TLA7AS00 Logic Protocol Analyzer Setup Window

A “Soft” Front Panel for Diagnosing Link Health

Crossing the confidence threshold is a huge part of any debug activity using a test and measurement instrument. How can you be certain the instrument is configured properly to avoid hours of wasted time chasing false bugs?

In the newest release of the Tektronix Logic Protocol Analyzer (LPA), the Setup window not only provides immediate feedback about the instrument’s operation, it provides immediate feedback about the health of the System Under Test (SUT) itself – without taking an acquisition.

This whitepaper covers the capabilities of the new Setup window including hands-free configuration, one-button calibration, and acquisition-free health of system indicators. All of these reduce the time to actionable information to mere minutes, and equally importantly, minimize the need to switch among data views simply to determine whether the SUT or the LPA are behaving as expected.

Introduction

Setting up a measurement instrument is the last thing any engineer wants to do when they’re trying to debug a problem. The best situation is when the instrument requires no configuration and just works “right out of the box.”

For many situations, an instrument’s defaults do work just fine. But when it comes to PCIE Express® (PCIE) Gen 3.0, a protocol analyzer will likely need to be configured to match the operating conditions of the System Under Test (SUT).

The effort to configure an instrument ranges from setting Equalization for each of the lanes to associating lanes in the upstream and downstream direction, with dozens of other settings in between.

A protocol analyzer that auto-configures based on the traffic flowing on the PCIE link is a must-have to reduce the time to acquire actionable data. But ease of configuration only goes part way to reducing an engineer’s effort. What if the same screen that configures the instrument provides key insights into the behavior of the SUT?

The Tektronix Logic Protocol Analyzer (LPA) introduces the novel concept of near-real-time display of configuration information as a means of debugging PCIE link behavior. The LPA provides this novel functionality through two features: Auto-configuration and One-Click Calibration.

Auto-configuration

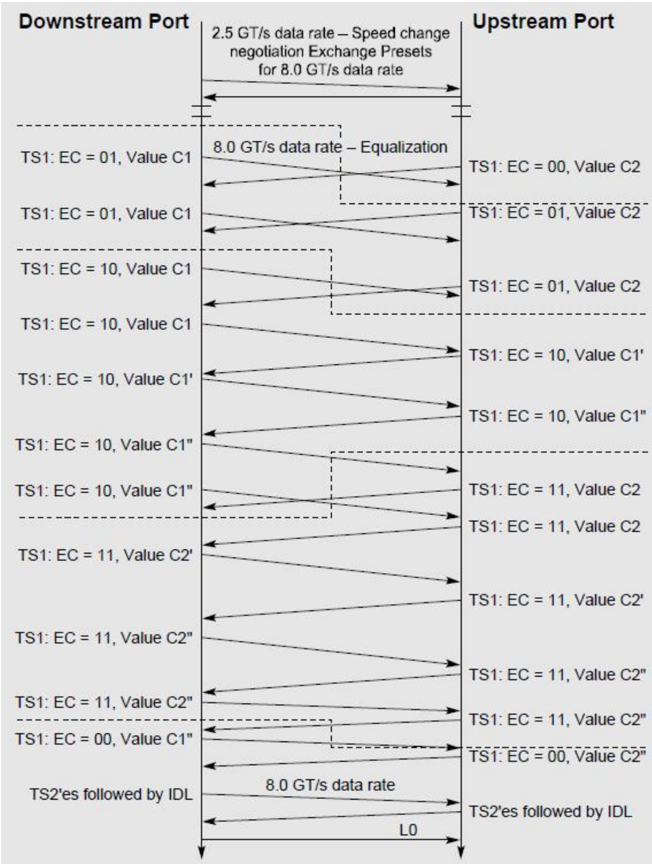
The LPA reduces the time to actionable information by automatically configuring its operating parameters based on the characteristics of the SUT’s link. Under normal operating conditions, a PCIE link starts at 2.5 GT/s (Transfers / second), issuing TS1 training sets. During this training cycle, the two ends of the link advertise their possible operating speeds, the number of lanes, the lane ordering, descrambling and polarity characteristics.

