HDMI: the need for a Robust Cost Effective Solution

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HDMI™ (High Definition Multimedia Interface) adoption has been growing rapidly since its first introduction at International Consumer Electronics Show (CES) in January 2003. Manufacturers and consumers alike have embraced the new digital interface standard as synonymous to high definition television.

Today the standard is transitioning from its position on the market as a single port feature on high-end set top boxes and TVs to a multiple-port feature incorporated on multiple applications. With this comes increased pressure to deliver more cost-effective products traded off with the cost and time to take new products through the rigorous HDMI™ compliance testing. Such a trade-off centres around how to deal with the challenges of transmitting and receiving high bandwidth video signals transported over cables of varying quality and length. TV manufacturers need new approaches which deliver lower cost while not compromising quality.

This paper looks at the performance of the HDMI™ transmission system with a view to optimising the overall cost to the manufacturer and consumer for a wide variety of cable lengths and quality, while further facilitating compliance testing.

The High Quality Challenge

Because the data is exchanged at much higher data rates than previously used in Consumer Electronics products, transfer of video & audio from source to display in HDMI™ systems faces technical challenges. In particular, the video signal is transmitted over a cable where it is subjected to jitter, skew, crosstalk and attenuation as a function of the design and manufacture of the cable, not to mention the effect of compressing, twisting and bending as a result of installation constraints or simply general wear and tear.

Cable manufacturers are attempting to address these issues, but improving performance of one cable characteristic can cause reduced performance in another. For example, cables with nitrogen gas injected PE do achieve less loss at high frequencies. However, they will also have less consistent impedance and greater return loss as a result of reflections than standard hard-cell or non-foamed cables. Some manufacturers have increased the thickness of the copper conductors to reduce the cable impedance. Typical copper conductors used are 28AWG (0.33mm diameter) and new larger, heavy gauge cables are using 24 AWG (0.51mm) to improve performance. Using thicker wires increases the cost to the manufacturer and limits the ability of the cable manufacturer to achieve equal length and twist symmetry, jeopardising the skew between the differential data inputs. All cable improvements ultimately affect cost to either the equipment manufacturer or the consumer. In summary, a major challenge remains today to produce an economical consumer grade cable which performs well at the upper data rates for HDTV and particularly for longer cable.

Silicon designers are also working to improve the HDMI™ channel. Because of the cable performance limitation mentioned above, new silicon designs focus on the receiver device, as it is charged with interpreting and reconstructing the data. Multi-gigabit enterprise communications solutions such as complex equalization techniques have been applied to consumer electronics solutions. Other techniques such as noise filtering and data over-sampling have also been developed to great effect at very high speeds. However these solutions require the use of additional components (and costs) or, due to design complexity when integrated, are often large in size and heavy in power consumption resulting in higher silicon and packaging costs.

To solve HDMI™ channel quality problems, it is possible to specify higher grade cables or improve data recovery performance in the receiver application, predominantly TVs and displays. Either the consumer is obliged to spend more for higher grade cables, booster amplifiers, repeaters or fibre optic extension systems or equipment manufacturers must provide more robust solutions. The solutions facing manufacturers today typically impose design restrictions on boards, and additional component costs as well as increased time and effort costs in achieving HDMI™ compliance. The CE industry continues to resist and cost increase and alternative design approaches for the HDMI™ channel are needed.

Data Recovery in the Receiver

So what are the design challenges in the receiver and what can be done about them? Essentially there are two main problems and they are related to receiving data at high data rate over long, low-cost cables.

1) HDMI™ data is transmitted in differential form, i.e. as a pair of negative and positive data lines. Matching transit times so that both these signals arrive at the same time across the cable is a challenge, particularly for the simpler, lower cost cables. The end result is timing skew between the two data lines, referred to as the intra-pair differential **timing skew** problem.

2) At high data rates, the high frequency components of a HDMI™ signal are typically suppressed by cables. This is the **limited bandwidth** problem. This problem limits the distance allowed between the transmitter and receiver and is also a primary source of problems in achieving HDMI™ compliance for a new design.

Intra-pair Differential Timing Skew

Data is carried over a HDMI cable at data rates of up to 1.65Gbps in the form of four differential pairs, three for data, one for the clock. Each of these high speed data lines is carried as a +/- pair over individual STP (Shielded Twisted Pair) cables within the HDMI cable.

