HDMI Active Cable Testing

David Guthrie
Principal Engineer, RedMere

Dr. John Horan
Chief Technology Officer, RedMere

Introduction

Video data rates have quadrupled in the last five years. To support these data rates the bandwidths of transmission media needs to keep pace. For example the current video standard (HDMI) requires that a cable is capable of transmitting at 10.2Gbps. This data rate with a bit time of 297 Pico-seconds on each of 3 channels demands considerable performance from the cable. With this performance requirement there is an increased need for quality in the cable materials. Even more important is that there is now a requirement for in-production test and characterization to guarantee the data integrity in the cable.

In this article, we will discuss the potential defects in cable manufacturing and outline the challenges associated with doing the “In Production Cable Test”. The existing cable test methodologies will be examined and we will show how features of a new generation of active cables can be used to facilitate Built In Self Test through semiconductor microchip technology.

An example of the resulting thinner, more flexible and higher quality active cable is shown in Figure 1.

Figure 1: Sample Active HDMI C to A Cable

Difference between Active Cables & Passive Cables

Passive cables are the standard in today’s cable market; they are comprised of several insulated wires surrounded by an outer coating with connectors at each end. Active cables are an evolution of these cables in that they add an integrated circuit to the passive cable. The principal purpose of this integrated circuit is to offset the naturally occurring losses in the passive cable. This active boosting means that active cables can be more compact, thinner, longer and faster than their passive equivalents.

Figure 2 shows an Active HDMI Cable with exposed connectors. Close examination reveals that there is an integrated circuit on only one end of the cable. This is because the high speed channels in HDMI are unidirectional and the lossy signal will also need boosting at the same end of the cable. In cables like USB3 cables there will be two active ends, as the cable is bi-directional. A close up of the active end of a HDMI cable is also shown in clearly showing the integrated circuit or IC.

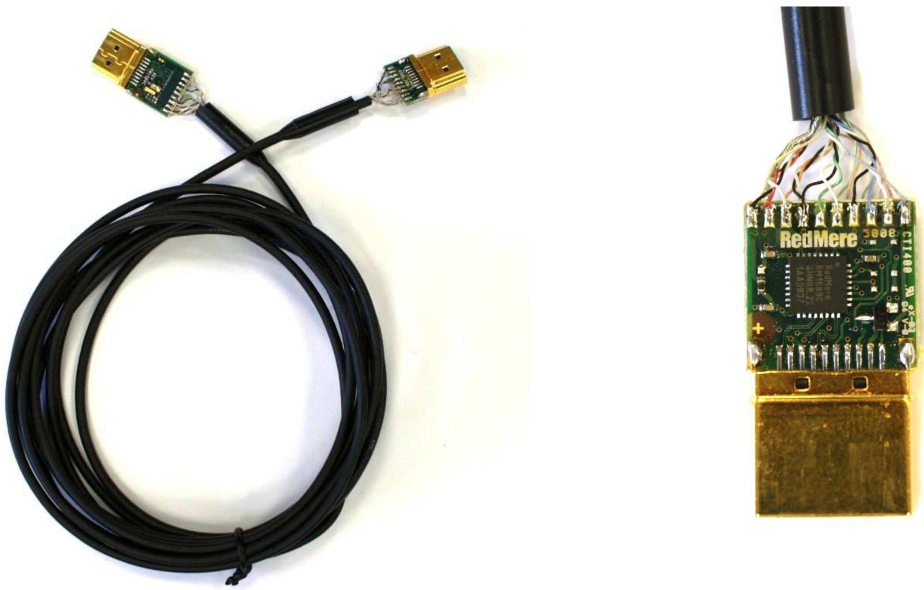

Figure 2: Active HDMI Cable with exposed connectors

Potential Defects in Cables

When manufacturing any kind of component, there are always defects. Good process engineering will greatly reduce the probability of the magnitude of the defects impacting the quality of the product. It also important to understand that today's high speed interconnects are complex constructions. USB, Infiniband and HDMI cables don't just have a single wire covered in an insulated coating. They can have as many as 20 individual wires inside the cable. Figure 3 shows a HDMI cable with exposed wires. As you can see what can appear as a simple cable is made up of several individual wires. Any defect with these wires can render the cable non-functional or limit its performance.

