VGA 编程输出测试实验

黑金动力社区 2023-02-24

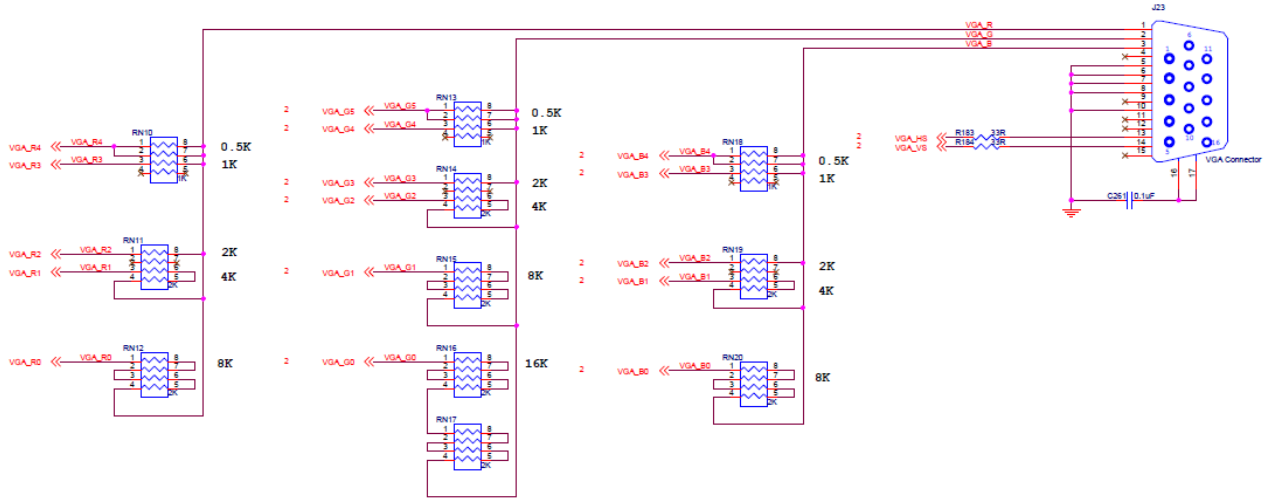
1 实验简介

VGA 接口即电脑采用 VGA 标准输出数据的专用接口。VGA 接口共有 15 针，分成 3 排，每排 5 个孔，显卡上应用最为广泛的接口类型，绝大多数显卡都带有此种接口。它传输红、绿、蓝模拟信号以及同步信号(水平和垂直信号)。本实验将介绍在 AX701 和 AX7102 开发板上如何实现 VGA 图像的显示。

