TECHNICAL OVERVIEW

FlexDCA Sampling Oscilloscope Software

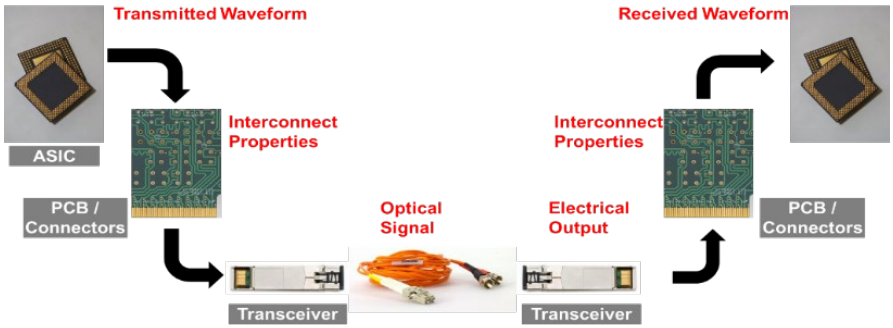
Keysight DCA Family

What is FlexDCA?

Keysight's N1010A FlexDCA is the software that runs Keysight's DCA family of sampling oscilloscopes (also known as equivalent-time oscilloscopes). A Digital Communication Analyzer (DCA) is an instrument designed to visualize and analyze the analog properties of high-speed signals like the ones used in wireline telecom and datacenter links. FlexDCA runs on the N1000A DCA-X mainframe or any instrument or PC/laptop that uses Microsoft Windows 7 or 10. It is used to control measurement hardware (i.e., the DCA family of oscilloscopes and clock recovery hardware), both as a local user interface (UI) and for remote control. FlexDCA is also a visual output for simulation (such as Keysight's ADS and SystemVue products) and for remote access to supported DCA mainframes.

In addition to acquiring data and making measurements, FlexDCA also encompasses powerful tools that boost productivity and provide insights into root causes of issues with the signal or device under test. FlexDCA has been used and continues to evolve for applications like:

- Research and design verification of electrical transmitters (ASICs, FPGAs, PHYs)
- Research, development, and manufacturing of optical transmitters/transceivers
- Analysis of reflections and transmission characteristics of electrical components and channels
- General-purpose analysis of analog and digital signals



KEYSIGHT TECHNOLOGIES

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This document was updated based on FlexDCA revision A.06.80. Some features described here don't exist or are different in earlier versions.

FlexDCA offers a variety of color schemes and other choices to address the preferences of different users. Screen captures in this document deliberately use a variety of aesthetic settings to show possibilities. For example, some people prefer dark backgrounds on instrument or computer screens, and light backgrounds in printed documents such as reports or data sheets.

FlexDCA Software Running on Mainframes

FlexDCA comes pre-installed on all DCA-X sampling oscilloscope mainframes. It instantly recognizes supported modules in any of the four available slots and allows hot-swapping them. In addition, virtual slots 5 through 8 can be used for up to four DCA-Ms connected via USB, resulting in a total of 32 measurement channels (four quad-channel mini-modules plus four quad-channel DCA-Ms).

Figure 1. N1000A with N1060A module (left) and N1000A with four N1046A modules (right).

FlexDCA Software Driving Mini DCAs (DCA-Ms), Clock Recovery Units

Standalone “mini DCAs” (DCA-Ms) provide optical and electrical measurement channels and clock recovery (CR) capabilities in a half-rack-width form factor. They don’t have a front panel user interface. Instead FlexDCA – running either on a PC/laptop or on a DCA-X mainframe - drives them for both manual operation and remote control.

Figure 2. FlexDCA on a laptop controlling N1092X series DCA-Ms and a N1077B clock recovery.

FlexDCA Software to Display/Analyze SystemVue, ADS Simulations

Many serial link design engineers have been using Keysight's SystemVue or Advanced Design System (ADS) as their primary design tool. The Channel Simulator from ADS provides very fast yet accurate channel simulation by bit-by-bit and statistical simulation technology. Along with the support of industry standard IBIS-AMI models, ADS offer comprehensive solutions for most serial link standards such as PAM4. However, some engineers want to use FlexDCA's built-in measurement capability such as TDECQ with the simulated data from ADS, or compare the simulation results directly with the measured data in FlexDCA. With the new "FlexDCA Probe" feature of ADS, design engineers will be able to output the simulated results directly to FlexDCA.

The new FlexDCA Probe supports two modes, Static and Dynamic. The static mode allows design engineers to write the waveform files to text (.txt) format which can be read in to FlexDCA later[1].. Whereas, the Dynamic mode automatically invokes FlexDCA and populates the specified memory channels or slots with the waveform data, up to 8 channels, streamlining the workflow.

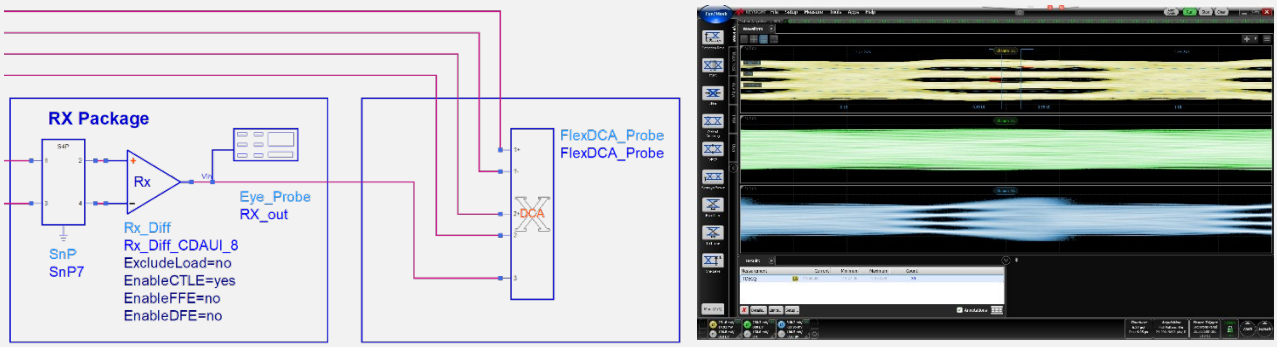


Figure 3. After connecting a "FlexDCA Probe" in ADS (left) FlexDCA can display and further analyze the simulation results (right) using FlexDCA's math and signal processing functions.

1 Data transfer from ADS to FlexDCA requires a license for the R&D Package (see **Error! Reference source not found.** and **Error! Reference source not found.**)

Main Components

Oscilloscope Mode

Oscilloscope Mode provides the traditional amplitude-versus-time display. Measurements made in this mode are designed for single-valued waveforms (as opposed to eye diagrams).

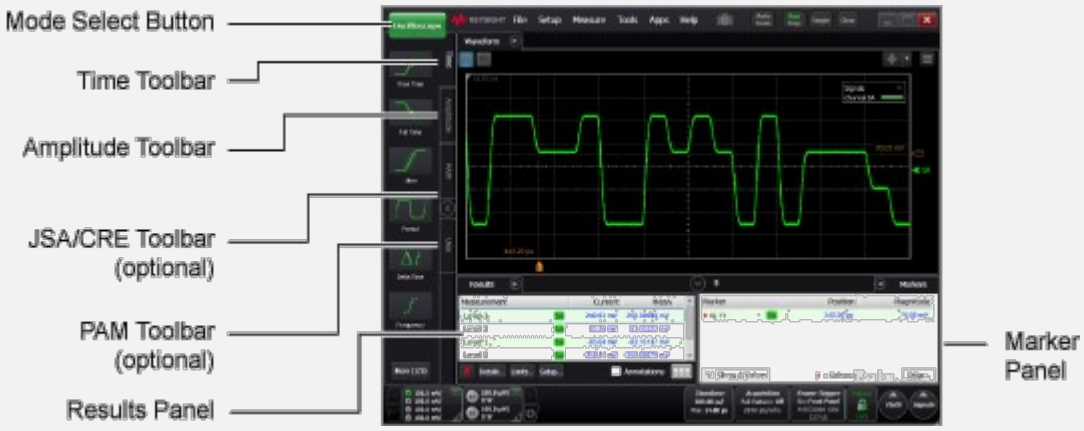


Figure 4. Oscilloscope Mode.

Eye/Mask Mode

Digital signals consist of a sequence of symbols that are often coded in binary (NRZ) or multilevel (PAM-N) formats. The overlay of many sequences consisting of three consecutive unit intervals creates eyes that can be statistically analyzed to gain insights into how well a transmitter will perform in a system (Figure 5).

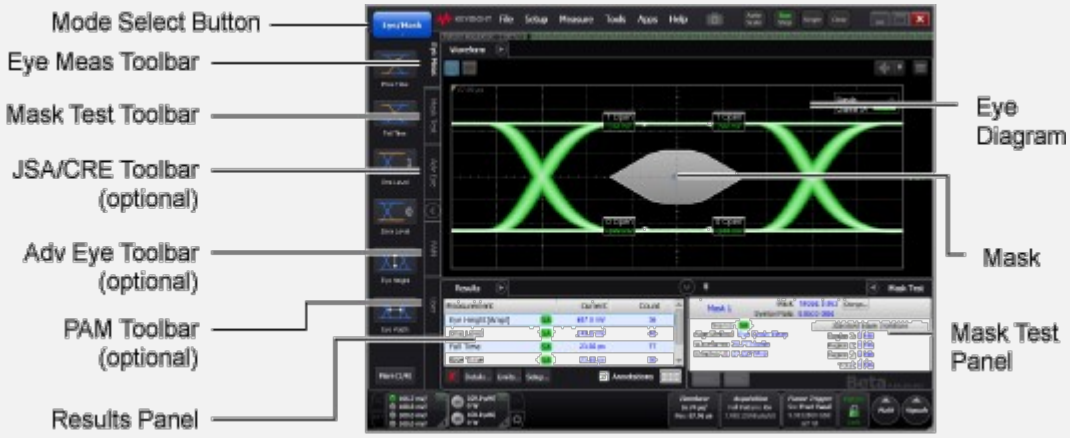


Figure 5. Eye Diagram / Eye Mask Mode.

Jitter/Noise Mode

Jitter Mode allows you to quickly measure and troubleshoot the components of jitter for signal edges and noise/interference for signal levels. Measurements can be made on optical or electrical input NRZ and PAM4 coded signals.

Figure 6. Jitter/Noise analysis mode.

TDR/TDT and S-Parameters Mode

Time Domain Reflectometry (TDR) and Time Domain Transmission (TDT) waveforms provide an intuitive view of an electrical channel's impedance profile (reflection and transmission characteristics) versus distance or time. T-parameter waveforms (i.e., TDR/TDT graphs in the time domain) display amplitudes in volts, ohms, or percent. S-parameter waveforms (i.e., graphs in the frequency domain) provide magnitude, group delay, or phase information.

Figure 7. TDRTDT and S-Parameters mode.

Acquiring Data

Channels

FlexDCA takes data from actual measurement hardware, such as DCA-X mainframes or DCA-M mini-DCAs, or from virtual modules. For DCA-X mainframes FlexDCA counts channels installed in the module bay from 1 (leftmost slot) to 4 (rightmost slot) and A (top channel within a slot) to D (bottom channel within a slot).

For DCA-Ms FlexDCA assigns a virtual module number that is displayed on the front panel of the DCA-M itself. Labels next to each channel identify the channel letter (A to D) if the DCA-M has multiple channels.