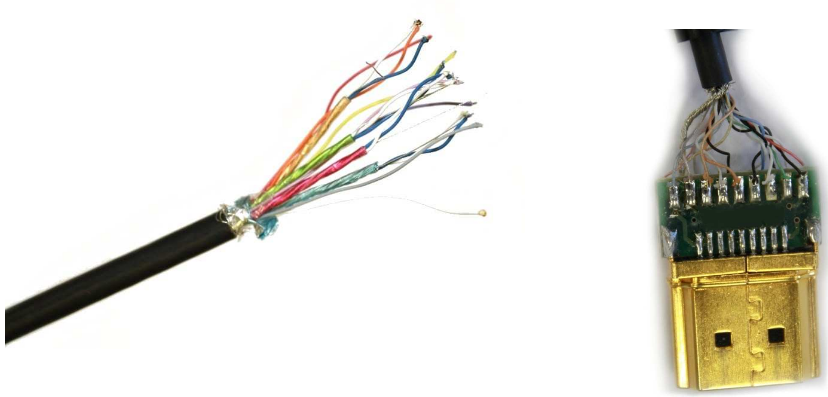

Figure 3: HDMI Cable Stripped back and Connector

The first source of catastrophic error in a cable is the existence of unintentional opens or shorts in the structure. These can arise due to failures at the myriad of soldering points in the cable. Short circuits can easily occur at these solder joints with inaccurate soldering causing bridges between wires, given that much of the soldering in these cables is still done by hand. The solder joints can also be poorly formed and can break in the follow on processing, leading to open circuits.

Another area of such defect is the existence of insulation pinholes in the individual conductors which will cause destructive conductive paths. Figure 4 shows an example of a solder defect in a cable. In this example, the wires from a HDMI cable are connected to a PCB on a HDMI connector. Looking at photo A, it is seen that the solder on some of the landing pads is poor. Looking closer at B and C, the solder is seen to create a short circuit between adjacent wires on the PCB.

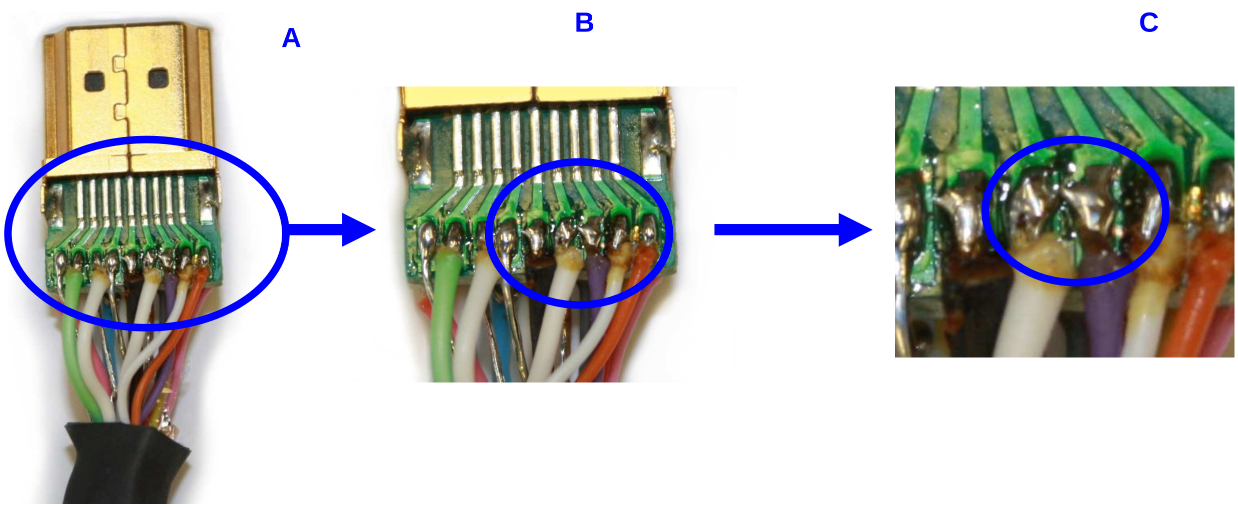

Figure 4: Solder Defect in Cable Connector

In addition to the catastrophic short/open defects that can occur with every cable, high speed cables have a further constraint in that they are subject to stringent signal loss requirements. All copper cables have limited bandwidth that is to say that while the low frequency signal's energy will be passed unaltered, the high frequency energy in the signal will be attenuated. The magnitude of this attenuation actually constitutes a pass/fail requirement in high speed cables. The logic behind this is that beyond a certain level of attenuation high speed signal integrity will be lost in the cable. The variation in attenuation in cables comes from the two sources.