Based on the two endpoints’ capabilities and the design of the system, the link may attempt to move up to the highest advertised rate. If successful, it issues additional training sets at the higher rate. At higher rates, the training sequences include equalization settings in addition to the other parameters.

TLA7SA00 Logic Protocol Analyzer Setup Window

A “Soft” Front Panel for Diagnosing Link Health

Based on the two endpoints’ capabilities and the design of the system, the link may attempt to move up to the highest advertised rate. If successful, it issues additional training sets at the higher rate. At higher rates, the training sequences include equalization settings in addition to the other parameters.



The LPA listens in to the link as it proceeds through its training cycle, translating the TS1/TS2 values (as shown in Figure 1) into graphical indicators on the Setup window. In this way it acts as a “soft” front panel. Rather than having to take an acquisition, interpret the TS1/TS2 values and figure out how to configure the instrument by hand, the engineer can observe the graphical indicators and confirm the LPA did the right thing (see Figure 2).

In addition to configuring itself to the link’s characteristics, the LPA “maps” the link’s lanes to the LPA’s probe channels with connector lines. No matter how complicated the mapping, the system draws the connections in a fraction of a heartbeat.

When everything proceeds according to plan, the LPA configures itself in less than 1 second. By default, the LPA “tracks” the condition of the SUT: if the link downtrains in width, speed, or the like, the LPA follows along near-instantaneously, always attempting to stay synchronized with the link.

Of course the reason an engineer uses the LPA is to debug a link that isn’t well behaved. What if the link doesn’t move through its training sequences as it should? What if an endpoint fails to issue or honor advertised characteristics as it should?

Figure 1. Excerpt from PCIE Gen 3.0 Specification, Equalization Flow and Training Sequences between Upstream and Downstream sides of a link.

