Switching Solutions for Multi-Channel BERT Testing

Application Note

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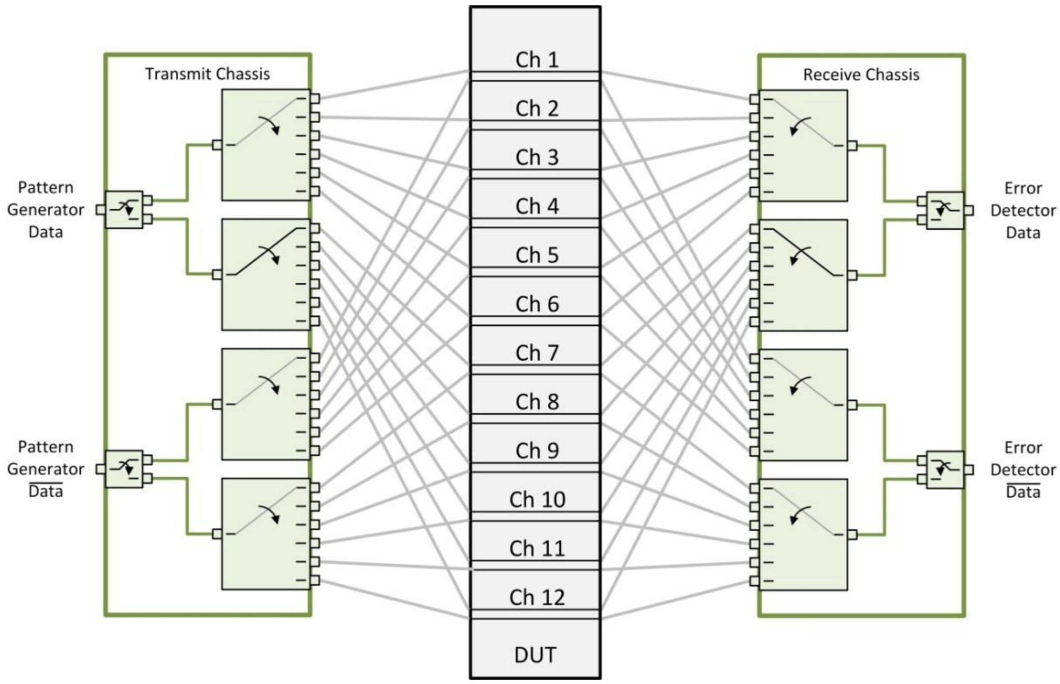


Product Description

The Giga-tronics 8000 Series Microwave Switching is very useful in multiplexing the input and output channels of costly test equipment such as Bit Error Rate Testers or BERT's. These signal switching units can be specially configured for use with BERT's, allowing a single BERT to test various types of Devices-Under-Test (DUTs), or across multiple DUT channels.

Application Description

Differential vs. Single Ended – many BERTs have the ability to operate in either single-ended or differential mode. The diagram above depicts a BERT being operated in differential mode. Since the Transmit and Receive switching systems are identical, they can also be separated for use in single ended applications. This method of switching system construction provides the utmost in flexibility at minimal additional cost. Solutions can also be provided in a single chassis if preferred. It is important that the switches and cables be selected to meet the BERT testing requirements and to prevent the Switching system from interfering with or distorting the test results. The design considerations section that follows explains the relevant switching system selection criteria, how to relate the common microwave specifications to BERT testing and to quantify the effects of the switching system on the measurements.

Design Considerations for BERT Testing

Bandwidth

Since the BERT's test signals are digital signals, the highest frequency components are in the rising and falling edges rather than in the data rates. The effect of insufficient switching system bandwidth is to slow down the edge transition times similar to the effect of a low pass filter. The effect on the BERT's "eye" diagram is to cause narrowing where the transitions have slowed. The diagram to the right (Figure 1) illustrates the difference between the normal signal transitions (in green) versus the effected signal transitions (in red) which has had its edge speeds reduced by a bandwidth limiting switching system.