FlexDCA also has a built-in signal simulator that provides many common signals (e.g., NRZ, PAM4, sine/square, “Load From File”). Simulated modules can be assigned to any available slot.

Figure 8 shows a DCA-X mainframe has a 8-slot wide module bay, four simulated electrical channels in slot 1, and the remaining 7 slots can be configured with any extended module listed in the Hardware and Simulation. Having instrument hardware next to virtual channels allows the comparison of real signals with simulations, and verifying that the actual design meets the predicted behavior.

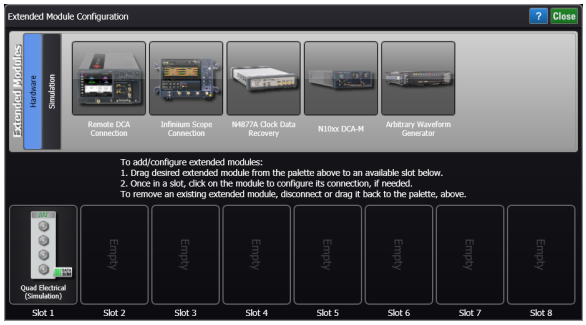


Figure 8. DCA-X frame with a 8-slot wide module bay.

Functions

Functions are mathematical operations on signals. They require at least one input signal and create at least one output signal. Some functions can have parameters: for example, the “Butterworth” low-pass filter function requires the order and the bandwidth of the filer.

Figure 9. Example of a function with a parameter: the signal coming from channel 5A is delayed by 9.19 ps and then displayed as F1.

Trigger & Pattern Lock

In most situations a sampling oscilloscope requires a trigger signal (either provided from an external source or a hardware clock recovery) that is synchronous with the data. The trigger signal provides a reference for the timing of when the actual sampling occurs.

When trying to acquire a repeating pattern, the timebase of the oscilloscope may need to create a long delay after being triggered but before sampling the data. An example when this occurs is if an external pattern trigger (from a BERT or Pattern Generator) is used to trigger the oscilloscope as shown in the top part of Figure 10. Longer delays result in bigger timing error (the accuracy of delay is a percentage of the total delay).

If a clock synchronous with the data instead of the repeating pattern is used, then FlexDCA can drastically reduce delay uncertainties. First, FlexDCA determines the pattern length (i.e., how many clock cycles it takes until the pattern repeats). Second, it uses only the closest clock edge to trigger the timebase, resulting in much shorter delays and therefore smaller timing errors (bottom part of Figure 9). In essence, the clock allows FlexDCA to digitally “walk” through a pattern and position the sampling very accurately at any arbitrary moment within a pattern’s repetition period.

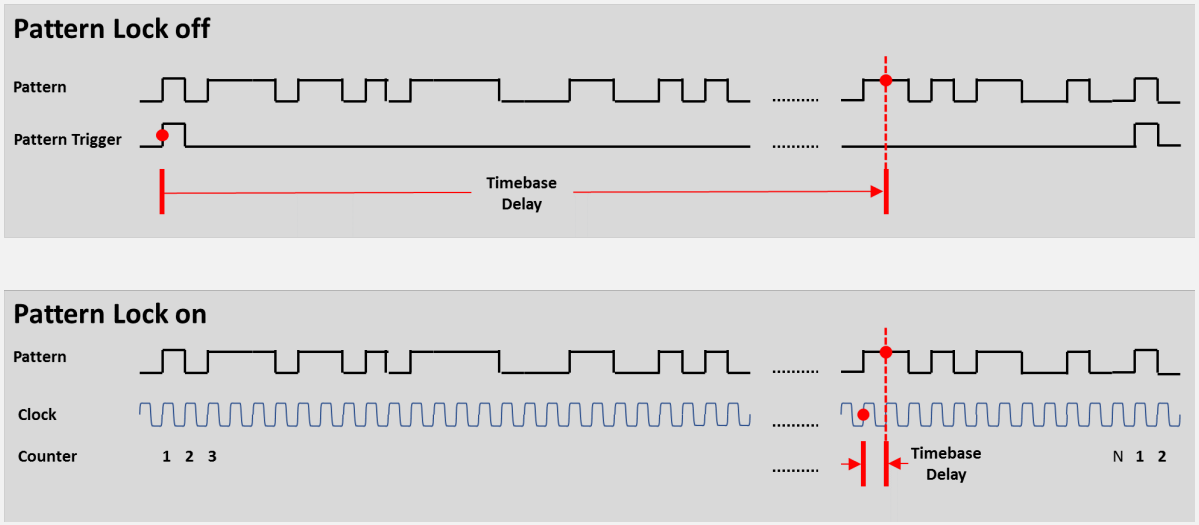


Figure 10. Effect of Pattern Lock

Pattern Lock is a necessity for many deeper insights, for example jitter and interference analysis (page 24), finding bit sequences on- and offscreen (page 23), processing of waveforms (page 29), and more.

Deskew

Electrical high-speed digital communication often uses differential signals. Tolerances in semiconductors, cables, fixtures and instrumentation can lead to differences in when the two signals arrive at the oscilloscope. This so-called skew usually is undesirable. Measurements need to deal with two aspects:

- Remove all skew: independent of the sources of skew you want to have the measurement of a differential signal to be unaffected by skew. FlexDCA provides support for both hardware and software de-skewing. Hardware deskew works in all measurement modes but is limited to tens or hundreds of picoseconds. Software deskew works even for very long time spans (up to the pattern period when Pattern Lock is on) but is limited to Oscilloscope and Eye/Mask modes.
- Characterize a DUT's skew: you want to know how much skew is on the signal, but you want to exclude any skew contribution from the instrumentation setup. FlexDCA provides a wizard that is specifically designed to only remove skew stemming from fixtures and cables.

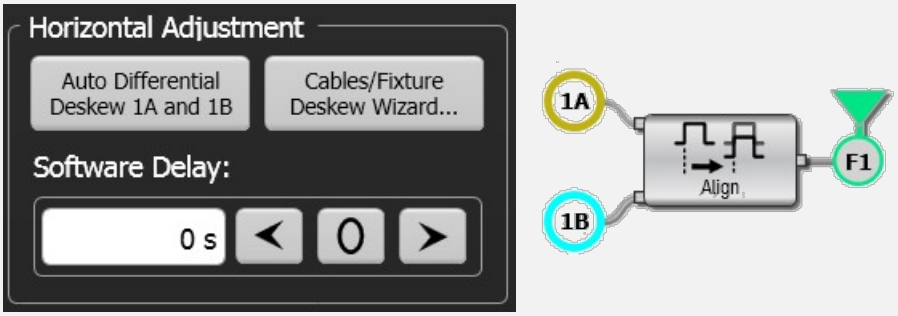


Figure 11. Hardware Deskew and Cable/Fixture Deskew (left), software deskew (right). The Align function shifts the signal from the upper input so that its output aligns with the signal at its lower input.

External HW

Optical and electrical front ends built into the DCA provide calibrated and accurate measurement channels. In addition, FlexDCA supports external converters and attenuators/amplifiers. Figure 12 shows how to model an external photodiode followed by an amplifier ("negative dB" attenuator) in front of an electrical oscilloscope channel. Consequently, FlexDCA will display the signal in Watts and with the correct amplitudes, even when the actual measurement is in volts.

The transducer is a generic linear model and can be used for any type of converter, whether it is optical, electrical (e.g., current probe), or anything else.

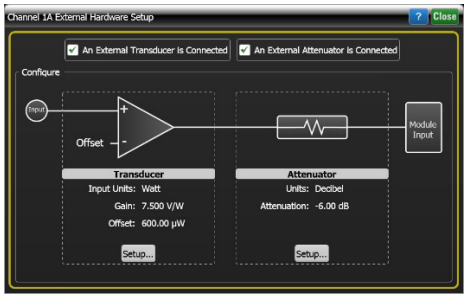


Figure 12. External O/E converter followed by an amplifier.

System Impulse Response Correction (SIRC)

Many standards require optical measurements to be made with an oscilloscope that has a frequency response approaching the behavior of a 4th order Bessel-Thomson filter. As data rates get higher it becomes increasingly difficult to build oscilloscope channels with such a frequency response.

Keysight has created an innovative approach called System Impulse Response Correction (SIRC) that:

- Improves the response of currently specified filters to be much closer to the desired Bessel-Thomson response
- Allows the user to perform measurements at rates other than those already specified within the reference receiver, including those well above and below the typical operating range of the receiver
- Maintains the measurement integrity for the eye quality, mask margin, jitter, amplitude interference, noise and extinction ratio

In principle, the SIRC technique de-embeds the complete oscilloscope channel and embeds a mathematical low-pass filter, therefore creating an almost ideal receiver whose bandwidth can be set at any value between about 0.5 times the hardware's lowest bandwidth setting and 1.5 times its highest bandwidth setting.

SIRC requires extensive data collection at the factory or a service center. It is offered as an option for practically all optical channels. Contact Keysight for availability on electrical channels.

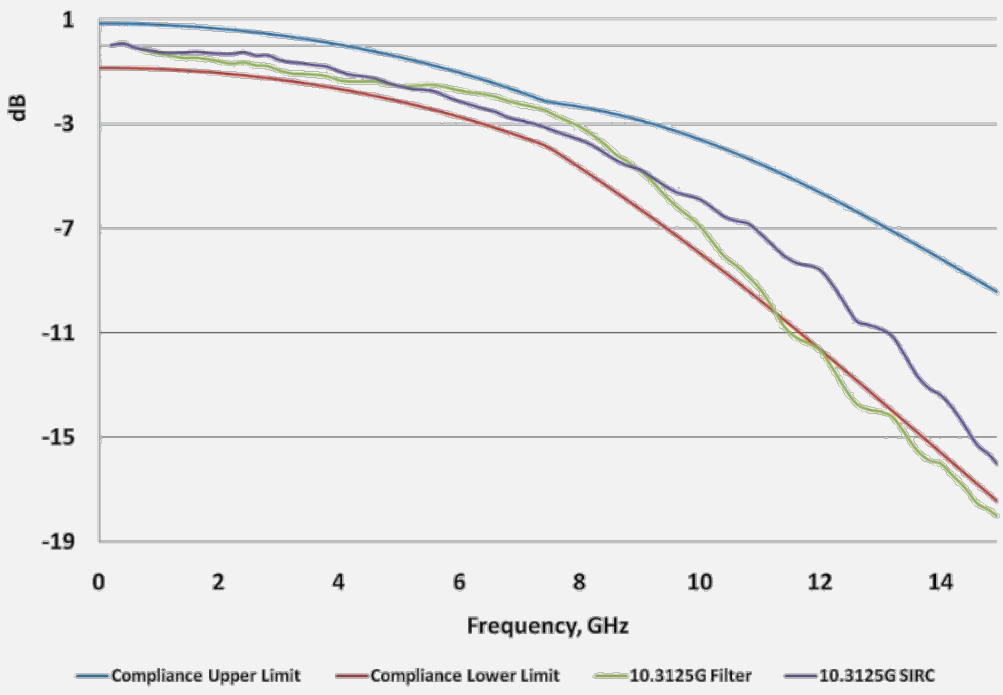


Figure 13. Compliance filter response on 86105C with filter intentionally set at bottom of tolerance window (green trace) and with SIRC (purple trace).