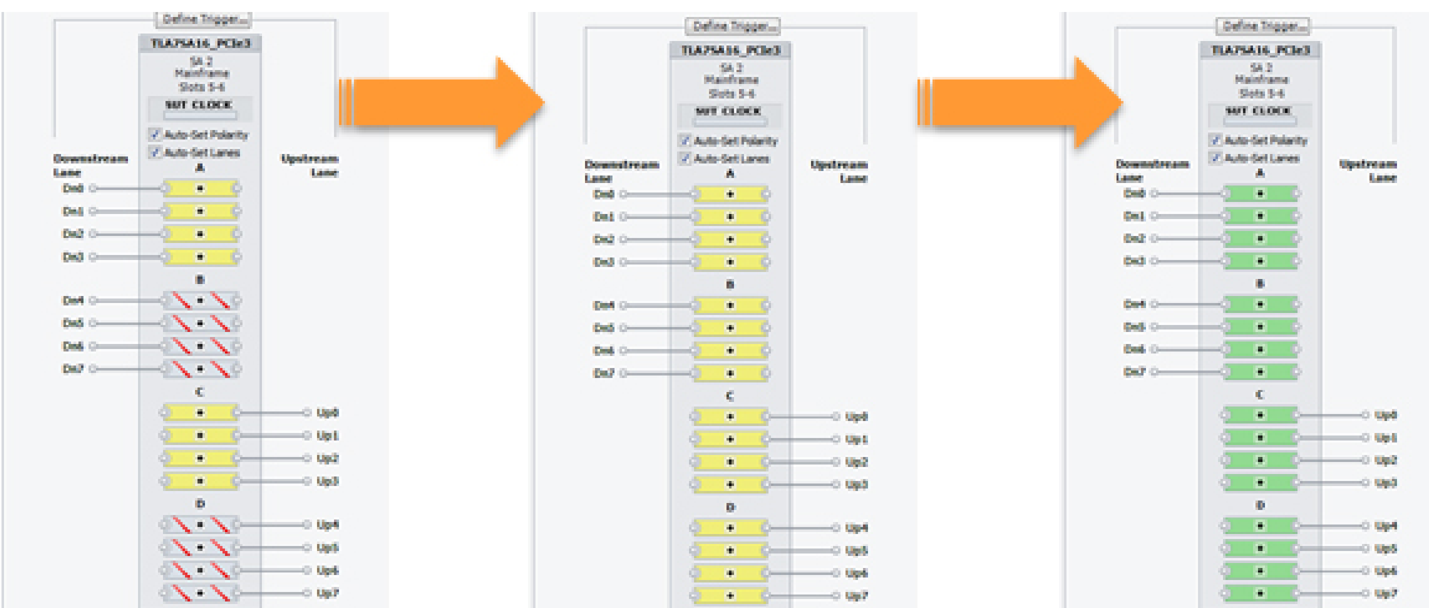


Figure 2. Setup window "soft" front panel synchronizing with link training sequences.

Tektronix

TLA7SA00 Logic Protocol Analyzer Setup Window

A “Soft” Front Panel for Diagnosing Link Health

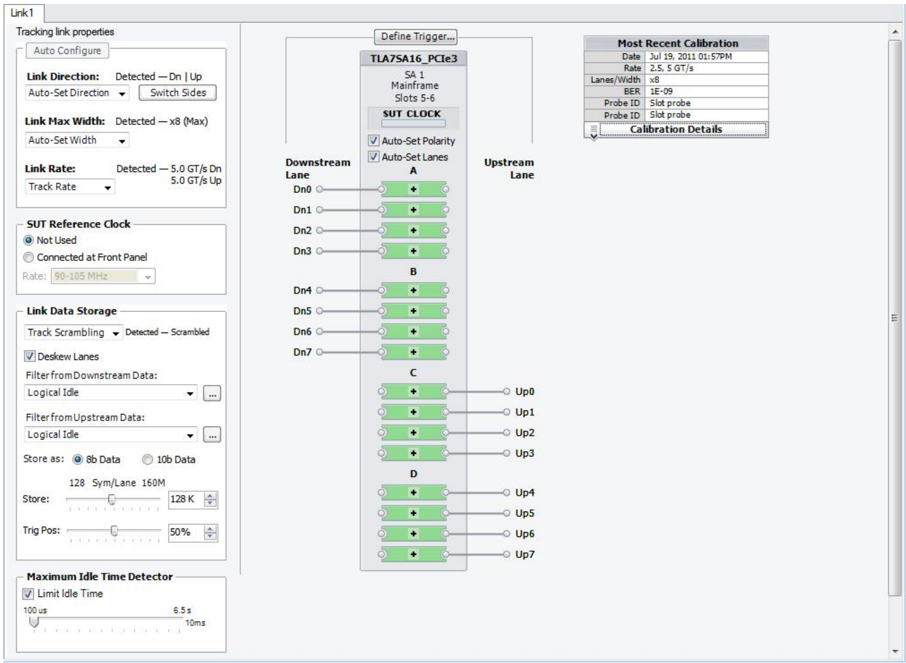


Figure 3. The LPA Setup window showing a successful configuration of a x8, 5.0GT/s link.

A well designed instrument should reduce the effort required to set it up, but it shouldn’t be so automatic as to remove an engineer’s control over its operation. The LPA’s Auto-configuration strikes an optimal balance between these two requirements: by default it auto-configures, but the engineer can override any operating parameter with one-click operations. No matter what combination of manual and auto-configuration settings, the LPA honors the engineer’s request. To make things even easier, restoring the LPA to an auto-configured operation requires only one button click, regardless of how many parameters are set to manual.

The design of the configuration capabilities of the LPA not only makes configuring the instrument both powerful and convenient, it permits a novel means of debugging the state of the PCIE link in near real-time, discussed in detail below.