2 实验原理

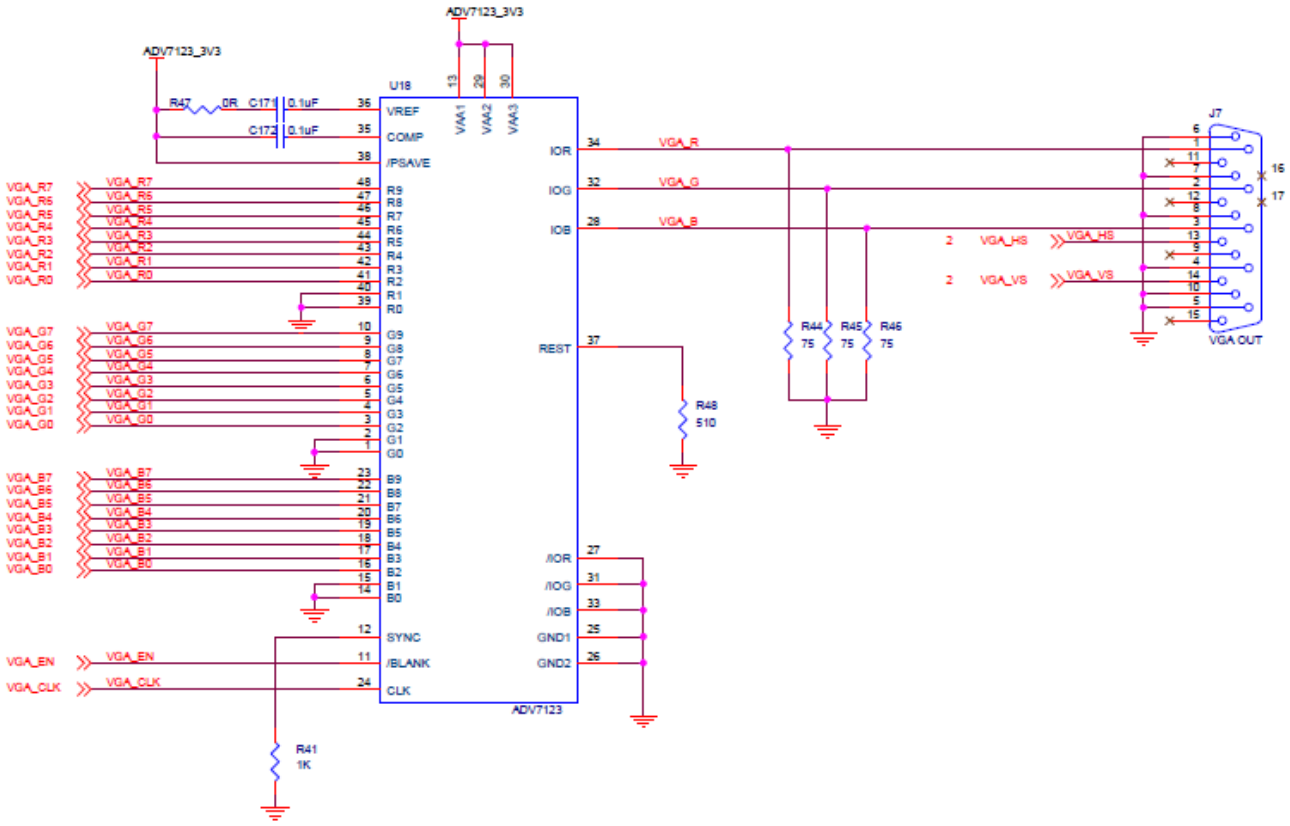
2.1 硬件设计

AX7101 开发板使用常用的 RGB565 数据输出,也就是 16 位的高彩色 VGA 显示, 其中红色信号占 5 位, 绿色信号占 6 位, 蓝色信号占 5 位。电路设计上通过电阻匹配网络实现 RGB 数字信号到模拟信号的转换。



AX7101 VGA 输出部分电路

AX7102(AX7202)开发板使用了 ADI 公司的 ADV7123 芯片实现 VGA 输出，ADV7123 内含三路 10 位 D/A 转换器，对输入的 RGB 数字信号进行模拟转换输出 VGA 视频信号，最高支持 1080p@60Hz 输出。FPGA 输出的 RGB 数字信号为 24 位色, 其中红绿蓝三种颜色各 8 位， FPGA 输出的红绿蓝各 8 位数据连接到 ADV7123 的 3 路 D/A 转换的数据输入高 8 位，数据输入的低 2 位置 0。下图为 ADV7123 的原理图设计:



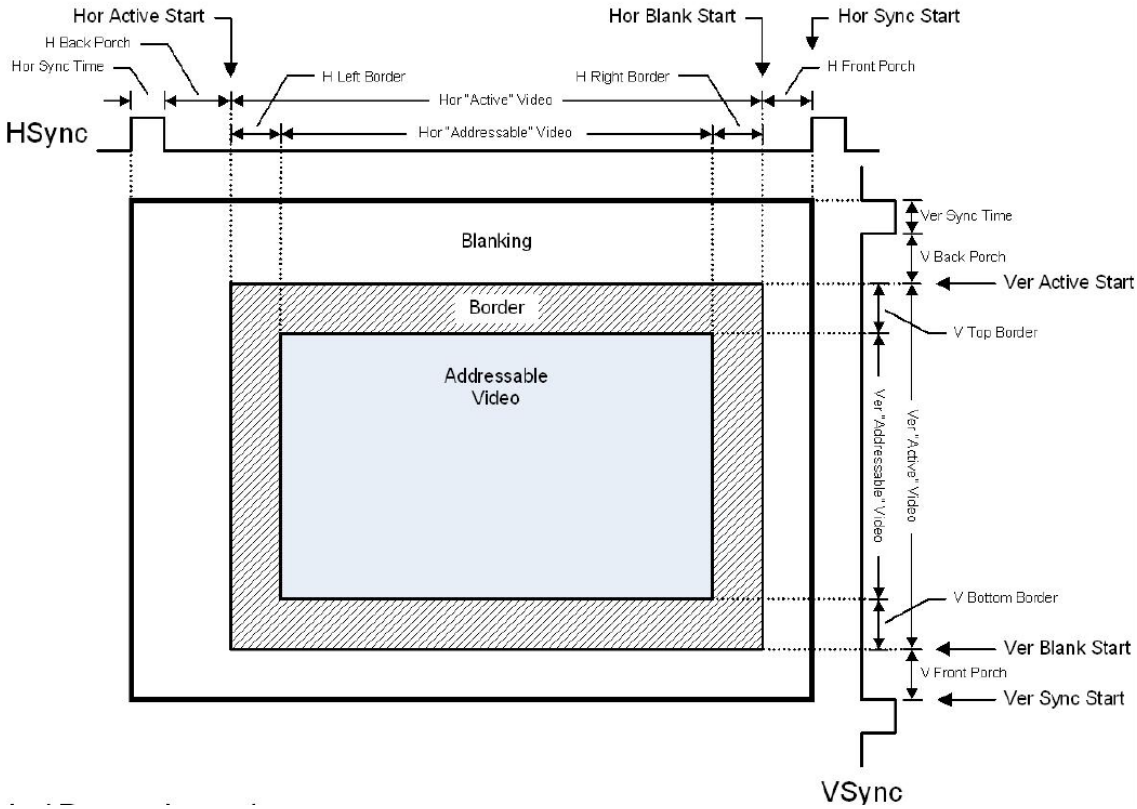
AX7102(AX7202) VGA 输出部分电路

2.2 视频时序标准

VGA 显示器扫描方式从屏幕左上角一点开始，从左向右逐点扫描，每扫描完一行,电子束回到屏幕的左边下一行的起始位置，在这期间，CRT 对电子束进行消隐，每行结束时，用行同步信号进行同步；当扫描完所有的行，形成一帧，用场同步信号进行场同步，并使扫描回到屏幕左上方，同时进行场消隐，开始下一帧。

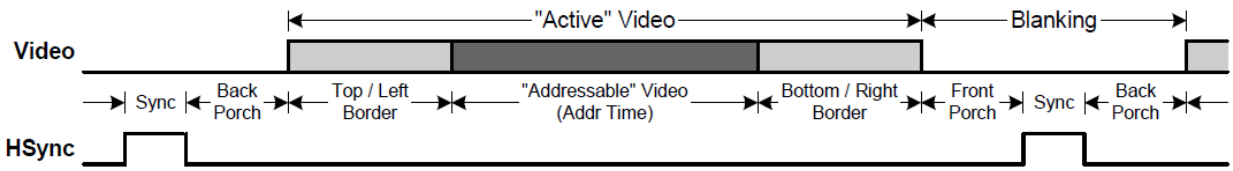
完成一行扫描的时间称为水平扫描时间，其倒数称为行频率；完成一帧（整屏）扫描的时间称为垂直扫描时间，其倒数称为场频率，即刷新一屏的频率，常见的有 60Hz，75Hz 等等。标准的显示的场频 60Hz。

时钟频率：以 1024x768@59.94Hz(60Hz)为例，每场对应 806 个行周期,其中 768 为显示行。每显示行包括 1344 点时钟,其中 1024 点为有效显示区。由此可知：需要点时钟频率：806*1344*60 约 65MHz。



视频时序

VGA 扫描，基本元素是行扫描，多行组成一帧，下图显示一行的时序，其中“Active” Video 是一行视频的有效像素，大部分分辨率时钟中 Top/Left Border 和 Bottom / Right Border 都是 0。“Blanking”是一行的同步时间，“Blanking”时间加上 Active” Video 时间就是一行的时间。“Blanking”又分为“Front Porch”、“Sync”、“Back Porch”三段。



行同步时序

2.3 常见分辨率时序

Timing Name	=	**640 x 480 @ 60Hz;**						
Hor Pixels	=	**640;**	// Pixels					
Ver Pixels	=	**480;**	// Lines					
Hor Frequency	=	31.469;	// kHz	=	31.8 usec	/	line	
Ver Frequency	=	59.940;	// Hz	=	16.7 msec	/	frame	
Pixel Clock	=	**25.175;**	// MHz	=	39.7 nsec		± 0.5%	
Character Width	=	**8;**	// Pixels	=	317.8 nsec			
Scan Type	=	**NONINTERLACED;**			// H Phase	=	2.0 %	
Hor Sync Polarity	=	**NEGATIVE;**	// HBlank	=	18.0% of HTotal			
Ver Sync Polarity	=	**NEGATIVE;**	// VBlank	=	5.5% of VTotal			
Hor Total Time	=	31.778;	// (usec)	=	100 chars	=	800 Pixels	
Hor Addr Time	=	25.422;	// (usec)	=	80 chars	=	640 Pixels	
Hor Blank Start	=	25.740;	// (usec)	=	81 chars	=	648 Pixels	
Hor Blank Time	=	5.720;	// (usec)	=	18 chars	=	144 Pixels	
Hor Sync Start	=	26.058;	// (usec)	=	82 chars	=	656 Pixels	
// H Right Border	=	0.318;	// (usec)	=	**1** chars	=	8 Pixels	
// H Front Porch	=	0.318;	// (usec)	=	**1** chars	=	8 Pixels	
Hor Sync Time	=	3.813;	// (usec)	=	**12** chars	=	96 Pixels	
// H Back Porch	=	1.589;	// (usec)	=	**5** chars	=	40 Pixels	
// H Left Border	=	0.318;	// (usec)	=	**1** chars	=	8 Pixels	
Ver Total Time	=	16.683;	// (msec)	=	525 lines		HT – (1.06xHA)	
Ver Addr Time	=	15.253;	// (msec)	=	480 lines		= 4.83	
Ver Blank Start	=	15.507;	// (msec)	=	488 lines			
Ver Blank Time	=	0.922;	// (msec)	=	29 lines			
Ver Sync Start	=	15.571;	// (msec)	=	490 lines			
// V Bottom Border	=	0.254;	// (msec)	=	**8** lines			
// V Front Porch	=	0.064;	// (msec)	=	**2** lines			
Ver Sync Time	=	0.064;	// (msec)	=	**2** lines			
// V Back Porch	=	0.794;	// (msec)	=	**25** lines			
// V Top Border	=	0.254;	// (msec)	=	**8** lines			

