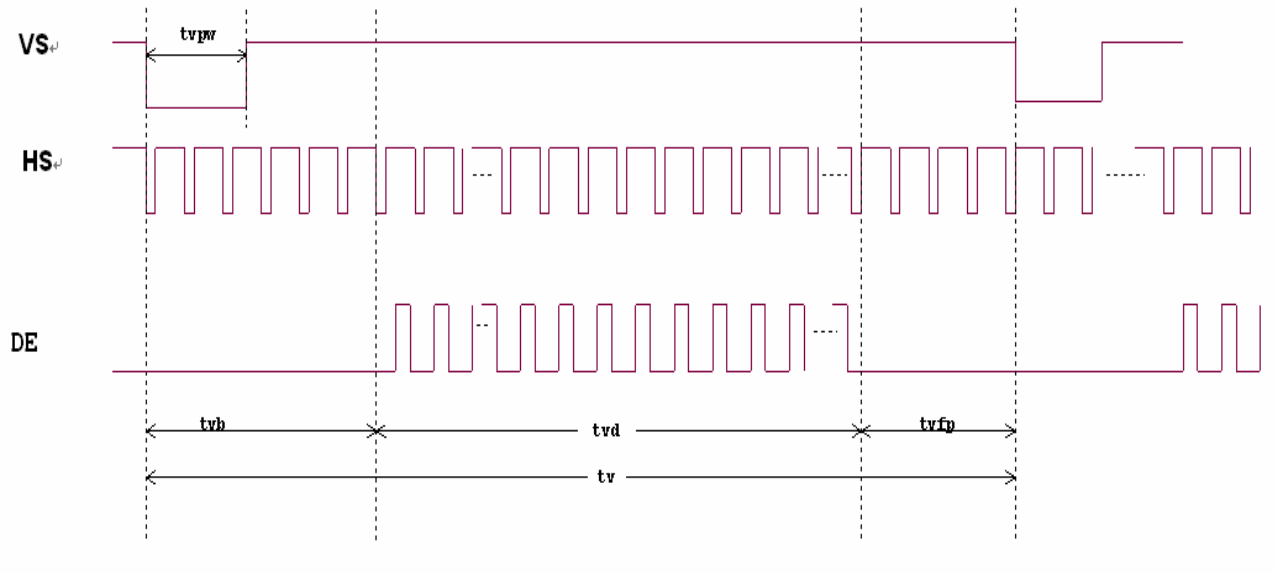
以 AT070TN92 Timing :

Item	symbol	value			Unit	Remark
		Min.	Typ.	Max.		
Horizontal Display Area	thd		800		DCLK	
DCLK Frequency(PCLK)	fclk	26.4	33.3	46.8	MHz	
One Horizontal Line	th	862	1056	1200	DCLK	
HS pulse width	thpw	1	-	40	DCLK	
HS Blanking(Back Porch)	thb	46	46	46	DCLK	
HS Front Porch	thfp	16	210	354	DCLK	

Item	symbol	value			Unit	Remark
		Min.	Typ.	Max.		
Vertical Display Area	tvd		480		TH	
VS period time	tv	510	525	650	TH	
VS pulse width	tvpw	1	-	20	TH	
VS Blanking(Back Proch)	tvb	23	23	23	TH	
VS Front Porch	tvfp	7	22	147	TH	