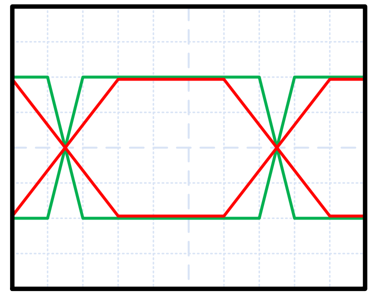


Figure 1

BERTs up to 32 GB/s generally have 20 ps edges, and BERTs up to 40 GB/s generally have 6 ps to 8 ps edges. To determine the minimum switching system bandwidth without signal degradation, we typically use the formula:

Bandwidth = 0.35/R_t where R_t is the Rise Time

Specified Bandwidth	Rise-time (Max)
6 GHz	58.333 ps
18 GHz	19.444 ps
26.5 GHz	13.208 ps
40 GHz	8.7500 ps
60 GHz (limited relay configurations)	5.8333 ps

It can be seen from the table that 18 GHz switching systems should generally be adequate for applications up to 32 GB/s, and that 40 GB/s applications require the use the 60 GHz switches. Unfortunately, 60 GHz switching systems are limited to 1x2 configurations at this time. Instead, most customers use the 40 GHz switching systems with the understanding that there will be some finite effect on the signals.

Insertion Loss

Since the digital output stream of the BERT is voltage programmable and is typically some value below 2 Volts, the concern is that excessive insertion loss in the switching system would cause the signals to fall below the BERT's detector input threshold. Since the insertion loss of a microwave switch is frequency dependent, we need to determine what frequency to use for the insertion loss calculation. The highest possible frequency is created with a data pattern of 10101010 which has the appearance of a pulsed DC signal with a 50% duty cycle. In the example, a data pattern of 11001100 would have a frequency of half the previous example (see Figure 2).

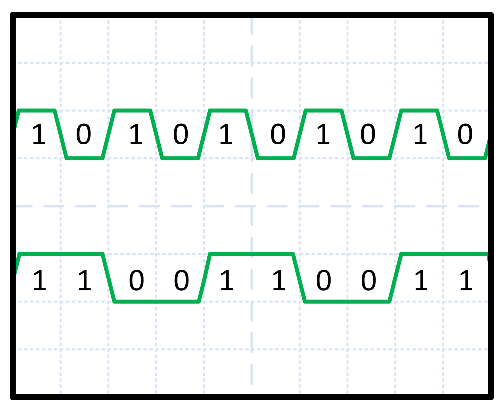


Figure 2

The highest possible frequency for the data stream is half of the data rate. We can use the formula typically used for electronic filters and calculate the "worst case" insertion losses. Typical insertion losses will be slightly lower and should generally not have a significant impact on the signal level.

$$\textbf{Insertion loss (dB)} = 20 \log_{10} \{|V_{in}|/|V_{out}|\} \quad \text{This becomes } V_{out} = V_{in} / \{10^{(0.2 * IL)}\}$$

Given a 2 Volt input signal

Data Rate	Required Bandwidth	Typical Switch Insertion Loss	Output Voltage
14 Gb/s	7 GHz	0.30 dB	1.74V
28 Gb/s	14 GHz	0.50 dB	1.59V
32 Gb/s	16 GHz	0.50 dB	1.59V
40 Gb/s	20 GHz	0.60 dB	1.52V

Phase Match

Phase matching signal paths is only of concern when the BERT is being used in the differential mode where all paths along the data+ and data- channel pairs must be phase matched. Since the purpose of the differential mode is to cancel out common mode noise, any phase shift between the + and – channels will cause portions of the leading and/or trailing edges to be removed effectively narrowing the center of the eye diagram. Since the switching system's design goal is signal preservation, properly phase matched paths are essential. The diagram to the right (Figure 3) illustrates three eye diagrams; the green illustrating the use of a good phase matched switching system, the yellow indicating distortion of the eye caused by incorrect phase matching, and the red indicating extreme distortion. The resulting eye is greatly reduced after the common mode noise is removed from the signal.

