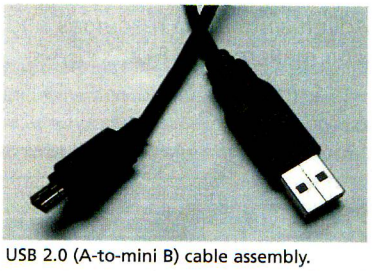
Simplifying HIGH-SPEED CABLE Assembly Testing

A set of simplified requirements can reduce the cost of testing high-speed cable assemblies in a production line.

BY SAM LIU AND RAFAEL HERRERA



USB 2.0 (A-to-mini B) cable assembly.

For high-speed serial bus applications such as Universal Serial Bus (USB) 2.0 and IEEE 1394, the integrity of the data transfer relies on the quality of the high-speed cable assemblies. Each standard specifies the test criteria that the cable assemblies must meet. Although necessary for laboratory testing and certification against the standard, complete specified testing on all of the production is expensive, complex and time-consuming. It is impractical to perform the specified testing on a full production line of cable assemblies. A set of simplified requirements can reduce the cost of production testing high-speed cable assemblies and, thus, provide a practical means for cable assembly manufacturers to ensure the quality of their production against the standards.

Test Criteria

The USB 2.0 standard specifies the testing of impedance, propagation delay and delay skew in the time domain using a time domain reflectometer (TDR), and the testing of attenuation in the frequency domain using a network analyzer. The IEEE 1394 Performance Group I specifies the testing of characteristic impedance in the time domain, and attenuation, velocity of propagation delay, skew and crosstalk testing in the frequency domain. Direct current (DC) resistance is also specified, and it is usually measured with an inductance, capacitance and resistance measurement meter, an LCR meter.

Both USB 2.0 and IEEE 1394 electrical test criteria are necessary for establishing the performance standard for high-speed connectors and cable assemblies. For production volumes, the test requirements can be simplified to lower the initial investment and cost of testing, and still ensure the performance requirements are being met. By doing so, cable assembly manufacturers have a practical means of certifying that their cable assemblies meet the high-speed serial bus standard.

Testing can be simplified by taking it as far as possible out of the time domain and into the frequency domain. This can be achieved by converting the time domain requirements to the frequency domain by Fourier transforms, and then testing in the frequency domain against these limits.

Simplified Test Method

Using the test criteria specified in the IEEE 1394 Performance Group I as an example, one can see how the simplified method works. It reduces the complexity and cost of testing cable assemblies and still ensures the cable performance against the standard.

1. Test Impedance in the Frequency Domain

Time domain reflectometer impedance testing applies a fast-edge step function (greater than 200 ps) to both the assembled cable and raw cable to measure the size of the reflected energy. The information obtained from this reflected energy is used to determine if the conductors and the pairs meet the impedance specification requirements. The

Table 1. Impedance measurement: TDR vs. network analyzer.

High-speed cable assembly	TDR*	Network analyzer (scan up to 400 MHz)
Sample 1: signal pair A	114.51 Ω	114.65 Ω, average
Sample 1: signal pair B	115.31 Ω	116.06 Ω, average
Sample 2: signal pair A	115.99 Ω	116.05 Ω, average
Sample 2: signal pair B	114.92 Ω	115.30 Ω, average

*The differential mode TDR impedance is calculated using the individual conductor impedance measured at 2 and 5 ns, as specified in current Group I requirements.

SPEC SHEET

End Applications:
High-speed serial bus networks

Related Products:
Cable assemblies, connectors, TDRs, network analyzers

Main Point:
The current USB 2.0 and IEEE 1394 high-speed serial bus test standards should apply to laboratory and certification testing of high-speed cable assemblies. A less complex and less costly test protocol, however, is recommended for cable assembly production. This method allows cable assembly manufacturers to ensure the standards are consistently met.

Table 2. Comparison of velocity of propagation delay between a raw cable and a cable assembly made from the same raw cable.

Frequency (MHz)	Cable (30.0 m) total ns	Cable normalized (ns/m)	Cable assembly (4.5 m) total propagation time ns*	Cable assembly normalized (ns/m)
50	135.24	4.53	20.01	4.53
50	134.36	4.49	19.89	4.49
100	135.01	4.53	19.93	4.49
100	134.11	4.49	19.81	4.49
200	134.79	4.53	19.91	4.49
200	133.91	4.49	19.78	4.46

*Actual measurement minus 0.3 propagation delays for each connector. The same analysis can be done for skew.

high-speed serial bus standard requires impedance testing (at 2 and 5 ns beyond the connector launch plane) for both the individual conductors and for the pair.

