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Wide-bandwidth Video Switches Solve High Resolution Video Design Challenges

Introduction

The consumer market has witnessed the functional convergence in display units such as LCD TV, and multiple-function LCD monitors. Most of these high-tier models support dual or even more component inputs such as PC RGB and progressive YPbPr inputs from external equipment such as DVD players. The LCD monitor will never be a simple desk display but an intelligent unit with multiple analog inputs for potential picture-in-picture (PIP) functions that allows users to simultaneously watch a movie while typing on the same display. In addition, with the transition to HDMI or DVI digital I/Os in both PC and consumer electronics, wide-bandwidth differential analog switches play an important role in routing the digital video signals to reduce the hardware cost. In this application note, design challenges are first analyzed in terms of bandwidth requirements. This is followed by an examination of some applications in notebook and LCD TV designs. Finally, some suggestions are provided to speed up the design in terms of PCB layout and noise reduction in terms of the data path jitter.

High Definition Video Design Challenges

With the migration of computer RGB component input to LCD TV designs, the designer is challenged with signal integrity issues such as undershoot, overshoot and edge distortion for high definition signals. Figure 1 is a typical LCD TV analog front end video processing architecture with video switch used to select either from computer RGB input or high definition YPbPr input to share the same video ASIC in order to reduce the cost. For traditional RGB signals with a resolution smaller than XGA, RGB signal bandwidth is typically smaller than 30MHz. Analog switches with −3dB bandwidth of 300MHz are good enough for such applications. But for high resolution monitors such as UXGA and QXGA displays, for best visual effect, the minimum bandwidth required for video switches needs to be 400MHz (or even higher) under system capacitive loads to minimize the nonlinear distortion for frequency in the low to medium frequency region. This is the region where most high resolution RGB video signals fall in. Smaller bandwidth causes greater fluctuations of AC gain over this frequency region. This can be also reflected into the system specifications such as differential gain and phase, which is the direct cause of the variation of color saturation and hue. For typical LCD TV design in Figure 1, A/D converters also play a key role in terms of image stability. During each pixel time, the analog input video signal needs to settle down whenever the magnitude varies.The analog video signal must settle down to its stable value before being sampled by the pixel clock generated from the phase locked loop circuit inside the A/D converters. For high definition video displays, the challenge is that the total sampling cycle time gets smaller. In order to get a more reliable and stable image, the settling time needs to be smaller. One of the key factors affecting this settling time is the bandwidth of the physical video signal data path. A wide bandwidth video switch with minimum ON Capacitance in Figure 1 is highly desirable to avoid increasing the settling time along the video data path.

In addition to the bandwidth challenges in high definition video design, the ghost image is another tough task for most designers. SYNC pulses embedded in most video luminance signal or green channel (SOG) usually has a magnitude of about −300mv. This is particularly true for high definition component video with tri-level SYNC on each component video signal. As an example, for applications in Figure 1, when the YPbPr inputs are switched OFF and the RGB inputs are routed to the A/D converter inputs, ideally the DVD video inputs (YPbPr) should be blocked and has negligible effect on the RGB channels. This is referred to as “OFF Isolation” in general video switch datasheets. Unfortunately, in some LCD TV designs, designers experience the ghost image coupling from DVD channels to RGB channels. The actual reason for this is that the OFF channel is not totally shut OFF due to the sub-threshold of NMOS devices inside the switch. This is particularly true when the magnitude of SYNC tip is close to −500mV, which makes the internal NMOS device very hard to be completely turned OFF. One of the proposed solutions is to AC couple the input video switch with DC restoration afterwards to lift the tip above ground. Only the Y channel is DC biased in Figure 1 but designers might need to offset other component video inputs if necessary. The bandwidth of the high pass filter formed by the AC coupling capacitor and resistor divider network needs to be much smaller (>10) than the lowest frequency inside the video signal.

Figure 2 is another application of the high bandwidth video switch in a notebook design. Analog RGB component video output from the DAC needs to drive two displays. One goes to the regular VGA connector and another goes to the docking station on the notebook. In most analog video designs, an optional EMI filter is used to reduce the magnetic emission. Unfortunately, EMI filter and external ESD protection devices contribute a high capacitive load to the switch. This extra capacitance, trace inductance and video switch On Capacitance work together resulting in the degraded bandwidth along video signal path. This is particularly true for PC RGB signal with resolution higher than UXGA, which needs the bandwidth of at least 400MHz for optimal signal edge shape under such high capacitive load. In addition, unfortunately the lower bandwidth always correlates to slow rise time, which is critical for video resolution especially for high definition content. In such applications, video switches with minimal On Capacitance and high bandwidth is desired to save some capacitive budget for EMI filter and ESD protection devices particularly for high definition video signals such as UXGA and QXGA modes. Fairchild's newly released 1.1GHz (FSAV430) video switch works for such applications perfectly by offering all those benefits above but still maintains the video signal edge and offers low insertion loss (typically

High Definition Video Design Challenges (Continued)

−0.6dB for 75Ω load). The crosstalk performance offered by Fairchild FSAV430 is −75dB, which offers ignorable video interference between active channels particularly for high definition video with fast edge rate. Due to the highly linear behavior of this device, it offers differential gain less than 0.2% and differential phase of less than 0.1 degree. Minimal differential gain and phase of video switches is important to minimize the color saturation variation dependence on brightness.

