DDR Analysis

Online Help

077-0231-00

Tektronix

DDR Analysis
Online Help

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- In North America, call 1-800-833-9200.
- Worldwide, visit www.tektronix.com to find contacts in your area.

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General Safety Summary

Review the following safety precautions to avoid injury and prevent damage to this product or any products connected to it.

To avoid potential hazards, use this product only as specified.

Only qualified personnel should perform service procedures.

While using this product, you may need to access other parts of a larger system. Read the safety sections of the other component manuals for warnings and cautions related to operating the system.

To Avoid Fire or Personal Injury

Use Proper Power Cord. Use only the power cord specified for this product and certified for the country of use.

Connect and Disconnect Properly. Do not connect or disconnect probes or test leads while they are connected to a voltage source.

Connect and Disconnect Properly. Connect the probe output to the measurement instrument before connecting the probe to the circuit under test. Connect the probe reference lead to the circuit under test before connecting the probe input. Disconnect the probe input and the probe reference lead from the circuit under test before disconnecting the probe from the measurement instrument.

Observe All Terminal Ratings. To avoid fire or shock hazard, observe all ratings and markings on the product. Consult the product manual for further ratings information before making connections to the product.

Do Not Operate Without Covers. Do not operate this product with covers or panels removed.

Do Not Operate With Suspected Failures. If you suspect that there is damage to this product, have it inspected by qualified service personnel.

Avoid Exposed Circuitry. Do not touch exposed connections and components when power is present.

Terms in this Manual

These terms may appear in this manual:

WARNING. *Warning statements identify conditions or practices that could result in injury or loss of life.*

CAUTION. *Caution statements identify conditions or practices that could result in damage to this product or other property.*

Welcome

DDR (Dual Data Rate) is a dominant and a fast growing memory technology. It offers the high data transfer rates needed for virtually all computing applications, from consumer products to the most powerful servers. The high speeds of these signals require high performance measurement tools.

The DDRA application includes compliance measurements as part of our DDR Analysis solution. The DDR Analysis solution enables you to achieve new levels of productivity, efficiency, and measurement reliability. It requires the Jitter and Eye Diagram Analysis tool (Opt. DJA) and the Advanced Search and Mark capability (Opt. ASM).

Some of the DDRA features are:

- Provides debug, analysis, and compliance into one solution for multiple DDR standards such as DDR, DDR2, DDR3, LPDDR and GDDR3
- Enables analysis of compliance measurements either through the DDRA or DPOJET application for all bursts in an acquisition
- Differentiates data reads from writes, or analyzes signal integrity on the clock or on a data (DQ) line during Read or Write cycles, or measures Data to Strobe setup and hold during Write cycles
- Includes limit files to test measurement pass/fail status per the selected standard
- Includes comprehensive measurement statistics
- Includes sophisticated graphical analysis tools such as Histograms, Time Trends, Spectrums, Bathtub Plots, and Real-Time Eye® diagrams with superimposition of the strobe eye with the data eye
- Produces consolidated HTML reports automatically with pass/fail information, statistical measurement results, setup information and plots

DDR

DDR is the DRAM (Dynamic Random Access Memory) technology responsible for increasing data transfer rates to meet high-speed requirements and data capacity of computer systems.

DDR2

DDR2 is the Double Data Rate 2 SDRAM and is widely available in products with data rates up to 800 MT/s.

DDR3

DDR3 DRAM memory is widely available in products and extends data rates to 1600 MT/s and faster rates to come.

Low Power DDR

LPDDR (Low Power DDR) is an emerging technology for mobile phones and portable computing devices, driven by the need for faster operation with long battery life.

Graphic DDR3

GDDR3 (Graphic DDR) offers faster access and is used in graphics-intensive applications such as video cards and gaming systems.

Related Documentation

Tektronix manuals are available at: www.tektronix.com/manuals and www.tektronix.com/software. Use the following table to determine the document that you need:

Table 1: List of reference documents

For information on	Refer to
■ Operating the Oscilloscope	Oscilloscope user manual. Oscilloscope user online help.
■ Software warranty ■ List of available applications ■ Compatible oscilloscopes ■ Relevant software and firmware version numbers ■ Applying a new option key label ■ Installing an application ■ Enabling an application ■ Downloading updates from the Tektronix Web site	*Optional Applications Software on Windows-Based Oscilloscopes Installation Manual*, which is provided on the Optional Applications Software on Windows-Based Oscilloscopes DVD, in the Documents directory.