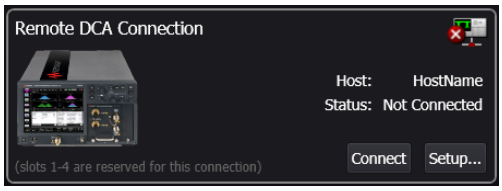
Analysis Packages

Analysis Packages offer additional features that provide deep insights into signal or DUT properties, significantly improve throughput, and transform raw data into powerful graphics. The packages combine many separate items that are described below and were sold previously under individual licenses (see page 17 for how these features map into the new license packages).

Licensed features

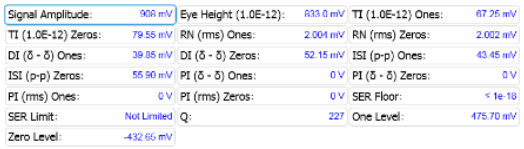
Access to Licenses on Remote DCA [2]

Access to Licenses on Remote DCA applies when using a separate PC to control a DCA-X. It allows FlexDCA to use licenses installed on the instrument in addition to those installed on the computer it is running on. Features will be enabled if FlexDCA can detect a license – such as jitter or PAM-N – at “either end of the cable”. Instruments connected via USB are considered “local” and all their licenses immediately enable the corresponding features.



Advanced Amplitude Analysis/RIN/Q-Factor

Advanced Amplitude Analysis/RIN/Q-Factor is part of Jitter Mode and a companion to jitter analysis. It decomposes level amplitudes into noise and interference components, hence providing insights why a waveform or eye diagram is not achieving the desired bit error ratio (BER).



Advanced Eye Analysis

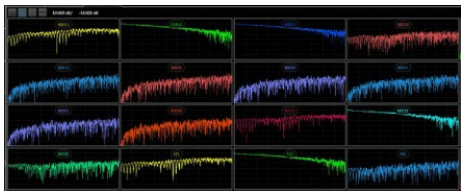
Advanced Eye Analysis is based on eye diagrams and provides jitter and interference analysis on patterns longer than 2^16-unit intervals (UI) or live traffic for which the more accurate jitter and the amplitude analysis doesn’t work. It also offers BER contour mask testing.

Automatic Fixture Removal (AFR)

Automatic Fixture Removal removes the effects of setups (cables, fixtures, sockets) from TDR/TDT measurements. A very powerful tool included with Automatic Fixture Removal is One-Port AFR. For some 2-port fixtures, One-Port AFR will calculate the 2-port S-parameter file after the user measures S11 (or SDD11 for differential fixtures) for one port with the other port open and/or shorted. The 2-port fixture can then be de-embedded from the TDR or TDT measurement.

Enhanced Impedance And S-Parameters

Enhanced Impedance and S-Parameters transform raw TDR/TDT measurements into impedance profiles in the time-domain (T-parameters) and magnitude/phase/group delay plots in the frequency domain (S-parameters). It can calculate near and far end cross talk (NEXT/FEXT



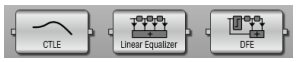
2 A license to access a remote DCA must be present at the local PC/laptop, such as a N1010x00A package. Otherwise FlexDCA cannot connect to a remote DCA-X. Furthermore, the Access to Licenses on Remote DCA feature doesn’t support subscription-based compliance app licenses to run on remote DCA-X.

Enhanced Jitter Analysis

Also known as Jitter Mode, Enhanced Jitter Analysis provides simple, one button setup and execution of jitter analysis. Jitter is defined as the deviation of transitions between signal levels from their nominal moments in time. Jitter mode decomposes jitter into its constituent components and presents jitter data in various insightful displays. This allows engineers to understand what contributes to jitter and consequently improve their designs.

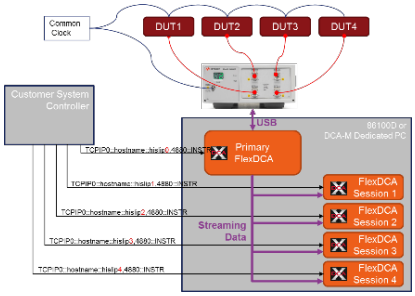
Equalizers

Equalizers consist of software blocks that process signals according to the desired function (CTLE, DFE, LFE).



FlexEye

FlexEye is an independent eye acquisition and analysis feature that creates the ability for the user or a remote program to operate a single instrument with multiple channels as if it were separate, independent single-channel instruments. For example, a remote program could start and stop data acquisition for each DUT/channel individually, even if the four channels are part of a quad-channel module plugged into a DCA-X, or a single DCA-M with 4 channels measuring four independent DUTs. FlexEye requires all signals to have synchronous clocks.



PAM-N Analysis

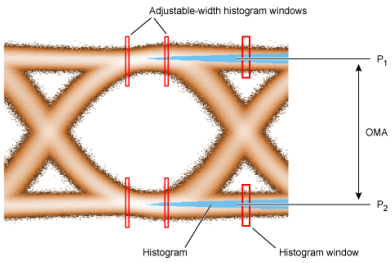
PAM-N Analysis is a set of measurement features dedicated to multilevel signaling, including level, eye, skew, linearity, noise and TDECQ measurements.

Send Data to Analytics Web Service

Send Data to Analytics Web Service (such as Keysight's N8844A) supports the collection of data for later analysis on cloud or other servers. The N8844A software enables designers and validation engineers to capture and store their test data. It includes machine learning (causation diagram) for accelerated data analysis and provides access to analytics for their globally-distributed teams in real-time.

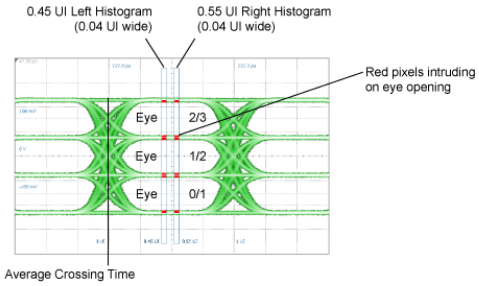
Transmitter and Dispersion Eye Closure (TDEC)

Transmitter and Dispersion Eye Closure is a metric for NRZ signals found in Ethernet and other standards that qualifies the waveforms of optical transmitters. In short, a real transmitter with X dB of TDEC would result in the same bit error ratio as an ideal transmitter with X dB of random (Gaussian) noise added.



Transmitter and Dispersion Eye Closure for Quaternary Signals (TDECQ)

Transmitter and Dispersion Eye Closure for Quaternary Signals is a subset of the PAM-N Analysis feature set and a measurement similar to TDEC. It compares the actual signal from an optical PAM4-modulated transmitter with an ideal scenario and reports a penalty metric.

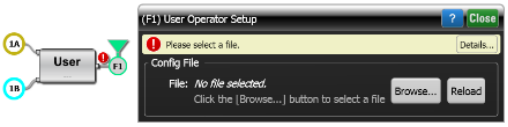


Unrestricted Data File Import

Unrestricted Data File Import allows FlexDCA to operate on waveforms from sources other than supported Keysight hardware. For example, the transfer of waveforms from Keysight ADS, Microsoft Excel® or non-Keysight hardware requires a license for a package that enables the Unrestricted Data File Import feature (see page 17).

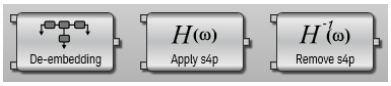
User Defined Measurements and Functions

FlexDCA can send waveforms to external program scripts that can apply mathematical operations and return vector (waveforms) or scalar (measurement) results. FlexDCA currently supports MATLAB® and Python™ scripts. Such scripts are called User functions if their output is a waveform, and User measurements if the output is a scalar number, such as a figure of merit. User Defined Measurements and Functions allow the end user to extend the capabilities of FlexDCA to accommodate emerging



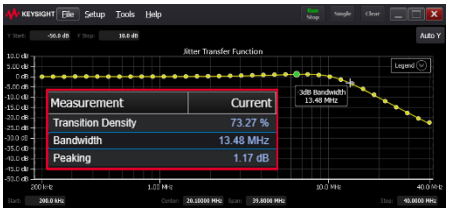
Waveform Transformations

Waveform transformations embed or de-embed channels into/from oscilloscope measurements. Common use cases include “what will the signal look like before or after it passed through a channel (assuming the measurement is made on the other side).” Embedding/de-embedding uses 2-port and 4-port S-parameter files or more complex networks that a user can setup within FlexDCA.



FlexPLL Phase-Locked Loop (PLL) Analysis

FlexPLL performs fast and accurate PLL bandwidth and peaking measurements using a stimulus-response system. FlexPLL manages calibration of a Keysight jitter source and jitter receiver, and measures the jitter transfer function (JTF) on a wide-variety of phase-locked loop designs, including those used in PCI Express designs. This feature is enabled with the N1010300A Signal Integrity SW Package.



FlexRT Optical TX test using a UXR-Series real-time oscilloscope + External O/E

Leveraging FlexDCA’s proven measurement algorithms, FlexRT performs fast and accurate optical TX measurements using a UXR-Series real-time oscilloscope and an external optical-to-electrical converter (O/E) such as the N7004A/N7005A. Quickly and accurately measure key optical TX parameters such as TDECQ, Optical Modulation Amplitude (OMA), Extinction Ratio (ER), Optical Power and much more. This FlexDCA feature is enabled by the N1010100A R&D SW Package or N1010200A MFG SW Package.

N1010x00A Analysis Packages

R&D package

The N1010100A R&D Package is intended for R&D engineers who want to improve their design. Its primary purpose is to gain more insights into why a signal deviates from the expected performance. It also provides the measurements often needed in design verification to ensure that a signal meets the requirements of standards common to the digital communication industry.

Manufacturing package

The N1010200A MFG package focuses on cost of test in optical transmitter manufacturing applications.

- FlexEye is an independent eye acquisition and analysis feature that operates DCA channels as independent single-channel instruments to maximize the throughout and provide more flexibility for your manufacturing design.
- Limits on measurement uncertainty ensure only the minimum amount of data is taken to decide on pass/fail.
- Measurements needed in optical transceiver manufacturing (e.g., TDECQ).

Signal integrity package

The N1010300A SI package adds powerful tools like Automatic Fixture Removal to measure impedances, transfer characteristics, and S-parameter calculations to the basic TDR/TDT measurements.

Licenses types

Packages and DCA applications (see page 23) are licensed in a variety of ways:

License types	Description
Node-locked license	License may be used on one specified instrument/computer
Transportable license	License may be used on one instrument/computer at a time but may be transferred to another using Keysight's online tools (Keysight Software Manager).
USB portable license	License on a USB dongle may be used on one instrument/computer at a time but can be transferred to another by moving the USB dongle.
Floating license	This type of license is locked to a license server, a host PC that manage pools of licenses. This enables geographically-distributed users to share licenses across a common network.

License terms	Description
Perpetual	This term of license usage allows you to use the product indefinitely. Perpetual licenses include software updates and support for the first year. Support may be renewed annually for a fee after that.
Subscription	This term of license usage allows you to use the product for a specific limited time. Subscription licenses include software updates and support through the term of the license.

Software Support Subscription

Perpetual licenses include software updates and support for the first 12 months. After that, support may be renewed annually for a fee. Subscription licenses include software updates and support through the term of the license. When the subscription licenses expire their features will no longer work.

When the subscription of a perpetual license expires all its features will be “frozen”: they are available as of the last download, but you can’t get updates newer than the expiration date.