The impedance of the pair may also be measured in the frequency domain using a network analyzer. The impedance is calculated from the magnitude and phase of the reflection coefficient measurements performed by the network analyzer. Care must be taken in the selection of the frequency range (start and stop frequencies) and the number of discrete frequency points selected in the range. A plot of impedance vs. frequency provides a complete analysis of impedance over the complete frequency range specified.

The impedance of the individual conductors does not change with the cable assembly process. However, the cable assembly process may alter the impedance of the signal pairs when the shield is removed and the conductors are separated to solder the modular connector. These impedance changes can be detected when measured in the frequency domain.

The impedance specification in the frequency domain can be converted to time domain by using inverse Fourier transform. The results would be the same as the current Group I impedance specification for the signal pair. Only one test is required for impedance measurement. It saves time and still provides the analysis required to prove the quality of the pair. Laboratory tests show direct correlation between TDR testing and network analyzer testing of impedance for the signal pairs (see Table 1).

2. Test AC Resistance

Power pair conductor resistance can be measured by using an LCR meter, as specified in the current test criteria of high-speed cable assemblies. However, it is possible to correlate the DC resistance with alternating current (AC) resistance at a given frequency due to "skin effect" when frequency increases.

At high frequencies, most of the energy is transported in the outer layer of the conductor. The thickness of the conducting layer is called "skin depth," which is associated with the conductivity of the wire.

To correlate the AC resistance to the DC resistance, it is necessary to know the frequency of the AC resistance and the wire diameter of the conductor. Once the AC is calculated, a specification limit is set at this frequency. The DC resistance-to-AC resistance ratio can be measured with a network analyzer at the same frequency. Therefore, the DC resistance can be determined.

3. Remove Velocity of Propagation Delay and Skew Test

Velocity of propagation delay measures the transmission speed of a signal through a medium compared to the speed of light. It is defined at a given frequency in a length of cable. The measurement of the velocity of propagation delay is based on the phase delay measurement. Skew is the difference in velocity of propagation delay between pairs.

The phase delay is completely defined by the materials used to manufacture the cable (insulating material and copper). The cable assembly process does not change the properties of cable materials and, thus, the velocity of propagation delay is independent of the cable assembly process. Laboratory tests show exact correlation of velocity of propagation delay between the raw cable and a cable assembly made from the same batch of raw cable (see Table 2).

Figure 1. Simplified test setup with network analyzer, test fixture and automatic switch.

4. No Change for Crosstalk and Attenuation

Crosstalk and attenuation are both influenced by the cable assembly process. They should be tested in accordance with the current Group I test criteria.

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Table 3. Comparison of Group I criteria to simplified criteria.

Group I criteria	Group I test equipment	Frequency	Simplified test equipment	Simplified criteria
Characteristic impedance	TDR	1-400 MHz	Network analyzer	Characteristic impedance
Attenuation	Network analyzer	100, 200, 400 MHz	Network analyzer	Attenuation
Crosstalk	Network analyzer	1-75 MHz	Network analyzer	Crosstalk
DC resistance	LCR meter	Not applicable for DC resistance	Network analyzer	AC resistance
Propagation delay	Network analyzer	50, 100, 200 MHz	Not applicable	Not applicable
Skew	Network analyzer	50, 100, 200 MHz	Not applicable	Not applicable

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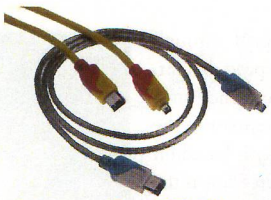
Simplified Test Setup

The simplified test setup includes these elements:

- The network analyzer is used to perform the fundamental frequency domain measurements.
- The test fixture is used to provide a constant interface between the measuring instrument and the cable assembly under test. The automatic switch provides a controlled, reliable signal path, which automates and simplifies the test process to produce repeatable results (see Figure 1).
- The control and reporting software is used to automatically control the network analyzer, process the test data and provide test reports. The software permits nontechnical personnel to run the tests, enables automatic comparison of test data to the standard, eliminates operator error, improves test time, and results in more consistent, reliable test results.



Patent-pending IEEE 1394 cable.