Conventions

Online Help uses the following conventions:

- When steps require sequence of selections using the application interface, the ">" delimiter marks each transition between a menu and an option. For example, **Analyze > DDR Analysis.**

- The terms “DDR application” and “application” refer to DDRA.
- The term “DPOJET application or “DPOJET” refers to Jitter and Eye Diagram Analysis Tool.
- The term “oscilloscope” refers to any product on which this application runs.
- The term “DUT” is an abbreviation for Device Under Test.
- The term “select” is a generic term that applies to the methods of choosing an option: with a mouse or with the touch screen.
- User interface screen graphics are taken from a DPO7000 series oscilloscope.

You can find a PDF (portable document format) file for this document in the Documents directory on the *Optional Applications Software on Windows-Based Oscilloscopes DVD*. The DVD booklet contains information on installing the application from the DVD and on how to apply a new label. You can also find the PDF and the Online Help at **Start > Programs >TekApplications > DDRA**.

Table 2: Icon descriptions

Icon	Meaning
	This icon identifies important information.
	This icon identifies conditions or practices that could result in loss of data.
	This icon identifies additional information that will help you use the application more efficiently.

Technical Support

Tektronix welcomes your comments about products and services. Contact Tektronix through mail, telephone, or the Web site. Click Contacting Tektronix for more information. Tektronix also welcomes your feedback. Click Customer feedback for suggestions for providing feedback to Tektronix.

Customer Feedback

Tektronix values your feedback on our products. To help us serve you better, please send us your suggestions, ideas, or other comments you may have regarding the application or oscilloscope.

Direct your feedback via e-mail to

techsupport@tektronix.com

Or FAX at (503) 627-5695, and include the following information:

General Information

- Oscilloscope model number (for example: DPO7000 or DSA/DPO70000 series) and hardware options, if any.
- Software version number.
- Probes used.

Application-specific Information

- Description of the problem such that technical support can duplicate the problem.
- If possible, save the oscilloscope and application setup files as `.set` and associated `.xml` files.
- If possible, save the waveform on which you are performing the measurement as a `.wfm` file.

Once you have gathered this information, you can contact technical support by phone or through e-mail. In the subject field, please indicate "DDRA Problem" and attach the `.set`, `.xml` and `.wfm` files to your e-mail. If there is any query related to the actual measurement results, then you can generate a `.mht` report and send it.

The following items are important, but optional:

- Your name
- Your company
- Your mailing address
- Your phone number
- Your FAX number

Enter your suggestion. Please be as specific as possible.

Please indicate if you would like to be contacted by Tektronix regarding your suggestion or comments.

Product Description

DDR Analysis is a standard specific solution tool for Tektronix Performance Digital Oscilloscopes (DPO7000 and DSA/DPO70000 series). DDR Analysis requires Jitter and Eye Diagram Analysis Tool (Opt.DJA) and the advanced Search and Mark capability (Opt. ASM).

The features of DDRA are:

- Provides debug, analysis, and compliance into one solution for multiple DDR standards such as DDR, DDR2, DDR3, LPDDR, and GDDR3
- Supports multiple standards such as DDR, DDR2, DDR3, LPDDR and GDDR3
- Identifies Read and/or Write operations automatically
- Custom data rates and input levels to tailor DDRA Read and/or Write burst identification
- Analyze compliance measurements either through DDRA or Jitter and Eye Diagram Analysis Tool
- Limit files to test measurement pass/fail status

DDRA Option Levels

To use DDRA application, you need to have Opt. ASM (Advanced Search and Mark Tool) and DPOJET Advanced (Opt. DJA) enabled.

Requirements and Restrictions

Microsoft .NET Framework version 2.0 or higher, and MATLAB Component Runtime 7.5 are required to operate DDRA on your oscilloscope. These are included in the distribution and automatically installed with DDRA, if not already present.