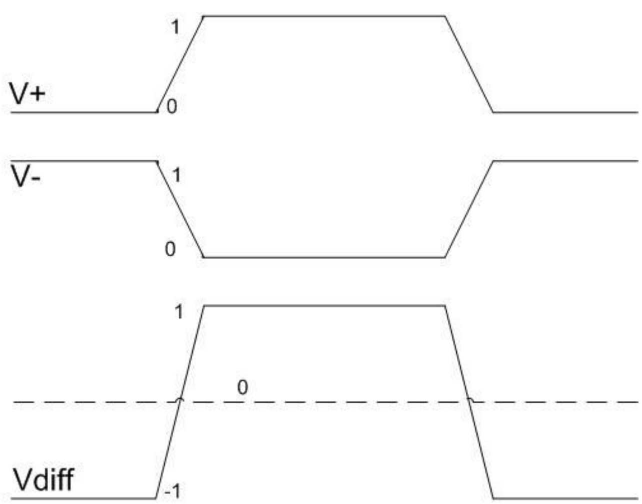

Figure 1. Ideal Differential Data Transmission

Figure 1 shows the two single ended components (V+, V-) of the differential data on a HDMI channel. Note that the differential signal is clean and easily read for the conditions depicted in the diagram.

In reality, however, the two single-ended components are transmitted over a non-ideal line subjected to asymmetry of length or twist or dielectric environment and the end result is that there is a skew or delay between the positive and negative components on arrival at their sink destination. In Figure 3 below, we can see the effect of what happens when V+ and V- are skewed in time with respect to each other.

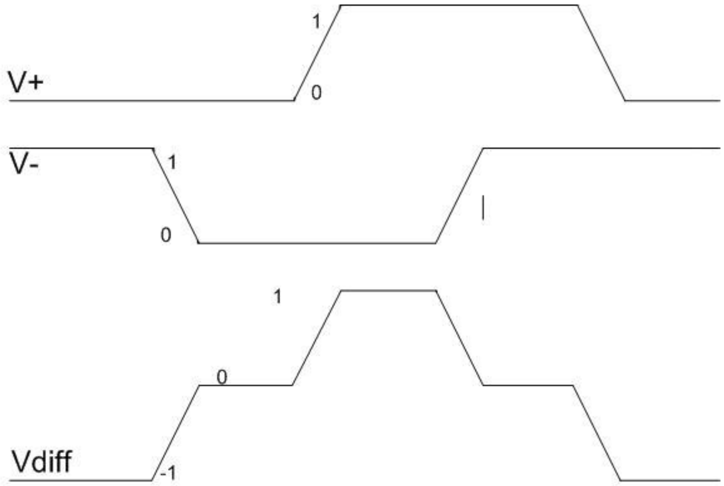

Figure 2. Skewed Differential Data

As a consequence of the skew, the differential signal is now completely distorted with clearly visible plateaux in the signal where the differential signal is zero. These plateaux regions can only be interpreted as noise by the receiver, the result of which is to reduce the width of the window of valid data. This reduction is seen as closure of the receive data eye and directly compromises the channel quality.

Let us consider a standard cable which can have an intra-pair skew of up to 34ps/meter (e.g. Hitachi Cable Manchester HDMI cables 40516-14/15). At 10 meters, the intra-pair skew can be up to 340ps which is greater than the max intra-pair differential skew of 303ps (or 0.5*T_{BIT}, where T_{BIT} = the bit size of the data transmitted over the HDMI™ cable) offered by most silicon vendors at the maximum date rate. Table 1 below shows the lengths of cables and resultant skew and the impact for each HDTV resolution standard using a receiver restricted to tolerating +/- 0.5*T_{BIT} differential input intra-pair skew. The shaded cells in Table 1 show cable lengths and skew which prevent reception of valid HDMI™ data at each resolution standard.

