芯驿电子科技（上海）有限公司
021-67676997
www.alinx.cn
www.heijin.org

HDMI 测试实验

1   实验简介

HDMI 做为视频输出输入接口已经广泛使用很长时间，主要通过 TMDS 差分编码传输。本实验通过在 HDMI 屏幕上显示彩条和输入输出环通实验，来练习视频的时序和视频颜色的表示，为后面视频处理实验做个基础。

2   实验原理

2.1   硬件介绍

AXP100 开发板使用 4 对 TMDS 差分显示, 其中一对是时钟，其他三对是数据。

HDMI 采用和 DVI 相同的传输原理——TMDS（Transition Minimized Differential signal），最小化传输差分信号。

TMDS 传输系统分为分为两个部分：发送端和接收端。TMDS 发送端收到 HDMI 接口传来的表示 RGB 信号的 24 位并行数据（TMDS 对每个像素的 RGB 三原色分别按 8bit 编码，即 R 信号有 8 位，G 信号有 8 位，B 信号有 8 位），然后对这些数据进行编码和并/串转换，再将表示 3 个 RGB 信号的数据分别分配到独立的传输通道发送出去。接收端接收来自发送端的串行信号，对其进行解码和串/并转换，然后发送到显示器的控制端。与此同时也接收时钟信号，以实现同步。
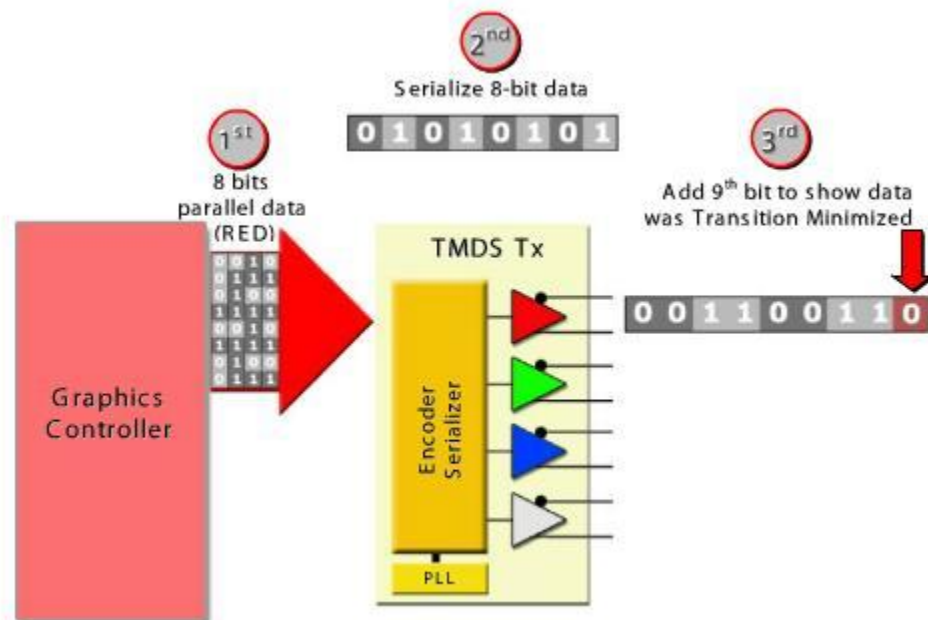
TMDS 的原理

每一个 TMDS 链路都包括 3 个传输 RGB 信号的数据通道和 1 个传输时钟信号的通道。每一个数据通道都通过编码算法，将 8 位的视、音频数据转换成最小化传输、直流平衡的 10 位数据。这使得数据的传输和恢复更加可靠。最小化传输差分信号是通过异或及异或非等逻辑算法将原始 8 位信号数据转换成 10 位，前 8 为数据由原始信号经运算后获得，第 9 位指示运算的方式，第 10 位用来对应直流平衡。

一般来说，HDMI 传输的编码格式中要包含视频数据、控制数据和数据包（数据包中包含音频数据和附加信息数据，例如纠错码等）。TMDS 每个通道在传输时要包含一个 2bit 的控制数据、8bit 的视频数据或者 4bit 的数据包即可。在 HDMI 信息传输过程中，可以分为三个阶段：视频数据传输周期、控制数据传输周期和数据岛传输周期，分别对应上述的三种数据类型。

下面介绍 TMDS 中采用的技术：

1.传输最小化

8 位数据经过编码和直流平衡得到 10 位最小化数据，这仿佛增加了冗余位，对传输链路的带宽要求更高，但事实上，通过这种算法得到的 10 位数据在更长的同轴电缆中传输的可靠性增强了。下图是一个例子，说明对一个 8 位的并行 RED 数据编码、并/串转换。