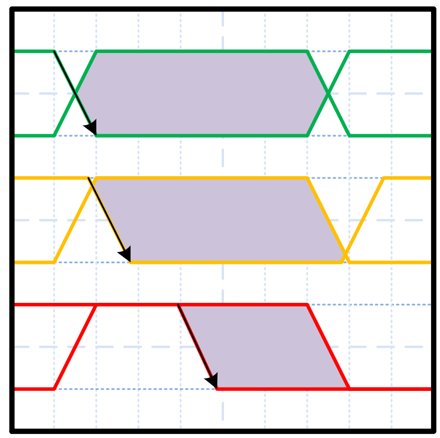


Figure 3

Manufacturers of Microwave cables can typically match the length of a pair of cables to about 0.001". At 26.5 GHz, this equates to about 20° of phase shift, but in the digital world this information is only useful in picoseconds. It should be noted that as the frequency increases, the physical length of a wave decreases and since the physical match length remains constant, the ability to phase match cables at higher frequencies is diminished. Using the formula:

Phase Shift (ps/deg) = (1/f) / 360° at 26.5 GHz is 0.104822 ps/deg, and at 20° is 2.09644 ps

It is possible to match cables closer than 20° or 2 ps, but this becomes difficult and drives higher cost. Either special manufacturing processes are employed or the more brute force method of simply building extra cables and hand matching pairs is employed. It must also be taken into account that it is not uncommon for a path to consist of several switches and cables, thus the matching of two paths may involve measuring and matching several cables. A manufacturer may build a group of cables all matched to within 2 ps, but some will be a perfect match at 0 ps, and some will be +1 ps and some will be -1 ps. Overall system phase match can be improved by measuring and tabulating all of the cable lengths by serial number, such that a +1 ps cable and a -1 ps cable are in the same path, this path will have the same overall electrical length as a path built from two 0 ps cables. The illustration (Figure 4) shows an example where a switching system has been constructed of numerous mis-matched cables to provide a system which is completely phase matched. Note that the important match is between the two data channels as highlighted in yellow, and not between the channels of any particular switch. It should be obvious that the engineering effort involved in this process can be a considerable cost driver.

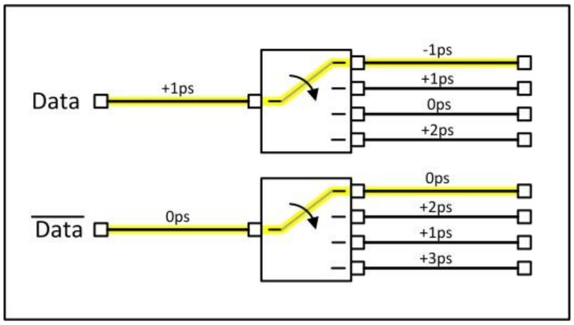


Figure 4

One other issue which must be considered is phase stability of the cables. The two enemies of phase matching are temperature change and cable flex. Since the equipment will likely be used in a temperature controlled environment, temperature effects should be minimized and consistent. Bending, even a good phase stable cable around a 5 cm mandrel can result in 2° to 5° of phase shift or 0.524 ps. Several bends can easily add over a picosecond. It is for this reason that semi-rigid cables are usually recommended for the front panel interconnecting cables. Cables to the DUT typically need to be flexible cables, and all efforts should be made to minimize any bends.

Switching System Example

Below is an example of a switching system designed recently for a customer (Figure 5). In this instance, the customer was using a BERT which had a single stressed channel and three non-stressed channels. The goal was to load the non-stressed channels with data to detect interference issues. Although a "non-blocking matrix" switching solution would have allowed any BERT channel to connect to any input port, the solution shown below is far simpler and more cost effective. The Terminated 1x4 switch on the output side of the DUT provides a 50Ω load to the unused channels for proper termination. There was some additional switching provided to allow the customer to connect an Oscilloscope to either the input or the output side of the DUT. This switching system satisfied the customer's requirements of phase matching, flexibility and insertion loss.