HDTV	Pixel Clock	T_{BIT}	5 meter skew	10 meter skew	15 meter skew	20 meter skew	30 meter skew	40 meter skew
1080i	55.68MHz	1.8ns	170ps	340ps	510ps	680ps	1020ps	1360ps
720p	74.25MHz	1.35ns	170ps	340ps	510ps	680ps	1020ps	1360ps
1080p	148MHz	675ps	170ps	340ps	525ps	680ps	1020ps	1360ps

Table 1. Intra-pairs skews and limitations of +/- 0.5 T_{BIT} tolerance

These calculations demonstrate the limits of the channel at the highest data rate and the highest cable intra-pair skew. They consider only the skew impact and do not take into account the other performance degradations such as high frequency suppression, jitter and crosstalk which limit the performance further. These skews are also not worst case – in lab tests, RedMere have measured up to 984ps of intra-pair skew for a 15 meter cable from cable vendors, i.e. almost double the skews of the example given above.

High Frequency Bandwidth Limitations

As frequencies increase, signal attenuation within a cable increases due to what is known as the 'skin effect'. What this means is that as the frequency of a signal increases, the more it tends to travel on the outer portion of the cable conductor. Low frequency AC signals will travel through the entire cross sectional area of a conductor, whereas high frequency ones drift to the outer edges or 'skin' thereby exposing them to higher impedance which causes the high frequency elements to be suppressed. This phenomenon results in signal distortion which is referred to as Inter Symbol Interference.

The impact of this ISI is depicted in Figure 4 below.

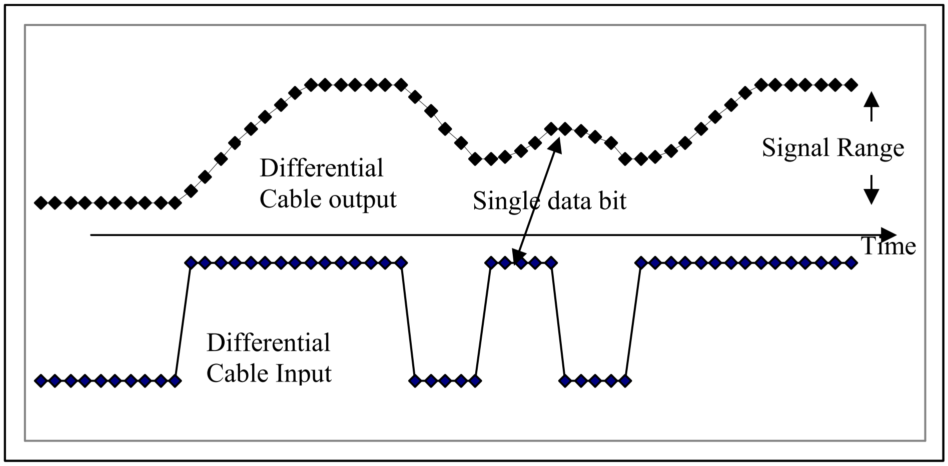

Figure 3. Impact of ISI.

The output of the cable shows a low pass filtered response and thus there is significant distortion to the incoming signal. The challenging features of the distorted signal are increased rise times and the fact that a single data bit change does not cause the signal to traverse the signal range.

A simplified transfer function of a cable shown below in Figure 5 shows this reduction in gain at high frequencies for a 15 meter HDMI cable.