Supported Probes

The application supports the following probes:

- TAP2500
- TAP1500
- TCP0030
- P6158

- P6101B
- P6246
- P6247 (DPO7254 only)
- P6248 (DPO7254 only)
- P6249
- P6150
- P6158
- P7240
- P7260
- P7330
- P7340A
- P7350
- P7360A
- P7380A
- P7313A
- P7513
- P7500 Series TriMode

Installing the Application

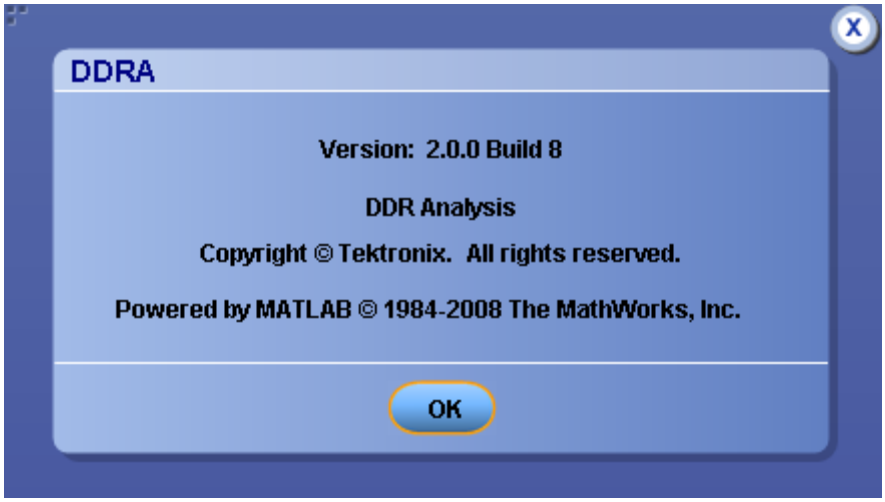
Refer to the *Optional Applications Software on Windows-Based Oscilloscopes Installation Manual* for the following information:

- Software warranty.
- List of available applications, compatible oscilloscopes, and relevant software and firmware version numbers.
- Applying a new option installation key label.
- Installing an application.
- Enabling an application.
- Downloading updates from the Tektronix Web site.

You can find a PDF (portable document format) file for this document in the Documents directory on the *Optional Applications Software on Windows-Based Oscilloscopes DVD*. The DVD booklet contains information on how to install the application from the DVD and on how to apply a new option installation key label.

About DDRA

Click **Help > About DDRA** to view application details such as the software released version number, application name and copyright.



Starting the Application

On the oscilloscope menu bar, click **Analyze > DDR Analysis** to open the application.

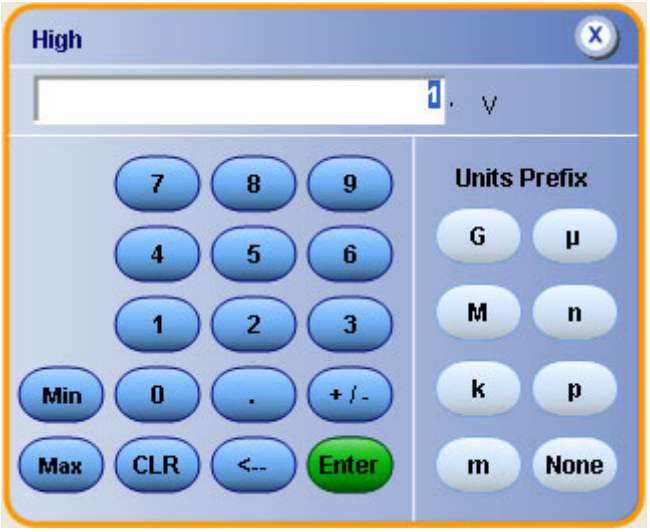
Menu Controls

Table 3: Application Menu Controls descriptions

Item	Description
Tab	Shortcut to a menu in the menu bar or a category of menu options; most tabs are short cuts.
Area	Visual frame with a set of related options.
Option button	Button that defines a particular command or task.
Field	Box that you can use to type in text, or to enter a value with the Keypad or a Multipurpose knob.
Check Boxes	Use to select configuration options or clear preferences.
Browse	Displays a window where you can look through a list of directories and files.
Command button	Button that initiates an immediate action such as Run command button  in the control panel.
Virtual Keypad icon 	Click to use on-screen keypad to enter alphanumeric values.
MP knob references (a or b)  	Identifiers that show which Multi Purpose Knob (MPK) may be used as an alternate means to control a parameter; turn the knob on the oscilloscope front panel to adjust the corresponding parameter. Also, the value can be entered directly on the MPK display component.