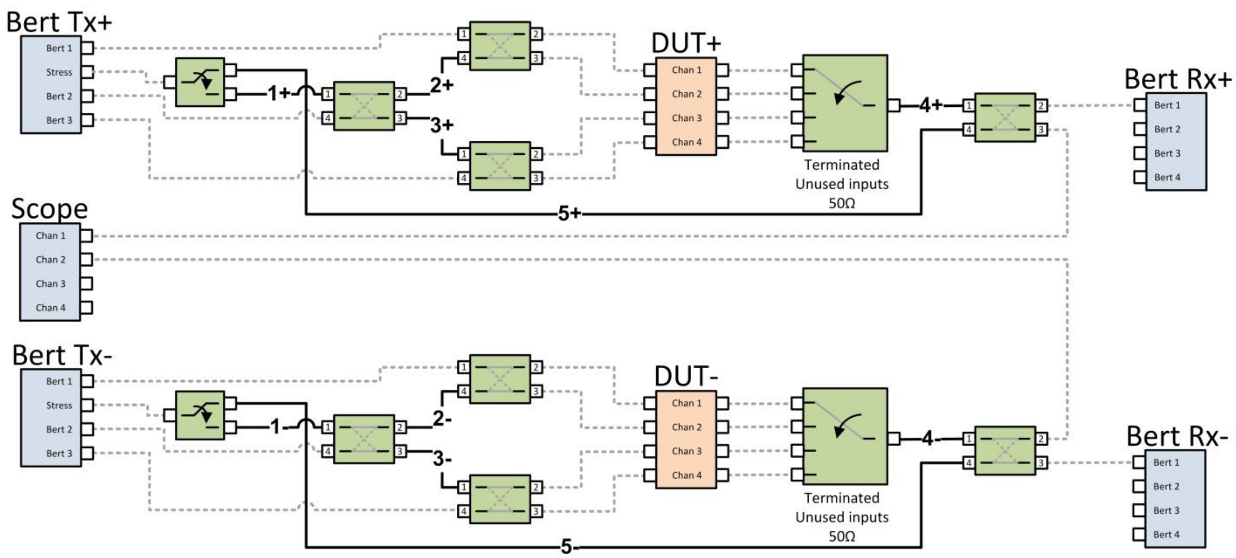
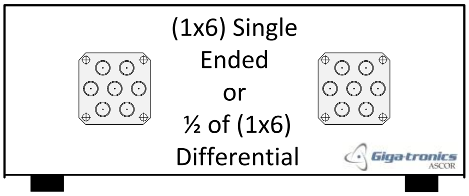
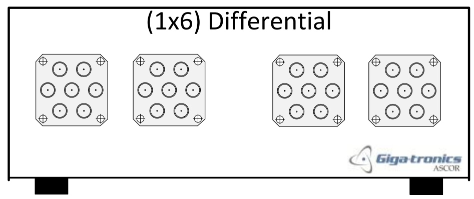


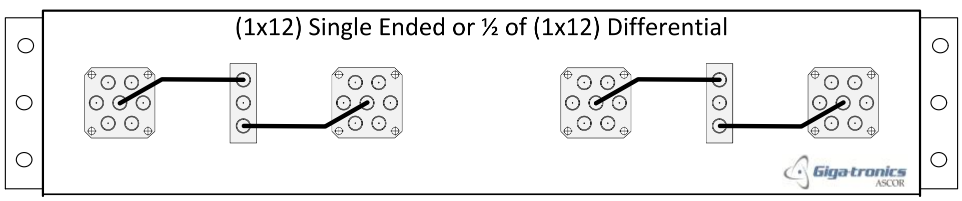
Figure 5

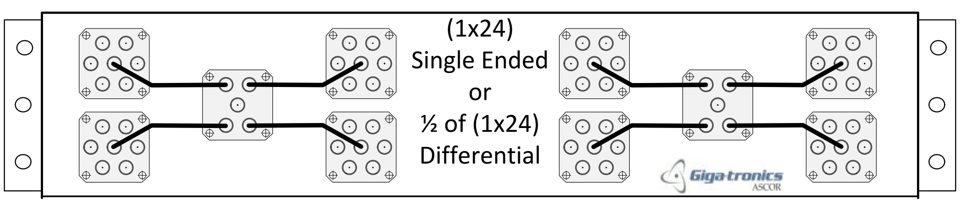
Sample Configurations for Giga-tronics Model 8901 and 8902 Switching Systems

All cabling shown is phase matched Semi-Rigid Coax Cable. The user is encouraged to use high quality, phase-stable flexible cables to connect between the switch, instrument and DUT.