第一步：将 8 位并行 RED 数据发送到 TMDS 发送端。
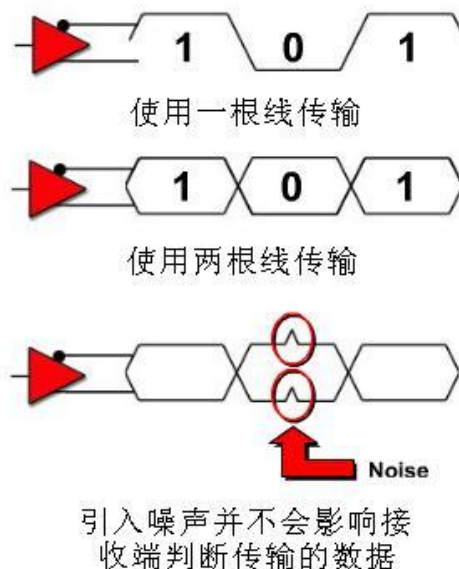
第二步：并/串转换.

第三步：进行最小化传输处理，加上第 9 位，即编码过程。第 9 位数据称为编码位。

2.直流平衡

直流平衡（DC-balanced）就是指在编码过程中保证信道中直流偏移为零。方法是在原来的 9 位数据的后面加上第 10 位数据，这样，传输的数据趋于直流平衡，使信号对传输线的电磁干扰减少，提高信号传输的可靠性。
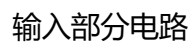
3.差分信号

TMDS 差分传动技术是一种利用 2 个引脚间电压差来传送信号的技术。传输数据的数值（"0"或者"1"）由两脚间电压正负极性和大小决定。即，采用 2 根线来传输信号，一根线上传输原来的信号，另一根线上传输与原来信号相反的信号。这样接收端就可以通过让一根线上的信号减去另一根线上的信号的方式来屏蔽电磁干扰，从而得到正确的信号。

如下图所示:

另外，还有一个显示数据通道（DDC），是用于读取表示接收端显示器的清晰度等显示能力的扩展显示标识数据(EDID)的信号线。搭载 HDCP（High-bandwidth Digital Content Protection，高带宽数字内容保护技术）的发送、接收设备之间也利用 DDC 线进行密码键的认证。

HDMI 输出部分电路

输入部分电路

2.2　视频时序标准

　　HDMI 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

ALINX

2.3 常见分辨率时序

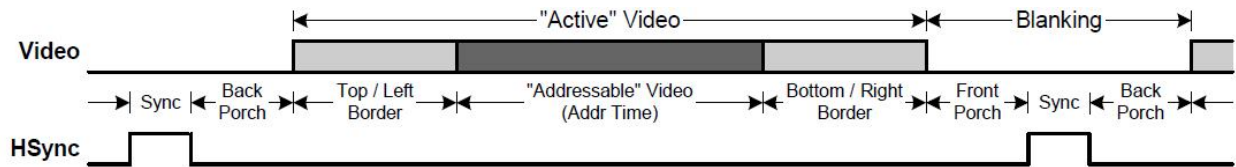| Timing Name	=	**640 x 480 @ 60Hz;**					
Hor Pixels	=	**640;**	// Pixels				
Ver Pixels	=	**480;**	// Lines				
Hor Frequency	=	31.469;	// kHz	=	31.8 usec	/	line
Ver Frequency	=	59.940;	// Hz	=	16.7 msec	/	frame
Pixel Clock	=	**25.175;**	// MHz		39.7 nsec	± 0.5%	
Character Width	=	**8;**	// Pixels		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

ALINX

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

ALINX

```
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

ALINX

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

ALINX

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

```
Timing Name           =  1920 x 1080 @ 60Hz;

Hor Pixels            =  1920;          // Pixels
Ver Pixels            =  1080;          // Lines

Hor Frequency         =  67.500;        // kHz      =      14.8 usec   /  line
Ver Frequency         =  60.000;        // Hz       =      16.7 msec   /  frame

Pixel Clock           =  148.500;       // MHz      =       6.7 nsec        ± 0.5%
Character Width       =  4;             // Pixels   =      26.9 nsec

Scan Type             =  NONINTERLACED;              // H Phase  =     1.4 %

Hor Sync Polarity     =  POSITIVE       // HBlank   =   12.7% of HTotal
Ver Sync Polarity     =  POSITIVE       // VBlank   =    4.0% of VTotal

Hor Total Time        =  14.815;        // (usec)   =    550  chars  =   2200 Pixels
Hor Addr Time         =  12.929;        // (usec)   =    480  chars  =   1920 Pixels
Hor Blank Start       =  12.929;        // (usec)   =    480  chars  =   1920 Pixels
Hor Blank Time        =  1.886;         // (usec)   =     70  chars  =    280 Pixels
Hor Sync Start        =  13.522;        // (usec)   =    502  chars  =   2008 Pixels