Horizontal Input Timing Diagram



Vertical Input Timing Diagram

```
DE_PCLK_Falling();
PDATA_Set_RGB();
LCD_CmdWrite(0x13);          // de --> low active
LCD_DataWrite(0x00);
delay_us(100);
//Horizontal display width(pixels) = (HDWR + 1) * 8 + HDWFTR Maximum value cannot over 2048
//Horizontal display width(pixels) = (0x63+1) * 8 + 0 = 800
LCD_CmdWrite(0x14);        //HDWR//Horizontal Display Width Setting Bit[6:0]
LCD_DataWrite(0x63);       //Horizontal display width(pixels) = (HDWR + 1)*8
delay_us(100);
LCD_CmdWrite(0x15);      //Horizontal Display Width Fine Tuning (HDWFT) [3:0]
LCD_DataWrite(0x00);
delay_us(100);

//Horizontal non-display period(Back porch) = (HNDR + 1) * 8 + HNDFTR = (4+1)*8 + 6 = 46
LCD_CmdWrite(0x16);        //HNDR//Horizontal Non-Display Period Bit[4:0]
LCD_DataWrite(0x04);      //Horizontal Non-Display Period (pixels) = (HNDR + 1)*8
delay_us(100);
LCD_CmdWrite(0x17);        //Horizontal Non-Display Period Fine Tuning(HNDFT) [3:0]
LCD_DataWrite(0x06);
delay_us(100);
```

```
//HSYNC Start Position(Front porch) = (HSTR + 1)*8    = (0x19 + 1)*8 = 208
LCD_CmdWrite(0x18);         //HSTR//HSYNC Start Position[4:0]
LCD_DataWrite(0x19);        //HSYNC Start Position(PCLK) = (HSTR + 1)*8
delay_us(100);

//HSYNC Pulse Width(pixels) = (HPW + 1)x8 = (0 + 1)*8 = 8
LCD_CmdWrite(0x19);         //HPWR//HSYNC Polarity ,The period width of HSYNC.
LCD_DataWrite(0x00);        //HSYNC Width [4:0]     HSYNC Pulse width(PCLK) = (HPWR + 1)*8
delay_us(100);

//Vertical Display Height(Line) = VDHR + 1 = (256 + 223 ) +1 = 480
LCD_CmdWrite(0x1A);         //VDHR0 //Vertical Display Height Bit [7:0]
LCD_DataWrite(0xdf);         //Vertical pixels = VDHR + 1
LCD_CmdWrite(0x1B);         //VDHR1 //Vertical Display Height Bit[10:8] = 256
LCD_DataWrite(0x01);        //Vertical Display Height(Line) = VDHR + 1
delay_us(100);

//Vertical Non-Display Period(Back porch) = (VNDR + 1) =    (0 + 0x15) + 1 =22
LCD_CmdWrite(0x1C);         //VNDR0 //Vertical Non-Display Period Bit [7:0]
LCD_DataWrite(0x15);        //Vertical Non-Display area = (VNDR + 1)
delay_us(100);
LCD_CmdWrite(0x1D);         //VNDR1 //Vertical Non-Display Period Bit [8]
LCD_DataWrite(0x00);        //Vertical Non-Display area = (VNDR + 1)
delay_us(100);

// VSYNC Start Position(Front porch) = (VSTR + 1) = ( 0x16 + 1 )=23
LCD_CmdWrite(0x1E);         //VSTR0 //VSYNC Start Position[7:0]
LCD_DataWrite(0x16);        //VSYNC Start Position(PCLK) = (VSTR + 1)
delay_us(100);

//VSYNC Pulse Width(Line) = (VPWR + 1) = (0 + 1) = 1
LCD_CmdWrite(0x1f);         //VPWR //VSYNC Polarity ,VSYNC Pulse Width[6:0]
LCD_DataWrite(0x01);        //VSYNC Pulse Width(PCLK) = (VPWR + 1)
delay_us(100);
```

附录 4：RAIO 自建字库

RAIO 自制自建字库，提供三种大小的 ASCII 字体，分别为 8x12、16x24、32x48，本章节 API 支援 MCU 8bit color depth 8bpp、MCU 8bit color depth 16bpp、MCU 8bit color depth 16bpp、MCU 16bit color depth 16bpp、MCU 16bit color depth 24bpp mode2 几种模式，但并不支持 MCU 16bit color depth 24bpp mode 1。