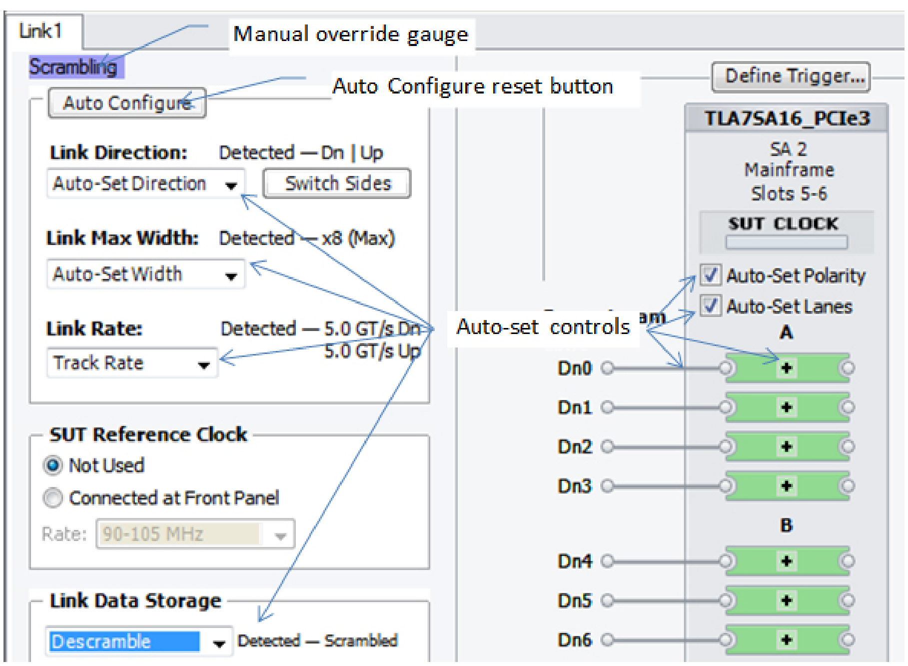


Figure 4. Independent manual overrides of key configuration parameters along with single button auto-configuration.

Before the LPA can auto-configure properly, it may need to be calibrated. The LPA’s Calibration Dashboard, located conveniently on the Setup window provides at-a-glance indications whether calibration is required (see Figure 5).

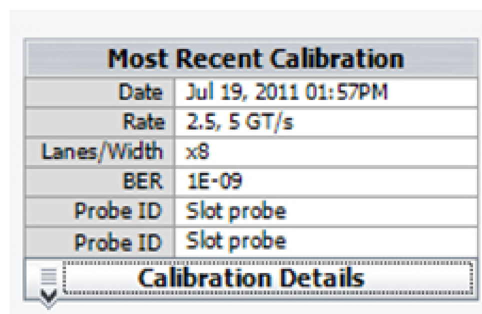


Figure 5. Calibration Dashboard providing at-a-glance confirmation of most recent calibration,

If calibration is required, here again, what might have been tedious, time-consuming and/or require separate applications or screens, becomes a valuable tool to gauge the link’s health.

TLA7SA00 Logic Protocol Analyzer Setup Window

A “Soft” Front Panel for Diagnosing Link Health

One-click Calibration

If you are debugging PCIE links operating at Gen 1 (2.5GT/s) or Gen 2 (5.0 GT/s), the factory default settings for the LPA are usually sufficient to operate the instrument with an approximate BER of 10^{-12}. But when the link is operating at Gen 3.0 rates (8.0 GT/s), calibration is almost guaranteed to be required. Several changes in the PCIE Gen 3.0 specification contribute to the need, most notably the introduction of *dynamic* equalization between the link endpoints. The number of possible equalization settings has increased from 2 *static* values to 2^7 possible *dynamic* values, meaning each side of the link has to agree on the specific equalization profile. The LPA doesn’t participate in this negotiation; instead, it has to identify the best equalization value to use without affecting the link’s native equalization.

The technical details of the LPA’s calibration process and additional reasons for it are covered in a separate technical paper, TLA7ASA00 *One-click Calibration: Efficiently Tuning the Tektronix Logic Protocol Analyzer*. For the purposes of this discussion, the LPA’s calibration routines exhaustively test up to thousands of possible settings to determine the best possible operating conditions for the instrument on a specific link.