The first is the variation in insulation thickness for an individual wire, and the second is the changing distance that an individual wire will have to its partner in its differential pair and its proximity to other wires/shields. The materials and control procedures in the cable construction as well as the particular cable style will directly affect the resulting spread in the attenuation levels in the cable.

Another performance limiting feature of high speed interconnect is intrapair skew. Differential skew is a measure of the difference between the time taken for a signal to propagate along the positive and negative wires in a differential pair. This skew at low levels degrades the performance of the cable but it can be catastrophic at higher levels. Targets for HDMI are a total of 111ps at a 3.4Gbps data rate. One reason for this skew is a variation is the wire insulation thickness and proximity of other wires. These cause a change in the electrical length seen in the two wires in a differential pair.

Another equally common cause of skew is a physical length difference that can exist between the two wires as a result of a non optimal cable winding process. As with attenuation precision in the cable construction and the use of higher performance materials skew cable be controlled to a reasonable level.

Cable Test Technology

With an understanding of the significant number of defects that can arise in cables, coupled with the fact that there is an ever increasing requirement for faster and thinner cables, there is clearly a need for in production test for cables. There are a number of technologies in use today to test the quality and functionality of cables.

The first approach uses a cable continuity tester. This is a piece of equipment which checks the resistance between the endpoints of a cable. For a passive cable this tester builds a resistance profile of the cable and from this it can point to some of the catastrophic opens short failures that occur. The limitation with the continuity test however is that the information gathered is all based on DC resistance measurements and the device has no ability measure frequency dependant component of the cable, such as capacitance and inductance. Without this high frequency response information, no assessment of attenuation or high frequency performance can be made. From this it is clear that a continuity tester is not sufficient to guarantee the signal integrity of the cable.

To measure the high frequency performance of a cable more advanced equipment is required. For example, a high speed data generator and an oscilloscope are equipment that is commonly used be used to do this. Typically prescribed high frequency data patterns are passed through the cable and an oscilloscope quantifies the damage done by the cable using an eye diagram. An eye diagram measurement gives a complete picture of signal integrity at the end of the cable, all DC or high frequency performance limitations will be captured by the diagram. The diagram is also easy to read in that results are also instantly obvious. It also gives easily interpreted feedback on the quality of the cable as seen in Figure 5.

The images show the eye diagram for a HDMI cable running at 3.4 Gbps. The picture on the left is a measure on a poor quality passive cable; it shows a “closed eye”. On the right is the eye from an active cable which boosts the high speed signals, thus resulting in an “open eye” which confirms the signal integrity of the cable. The degree to which the eye is open is direct measure of the quality of the cable.