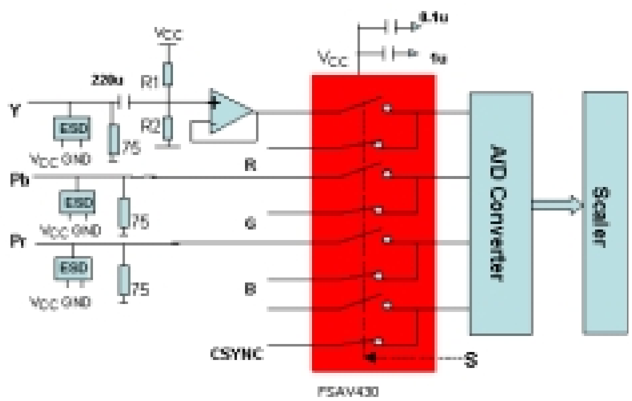


FIGURE 1. Wide-bandwidth Video Switch Used to Route PC RGB Signals Up to QXGA Resolution

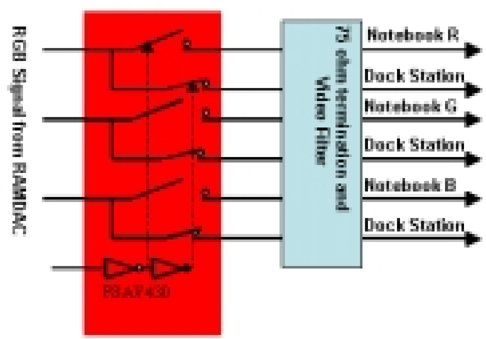
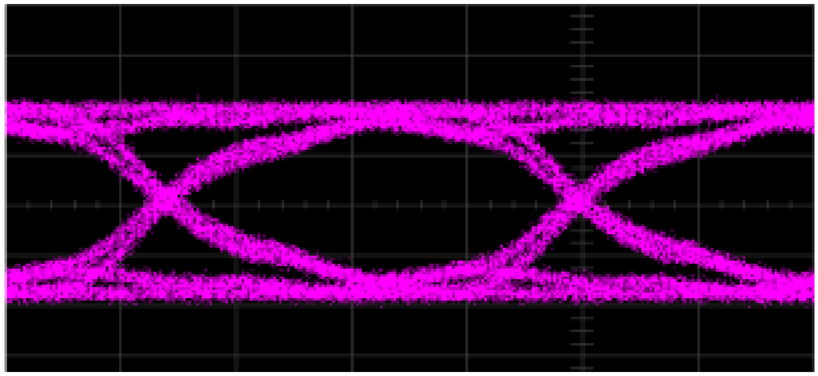


FIGURE 2. Wide-bandwidth Video Switches Offer Great Bandwidth Headroom to Route High Resolution Video Signals with Minimal Edge Distortion

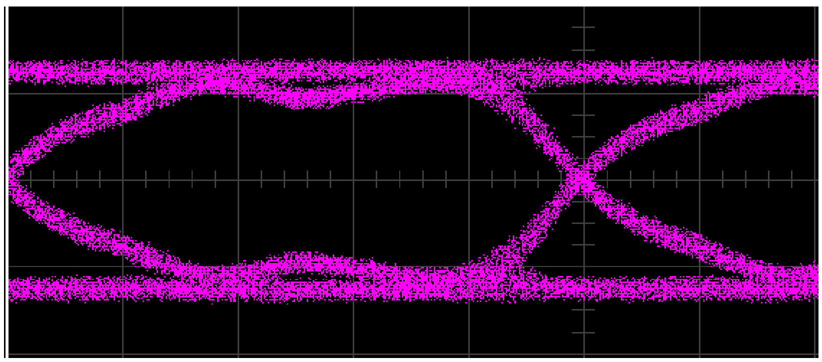
With the advent of high speed digital video connections in consumer applications such as DVI and HDMI interfaces, typically four pairs of differential signals (TMDS) are used to transmit even uncompressed digital video information. This creates a great opportunity for high throughput analog switch in applications such as digital video pin sharing. The higher bandwidth of the switch allows for routing the picture with a higher frame rate to reduce the visual noise. Due to the ultra low power (1uA quiescent current) consumption feature, high bandwidth analog switch can be widely used in portable and handheld designs such as portable DVD devices or notebooks with much lower power consumption for high resolution video signal routing than typical active differential switches. In such designs, additive jitter, pulse skew and channel-to-channel skew is a key specification for clock recovery circuits on the receiver side. Considering the typical analog switch is designed based upon the pass gate architecture, the major source of jitter comes from the On Resistance mismatch between channels, which might contribute to channel-to-channel skew and consequently, the deterministic jitter from both the rise and fall edges. There is a trade-off in design of routing high throughput signals in such applications in term of edge rate choices. Fast edge rates of the differential signal usually relates to smaller deterministic jitter due to the less rising time. But it could challenge the switch in terms of transmission line effect such as reflections. In addition, fast rising edge rates call for wide bandwidth switches since low bandwidth could result in the slow down of the edge by losing some high frequency component of the edges. On the contrary, slow edge does the reverse things. In order to alleviate such design challenges, switches offering both high bandwidth