Virtual Keypad

Select the  icon and use the virtual keypad to enter alphanumeric values, such as reference voltage levels.



Tips on the DDRA User Interface

Here are some tips to help you with the application user interface:

- Use the Single button to obtain a set of measurements from a single new waveform acquisition. Pushing the button again before processing has completed will interrupt the processing cycle.
- Use the Run button to continuously acquire and accumulate measurements. If prior measurements have been acquired and have not been cleared, the new measurement are added to the existing set. Push the button again to interrupt the current acquisition.
- Use the Recalc button to perform measurements on the waveform currently displayed on the oscilloscope without performing a new acquisition. This is useful if you wish to modify a configuration parameter and re-run the measurements on the current waveform.
- Use the Clear button to clear all existing measurement results. Note that adding or deleting a measurement, or changing a configuration parameter of an existing measurement, will also cause measurements to be cleared. This is to prevent the accumulation of measurement statistics or sets of statistics that are not coherent.

Application Directories

The installation directory for DDRA executables is `C:\Program Files\TekApplications\DDRA` and the installation directory for user files is `C:\TekApplications\DDRA`. During installation, the

application sets up a limits folder in the user directory. This folder contains limit files for various DDR standards and speed grades.

File Name Extensions

Table 4: File name extensions

File Extension	Description
.csv	An ascii file containing Comma Separated Values. This file format may be read by any ascii text editor (such as Notepad) or may be imported into spreadsheets such as Excel.
.xml	An ascii file containing measurement setup information, limits or other data in Extensible Markup Language.
.set	A binary file containing oscilloscope setup information in a proprietary format.
.mht	An HTML archive file, compatible with common Windows applications; contains the full report, including text and graphics.
.wfm	A binary file containing an oscilloscope waveform record in a recallable, proprietary format.

Returning to the Application

When you access oscilloscope functions, the DDRA control windows may be replaced by the oscilloscope control windows or by the oscilloscope graticule. You can access oscilloscope functions in the following ways:

- From the menu bar on the oscilloscope, choose **Analyze > DDR Analysis**.
- Alternatively, you can switch between recently used control panels using the forward or backward arrows on the right corner of the control panel.

Control Panel

The Control Panel appears on the right of the application window. Using this panel, you can start or stop the sequence of processes for the application and the oscilloscope to acquire information from the waveform. The controls are Clear, Recalc, Single, and Run. The following table describes each of these controls:

Item	Description
Clear	Clears the current result display and resets any statistical results and autoset ref levels. For any input sources that have reference level autoset enabled, clears the current ref levels so that they will be recalculated during the next acquisition.
Recalc	Runs the selected measurements on the currently displayed waveform(s), without first performing a new acquisition.
Single	Initiates a single new acquisition and runs the selected measurements.
Run	Initiates new acquisitions and runs the selected measurements repeatedly until Stop is clicked. For any non-live sources (Reference waveforms or Math waveforms not dependent on a live channel), only a single processing cycle will occur.
Show Plots	Displays the plot summary window when clicked. This button appears in the control panel only when one or more plots have been defined.
Advanced Setup DPOJET 	Transitions to the Jitter and Eye Diagram Analysis application when clicked, importing all currently defined DDRA measurements. This button appears in the control panel when you open the DDR analysis application. This is useful if you wish to add additional measurements not defined in DDRA, or wish to change measurement configurations to intentionally deviate from those recommended by DDRA.

Saving a Setup

The DDRA application state is automatically saved along with the oscilloscope state. To save the oscilloscope settings and the application state, follow these steps:

1. Click **File > Save As > Setup**.
2. In the file browser, select the directory to save the setup file.
3. Select or enter a file name. The application appends `*_DDRA.xml` and `*_DPOJET.xml` to store the DDR setup, and *.set to store the oscilloscope settings.
4. Click **Save**.