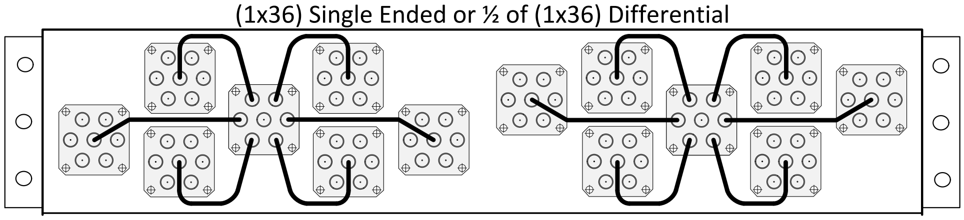


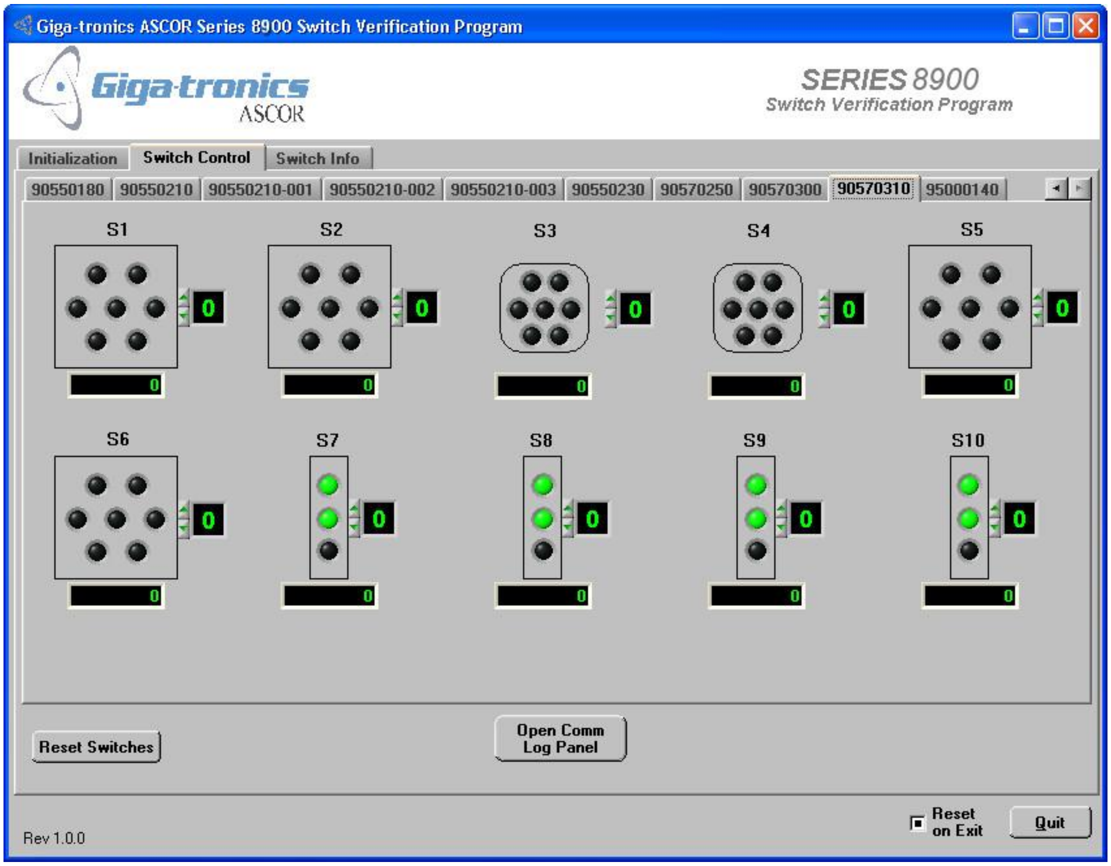






(1x36) Single Ended or ½ of (1x36) Differential





Model 8902 Switch Control Software Sample

Giga-tronics point-to-point software features:

- Just point and click and the software closes the appropriate relays
- Relay closure counter for preventative maintenance
- Path storage and recall to simplify test development
- Manual control with position indicator lights for troubleshooting

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