// H Right Border     =  0.000;         // (usec)   =      0  chars  =      0 Pixels
// H Front Porch      =  0.593;         // (usec)   =     22  chars  =     88 Pixels
Hor Sync Time         =  0.296;         // (usec)   =     11  chars  =     44 Pixels
// H Back Porch       =  0.997;         // (usec)   =     37  chars  =    148 Pixels
// H Left Border      =  0.000;         // (usec)   =      0  chars  =      0 Pixels

Ver Total Time        =  16.667;        // (msec)   =   1125  lines      HT – (1.06xHA)
Ver Addr Time         =  16.000;        // (msec)   =   1080  lines        = 1.11
Ver Blank Start       =  16.000;        // (msec)   =   1080  lines
Ver Blank Time        =  0.667;         // (msec)   =     45  lines
Ver Sync Start        =  16.059;        // (msec)   =   1084  lines

// V Bottom Border    =  0.000;         // (msec)   =      0  lines
// V Front Porch      =  0.059;         // (msec)   =      4  lines
Ver Sync Time         =  0.074;         // (msec)   =      5  lines
// V Back Porch       =  0.533;         // (msec)   =     36  lines
// V Top Border       =  0.000;         // (msec)   =      0  lines
```
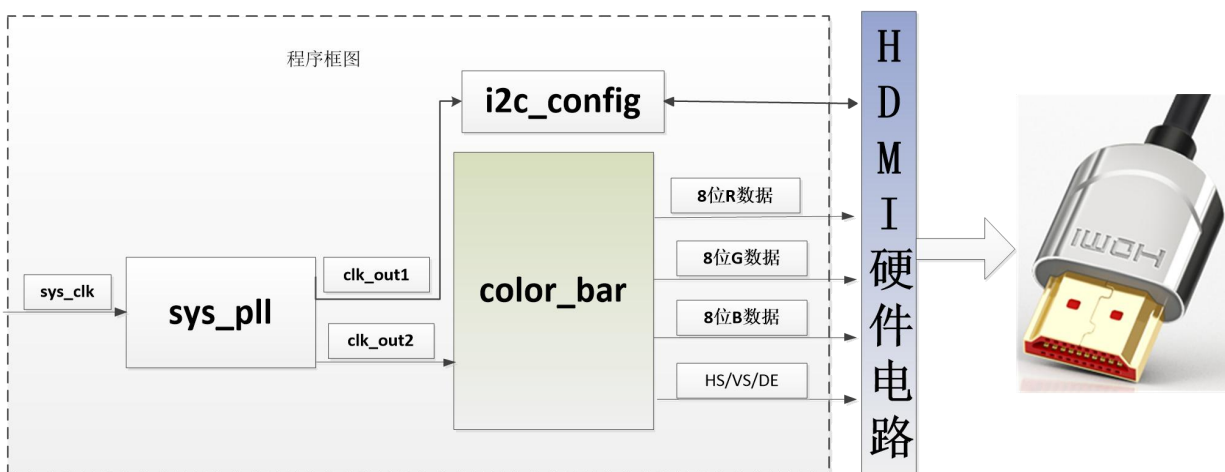
1920x1080@60Hz 时序参数

3　程序设计