Annual renewals of subscriptions provide major benefits:

- Access to new measurements. In the past you had to purchase additional licenses when Keysight added more capabilities to incorporate the latest emerging standards. Now Keysight adds new features to existing packages which you can get with a simple download of FlexDCA.
- Access to improved measurements. Measurement science is continuously evolving, and data from real devices help Keysight to further fine-tune algorithms in subsequent releases of FlexDCA.
- Depending on a company’s accounting policies and applicable laws, renewal fees for analysis packages could be operational expenditures (OPEX) instead of capital expenditures (CAPEX).

Checking what licenses are installed

Click on Tools, Licenses to get a list of all licenses available for the version of FlexDCA currently running. Checkmarks indicate which licenses are installed. In addition, the Licensed Features tab shows what features each license enables (Figure 14).

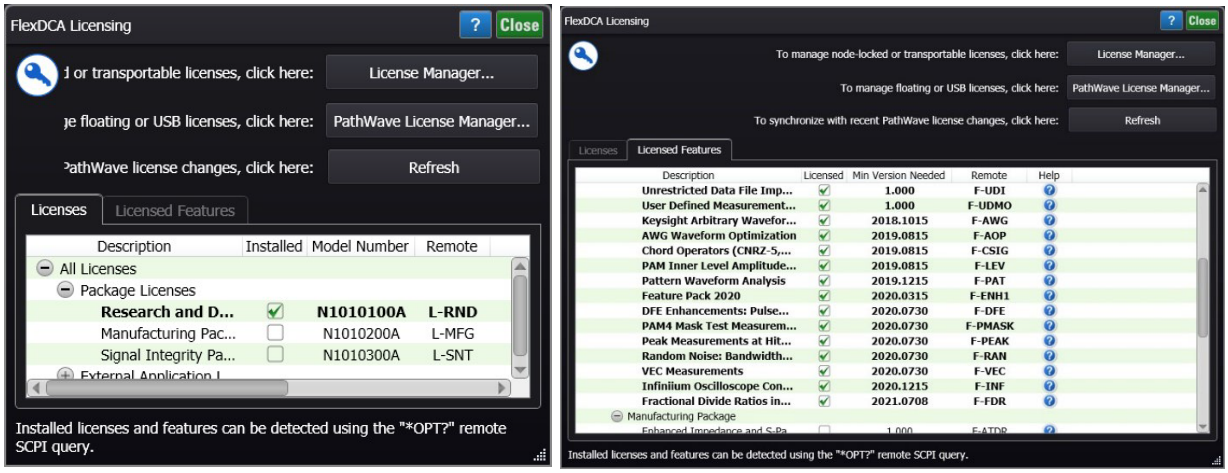


Figure 14. The Licenses tab (left) displays what licenses are available and/or installed, the Licensed Features tab (right) shows the features enabled by each license and the minimum version renewal date for KeysightCare (https://www.keysight.com/find/keysightcare).

Mapping of Licenses

The following table shows how features of legacy options map into the FlexDCA software packages:

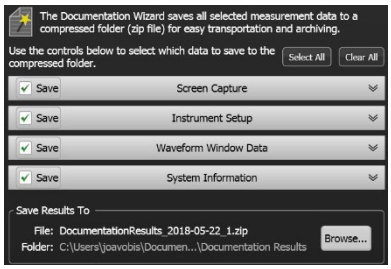
Feature description	Legacy option	N1010100A (RND)	N1010200A (MFG)	N1010300A (SI)
Advanced Amplitude Analysis/RIN/Q-Factor	300	X		
Advanced Eye Analysis	401	X		
Automatic Fixture Removal in TDR Mode	BFP			X
Enhanced Impedance and S-Parameters	202		X	X
Enhanced Jitter Analysis	200	X		
Equalizers (CTLE, DFE, LFE)	201	X		
Access to Licenses on Remote DCA	DCA	X	X	X
Independent Eye Acquisition and Analysis (FlexEye)	EFP	X	X	
PAM-N Analysis (Basic: includes TDECQ, EW/EH, Linearity: excludes 802.3cu measurements)	9FP	X	X	
Send Data to Analytics Web Service	-	X	X	X
TDEC Transmitter and Dispersion Eye Closure for NRZ	500	X	X	
TDECQ Measurement and Equalizer, OOMA, OER, Ceq, noise margin	TFP	X	X	
Partial TDECQ, Noise Margin, and SER Measurements	TFP/9FP	X		
Unrestricted Data File Import	-	X		
User Defined Measurements and Operators	201	X		X
Waveform Transformations (embedding/de-embedding)	SIM	X		
AWG Waveform Optimization	-	X		
Keysight Arbitrary Waveform Generator Control	-	X		
Chord Operators (CNRZ-5-EE, ENRZ)	-	X		
Overshoot, Undershoot and Peak-to-Peak Amplitude (802.3cu)	-	X	X	
PAM4 Mask Test Measurements (OpenEye MSA)	-	X	X	
IEEE 802.3ck 53 GBd PAM4 Electrical test (CTLE, DFE, VEC in jitter mode)	-	X		
FlexPLL Phase-Locked Loop (PLL) Analysis	-			X
FlexRT – Basic (includes optical TX measurements such as TDECQ, OOMA, OER, Power)	-	X	X	
FlexRT – Advanced (basic and advance optical measurements, remote connection from PC to RT scope)	-	X		

Productivity & Usability

FlexDCA incorporates many elements specifically designed to increase its usability and the productivity of R&D and design verification engineers, as well as accelerate throughput on manufacturing lines.

Documentation wizard

Almost everyone needs to document his or her work at some point in time. With a simple click, the Documentation Wizard saves all data, graphics and setups into a single, compressed file. Users concerned about confidentiality can unselect items that they don't want to be included.

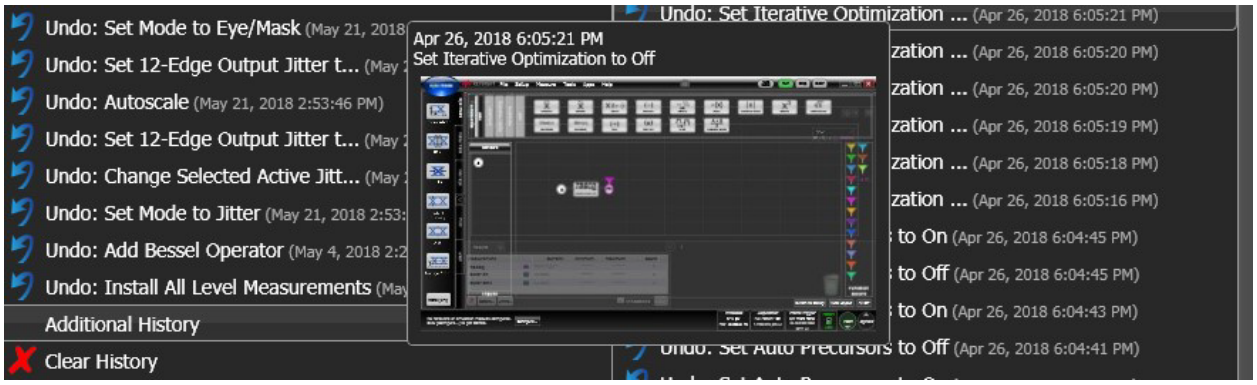


Copy to clipboard

Need something quick for your report? Right-click on any graphics or measurement results window, and an icon appears to copy that item to the clipboard.

Undo/Redo/History

FlexDCA saves a long history of user actions, enabling the user to undo the most recent action or go back to a setup used days or even weeks ago.



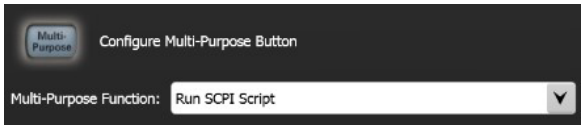
SCPI Recorder/Tools

Software engineers writing remote control programs used to read heavy Programmer's Guides. While such documentation is always available in the online help, a much faster and easier way is to simply record what an operator is doing manually and save the resulting command sequences as a text file. These *.SCPI files can be opened with any text editor.

The Interactive SCPI Tree then provides the detailed information behind each command. A programmer can even run a command or query to try out what will happen. In addition, the blue question mark icon provides a direct link to the detailed documentation for this item

Multi-Function Button

A multi-purpose button on the mainframe's front panel (or on the virtual front panel when FlexDCA is running on a PC/laptop) can be assigned to load a measurement setup, make a screen capture, run the documentation wizard, or run a SCPI script. The latter basically is equivalent to running a macro, hence saving the need to write a remote control interface for simple and repetitive tasks.

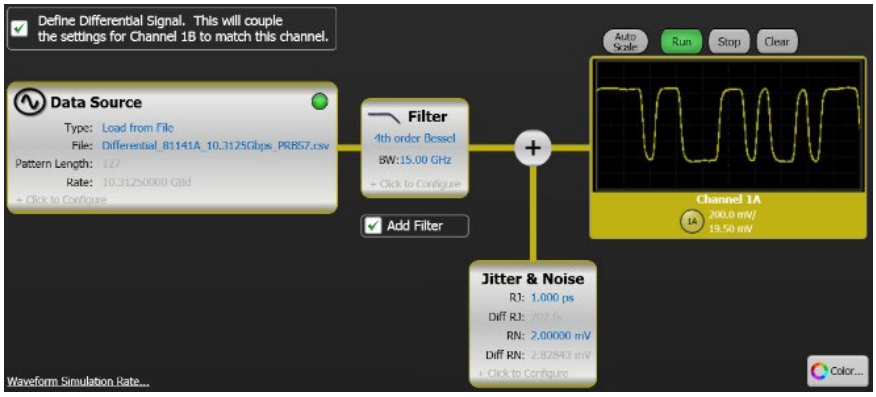


Built-In Simulator

In addition to acquiring data from hardware, FlexDCA can also simulate a variety of signals, such as PRBS sequences (NRZ or PAM4 encoded), sine/square waves, or load waveform files provided by the user. It includes a flexible low-pass filter as well as jitter and noise injection in order to mimic the limited bandwidth of a physical signal source.

Common uses of the built-in simulator include:

- Education/training
- Writing remote programs (when no HW is available)
- Comparing simulated waveforms (design goals) with acquired waveforms (actual DUTs)
- Replay waveforms saved earlier or on another instrument.



Import & Replay Waveforms

The built-in simulator can be used to replay recorded waveforms, even if recorded on another instrument. This allows you to look at a signal as if it was currently measured (particularly if the random noise and the random jitter in the original measurement is known). You can apply all analysis capabilities to the replaying waveform (e.g., jitter and interference decomposition, eye mask testing, PAM4, limit lines, etc.).

A common use case is “virtual device demonstration”. Engineers in a lab with access to new semiconductors may save its averaged waveform as well as their random noise (mV or µW rms) and jitter (fs rms) values. Their colleagues in marketing/sales can then demonstrate the performance of these semiconductors to potential clients using only a PC/laptop.

Offline S-Parameter Visualization

Whether you want to use S-Parameter files to embed or de-embed a waveform (see page 36) or just see the results of TDR/TDT measurements made earlier, FlexDCA has a viewer to display S-parameters. Simply load any S-parameter file into a S-parameter memory and create the chart you like (Figure 15).