Theoretically, we all want our instruments to operate without introducing any errors, but in the real world, instruments themselves can introduce errors. Similarly, in theory we all want the most error-free operating conditions in our circuits, but again, in the real world, depending on the nature of our investigation and time pressures, we are willing to accept a certain number of errors.

For example, we may know that our link is not operating error-free, but we don’t want to hold up our investigation just because the link won’t calibrate to a 10^{-9} (or better) error rate. Instead, we may want to capture something and begin our analysis, saving the error-free acquisitions for later.

LPA One-click Calibration Reduces Time to Actionable Information in Several Ways

- It puts the engineer in control of the target BER. The default setting of 10^{-9} is easily adjusted with a simple control. Using the default setting lets the engineer complete calibration quickly to pursue debug activities as soon as possible.
- If calibration fails to achieve the desired BER, it reports back the best BER it was able to achieve, allowing the engineer to decide whether its best is good enough.
- One-click calibration allows the engineer to “cherry-pick” lanes to recalibrate at a later time. Here again, the engineer is in control of the process.

The calibration process mirrors the tasks an engineer would have to do: construct a trigger to count errors during a specific period of time (stopping if the number of errors exceeds a threshold), then inspect the lanes and manually count the errors. By doing these tasks in machine-time, the calibration process can try all possible combinations of operating parameters in far less time than the engineer can, returning the best possible results.

After finishing calibration, the system provides Information about the calibration in the Calibration Dashboard, visible at a glance from the module’s Setup window. If the calibration was successful, the dashboard data, including the date, rate, width and BER values are rendered in a normal color as Figure 6 displays.

In those cases when calibration encounters a problem, it reports the issue in the dashboard as well, highlighting the item. In addition to the summary information, the system reports the best BER achieved on a lane by lane basis. By seeing BER results, the engineer is in control about what to do next: continue to debug with a sub-optimal system or attempt to improve the link characteristics and re-calibrate. Even here, the LPA has been designed to reduce work: the engineer can “cherry-pick” the lanes to be re-calibrated using the associated checkbox. The LPA will only recalibrate lanes that are checked.

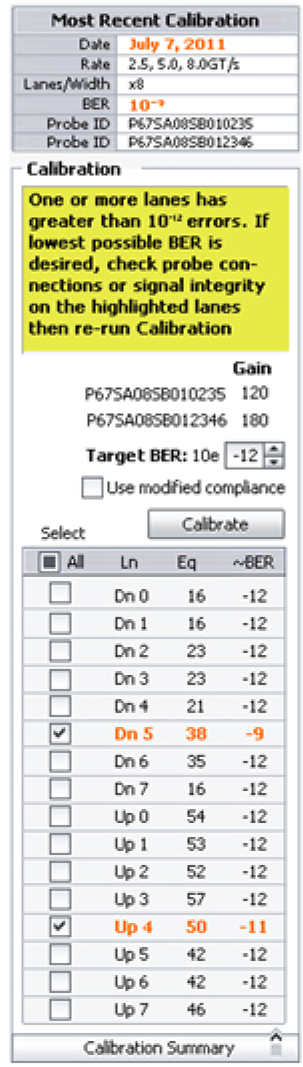


Figure 6. After an unsuccessful calibration the system displays the results of its analysis.

Tektronix

TLA7SA00 Logic Protocol Analyzer Setup Window

A “Soft” Front Panel for Diagnosing Link Health

Configuration or Debug Tool?

These new features, Auto-configuration and One-click Calibration, reduce the effort to set up the LPA. But they go much further, providing key debug information about the link itself without the engineer having to take an acquisition.

Calibration

Results from the calibration routines provide information about the health of the system in two ways:

1) The time required to calibrate identifies links that may be problematic.

    a) Very short calibration times may actually indicate the link is in trouble – calibration may complete early because there are too many errors on the lanes or the SUT cannot stay out of recovery very long

    b) Very long calibration times may indicate a few lanes are misbehaving

2) The estimated BER achieved on a lane-by-lane basis provides the engineer with insights about problematic lane(s) without having to take an acquisition and count errors manually.