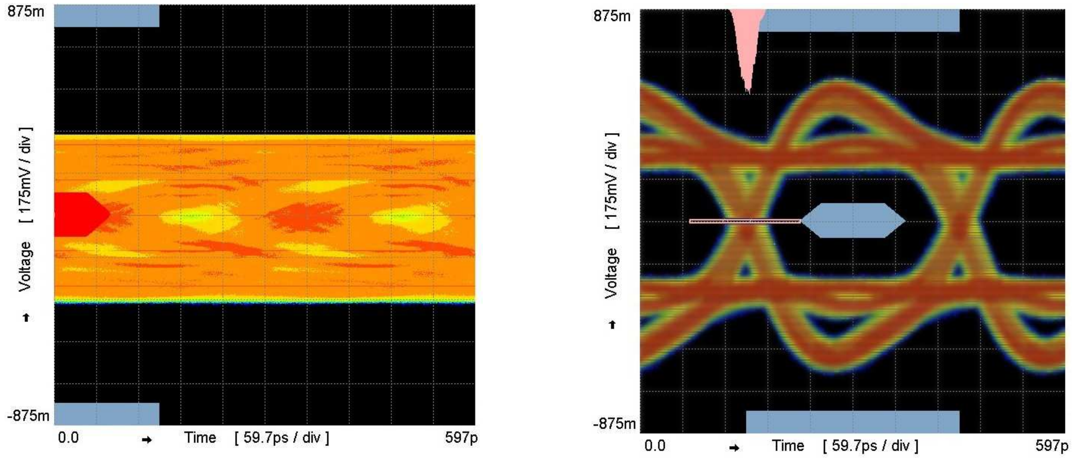

Figure 5: Oscilloscope Eye Diagram Snapshot of Passive (left) and Active Cables (right)

While the oscilloscope and data generator is clearly very effective this kind of test equipment may cost up to $200k. Along with this the equipment is difficult to use and even a single cable measurement can take five minutes. With these drawbacks this system is really only used in pre production qualification of cables and random sampling of production lots. It is not a solution for 100% production testing.

A final method used to guarantee high speed cable performance is to use a Bit Error Rate checker (BER). This tester generates and transmits high speed data through the cable under test to a receiver. The receiver will have a prior knowledge of the transmitted data sequence and thus any errors received at the cable output are easily counted. This error count or error rate, produced by this system, is then used to give a coarse pass/fail indication for the cable. The goal is to use a receiver which is representative of that which might be attached to the cable in the field. To find this is in fact one of the weakness of the scheme. Clearly the use of an atypically high performing receiver in this setup would lead to optimism in the pass fail assessment.

A further note on this approach is that there is not a one to one correspondence between the bit error rate and the cable eye opening. This is clear for the fact that the eye diagram has two dimensions of information (time and signal swing) and the BER test produces a single number to characterize the cable and as such does not provide a quantitative statement of quality for the cable nor does not guarantee compliance for such standards as HDMI.

Environment and features for cable Test system

There are many aspects to producing a cable such as those used in HDMI, DisplayPort, USB and Infiniband. Among the many steps are copper extrusions, insulation of conductors, adding the outer protective coating for the bulk cable and then the final steps of adding the connectors and sealing the cable ends. The final steps of adding the connector begins with terminating the individual wires on the connector. This process is primarily completed manually today and this defines the kinds of environments where final cable test takes place.

These environments are large warehouse structures with large numbers of assembly workers and do require the test device to be electrically and mechanically robust. The large numbers of assembly workers produce cables at rates of one every few seconds and these have to be testing and approved in this time to maintain the throughput. Another key feature of the test device is to be able to track the defects that occur this ultimately allows the Process Engineers take appropriate actions to remedy the cause of the defects.

In fact Process Engineers want to be able to analyze the production run data at the end of a day or a shift so the test device should allow easy access to data. The ideal solution for them is a cable tester which integrates itself into the IT infrastructure of the production plant and stores results to a database for easy post processing.

Built in Cable Test

For the semiconductor microchip the idea of Built In Self Test (BIST) is well accepted. So in addition to the circuitry for normal tasks performed by a particular microchip, it will also include blocks of circuitry to ensure that the microchip’s normal task blocks are functional. This basic idea has been employed in a new generation of active cables where circuitry has been added to the cable to check the finished performance of the cable. As well as providing a final statement of the quality of the cable the BIST function in these cables can be used to find the optimum equalisation setting for a particular channel in a particular cable. This ability greatly influences the end quality of the cable.

To test the high speed data channels on a cable, a data generator and some kind of measurement equipment are needed. The BIST function in an active cable does both functions. The BIST block generate data at the sink end of the device and passes it through the source end of the cable, through a connecting card called the “Plug-in Sacrificial Card” to the source end of the cable. From here it passes through the cable to itself and back to the sink side. At the sink side it is now measure and the damage done by the cable configured in a loop can be assessed.