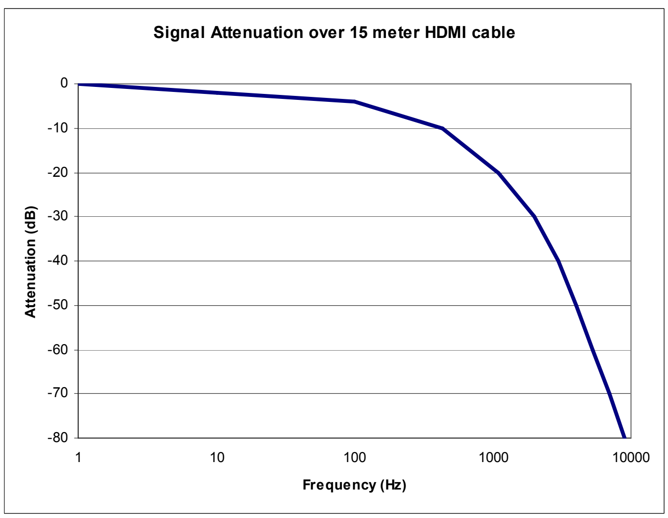

Figure 4. Cable Bandwidth Limitations as a Function of Cable Length

Improved Data Recovery

Careful receiver design in the IC solutions for HDMI™, using techniques such as data processing, equalization, noise-filtering, over-sampling and sophisticated phase recovery can eliminate the impact of intra-pair skew and channel bandwidth limitations in HDMI™ designs. To deliver the performance required at a cost which is acceptable to Consumer Electronics equipment manufacturers requires a completely novel approach to the traditional problems of high-speed channel quality. Figure 5 below shows the data recovery of RedMere's MagnifEye™ receiver technology correcting for both intra-pair skew and bandwidth limitations over a range of cable solutions. MagnifEye™ delivers improved HDMI™ channel performance at a fraction of the power and cost.

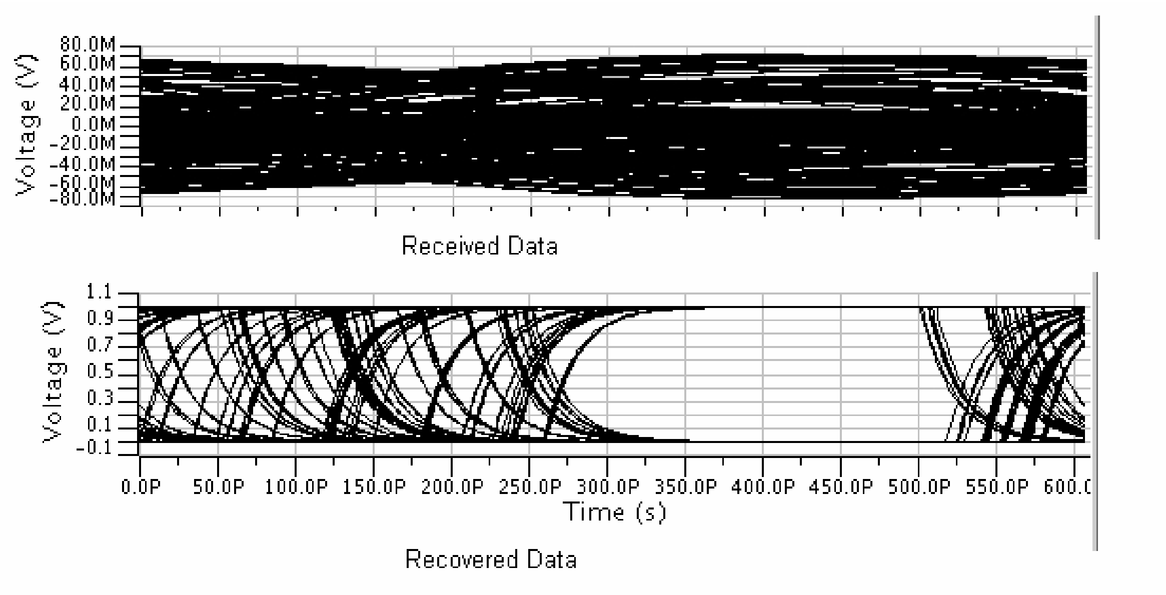

Figure 5. Data Recovery in the RM2602

Cost-Effective Solutions for Manufacturers

Effective solutions to the problems of implementing reliable HDMI™ must take into account the need to eliminate differential skew and high frequency bandwidth. Elimination of differential skew is vital to ease design constraints on equipment manufacturers and to enable the use of cheaper cables. Elimination of high bandwidth restrictions will not only save TV manufacturers the cost of additional components on the receiver board, but will also save $10ks of engineering effort and compliance testing costs by introducing significant design margin into cost-sensitive application designs.

What is needed for the consumer electronics market is a low cost silicon solution which not only emulates complex equalization methods to address the limited bandwidth problem, but also outperforms by addressing the differential skew problem. This solution must be incorporated into the HDMI™ receiver silicon and be area and power efficient. Only such a low ASP solution will meet the demands for the consumer electronics market to reliably implement the link performance now required with the arrival of high definition TV and HDMI™.

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RedMere Technology is a leading developer of communications and networking semiconductor solutions for multimedia and consumer electronics applications.