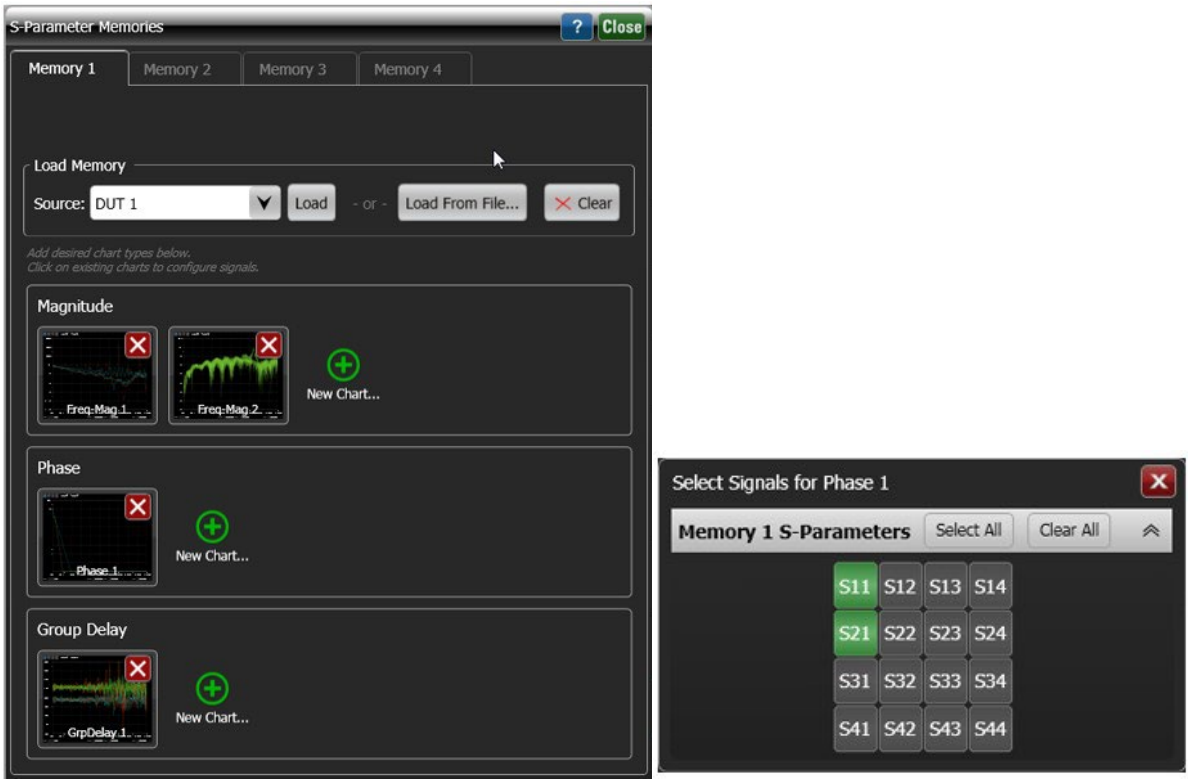


Figure 15. FlexDCA has four S-parameter memories. You can display one or multiple magnitude, phase and group delay graphs.

Send Waveforms To AWG

An Arbitrary Waveform Generator (AWG) is an instrument that can create almost any high-speed electrical signal[3] . In principle it converts a table (amplitude versus time) stored in memory into a single-ended or differential electrical output. Such signals can be used to stimulate devices (such as an electrical receiver or a clock recovery unit) in order to test their behavior under normal and under stress conditions.

If you have a waveform in FlexDCA (acquired or simulated) then FlexDCA can convert and download it to a Keysight AWG, such as the M8194A, M8195A or M8196A. Although the waveform in FlexDCA may have any record length or sampling density that FlexDCA can handle, FlexDCA ensures that the data will fit into the AWG's hardware and software constraints. In addition a feature called Signal Optimization allows users to get the signal they want at the end of the cable that connects to the DUT (as opposed to the AWG output connectors).

Figure 16. AWG signal examples: PAM4, chirps, 16QAM.

3 Within limits, such as the AWG's bandwidth, memory depth, and vertical resolution.

Export to Vector Signal Analysis Software

Keysight's 89600 (VSA) software is a comprehensive set of tools for demodulation and analysis of signals in cellular, wireless connectivity, aerospace, defense and general-purpose applications. The signals can be acquired on many Keysight instruments, including the DCA series of oscilloscopes. FlexDCA offers an export function that formats two waveforms (usually called I and Q waveforms) so that Keysight's VSA software can import and analyze them (Figure 17).

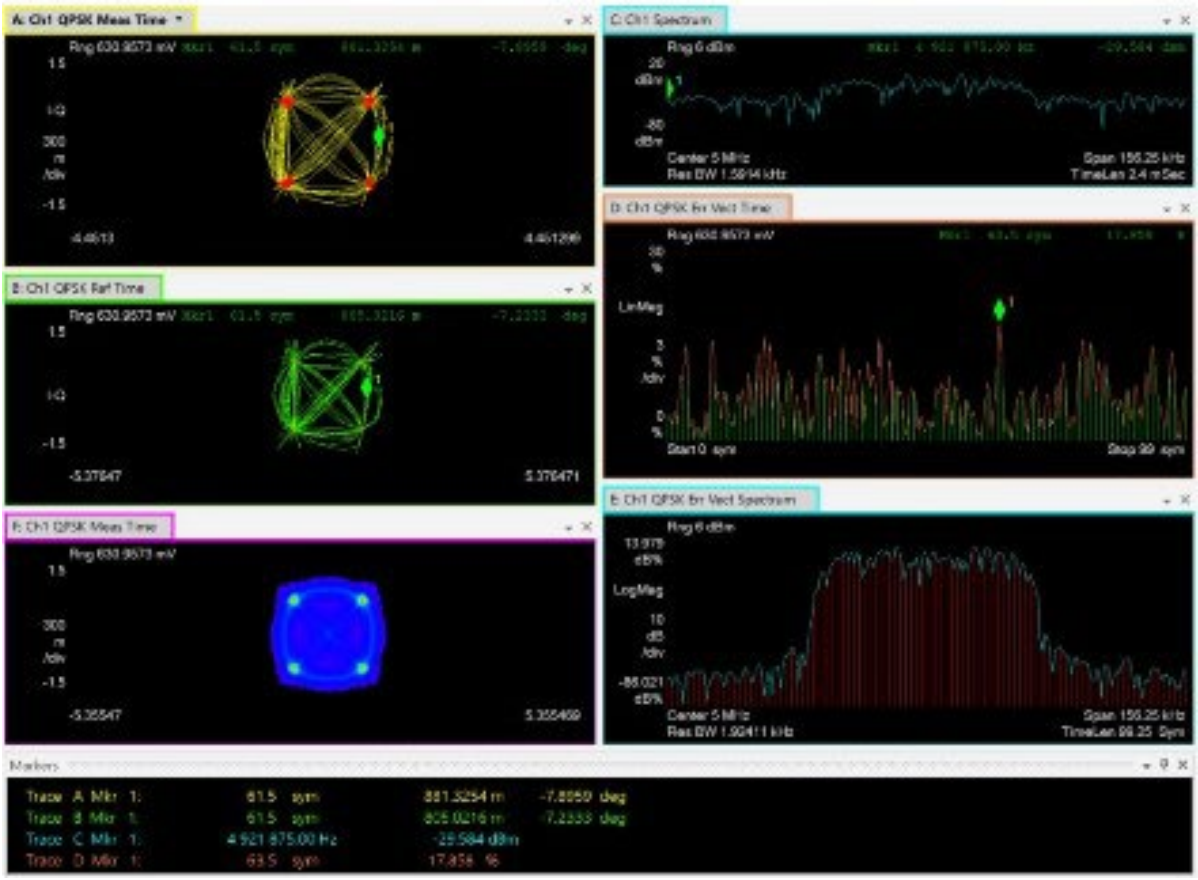


Figure 17. Analyze modulation types ranging from AM/FM/PM to QPSK.

DCA Compliance Applications Overview

DCA Compliance Applications are software products that run on top of FlexDCA. Many of them are specific to particular standards and consequently require particular hardware setups (see their data sheets for details).

The major benefits of Keysight's compliance applications include:

- No need for you to learn and interpret complex standards (Keysight often helped writing them!)
- Easy compliance verification with a detailed pass/fail report
- Debug mode(s) to characterize signals and DUTs beyond what the standard specifies

Application software

SW Application model	SW Application description See the application software datasheet to confirm hardware requirements.
N109228CA	Electrical TX Test SW for OIF-CEI-3.1
N109310CA	Electrical TX Test SW for SFF-8431 (SFP+)
D9010UDAA	User Defined Application Software (for DCA-X and RT Scopes)
N1091APCA	Electrical TX Test SW for IEEE 802.3ap/bj (10G/40G)
N1091BMCA	Electrical TX Test SW for IEEE 802.3bm
N1091BACA	Electrical TX Test SW for IEEE 802.3ba (40G/100G)
N1091BJCA	Electrical TX Test SW for IEEE 802.3bj (100G)
N1091BSCB	Electrical TX Test SW for IEEE 802.3bs/cd
N109256CB	Electrical TX Test SW for OIF-CEI-4.0
N1095BSCA	Optical TX Test SW for IEEE 802.3bs/cd
N1094BS1A	PAM4 Measurement Software Development Kit.
N1091CKCA	Electrical TX test SW for IEEE 802.3ck
N109212CA	Electrical TX Test SW for OIF-CEI-112G

Software development kit for PAM4 transceiver manufacturing

The N1094BS1A PAM4 Measurement SW Development Kit (SDK) is a programming interface that allows maximum utilization of DCA hardware. It separates the TDECQ analysis (see 4.1.12) from the data acquisition, allowing twice as many transceivers to be tested in the same amount of time for a given number of DCAs, or testing the same amount of transceivers in about the same time but with half the number of DCAs (Figure 19).

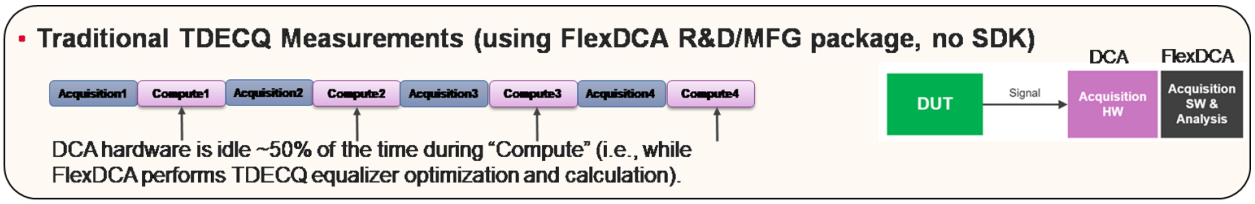


Figure 18. Acquisition and computation take about 9-10 seconds total for typical PAM4 transceivers.

Independent of how many measurement channels FlexDCA is running in Figure 18, only one license is required for making TDECQ measurements. Applicable licenses include the R&D Package, the Manufacturing Package, or the legacy licenses 9FP or TFP (9FP and TFP must be part of the DCA-M).