640x480@60Hz 时序参数

Timing Name	= **800 x 600 @ 60Hz;**						
Hor Pixels	= **800;**	// Pixels					
Ver Pixels	= **600;**	// Lines					
Hor Frequency	= 37.879;	// kHz	=	26.4 usec	/	line	
Ver Frequency	= 60.317;	// Hz	=	16.6 msec	/	frame	
Pixel Clock	= **40.000;**	// MHz	=	25.0 nsec	± 0.5%		
Character Width	= **8;**	// Pixels	=	200.0 nsec			
Scan Type	= **NONINTERLACED;**			// H Phase	=	2.3 %	
Hor Sync Polarity	= **POSITIVE;**	// HBlank	=	24.2% of HTotal			
Ver Sync Polarity	= **POSITIVE;**	// VBlank	=	4.5% of VTotal			
Hor Total Time	= 26.400;	// (usec)	=	132 chars	=	1056 Pixels	
Hor Addr Time	= 20.000;	// (usec)	=	100 chars	=	800 Pixels	
Hor Blank Start	= 20.000;	// (usec)	=	100 chars	=	800 Pixels	
Hor Blank Time	= 6.400;	// (usec)	=	32 chars	=	256 Pixels	
Hor Sync Start	= 21.000;	// (usec)	=	105 chars	=	840 Pixels	
// H Right Border	= 0.000;	// (usec)	=	**0** chars	=	0 Pixels	
// H Front Porch	= 1.000;	// (usec)	=	**5** chars	=	40 Pixels	
Hor Sync Time	= 3.200;	// (usec)	=	**16** chars	=	128 Pixels	
// H Back Porch	= 2.200;	// (usec)	=	**11** chars	=	88 Pixels	
// H Left Border	= 0.000;	// (usec)	=	**0** chars	=	0 Pixels	
Ver Total Time	= 16.579;	// (msec)	=	628 lines	HT – (1.06xHA)		
Ver Addr Time	= 15.840;	// (msec)	=	600 lines	= 5.2		
Ver Blank Start	= 15.840;	// (msec)	=	600 lines			
Ver Blank Time	= 0.739;	// (msec)	=	28 lines			
Ver Sync Start	= 15.866;	// (msec)	=	601 lines			
// V Bottom Border	= 0.000;	// (msec)	=	**0** lines			
// V Front Porch	= 0.026;	// (msec)	=	**1** lines			
Ver Sync Time	= 0.106;	// (msec)	=	**4** lines			
// V Back Porch	= 0.607;	// (msec)	=	**23** lines			
// V Top Border	= 0.000;	// (msec)	=	**0** lines			

800x600@60Hz 时序参数

Timing Name	= **1024 x 768 @ 60Hz;**						
Hor Pixels	= **1024;**	// Pixels					
Ver Pixels	= **768;**	// Lines					
Hor Frequency	= 48.363;	// kHz	=	20.7 usec	/	line	
Ver Frequency	= 60.004;	// Hz	=	16.7 msec	/	frame	
Pixel Clock	= **65.000;**	// MHz	=	15.4 nsec		± 0.5%	
Character Width	= **8;**	// Pixels	=	123.1 nsec			
Scan Type	= **NONINTERLACED;**			// H Phase	=	5.1 %	
Hor Sync Polarity	= **NEGATIVE;**	// HBlank	=	23.8% of HTotal			
Ver Sync Polarity	= **NEGATIVE;**	// VBlank	=	4.7% of VTotal			
Hor Total Time	= 20.677;	// (usec)	=	168 chars	=	1344 Pixels	
Hor Addr Time	= 15.754;	// (usec)	=	128 chars	=	1024 Pixels	
Hor Blank Start	= 15.754;	// (usec)	=	128 chars	=	1024 Pixels	
Hor Blank Time	= 4.923;	// (usec)	=	40 chars	=	320 Pixels	
Hor Sync Start	= 16.123;	// (usec)	=	131 chars	=	1048 Pixels	
// H Right Border	= 0.000;	// (usec)	=	**0** chars	=	0 Pixels	
// H Front Porch	= 0.369;	// (usec)	=	**3** chars	=	24 Pixels	
Hor Sync Time	= 2.092;	// (usec)	=	**17** chars	=	136 Pixels	
// H Back Porch	= 2.462;	// (usec)	=	**20** chars	=	160 Pixels	
// H Left Border	= 0.000;	// (usec)	=	**0** chars	=	0 Pixels	
Ver Total Time	= 16.666;	// (msec)	=	806 lines		HT – (1.06xHA)	
Ver Addr Time	= 15.880;	// (msec)	=	768 lines		= 3.98	
Ver Blank Start	= 15.880;	// (msec)	=	768 lines			
Ver Blank Time	= 0.786;	// (msec)	=	38 lines			
Ver Sync Start	= 15.942;	// (msec)	=	771 lines			
// V Bottom Border	= 0.000;	// (msec)	=	**0** lines			
// V Front Porch	= 0.062;	// (msec)	=	**3** lines			
Ver Sync Time	= 0.124;	// (msec)	=	**6** lines			
// V Back Porch	= 0.600;	// (msec)	=	**29** lines			
// V Top Border	= 0.000;	// (msec)	=	**0** lines			