NOTE. *After the oscilloscope application is started, DDRA needs to be launched at least once before any saved DDRA configuration can be recalled.*

Recalling a Saved Setup

To recall a previously saved set of application and oscilloscope settings, do the following steps:

1. Click **File > Recall..**.
2. Click **Setup** in the left column if it is not already selected.
3. Select the directory in the file browser from which you wish to recall the setup file.
4. Select a .set file and click **Recall**.

NOTE. *Only .set files can be selected for recall; any corresponding *_DDRA.xml and *_DPOJET.xml file in the same directory will be recalled as well, if DDRA has been launched at least once since the oscilloscope application was started. If DDRA has not been launched at least once, the oscilloscope settings will be recalled but the DDRA configuration will be ignored.*

Recalling the Default Setup

To recall the default application and oscilloscope settings, click **File > Recall Default Setup**.

NOTE. *Recalling default setup sets the DDRA application to DDR3 generation and data rate, None.*

Limits

A limits file allows you to configure the limits used to determine Pass or Fail status for tests. Each limits file includes a list of one or more measurements, and the ranges of acceptable values for any or all statistics for each measurement that include combinations of all measurements and statistical characteristics, and an appropriate range of values for each combination.

The application provides preconfigured limits files for many combinations of standards and speed grades. You can create one by specifying limits for any of the result parameters such as Mean, Std Dev, Max, Min, peak-to-peak, population, MaxPosDelta and MinPosDelta. For each of these result parameters, you can specify the Upper Limit Equality (ULE), Lower Limit Equality (LLE), or Both. The measurement names in the limits file must be entered as mentioned in About DDR Analysis.

To include Pass/Fail status in the result statistics, you can create a custom limits file in the following format using an XML editor or any other editor. If the file is created in any other editor such as Notepad, it should be saved in Unicode format.

The following is a sample of the limit file for DDR2 generation, the data rate being 667 MHz

```
<?xml version="1.0" encoding="utf-16" ?>
<Main>
<Measurement>
<NAME>DDR Hold-Diff</NAME>
<STATS>
<STATS_NAME>Min</STATS_NAME>
<LIMIT>BOTH</LIMIT>
<ULE>175e-12</ULE>
<LLE>0</LLE>
</STATS>
</Measurement>
<Measurement>
<NAME>tDH-Diff(base)</NAME>
<STATS>
<STATS_NAME>Min</STATS_NAME>
<LIMIT>BOTH</LIMIT>
<ULE>175e-12</ULE>
<LLE>0</LLE>
</STATS>
</Measurement>
</Main>
```

You can find limit files for various data rates of different DDR standards and speed bins at `C:/TekApplications/DDRA/Limits`.

DDR Standards and their Measurements

The following table lists the measurements displayed for each DDR standard:

Measurements	DDR	DDR2	DDR3	LP-DDR‡	GDDR3†
Write Measurements					
Data Eye Width	✓	✓	✓	✓	✓
tDH-Diff	✓	✓	✓	✓	
tDH-SE		✓			
tDQSH		✓	✓	✓	
tDQSL		✓	✓	✓	
tDS-Diff	✓	✓	✓	✓	
tDS-SE		✓			
Read Measurements					
Data Eye Width	✓	✓	✓	✓	✓
tDQSCK-Diff	✓	✓	✓	✓	
tDQSQ-Diff	✓	✓	✓	✓	

Measurements	DDR	DDR2	DDR3	LP-DDR ‡	GDDR3 †
tAC-Diff	✓			✓	
Clock Measurements					
tCH(abs)		✓	✓		
tCH(avg)		✓	✓		
tCK(abs)		✓	✓		
tCK(avg)		✓	✓		
tCL(abs)		✓	✓		
tCL(avg)		✓	✓		
tERR(11–50per)		✓			
tERR(2per)		✓	✓		
tERR(3per)		✓	✓		
tERR(4per)		✓	✓		
tERR(5per)		✓	✓		
tERR(6per)			✓		
tERR(7per)			✓		
tERR(8per)			✓		
tERR(9per)			✓		
tERR(10per)			✓		
tERR(11per)			✓		
tERR(12per)			✓		
tERR(6–10per)		✓			
tERR (13–50per)			✓		
tJIT(cc)		✓	✓		
tJIT(duty)		✓	✓		
tJIT(per)		✓	✓		
tHP		✓			

‡ The clock measurements displayed for LPDDR and DDR standards are tCH, tCK, tHP and tCL.