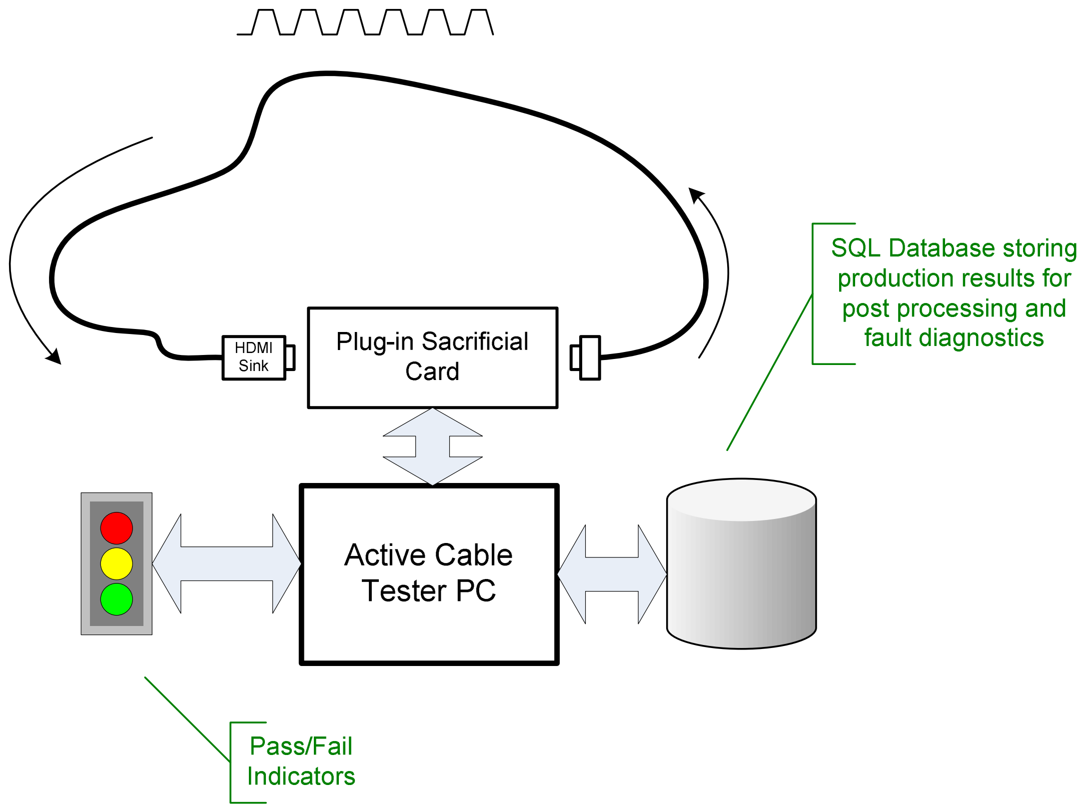

Figure 6: Active Cable Tester

Because this is a dedicated measurement system there are techniques to accelerate the measurement without compromising accuracy. Dedicated silicon solutions aren’t slowed down with huge software overheads or slow mechanical parts. The system shown in Figure 6 has the ability of testing the high speed channels of an active cable in less than 5 seconds. As well as doing measurements, the system is easily coupled to a PC system to store the results to a database for later analysis. The system is also easily enhanced to provide visual indicators which are useful for the production environments to flag passing/failing cables or any other production related issues.

Conclusion

A new breed of active cable is enabling higher performing portable cables. With this evolution there is a corresponding requirement for 100% in production cable test. In this paper the requirements of this tester were outlined and all the existing cable test methodologies were examined with a view to satisfying this requirement. Continuity testers, oscilloscopes, and BER testers all proved inadequate but a new cable BIST methodology was introduced to satisfy all requirements. Along with the basic test requirements the system linked to standard IT systems to allows easy access to production data which of course greatly improves process control and as a result the price of guaranteed quality.

About the Authors

David Guthrie

David Guthrie (david.guthrie@redmere.com) is a Principal Engineer at RedMere based in Cork, Ireland. He is responsible for the development and management of active cable testers for multi gigabit serial communication applications.

Dr. John Horan (john.horan@redmere.com) is Chief Technology Officer at RedMere, based in Cork, Ireland, and is responsible for the technology development for RedMere's high-speed communications channel products.