The Calibration Details table shows the troublesome lanes using “Exception Indicators” (bolded orange values). Using these indicators, the engineer can immediately see where to begin investigating the problem.

A reasonable next step, for example, would be to recalibrate; the system will only attempt to calibrate the problematic lanes (by default because they are automatically selected). If that doesn’t fix the problem, attention can be turned to the probe connections and eventually to the link itself. Ultimately the engineer may need to take a deeper look into the signal integrity of these specific lanes.

The point is the calibration process doesn’t simply provide a pass/fail judgment: its detailed results provide insights into possible problems not necessarily with the instrument and calibration but on the link itself.

The system isn’t infallible. If the link can’t stay out of recovery for the necessary time period, the calibration system will likely identify errors incorrectly and possibly throw away optimal EQ values. But even here the calibration results provide the engineer with valuable information: a very fast calibration with exception indications on all lanes likely indicates an unstable SUT.

For intractable systems, the LPA provides manual methods for calibration; a topic beyond the scope of this paper.

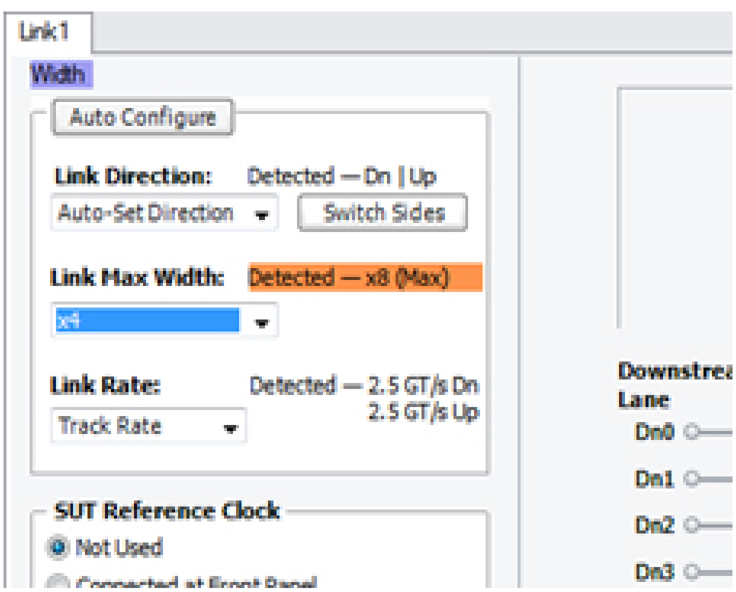


Figure 7. Exception indicator for manual width configuration

Auto-configuration

Perhaps of even greater value than calibration as a debug tool is the auto-configuration system. Consider a case in which the engineer truly believes the SUT should remain stable at 8 GT/s, but instead it cycles through 2.5, 5.0 and back to 8.0. With the LPA set to “auto-track” the data rate, the instrument will dutifully follow along as the SUT misbehaves.

Instead, if the engineer sets the LPA to a fixed data rate – 8.0 GT/s, then the LPA will immediately indicate a problem when the SUT cycles—without the engineer having to take an acquisition and browse through pages of data.

Similarly, the engineer may believe the SUT should never change width, but patterns of errors displayed in the LPA Setup’s window make it very clear if width changes have occurred. Again, these patterns are displayed without any action on the part of the engineer – no acquisition, no studying the data – just observing the behavior of the screen elements as the SUT is put through its paces.

Even though the engineer may have manually overridden a configuration parameter in the LPA, the instrument continues to monitor the SUT. When an operating condition on the link differs from the manual setting, the Setup window displays an Exception Indicator, providing a clear, graphical indication that something is amiss.