† The application displays a hint on selecting GDDR3 as the standard “GDDR3 not completely supported. Some features may not function”.

Defining Measurements

The DDRA setup supports the following measurements:

- Clock Measurements
- Read Measurements
- Write Measurements

NOTE. *You need to select and configure DQ and DQS before running any read or write measurement. Although DQS is not an input for some measurements such as tAC-Diff, it is required to enable the Search-and-Mark (ASM) to identify burst boundaries.*

Write Measurements

For DDR Write analysis, the signals always required are Strobe (DQS) and Data (DQ).

- Data Eye Width

  Data Eye Width measurement is common to both Read and Write measurements. It is the measured clear horizontal eye opening at the middle reference level.

- tDH-Diff(base)

  tDH-Diff(base) is the input hold time between DQ and differential DQS signal. It is the elapsed time taken from the mid-level of the DQS signal to the specific level ($V_{IH(dc)}$ and $V_{IL(dc)}$, where $V_{IH(dc)}$ is on a falling slope of DQ signal and $V_{IL(ac)}$ is on a rising slope of the DQ signal). The base measurement does not reflect the derating specified in JEDEC specifications based on the slew rate of the signals measured.

- tDH-SE(base)

  tDH-SE(base) is the input hold time between DQ and single-ended DQS signal. The base measurement does not reflect thederating specified in JEDEC specifications based on slew rate of the signals measured.

- tDS-Diff(base)

  tDS-Diff(base) is the input setup time between DQ and differential DQS signal. It is the elapsed time taken from the mid-level of the DQS signal to the specific level ($V_{IH(ac)}$ and $V_{IL(ac)}$, where $V_{IH(ac)}$ is on a falling slope of DQ signal and $V_{IL(ac)}$ is on a rising slope of the DQ signal). The base measurement does not reflect thederating specified in JEDEC specifications based on slew rate of the signals measured.

- tDS-SE(base)

  tDS-SE(base) is the input setup time between DQ and single-ended DQS signal. It is the elapsed time between $V_{IH(dc)}$ min of DQS and $V_{IL(ac)}$ max of DQ. The base measurement does not reflect the derating specified in JEDEC specifications based on the slew rate of the signals measured.

- tDQSH

  Amount of time the waveform remains above the mid reference voltage level.

- tDQSL

  Amount of time the waveform remains below the mid reference voltage level.

Clock Measurements

Clock measurements do not require DQ and DQS as inputs. DQ and DQS may be left unattached, and will be ignored even if they are attached.

- tCH(abs)

tCH(abs) is the high pulse width on the clock signal. It is the amount of time the waveform remains above the mid reference voltage level.

- tCH(avg)

  tCH(avg) is the average width of the high-half cycle calculated across a sliding 200-cycle window of clock cycles.

- tCK(abs)

  tCK(abs) is the absolute clock period. It is the elapsed time between consecutive rising crossings of the mid reference CK voltage level.

- tCK(avg)

  tCK(avg) is calculated as the average clock period across a sliding 200-cycle window.

- tCL(abs)

  tCL(abs) is the low pulse width on the clock signal. It is the amount of time the waveform remains below the mid reference voltage level.

- tCL(avg)

  tCL(avg) is the average low pulse width calculated across a sliding 200-cycle moving window.

- tHP

  tHP is the minimum half clock period for any given cycle and is defined by clock high or clock low. It is similar to DPOJET's Period measurement where the edge type is clock with edges selection set to both.

- tERR (n)

  tERR (Timing error) is the time difference between the sum of tCK transitions for a 200-cycle window to n times tCK(avg). The calculated value represents the accumulated error across many cycles (n). The number of cycles to be used is defined by n, which is configurable.

- tJIT(cc)

  tJIT(cc) is the difference in period measurements from one cycle to the next; that is, the first difference of the Period measurement.

- tJIT(duty)

  tJIT(duty) is the largest elapsed time between the tCH from tCH(avg) or tCL from tCL(avg) for a 200-cycle window. This value represents the maximum of the accumulated value across a 200-cycle moving window.