1024x768@60Hz 时序参数

Timing Name	=	**1280 x 720 @ 60Hz;**						
Hor Pixels	=	**1280;**	// Pixels					
Ver Pixels	=	**720;**	// Lines					
Hor Frequency	=	45.000;	// KHz	=	22.2 usec	/	line	
Ver Frequency	=	60.000;	// Hz	=	16.7 msec	/	frame	
Pixel Clock	=	**74.250;**	// MHz	=	13.5 nsec		± 0.5%	
Character Width	=	**1;**	// Pixels	=	13.5 nsec			
Scan Type	=	**NONINTERLACED;**			// H Phase	=	3.3 %	
Hor Sync Polarity	=	**POSITIVE;**	// HBlank	=	22.4% of HTotal			
Ver Sync Polarity	=	**POSITIVE;**	// VBlank	=	4.0% of VTotal			
Hor Total Time	=	22.222;	// (usec)	=	1650 chars	=	1650 Pixels	
Hor Addr Time	=	17.239;	// (usec)	=	1280 chars	=	1280 Pixels	
Hor Blank Start	=	17.239;	// (usec)	=	1280 chars	=	1280 Pixels	
Hor Blank Time	=	4.983;	// (usec)	=	370 chars	=	370 Pixels	
Hor Sync Start	=	18.721;	// (usec)	=	1390 chars	=	1390 Pixels	
// H Right Border	=	0.000;	// (usec)	=	**0** chars	=	0 Pixels	
// H Front Porch	=	1.481;	// (usec)	=	**110** chars	=	110 Pixels	
Hor Sync Time	=	0.539;	// (usec)	=	**40** chars	=	40 Pixels	
// H Back Porch	=	2.963;	// (usec)	=	**220** chars	=	220 Pixels	
// H Left Border	=	0.000;	// (usec)	=	**0** chars	=	0 Pixels	
Ver Total Time	=	16.667;	// (msec)	=	750 lines		HT – (1.06xHA)	
Ver Addr Time	=	16.000;	// (msec)	=	720 lines		= 3.95	
Ver Blank Start	=	16.000;	// (msec)	=	720 lines			
Ver Blank Time	=	0.667;	// (msec)	=	30 lines			
Ver Sync Start	=	16.111;	// (msec)	=	725 lines			
// V Bottom Border	=	0.000;	// (msec)	=	**0** lines			
// V Front Porch	=	0.111;	// (msec)	=	**5** lines			
Ver Sync Time	=	0.111;	// (msec)	=	**5** lines			
// V Back Porch	=	0.444;	// (msec)	=	**20** lines			
// V Top Border	=	0.000;	// (msec)	=	**0** lines			