High Definition Video Design Challenges (Continued)

and low RC delay will service such applications perfectly. In another words, analog switches with low On Capacitance, reasonable On Resistance and the wide −3dB bandwidth will be ideal for this application. The criterion of switch On Resistance is related to the noise margin. Higher On Resistance causes signal magnitude attenuation and the reduction of noise margin. As an example, for high speed LVDS signal switching, the typical LVDS driver has 350mV output swing. 10Ω On Resistance of the switch will cause about 17% signal swing loss in 50Ω trace environment. This means it will loose 24% noise margin for LVDS receivers with 100mV threshold. So the lower the On Resistance, the better the noise margin. Finally, low bandwidth is directly related to the increased data pattern dependent jitter for high speed pseudo random data inputs with fast edge rate and high swing magnitude. Higher phase jitter might cause the bit error and the failure of the eye mask. Figure 3 is the output eye diagram of Fairchild's new video switch FSAV430 (1.1GHz −3dB bandwidth and 5Ω typical On Resistance) with 1.4Gbps TMDS PRBS and 1Gbps LVDS data inputs. The additive jitter is only 66ps peak-to-peak for TMDS inputs and 38ps for LVDS inputs while the quiescent current consumption is only 1uA. This is important for battery based handheld devices such as notebooks or portable DVD players. The power consumption is also much lower than most other wide bandwidth video switches in the market based on charge pump solutions. Two FSAV430 devices are needed to switch 4 pairs of TMDS or LVDS differential signals.



a) Output Eye Diagram for TMDS Inputs (1.4Gbps)



b) Output Eye Diagram for LVDS Inputs (1Gbps)

FIGURE 3. FSAV430 Used to Route High Throughput Differential Signals

Design Suggestions

For analog design in application 1 and 2, in addition to bandwidth, differential gain and phase specifications are critical to most video designers. As a matter of fact, differential gain is related to the linearity of the analog data path. In order to improve the analog switch linearity in term of On Resistance flatness, it is always important to have decoupling capacitors of 0.01uF and 1uF sitting close to the V_{CC} supply pins. Wedge shaped ground copper on the top between adjacent video channels is very efficient to improve the OFF Isolation and crosstalk performance when needed. The distance from ground copper to the active signal needs to be much further than the distance between the signals to the ground plane in order to minimize the effect on trace characteristic impedance. For applications with EMI filters on video channels, it is important to minimize the trace length between drivers and connectors and also keep the termination resistor close to the connector to minimize the reflection. Minimal trace length is helpful to maintain the video data path bandwidth. For digital video signal routing, in addition to the suggestions above, channel-to-channel skew is very important in order to minimize the deterministic jitter. Equal length of traces for differential signals is required in addition to the equal parasitic capacitive load requirements along the data path. Jitter performance becomes more and more important for high definition digital video signals with smaller unit interval (UI) per bit. Jitter budget becomes tighter for each component along the video data path to minimize the bit error rate.

Summary

As the video displays migrate into higher definition and larger screens particularly with higher frame rate, wide bandwidth analog switches are being widely used in LCD TVs, DVD-RWs and set-top boxes to lower the cost by connector or hardware sharing. This is particularly true for both consumer electronics and personal computers when LCD monitors evolve to be multiple-function end devices with both PC RGB and progressive YPbPr signal inputs. In addition, for analog front or back end component video I/Os, wide-bandwidth analog switch can minimize the nonlinear distortion for high resolution video signals particularly with the presence of EMI filter. This is particularly true for RGB signal with resolution higher than UXGA.