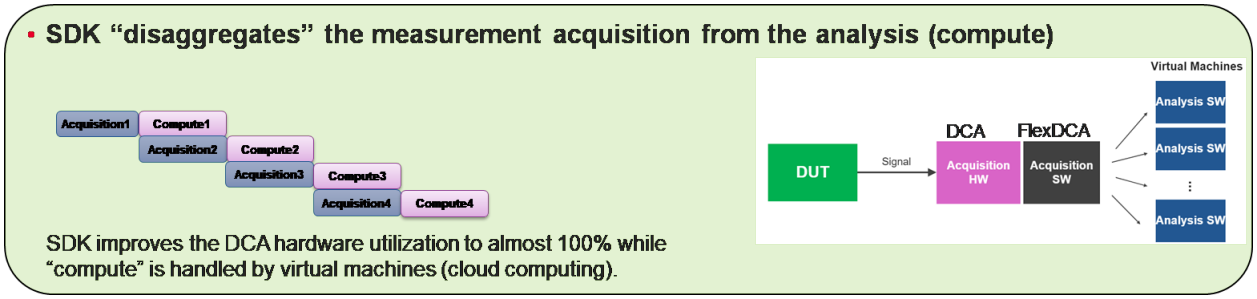


Figure 19. Acquisition and computation occur in parallel and therefore the SDK doubles the throughput

The SDK license eliminates the need for a separate TDECQ license, such as a package or legacy license. Instead a SDK license is needed for each measurement channel (for example, four SDK licenses for four virtual machines in Figure 19 if the acquisition hardware is a four-channel DCA-M like the N1092D).

Specifications and Requirements

The following tables include features and other details. FlexDCA is constantly evolving and the latest revision on Keysight.com may include additional enhancements not listed here.

General specifications

Recommended computer requirements

Minimum configuration:

Setup	1 Channel	4 Channels	8+ Channels
Processor:	≥2 cores	≥2 cores	≥4 cores
Memory	≥4 GBytes	≥8 GBytes	≥16 GBytes
Display	≥1280x1024 pixels ≥64K colors	≥1280x1024 pixels ≥64K colors	≥1280x1024 pixels ≥64K colors
Windows 7/8/10:	32-bit or 64-bit	64-bit	64-bit

Recommended for processing intensive tasks (e.g., TDECQ with equalizer optimization enabled):

Setup	1 Channel	4 Channels	8+ Channels
Processor:	≥2 cores with hyper-threading	≥6 cores with hyper-threading	≥12 cores with hyper-threading
Memory	≥8 GBytes	≥16 GBytes	≥16 GBytes
Display	≥1920x1080 pixels ≥64K colors	≥1920x1080 pixels ≥64K colors	≥1920x1080 pixels ≥64K colors
Windows 7/8/10:	64-bit	64-bit	64-bit
Disk Drive:	Solid State Drive	Solid State Drive	Solid State Drive

General waveform and measurement specifications

Feature	Limitations
Channels / Functions	1 to 64 channels and functions (any combination) Number of channels must be >0, maximum is limited by hardware: 16 in a mainframe, 32 when using DCA-Ms connected via USB or when using simulated modules (see page 9). Functions can have scales independent of the main scale (zoom feature)
Record Length	Without Pattern Lock: 2 to 128K samples/waveform With Pattern Lock[4]: 2 to 256M samples/waveform[5]
Pattern Length	Without Pattern Lock: infinite / live traffic With Pattern Lock & Acquire Whole Waveform: 2^{23}-1 UIs With Pattern Lock & Jitter Mode: 2^{16}-1 UIs
Measurements	Up to 64 measurements. Every measurement can be made on any waveform/function.
Color Grade Gray-Scale Database (CGS)	Vertical resolution: 521 Horizontal resolution: 751
Regions	Up to 8 measurement regions (section of the horizontal scale). Regions can arbitrarily overlap[6].
Markers	Up to 4 tracking markers (crosshair tied to waveforms) Up to 8 line markers (4 horizontal, 4 vertical)
Histograms	Up to 4 histograms. Each histogram can be placed on any side of the graphics window (top, bottom, left, right).
Static Memories[7]	Up to 8 waveforms Up to 4 S-Parameters[8] JSA Memory (see page 32)
Undo/Redo/History	> 500 steps back. History entries include timestamp and thumbnail screen capture.

4 In Pattern Lock samples/waveform = pattern length * samples/UI (1 ≤ samples/UI ≤ 4096)
5 Signal processing, use of multiple channels, and other activities consume memory and consequently reduce the maximum number of Samples/Waveform.
6 Measurements can be applied to either across whole screen/waveform or one region at a time
7 Not including data saved on disk drives
8 S-parameters loaded from Touchstone files (as opposed to those calculated in TDR/TDT mode)

Graphs and results windows

FlexDCA can display multiple signals in the same or multiple windows (see Figure 20 and Figure 21). Users can choose any mode that suits their needs.

Figure 20. Overlapped (left) and Stacked (right) display modes.

Figure 21. Tiled (left) and Zoomed Tiled (right) display modes.

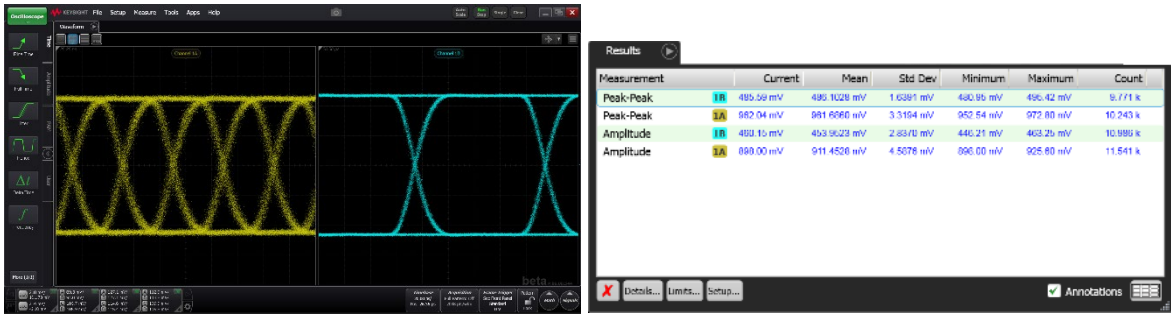


Figure 22. Waveform window (left) on main screen and results window (right) on second monitor.

Signal measurements

Oscilloscope mode

Tab	Measurements
Time	Rise/Fall Times, Jitter RMS/Peak-Peak, Period, Delta Time, Frequency, Pulse Width, Duty Cycle, Time at Min/Max, Time at Edge/Amplitude, Phase
Amplitude	Overshoot, Average Optical Power, Optical Modulation Amplitude (OMA), Peak-Peak/RMS/Average Amplitude, Maximum/Minimum Amplitude, Waveform Top/Base, Preshoot, Amplitude at Time, Amplitude at Upper/Middle/Lower Threshold
PAM	Linearity, Levels Amplitudes, Levels RMS
User	Scalar measurements from external MATLAB® or Python™ scripts calculated on live waveforms

Find Bit, Symbol, or Pattern

Sometimes it is hard for the human eye to find an isolated bit (e.g., “000010000”) or a particular pattern – in particular if there are many thousands or even millions of samples in a waveform. FlexDCA offers a “Find” tool that searches a binary or PAM4 sequence (see Figure 23). It is most effective when combined with Pattern Lock, and the Acquire Entire Waveform feature: then it will find the pattern even if it is off-screen.

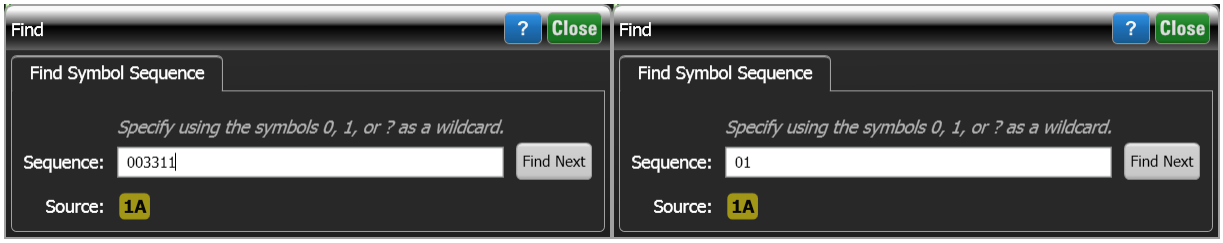


Figure 23. Find a “003311” sequence in a PAM4 signal (left), find a pulse after a long “quiet” period (right).

“Find” can also be used to find the beginning of a narrow pulse or burst signal that has a very long repetition period: searching for “01” or “10” will find the rising or falling edge.

Limit lines

Limit Lines are time- or frequency-domain constraints in oscilloscope or TDR/TDT mode to create pass/fail criteria. They can be used to decide if a device or signal meets its specifications, or to stop the acquisition when either at least one point violates a limit line or all points comply to them. Common uses cases include final quality control in manufacturing, tuning a device (until it passes), or observing drifts (detect when and how characteristics degrade too much).

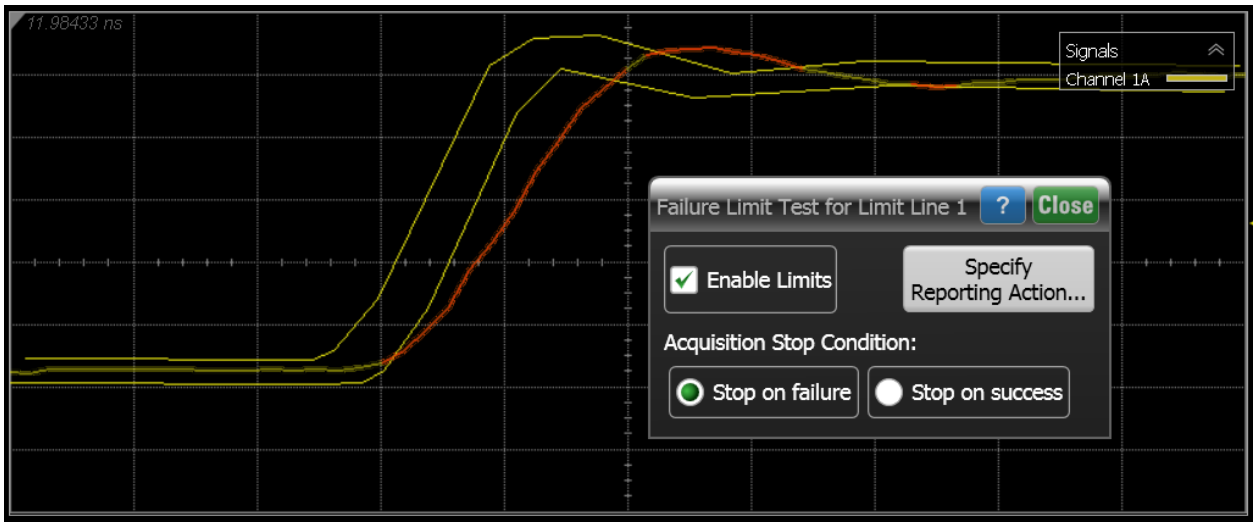


Figure 24. Limit lines provide flexible criteria and can trigger action upon pass or fail (red part of the trace).