TLA7SA00 Logic Protocol Analyzer Setup Window

A “Soft” Front Panel for Diagnosing Link Health

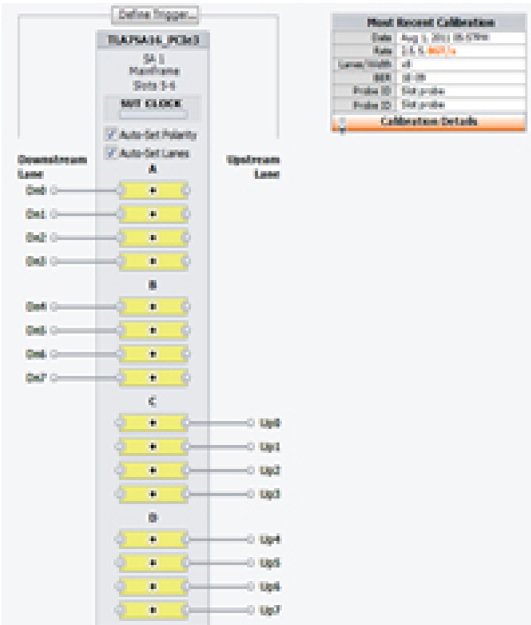


Figure 8. Calibration and Auto-configuration together indicate a problem with operating conditions.

In addition to the Exception Indicators for auto-configuration, the Setup window provides several other graphical indications of potential problems with the configuration or the link. By simply observing the readouts on the screen, the engineer avoids wasting time browsing through pages of data trying to find the problem.

Auto-configuration and Calibration Together

By having both functions available on one screen, the system can notify the engineer of operating conditions that might be problematic. Consider the case in which the engineer is expecting the SUT to operate only at Gen 2 rates or slower. In this case, the LPA is auto-configured and has been calibrated for Gen 1/Gen 2 rates.

But because the LPA is auto-tracking, if the SUT *does* go into Gen 3.0, several elements on the screen will immediately light up to indicate a problem to the engineer:

1) The central “LEDs” will all turn yellow
2) The Calibration Dashboard will “light up” orange

Additional examples of the Setup window’s indicating conflicts between the current configuration and the SUT behavior are shown in Figure 9.