本实验将实现 HDMI 输出显示，在 HDMI 显示器里显示测试图像彩条。程序由 3 个模块实现，分别是时钟模块 sys_pll, 彩条生成模块 color_bar 以及 HDMI 接口配置模块 i2c_config。实现的逻辑框图如下：

1.时钟模块 sys_pll

　　sys_pll 模块是倍频产生模块，通过输入的 sys_clk 时钟 2 组时钟信号 clk_out1 和 clk_out2，clk_out1 输出时钟 27MHz，用作 HDMI 接口配置模块的时钟；clk_out2 用来为 color_bar 模块和 HDMI 硬件电路提供时钟；模块中设置为 148.5MHz，用来满足 HDMI 显示分辨率为 1920x1080p 的要求。
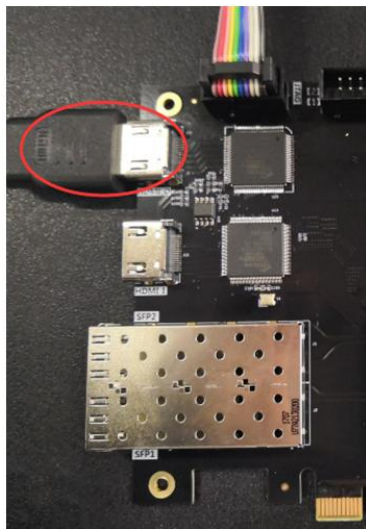
2. 彩条产生模块 color_bar.v

　　color_bar.v 是产生 8 种颜色的彩条，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。在 HDMI 输出中采用硬件芯片 Sil9134 来完成 HDMI1080P 输出显示。在进行 HDMI 环通（输入输出）实验中：输入中采用芯片 Sil9013/9011 进行 HDMI 采集，采用芯片 Sil9134 来完成 HDMI1080P 输出显示。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，详细设置请见提供的相关例程。
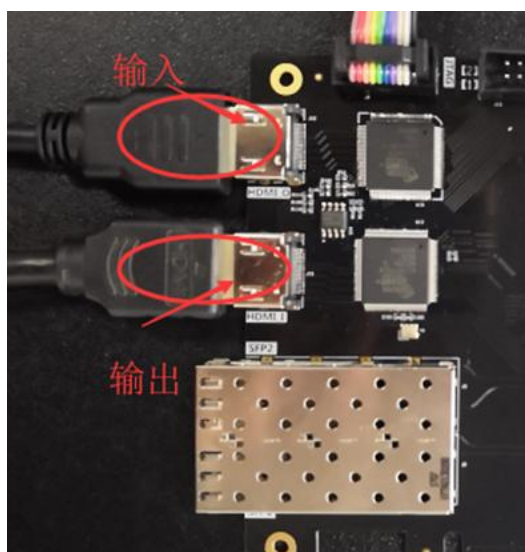
3. HDMI 接口配置模块 i2c_config.v

　　模块中配置了ＨＤＭＩ接口芯片Ｓｉｌ９１３４的寄存器，同时调用了 i2c_master_top 模块实现 IIc 接口通信，用来传递配置参数。

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 HDMI 输出设备，只能通过 HDMI 显示设备来显示，不要试图通过笔记本电脑的 HDMI 接口来显示，因为笔记本也是输出设备。操作如下图所示:
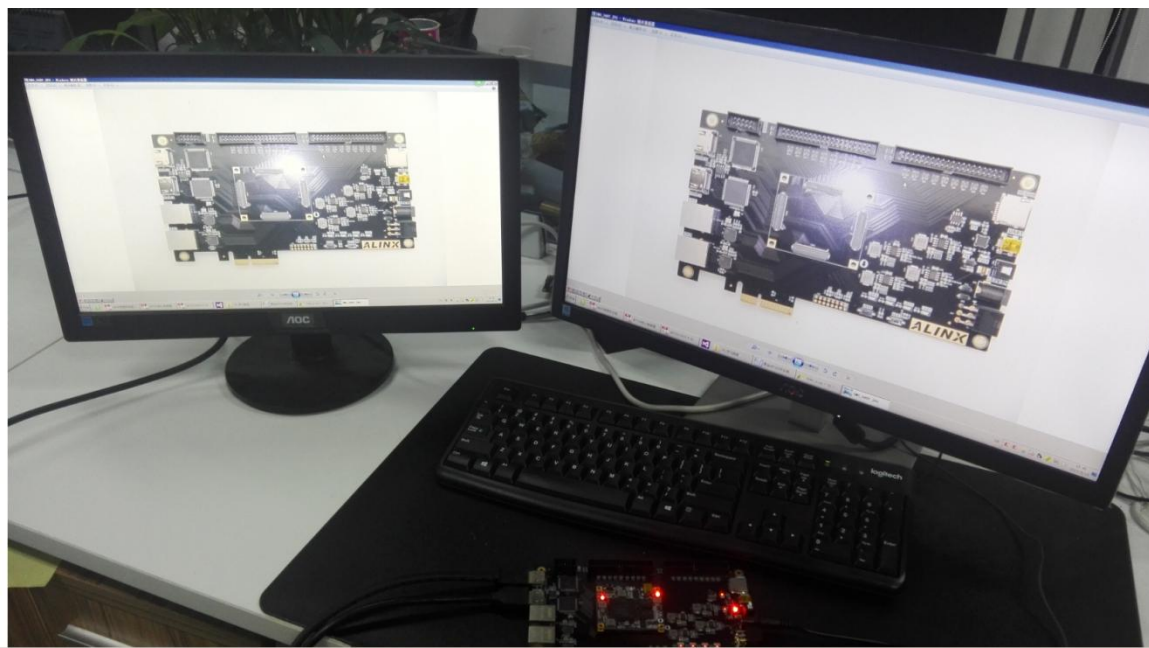

HDMI 显示器连接

HDMI 环通实验连接

彩条显示

　　在做 HDMI 环通实验时，把 HDMI 线一端连接天猫盒子或电脑 HDMI 输出，另一端到开发板的 HDMI_I(J15)上,HDMI 显示器的另一端连接到 HDMI_O（J12）接口，可在显示器上看到（HDMI 显示器需支持 1080P）。如下图所示:

HDMI 环通实验效果

在做 4.3 寸 LCD、7 寸 LCD 屏显示实验时，LCD 模块接 J11 扩展口，注意管脚不要接错。

开发板与 LCD 屏连接