Eye/Mask mode

Tab	Measurements
Eye Measurements	Optical Extinction Ratio, Transmitter and Dispersion Eye Closure (TDEC), Jitter RMS/Peak-Peak, Optical Modulation Amplitude at Crossing, Vertical Eye Closure Penalty (VECP), Average Optical Power, Rise/Fall Times, One/Zero Levels, Eye Height/Width, Crossing Time/Percentage, Signal-to-Noise Ratio, Duty Cycle Distortion, Bit Rate, Eye Amplitude, Delta Time, Database Peak Hits
Mask Test	Add (Select) Mask[9], Mask Test Margins, Mask Scaling
Adv. Eye	Eye Contour, Total Jitter, Deterministic Jitter (δ-δ), Random Jitter, Jn (BER associated jitter), Total Interference, Deterministic interference (δ-δ), Random Noise
PAM	Eye Contour, Transmitter and Dispersion Eye Closure for Quaternary Modulation (TDECQ), Ceq Noise Gain, Trans Time, Outer Optical Modulation Amplitude, PAM Overshoot/Undershoot, Outer Extinction Ratio, Linearity, Noise Margin, Peak-to-Peak Amplitude, Tx Power Excursion, Partial Symbol Error Rate (SER), Partial TDECQ, Partial Noise Margin, Levels Amplitudes/RMS/Peak-Peak, Levels Skews, Eye Levels, Eye Skews, Vertical Eye Closure (VEC), Eye Heights/Widths
User	Scalar measurements from external MATLAB® or Python™ scripts calculated on accumulated eye databases

9 FlexDCA includes masks for many telecom and datacom standards. In addition, customers can create a new mask using a text editor. The format of the mask file is documented in FlexDCA's Online Help.

Exporting eye diagrams

Eye/Mask can export the eye diagram to a comma-separated values (CSV) file that can be opened with any text editor or spreadsheet. The table contains the number of hits as a function of time (columns) and amplitude (rows).

Mask margin uncertainty

Mask Margin Uncertainty helps to increase throughput. As the instrument accumulates eye diagram data the uncertainty of the mask margin measurement decreases. To minimize measurement time, it is desirable to acquire only as much data as needed to make a pass/fail decision. Imagine a device whose specification is “20% mask margin”. A brute force approach would be to acquire an eye diagram over a minute or more and then decide the result. A better way for an instrument under remote control is to start with 5% Mask Margin Uncertainty[10] : the instrument will likely stop after only very few seconds. If the result is greater than 25% or less than 15% then the device is clearly good or bad. Only for those devices where the initial result is between 15% and 25% would the test continue until the uncertainty is less than 1% and then make the pass/fail decision. Therefore, the long measurement time is required only for marginal devices.

Jitter and interference mode

Tab	Measurements
Time	Total Jitter (TJ), Deterministic Jitter (DJ), Random Jitter (RJ), Periodic Jitter (PJ), Data Dependent Jitter (DDJ), Inter-Symbol Interference (ISI), Duty Cycle Distortion (DCD), Eye Width Histograms: RJ/PJ, TJ, DDJ, DDJ versus Symbol, Composite TJ, Composite DDJ, SER Bathtub, Aliased Spectrum
Amplitude	Separated by ones and Zeros: Total Interference (TI), Deterministic Interference (DI), Random Noise (RN), periodic Interference (PI), Inter-Symbol Interference (ISI), SER Floor, SER Limit Histograms: RN/PI, TI, ISI, UISI versus Symbol, Composite TI, SER Bathtub, Noise Spectrum
Meas.	12-edge Outer Jitter, Jn (BER associated jitter), Data Dependent Pulse Width Shrinkage, Uncorrelated Jitter, Even/Odd Jitter (F/2 jitter), Relative Intensity Noise (RIN), Uncorrelated Noise, Linearity, Preshoot (PCIe), De-Emphasis (PCIe)

10 Used for illustration purposes. All percentages can be set by the user or remote control software.

Exporting jitter data

Jitter mode allows you to export the results of the jitter analysis to a comma-separated values (CSV) file that can be opened with any text editor or spreadsheet. Key tables include different jitter histograms, such as RJ, PJ, TJ (number of hits versus edge deviation in time).

Pattern decode

The CSV file exported in jitter mode also contains a table showing DDJ and ISI versus symbol. This table shows the symbol count and the symbol value (e.g., 0/1 for NRZ, and 0/1/2/3 for PAM4) which is effectively a digital decoding of the acquired pattern.

Jitter spectrum analysis

Jitter Spectrum Analysis (JSA) is a tool based on data from a hardware clock recovery that displays the jitter spectrum of a clock or data signal (amplitude versus frequency). This provides insights into the source of low frequency jitter. JSA requires additional hardware in a clock recovery unit. Keysight currently offers it in its 86108B, N1060A, N1076B, N1077A, N1078A, and N1077B products.

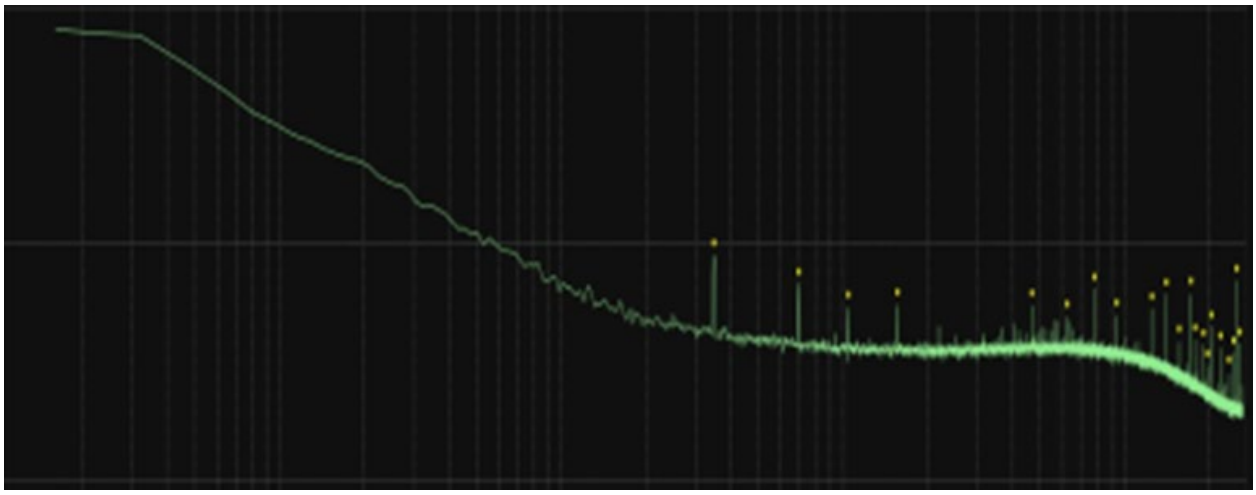


Figure 25. Jitter Spectrum.

Clock recovery emulation

Clock Recovery Emulation (CRE) is a solution to the fact that a “Golden PLL” as required by many standards cannot be built in real hardware[11]. CRE mathematically “de-embeds” the jitter results from a known hardware clock recovery and “embeds” them into a desired first (Golden PLL), second or third order model. Consequently, it is possible to make standards-compliant measurements of random jitter over the desired frequency range of interest.

11 A Golden PLL is defined as a PLL whose transfer function has only a single pole (similar to a RC low-pass). Hardware clock recoveries have at least three poles because their physical components (phase detector, loop amplifier and voltage-controlled oscillator) have finite bandwidth.

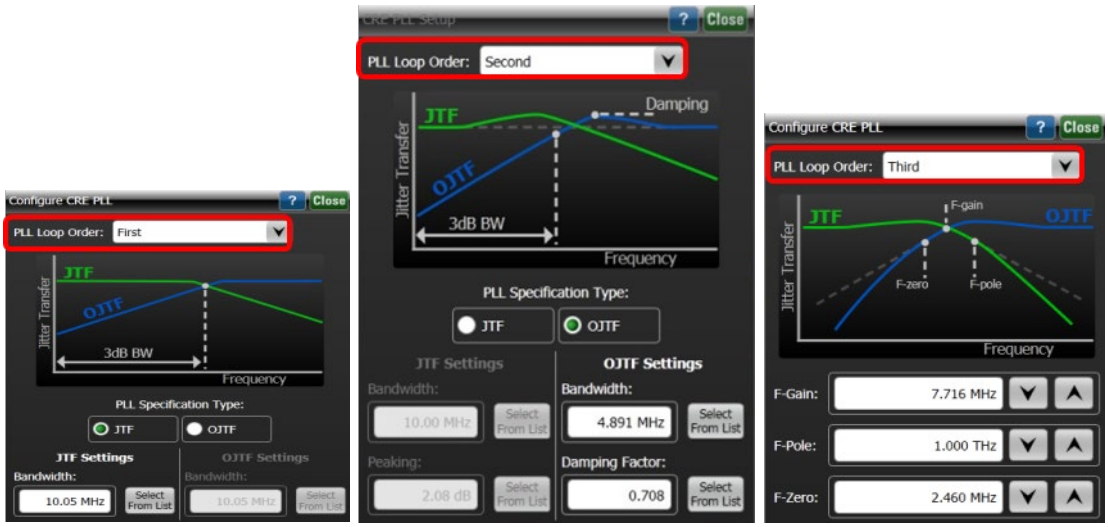


Figure 26. Clock Recovery Emulation based on first, second and third order PLL models (left to right).

TDR/TDT/S-Parameter mode

Tab	Measurements
Setup	1/2/4/8/16 Port Single-ended DUT, 1/2/4/8 Port Differential DUT, Common/Mixed/Differential/True Stimulus, Positive/Negative Step, Step Amplitude, Step Rate, TDR/TDT Calibration, Specify ECal or Calibration Kits, Setup Adapters, Display S-Parameters, Display T-Parameters, Automatic Fixture Removal
Time	Rise/Fall Times, Delta Time, Time at Min/Max, Time at Edge/Amplitude
Amplitude	Average/Maximum/Minimum Amplitude, Amplitude at Time, Excess Capacitance, Excess Inductance
User	Scalar measurements from external MATLAB® or Python™ scripts calculated on live TDR/TDT waveforms

Calibration

TDR/TDT calibration removes the effects of cables, adapters and other items from the measurement results, therefore increasing accuracy and repeatability. The calibration process can take advantage of:

- Electronic Calibration Modules (ECal): an ECal is a device with impedance properties stored in its memory. FlexDCA reads this information, measures the ECal module with the same cables and adapters as with the device under test, and is consequently able to calculate how the setup influences measurements.
- Mechanical Calibration Kit: these are collections of instrument-grade shorts, opens, loads and through adapters. Like with ECal, measuring these devices with the same cables and adapters as with the device under test provides information about the setup that then can be taken into account when measuring devices.

Automatic Fixture Removal (AFR): AFR is an advanced mathematical process that characterizes a fixture before a device is inserted and then removes the effects of the fixture (including the cables to the instrument) while measuring the device. A very powerful tool included with Automatic Fixture Removal (AFR) is One-Port AFR. For some 2-port fixtures, One-Port AFR will calculate the 2-Port S-parameter file after measuring S11 (or SDD11 for differential fixtures) for one port with the other port open and/or shorted. The 2-port fixture can then be de-embedded from the TDR or TDR measurement.