1280x720@60Hz 时序参数

Timing Name	= **1280 x 800 @ 60Hz;**						
Hor Pixels	= **1280;**	// Pixels					
Ver Pixels	= **800;**	// Lines					
Hor Frequency	= 49.702;	// kHz	=	20.1 usec	/	line	
Ver Frequency	= 59.810;	// Hz	=	16.7 msec	/	frame	
Pixel Clock	= **83.500;**	// MHz	=	12.0 nsec		± 0.5%	
Character Width	= **8;**	// Pixels	=	95.8 nsec			
Scan Type	= **NONINTERLACED;**			// H Phase	=	3.8 %	
Hor Sync Polarity	= **NEGATIVE;**	// HBlank	=	23.8% of HTotal			
Ver Sync Polarity	= **POSITIVE;**	// VBlank	=	3.7% of VTotal			
Hor Total Time	= 20.120;	// (usec)	=	210 chars	=	1680 Pixels	
Hor Addr Time	= 15.329;	// (usec)	=	160 chars	=	1280 Pixels	
Hor Blank Start	= 15.329;	// (usec)	=	160 chars	=	1280 Pixels	
Hor Blank Time	= 4.790;	// (usec)	=	50 chars	=	400 Pixels	
Hor Sync Start	= 16.192;	// (usec)	=	169 chars	=	1352 Pixels	
// H Right Border	= 0.000;	// (usec)	=	**0** chars	=	0 Pixels	
// H Front Porch	= 0.862;	// (usec)	=	**9** chars	=	72 Pixels	
Hor Sync Time	= 1.533;	// (usec)	=	**16** chars	=	128 Pixels	
// H Back Porch	= 2.395;	// (usec)	=	**25** chars	=	200 Pixels	
// H Left Border	= 0.000;	// (usec)	=	**0** chars	=	0 Pixels	
Ver Total Time	= 16.720;	// (msec)	=	831 lines		HT – (1.06xHA)	
Ver Addr Time	= 16.096;	// (msec)	=	800 lines		= 3.87	
Ver Blank Start	= 16.096;	// (msec)	=	800 lines			
Ver Blank Time	= 0.624;	// (msec)	=	31 lines			
Ver Sync Start	= 16.156;	// (msec)	=	803 lines			
// V Bottom Border	= 0.000;	// (msec)	=	**0** lines			
// V Front Porch	= 0.060;	// (msec)	=	**3** lines			
Ver Sync Time	= 0.121;	// (msec)	=	**6** lines			
// V Back Porch	= 0.443;	// (msec)	=	**22** lines			
// V Top Border	= 0.000;	// (msec)	=	**0** lines			

1280x800@60Hz 时序参数

Timing Name	=	**1280 x 960 @ 60Hz;**						
Hor Pixels	=	**1280;**	// Pixels					
Ver Pixels	=	**960;**	// Lines					
Hor Frequency	=	60.000;	// kHz	=	16.7	usec	/	line
Ver Frequency	=	60.000;	// Hz	=	16.7	msec	/	frame
Pixel Clock	=	**108.000;**	// MHz	=	9.3	nsec	± 0.5%	
Character Width	=	**8;**	// Pixels	=	74.1	nsec		
Scan Type	=	**NONINTERLACED;**			// H Phase	=	6.0 %	
Hor Sync Polarity	=	**POSITIVE;**	// HBlank	=	28.9%	of HTotal		
Ver Sync Polarity	=	**POSITIVE;**	// VBlank	=	4.0%	of VTotal		
Hor Total Time	=	16.667;	// (usec)	=	225	chars	=	1800 Pixels
Hor Addr Time	=	11.852;	// (usec)	=	160	chars	=	1280 Pixels
Hor Blank Start	=	11.852;	// (usec)	=	160	chars	=	1280 Pixels
Hor Blank Time	=	4.815;	// (usec)	=	65	chars	=	520 Pixels
Hor Sync Start	=	12.741;	// (usec)	=	172	chars	=	1376 Pixels
// H Right Border	=	0.000;	// (usec)	=	**0**	chars	=	0 Pixels
// H Front Porch	=	0.889;	// (usec)	=	**12**	chars	=	96 Pixels
Hor Sync Time	=	1.037;	// (usec)	=	**14**	chars	=	112 Pixels
// H Back Porch	=	2.889;	// (usec)	=	**39**	chars	=	312 Pixels
// H Left Border	=	0.000;	// (usec)	=	**0**	chars	=	0 Pixels
Ver Total Time	=	16.667;	// (msec)	=	1000	lines	HT – (1.06xHA)	
Ver Addr Time	=	16.000;	// (msec)	=	960	lines	= 4.1	
Ver Blank Start	=	16.000;	// (msec)	=	960	lines		
Ver Blank Time	=	0.667;	// (msec)	=	40	lines		
Ver Sync Start	=	16.017;	// (msec)	=	961	lines		
// V Bottom Border	=	0.000;	// (msec)	=	**0**	lines		
// V Front Porch	=	0.017;	// (msec)	=	**1**	lines		
Ver Sync Time	=	0.050;	// (msec)	=	**3**	lines		
// V Back Porch	=	0.600;	// (msec)	=	**36**	lines		
// V Top Border	=	0.000;	// (msec)	=	**0**	lines		