- tJIT(per)

  tJIT(per) is the largest elapsed time between the tCK from tCK(avg) for a 200-cycle window. This value represents the maximum of the accumulated value across a 200-cycle moving window.

Read Measurements

For DDR Read analysis, the signals always required are Strobe (DQS) and Data (DQ). Some measurements also require the Clock signal.

- tDQSCK-Diff

  tDQSCK-Diff is the elapsed time between the DQS and CK edges.

- tDQSQ-Diff

  tDQSQ-Diff is the elapsed time between DQS and associated DQ edges.

- tAC-Diff

  tAC-Diff is the elapsed time between DQ and CK edges.

About DDR Analysis

The DDR Analysis window allows you to select various standards, set up and run a pre-configured measurement either through the DDRA or the DPOJET application.

Select **Analyze > DDR Analysis** to open the DDRA application.

The setup panel in the DDR Analysis application includes the following steps:

- Generate Rate and Levels
- Measurements
- Sources
- Burst Detection
- Thresholds and Scalings

NOTE. *You can use the Next/Prev buttons or click directly on the step numbers to traverse through the steps in the DDR Analysis. The steps for which configuration is complete are denoted*  .

The setup panel displays hints to help you understand the configuration options wherever applicable.

You can run a set of measurement in either of the two ways:

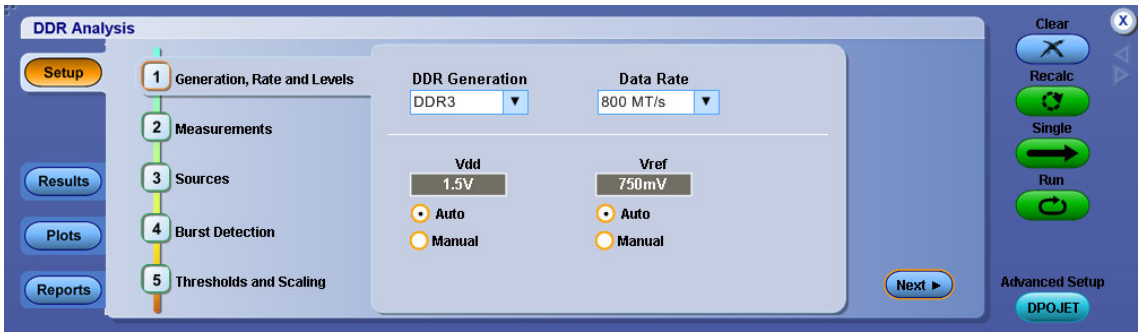
- Click **Run** to start the acquisition sequence using the selected settings and to view the results in the DDRA window. This is the normal way to generate results.
- Click 

to move to the DPOJET application, where you can add or modify measurements before sequencing. For more details, refer to the DPOJET Online Help. You need to click 

in the DPOJET application to return to the DDRA window. Alternatively, you can reselect **Analyze >DDR Analysis** from the menu bar.

Step1: Generation, Rate and Levels

Select the DDR generation, data rate and the voltage levels (if required). There are different speed bins for each standard data rate for specific DDR generations.



1. Select the DDR Generation from the drop-down list.
2. Select the Data Rate from the drop-down list. On selecting Custom, an edit box allows you to enter the value using the virtual keypad. Limit files are not defined for custom data rates for Pass/Fail status and as a result the application displays a hint at the bottom of the screen "Please provide a limits file under Jitter and Eye > Limits". Note that selecting non-standard data rates in ASM (under Search > DDR Read or DDR Write), changes the data rate to "None" in DDRA.
3. Set the voltage levels:
   - If you select Auto, the application calculates these levels for you.
   - If you select Manual, enter the Vdd or Vref voltage values using the virtual keypad.

Vdd

Is the supply voltage for each DDR standard. Vdd is based on DDR generation.

Vref

Is the reference voltage for each DDR standard. Vref is calculated using Vdd, which in turn is based on DDR generation. In most cases, Vref=0.5Vdd.