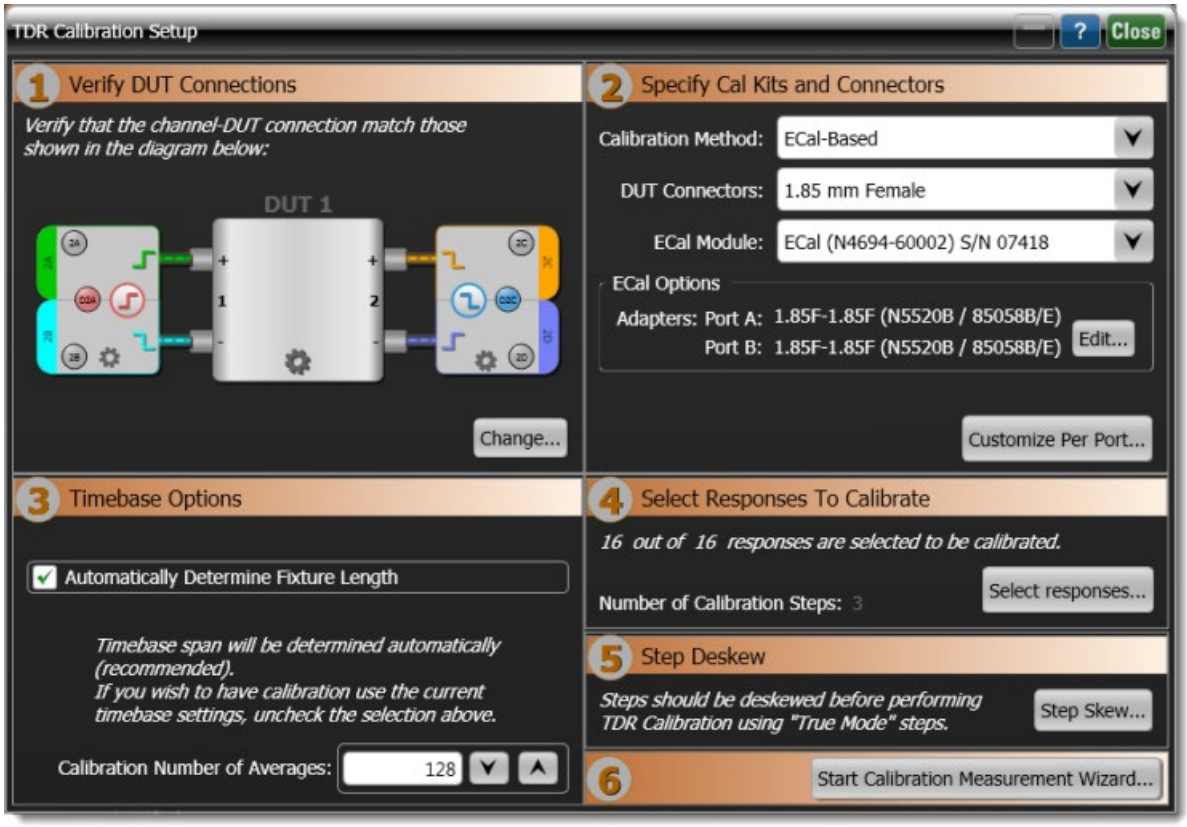


Figure 27. TDR/TDT calibration using an ECal module.

S-Parameters

Scattering parameters (S-parameters) are frequency-domain plots of a device's reflection or transmission characteristic. They are calculated by a Fast Fourier Transformation (FFT) of the TDR/TDT waveforms. FlexDCA can display magnitude, phase, and group delay versus frequency (see Figure 28).

Nomenclature: Sij is the graph observed at port i when stimulated at port j. For example, S11 is the input impedance, S21 the gain and S22 the output impedance of an amplifier. Sijmn is used for differential signals: i and j again are output and input port numbers, m and n indicate the mode (D=differential, C=common). For example, S31CD represents the transfer function between the common mode output observed at port 3 and the differential stimulus at port 1.

T-Parameters

T-parameters are the time-domain equivalent of S-parameters. The indices for single-ended and differential modes are the same as for scattering parameters. For example, T31CD represents the common mode output signal observed at port 3 when the device was stimulated with a differential signal at port 1.

Figure 28. TDR/TDT mode displaying live T-parameters and S-parameters.

Limit lines

TDR mode offers limit line capabilities like Oscilloscope Mode (see page 29 for details). Limit lines can be used for time-domain graphs (like T-parameters) or frequency-domain graphs (like S-parameters). Common use of limit lines in TDR/TDT mode is testing that a device's frequency response (e.g., S21) falls within tolerances allowed by standards.

Limit testing

Acquisition based limits

In manufacturing or other throughput-dominated environments, it is important to avoid wasting time. Acquisition limits are an easy way to take only as much data as needed. FlexDCA can stop acquiring data when a certain number of waveforms are acquired, or a certain number of samples are taken (number of samples = number of waveforms * samples/waveform). Reporting actions include saving the waveform and/or taking a screen capture.

Figure 29. Acquisition limit example: acquire only as many samples as necessary.

Results based limits

It may be unnecessary to complete a longer measurement when it already failed a criterion early on. Or you may want to run a measurement continuously until it eventually fails. Measurement limits allow FlexDCA to stop and take reporting action when:

- A limit line is crossed in Oscilloscope Mode
- A mask is violated in Eye/Mask Mode
- An oscilloscope or eye/mask measurement passes or fails a criterion (see Figure 30)

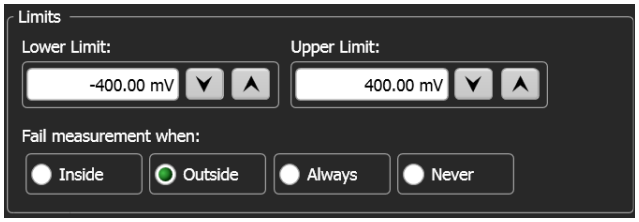


Figure 30. This signal is supposed to stay within ±400 mV.

Waveform signal processing

Tab	Measurements
Math	Add, Subtract, Multiply, Align, Common Mode, Invert, Amplify, Square, Square Root, Delay, Absolute Value, Average, Medium, Minimum, Maximum,
Simulation	Apply/Remove s2p file, Apply/Remove s4p file, Network Embedding/De-Embedding, Add Random Noise/Jitter
Signal Processing	Difference, Summation, Bessel Low-Pass, Butterworth Low-Pass, Gaussian Low-Pass, Sin(x)/x Filter, Interpolation, Continuous Time Linear Equalizer (CTLE), Linear Equalizer, Decision Feedback Equalizer (DFE), TDECQ Filter, TDR Peeling
Transforms	Fast Fourier Transformation (FFT), Channel Versus Channel
User	Waveform (vector function) calculated in external MATLAB® or Python™ scripts on live waveforms, CNRZ5 Decode, ENRZ Decode

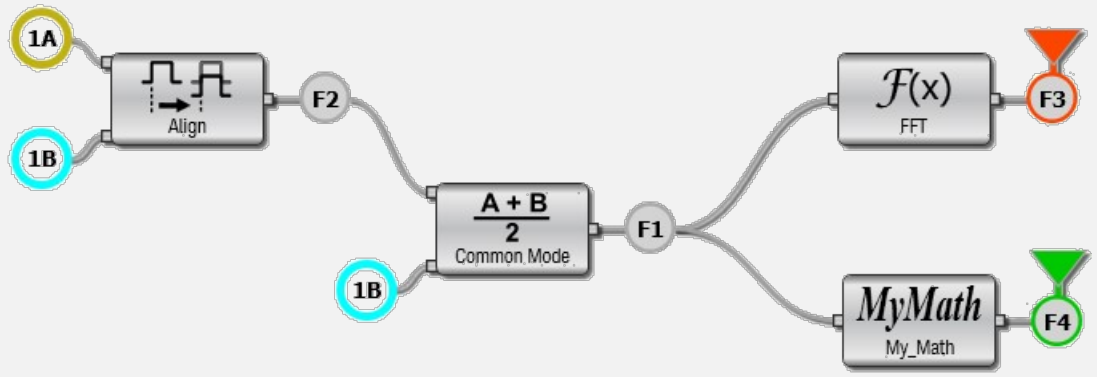


Figure 31. Signal processing example: functions can be cascaded, and live results can be displayed in separate windows (frequency-domain for the FFT and time-domain for the custom math).

Appendix

Online help

FlexDCA includes the complete documentation in its online help. It serves multiple purposes:

- How to get started (including configuration information)
- How to perform specific tasks / measurements / calibrations
- Specifications for all hardware supported by the current FlexDCA revision (current and discontinued model numbers)
- Algorithms used to calculate measurements
- Programmer's Guide
- Programming examples (including Python and MATLAB® interface information)

Remote control

FlexDCA use SCPI commands for remote control. Commands and queries are documented in the online help which also includes sample programs. A common practice to create remote control software often follows this sequence:

1. On a PC/laptop, setup FlexDCA using its built-in simulator to mimic the expected measurement system and signals (see page 20)
2. Turn on the SCPI recorder (see page 19) and make the measurements manually
3. Save the recorded SCPI commands and copy them into the software development system used to create remote control applications
4. Use the Interactive SCPI Tree to understand the details of the commands used, to add queries or other commands, and to dive into the online help for programming details
5. Debug the remote control script as much as possible without having access to an instrument
6. Connect to a DCA-X mainframe (or DCA-M hardware) and perform final debugging using real devices and signals

Module compatibility

FlexDCA is compatible with these products in Standard Mode:

- All N10xxx series of DCA modules
- All N109xx series of DCA-Ms
- All N107xx series of Clock Data Recovery Solutions

Please reference the supported modules table to determine if your modules are directly supported in FlexDCA.

Trial versions

Keysight offers free trials for many of its licensed software products. The trial period starts when the license gets installed and usually expires 30 days later. Go to www.keysight.com/find/flexdca_pro or contact your local representative for details. Trial licenses require the user to provide a host ID which can be found on any DCA-X (or after installing FlexDCA on a PC/laptop) in the Keysight License Manager (KLM). The KLM is a small application that comes with many Keysight instruments or software products like FlexDCA.

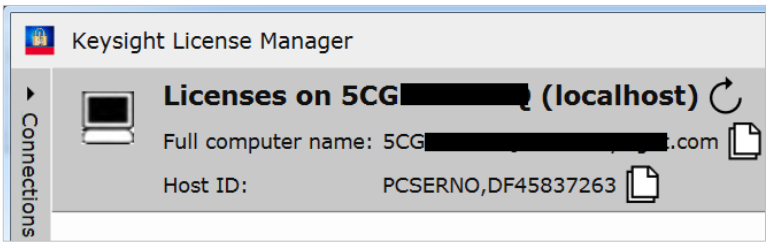


Figure 32. To request trial licenses from Keysight's web site simply click on the copy icon and then paste the Host ID into your web browser (in this example the Host ID is "PCSERNO,DF45837263").

References

Web resources

Generic: www.keysight.com/find/<product number> for any product number mentioned here

- Keysight Digital Communication Analyzer (DCA) Solutions: www.keysight.com/find/dca
- DCA-X Family: www.keysight.com/find/dca-x
- DCA-M Family: www.keysight.com/find/dca-m
- Clock Recovery Solutions: www.keysight.com/find/cdr
- FlexDCA (main page): www.keysight.com/find/flexdca_pro
- FlexDCA (download page): www.keysight.com/find/flexdca_download

Literature references

Generic literature link: literature.cdn.keysight.com/litweb/pdf/<literature number>.pdf

Description	Publication number
DCA Family - Brochure	5992-3301EN
DCA Wide-Bandwidth Oscilloscope Family - Configuration Guide	5992-3372EN
N1000A DCA-X Mainframe and Modules - Data Sheet	5992-3271EN
N1092A/B/C/D/E DCA-M - Data Sheet	5992-3886EN
N1094A/B DCA-M - Data Sheet	5992-3700EN
N1090A DCA-M - Data Sheet	5992-3655EN
Keysight DCA Family Clock Data Recovery Solutions - Data Sheet	5992-1620EN
DCA Accessories – Technical Overview	5991-2340EN

Learn more at: www.keysight.com

For more information on Keysight Technologies' products, applications or services, please contact your local Keysight office. The complete list is available at: www.keysight.com/find/contactus

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