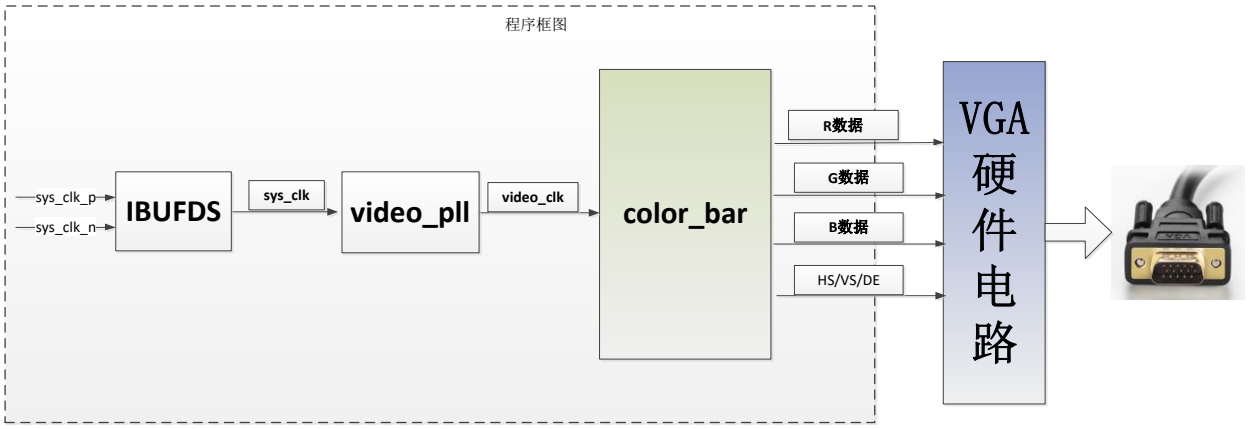
1280x960@60Hz 时序参数

Timing Name	= **1280 x 1024 @ 60Hz;**						
Hor Pixels	= **1280;**	// Pixels					
Ver Pixels	= **1024;**	// Lines					
Hor Frequency	= 63.981;	// kHz	=	15.6 usec	/	line	
Ver Frequency	= 60.020;	// Hz	=	16.7 msec	/	frame	
Pixel Clock	= **108.000;**	// MHz	=	9.3 nsec	± 0.5%		
Character Width	= **8;**	// Pixels	=	74.1 nsec			
Scan Type	= **NONINTERLACED;**			// H Phase	=	5.9 %	
Hor Sync Polarity	= **POSITIVE;**	// HBlank	=	24.2% of HTotal			
Ver Sync Polarity	= **POSITIVE;**	// VBlank	=	3.9% of VTotal			
Hor Total Time	= 15.630;	// (usec)	=	211 chars	=	1688 Pixels	
Hor Addr Time	= 11.852;	// (usec)	=	160 chars	=	1280 Pixels	
Hor Blank Start	= 11.852;	// (usec)	=	160 chars	=	1280 Pixels	
Hor Blank Time	= 3.778;	// (usec)	=	51 chars	=	408 Pixels	
Hor Sync Start	= 12.296;	// (usec)	=	166 chars	=	1328 Pixels	
// H Right Border	= 0.000;	// (usec)	=	**0** chars	=	0 Pixels	
// H Front Porch	= 0.444;	// (usec)	=	**6** chars	=	48 Pixels	
Hor Sync Time	= 1.037;	// (usec)	=	**14** chars	=	112 Pixels	
// H Back Porch	= 2.296;	// (usec)	=	**31** chars	=	248 Pixels	
// H Left Border	= 0.000;	// (usec)	=	**0** chars	=	0 Pixels	
Ver Total Time	= 16.661;	// (msec)	=	1066 lines	HT – (1.06xHA)		
Ver Addr Time	= 16.005;	// (msec)	=	1024 lines	= 3.07		
Ver Blank Start	= 16.005;	// (msec)	=	1024 lines			
Ver Blank Time	= 0.656;	// (msec)	=	42 lines			
Ver Sync Start	= 16.020;	// (msec)	=	1025 lines			
// V Bottom Border	= 0.000;	// (msec)	=	**0** lines			
// V Front Porch	= 0.016;	// (msec)	=	**1** lines			
Ver Sync Time	= 0.047;	// (msec)	=	**3** lines			
// V Back Porch	= 0.594;	// (msec)	=	**38** lines			
// V Top Border	= 0.000;	// (msec)	=	**0** lines			

1280x1024@60Hz 时序参数

3 程序设计

本实验实现 VGA 输出显示，在 VGA 显示器里显示测试的彩条图像。程序由 3 个模块实现，分别是差分转单端 IBUFDS 模块，时钟模块 vidio_pll, 彩条生成模块 color_bar。实现的逻辑框图如下：