API:

```
// Note. this API does not support the case that MCU=16bit, 24bpp and mode1
void putPixel
(
unsigned short x //x of coordinate
,unsigned short y //y of coordinate
,unsigned long color
/*color : 8bpp:R3G3B2
        16bpp:R5G6B5
        24bpp:R8G8B8 */
)


// Note. this API does not support the case that MCU=16bit, 24bpp and mode1
void lcdPutChar8x12
(
unsigned short x // x of coordinate
,unsigned short y // y of coordinate
,unsigned long fgcolor //fgcolor : foreground color(font color)
,unsigned long bgcolor //bgcolor : background color
/*8bpp:R3G3B2
16bpp:R5G6B5
24bpp:R8G8B8*/
, unsigned char bg_transparent
/*bg_transparent = 0, background color with no transparent
bg_transparent = 1, background color with transparent*/
,unsigned char code //code : font char
)
```

```
// Note. this API does not support the case that MCU=16bit, 24bpp and mode1
void lcdPutString8x12
(
unsigned short x //x of coordinate
,unsigned short y //y of coordinate
, unsigned long fgcolor //fgcolor : foreground color(font color)
,unsigned long bgcolor //bgcolor : background color
/*8bpp:R3G3B2
16bpp:R5G6B5
24bpp:R8G8B8*/
, unsigned char bg_transparent
/*bg_transparent = 0, background color with no transparent
bg_transparent = 1, background color with transparent*/
,char *ptr //*ptr: font string
)


// Note. this API does not support the case that MCU=16bit, 24bpp and mode1
void lcdPutChar16x24
(
unsigned short x //x of coordinate
,unsigned short y //y of coordinate
,unsigned long fgcolor //fgcolor : foreground color(font color)
,unsigned long bgcolor //bgcolor : background color
/*8bpp:R3G3B2
16bpp:R5G6B5
24bpp:R8G8B8*/
, unsigned char bg_transparent
/*bg_transparent = 0, background color with no transparent
bg_transparent = 1, background color with transparent*/
,unsigned char code //code : font char
)
```

```
// Note. this API does not support the case that MCU=16bit, 24bpp and mode1
void lcdPutString16x24
(
unsigned short x //x of coordinate
,unsigned short y //y of coordinate
, unsigned long fgcolor //fgcolor : foreground color(font color)
, unsigned long bgcolor //bgcolor : background color
/*8bpp:R3G3B2
16bpp:R5G6B5
24bpp:R8G8B8/*
, unsigned char bg_transparent
/*bg_transparent = 0, background color with no transparent
bg_transparent = 1, background color with transparent*/
,char *ptr //*ptr : font string
)



// Note. this API does not support the case that MCU=16bit, 24bpp and mode1
void lcdPutChar32x48
(
unsigned short x //x of coordinate
,unsigned short y //y of coordinate
,unsigned long fgcolor //fgcolor : foreground color(font color)
,unsigned long bgcolor //bgcolor : background color
/*8bpp:R3G3B2
16bpp:R5G6B5
24bpp:R8G8B8*/
, unsigned char bg_transparent
/*bg_transparent = 0, background color with no transparent
bg_transparent = 1, background color with transparent*/
,unsigned char code //code : font char
)
```

```
// Note. this API does not support the case that MCU=16bit, 24bpp and mode1
void lcdPutString32x48
(
unsigned short x //x of coordinate
,unsigned short y //y of coordinate
, unsigned long fgcolor //fgcolor : foreground color(font color)
, unsigned long bgcolor //bgcolor : background color
/*8bpp:R3G3B2
16bpp:R5G6B5
24bpp:R8G8B8*/
, unsigned char bg_transparent,
/*bg_transparent = 0, background color with no transparent
bg_transparent = 1, background color with transparent*/
char *ptr //*ptr: font string
)
```

范例:

```
Write_Layer(1); //set memory read/write layer.Reference Page.5~6
Show_Layer(1);//set LCD display layer. Reference Page.5~6
+
When color depth = 8bpp
lcdPutString8x12(0,0,0xe0,0x00,0,"sdfs6+55");
lcdPutString16x24(0,100,0x1c,0x00, 0,"sijsojfe565");
lcdPutString32x48(0,200,0x03,0x00,1,"sdjlfw5464ewr");
When color depth = 16bpp
lcdPutString8x12(0,0,0xf800,0x0000,0,"sdfs6+55");
lcdPutString16x24(0,100,0x07e0,0x0000, 0,"sijsojfe565");
lcdPutString32x48(0,200,0x001f,0x0000,1,"sdjlfw5464ewr");
When color depth = 24bpp
lcdPutString8x12(0,0,0xff0000,0x000000,0,"sdfs6+55");
lcdPutString16x24(0,100,0x00ff00,0x000000, 0,"sijsojfe565");
lcdPutString32x48(0,200,0x0000ff,0x000000,1,"sdjlfw5464ewr");
```

图 8-1： 再图层 1 写入自建字画面示意图