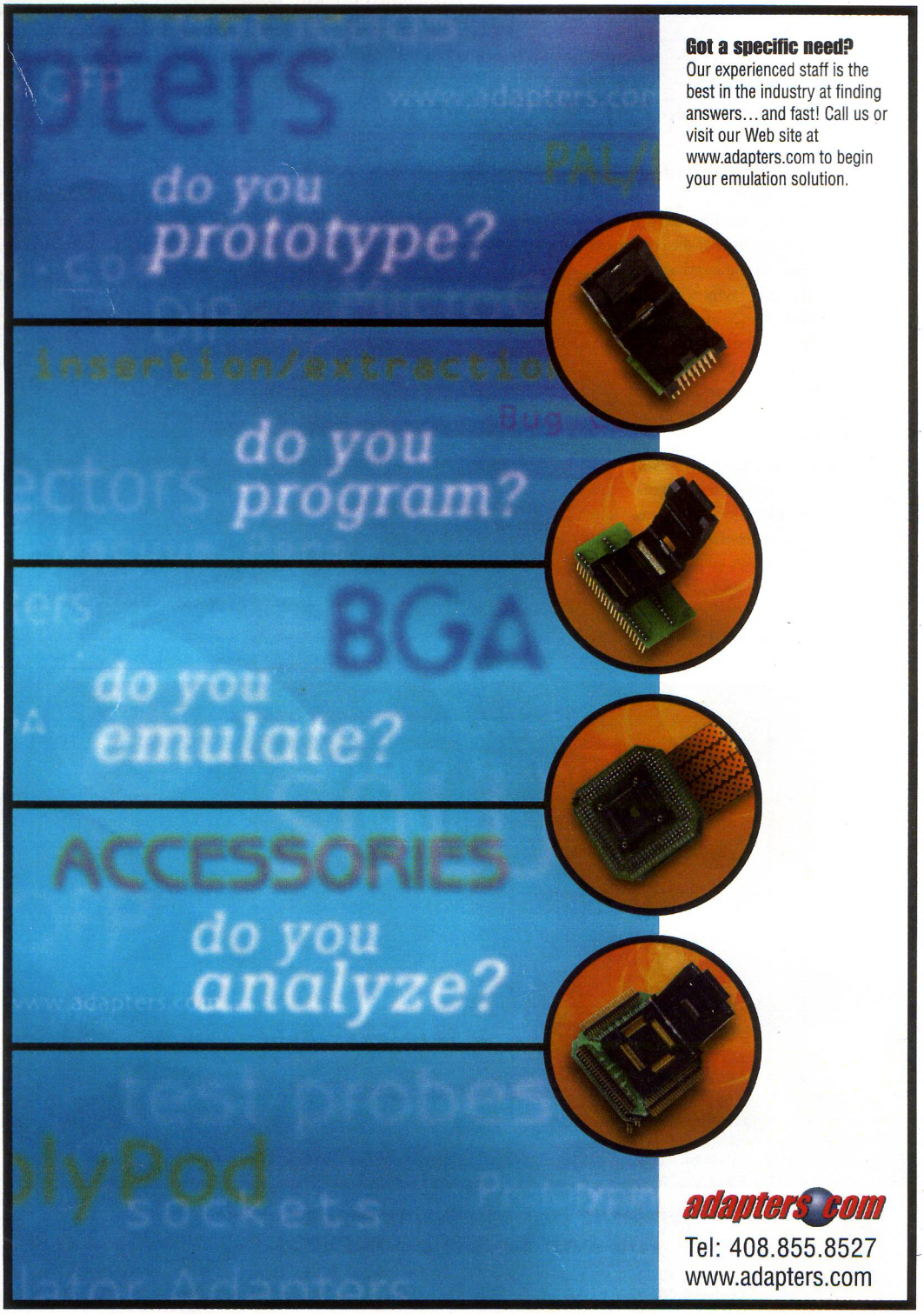
Comparison of Test Criteria

Group I specifies requirements for testing both the bulk cable and cable assemblies. The simplified method is suggested for testing of cable assemblies in a production line (see Table 3). A cost-effective test method enables both large and small cable assembly manufacturers to verify their production quality effectively. The cost considerations involve both the initial capital expenditure and the continuing cost of testing.

The current Group I criteria requires an investment in a network analyzer, an oscilloscope/TDR and an LCR meter. This combination enables the manual testing of cable assemblies by highly qualified and trained technicians. Automating this combination requires the addition of automatic test fixtures and controlling software. This automation increases the initial costs twofold. Whether it is done manually or automatically, Group I criteria demands capital expenditures beyond the means of many cable assembly manufacturers.

The simplified method requires only a network analyzer and automatic switch. The test software ensures that nontechnical personnel with minimal training can be used. This solution offers a lower cost to all cable assembly manufacturers and results in a much higher volume of cables tested.

Conclusion

The current USB 2.0 and IEEE 1394 high-speed serial bus test standards should apply to laboratory and certification testing of bulk cables and cable assemblies. A less complex and less costly test protocol is recommended for cable assembly production. This allows cable assembly manufacturers to test their production to ensure the high-speed serial bus test standards are consistently met. This results in more consistent and reliable quality assurance for high-speed cable assemblies, and helps ensure the success of the standards. ✓

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