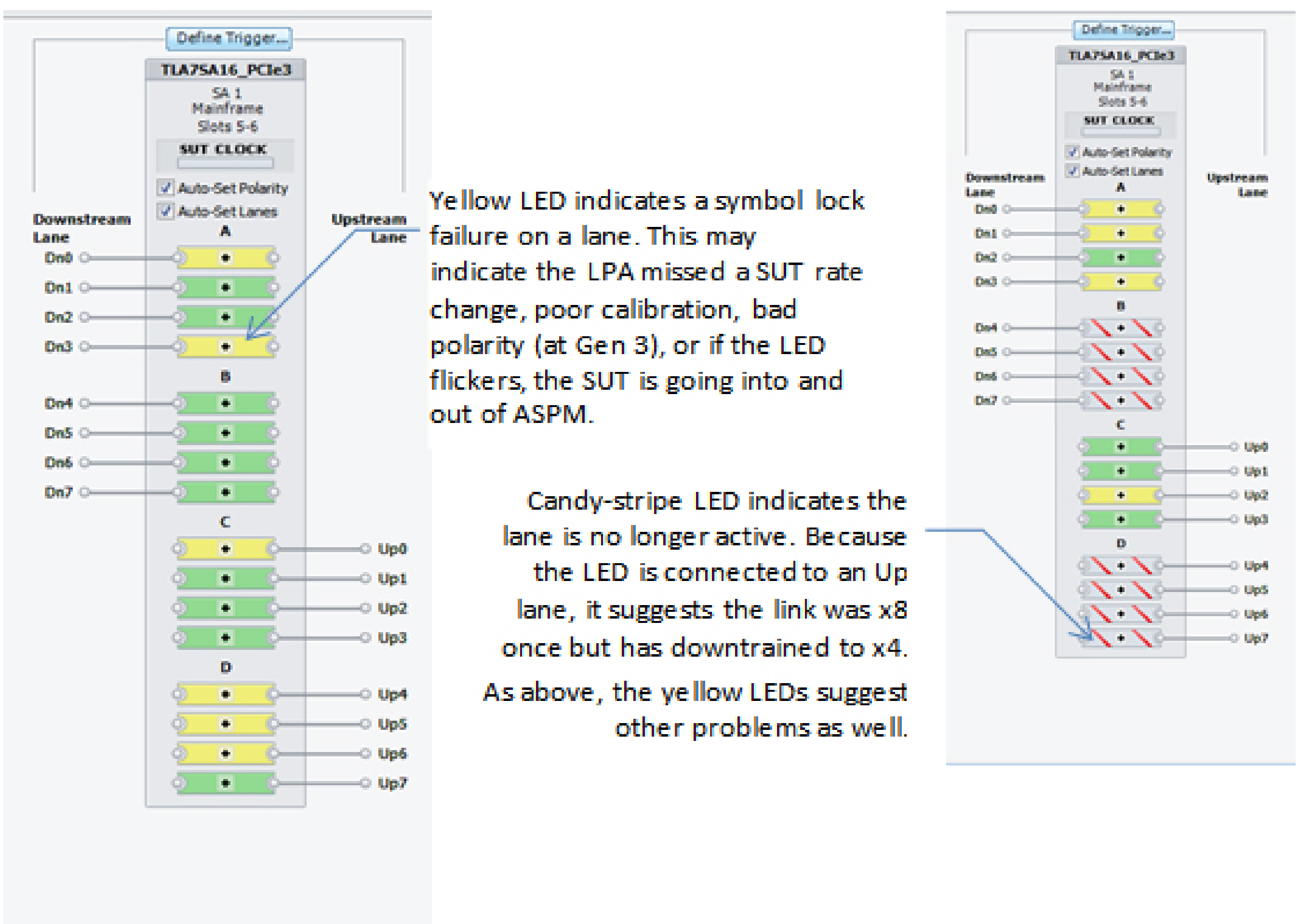


Figure 9. Setup window indicating problems.

Tektronix®

No System is Perfect

LPAs are rarely used if there isn't already a problem with the link. Of course, imperfection applies to the LPA as well. At times, especially when the LPA has been configured with a mixture of auto- and manual- configuration elements, and the engineer has been thrashing the SUT, the instrument may lose its way. The symptoms are fairly clear from the Setup window: link conditions are definitely not what they should be, lane indicators are green when they should be yellow (or vice versa), or exception indicators are showing up when they have no business being there.

The quickest way to get everything back in order is to click the Auto-configure button and reset the SUT. Alternatively, if the LPA was already in full Auto-configure mode, changing the rate from Auto-track to a fixed rate and back to Auto-track, and then resetting the SUT will quickly clear things up. In moments, the LPA will re-establish its operating conditions to match the SUT, prepared to assist in debugging issues once again.

Conclusion

Although it is similar to a front panel of indicators, the Setup window provides far greater detail about the link health, with the added advantage to the engineer of not having to be physically next to the instrument itself: results of experiments can be viewed from the quiet comfort of a workstation.

The Setup window GUI, including the Calibration Details table, provides the engineer with key indicators about the operating conditions of the SUT all in one convenient and easy-to-use screen. In the Calibration Details table, the engineer sees the results of a calibration run, determining which lane, if any, is problematic. In the Setup window GUI, the LPA displays conflicts between conditions the engineer expects on the link and those the instrument observes.

The LPA continues to display the SUT operating conditions as long as the Setup window is the active window, without requiring any effort on the part of the engineer. By observing the Setup window after stimulating the SUT, the engineer observes in near real-time the results of the stimulus as the LPA senses them.

The Tektronix LPA has been designed to reduce the time it takes for an engineer to take action on the data it displays. Rather than forcing the engineer to spend time configuring the system, acquiring and analyzing data just to figure out if the instrument is configured correctly, the LPA automatically presents the link's behavior directly, graphically and all on one screen. Through observing the Setup window's graphical indicators of link behaviors, the engineer receives actionable data immediately with minimal effort.

10/2011 52W-27494-0