1. IBUFDS 模块

功能是对输入时钟进行差分转单端输出。

2.VGA 时钟模块 video_pll

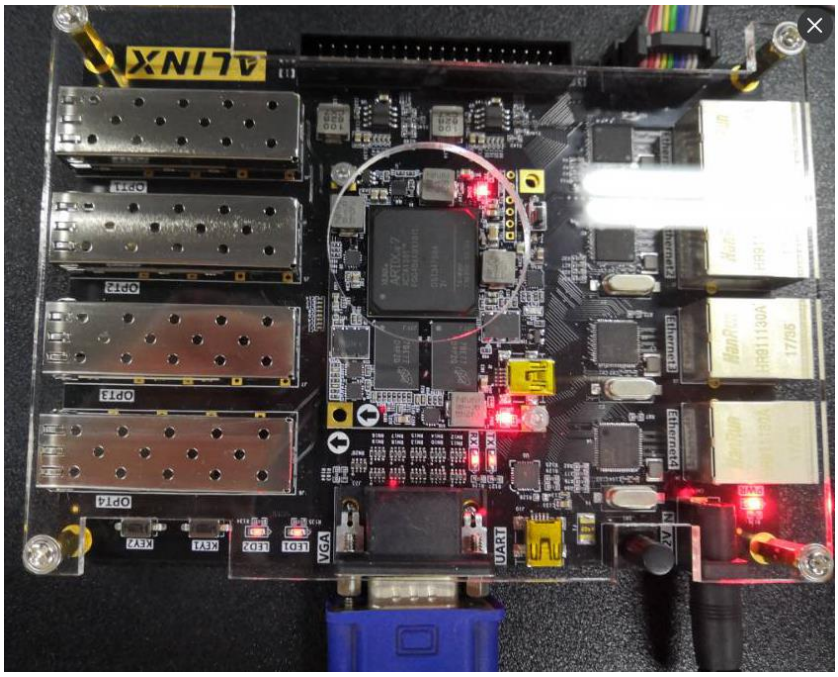
video_pll 模块是倍频产生模块，通过输入的 sys_clk 时钟产生 VGA 显示所需要的时钟信号，模块中设置为 65MHz，用来满足 VGA 分辨率为 1024x768 的要求。

3. 彩条产生模块 color_bar.v

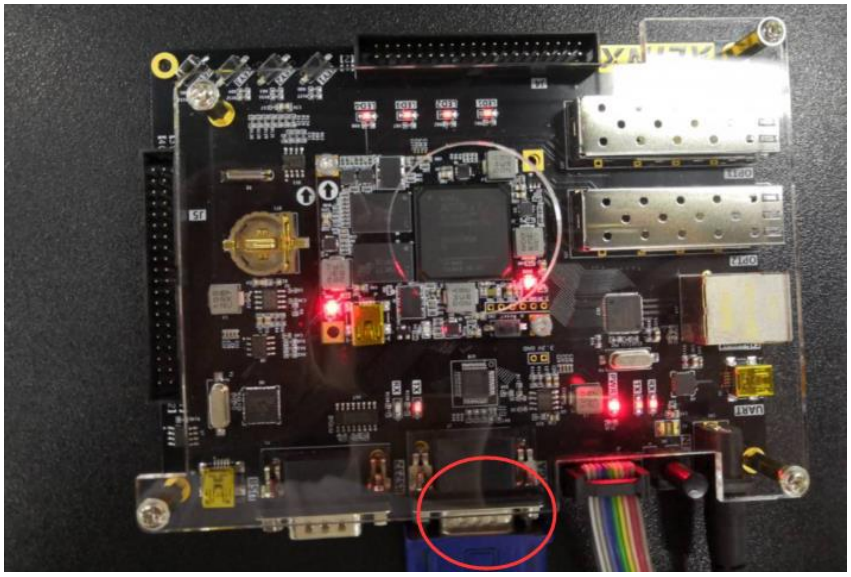
color_bar.v 是产生 8 种颜色的 VGA 格式的彩条，彩条分别为白、黄、青、绿、紫、红、蓝和黑。针对 VGA 的时序，行同步和场同步各使用一个计数器，行同步计数器用于产生行同步，行有效像素，场同步计数器用于产生场同步，场有效像素。同时根据计数器的值可以产生水平（X）和垂直（Y）坐标，通过坐标信息，可以实时显示一些图形。程序中预设了几种分辨率的时序参数，包括 2 款 LCD 液晶屏的，为后续的 LCD 验证试验做准备。

4 试验现象

连接好开发板和显示器，需要注意，开发板的各个连接器不要带电热插拔，下载好试验程序，可以看到显示器显示 8 条彩条。开发板做为 VGA 输出设备，只能通过 VGA 显示设备来显示，注意不要试图通过笔记本电脑的 VGA 接口来显示，因为笔记本也是输出设备。



AX7101(AX7201) VGA 显示器连接



AX7102(AX7202) VGA 显示器连接

彩条显示

在用 AX7101(AX7201)开发板做 4.3 寸 LCD、7 寸 LCD 屏显示实验时，LCD 模块接 J11 扩展口；在用 AX7102(AX7202)开发板做 4.3 寸 LCD 、7 寸 LCD 屏显示实验时，LCD 模块接 J5 扩展口，注意管脚不要接错。