The following table lists the minimum and maximum values of Vdd and Vref in manual mode for all DDR generations:

DDR Generations	Vdd		Vref	
	Min	Max	Min	Max
DDR	1.08 V	2.16 V	540 mV	1.08 V
DDR2	1.08 V	2.16 V	540 mV	1.08 V

DDR Generations	Vdd		Vref	
DDR3	900 mV	1.8 V	450 mV	900 mV
LPDDR	1.08 V	2.16 V	540 mV	1.08 V
GDDR3	1.08 V	2.16 V	540 mV	1.08 V

NOTE. *If you select Manual Threshold Settings in Step 5 and then subsequently choose manual Vdd or Vref voltages, the following message is displayed "You have selected manual control of measurement thresholds in Step 5. Please verify that they are appropriate for these settings". This is because the Vref voltage is normally used to determine the proper high, mid, and low thresholds. If these thresholds are under manual control, there is no point in manually setting Vref.*

Vdd and Vref

The configured values of Vdd and Vref are used to calculate $V_{IH(ac)}$min, $V_{IH(dc)}$min, $V_{IL(dc)}$max and $V_{IL(ac)}$max, which are applied on the input signal. These levels are further used for calculating Setup and Hold measurements.

The relationship between Vdd and Vref is as shown in the following tables:

Table 5: Input DC logic Level

Symbol	Parameter	Min	Max	Units
$V_{IH(dc)}$	DC input logic high	Vref+0.125	–	V
$V_{IL(dc)}$	DC input logic low	–0.3	Vref–0.125	V

Table 6: Input AC logic Level

Symbol	Parameter	DDR2–400, DDR2–533		DDR2–667,DDR2–800		Units
		Min	Max	Min	Max	
$V_{IH(ac)}$	AC input logic high	Vref+0.250	–	Vref+0.200	–	V
$V_{IL(ac)}$	AC input logic low	–	Vref–0.250	–	Vref+0.200	V

Speed Bins

For each DDR standard, the DDRA application automatically applies limits appropriate for the standard data rates without speed bins. Limit values are different for different speed bins. If you want to test according to a speed bin, you must manually configure the limit values from within DPOJET by manually overriding the limit file before running the measurements.

For more details, refer to the topic "**Limits**" of the DPOJET help.

The following table lists the speed bins available for which pre-configured limit files are provided:

DDR Generation	Speed bins
DDR-400	400A, 400B and 400C
DDR2	
DDR2-667	800C and 800D
DDR2-800	800C, 800D and 800E
DDR3	
DDR3-800	800D and 800E
DDR3-1066	1066E, 1066F and 1066G
DDR3-1333	1333F *, 1333G, 1333H and 1333J *
DDR3-1600	1600G †, 1600H, 1600J and 1600K †

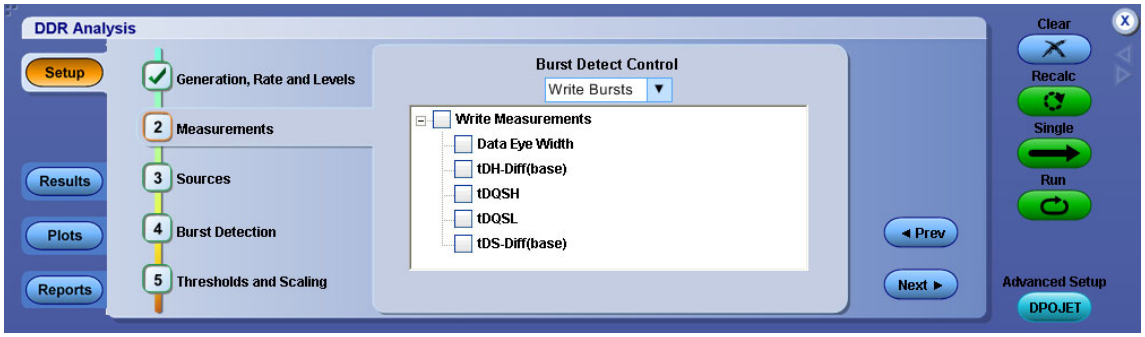
* **1333F and 1333J are optional**

† **1600G and 1600K are optional**

NOTE. *You can find limit files for various speed bins at* `C:\TekApplications\DDRA\Limits`*. You need to manually select these limit files by clicking* ***Analyze > Jitter and Eye Analysis > Preferences > Limits****.*

Step2: Measurements

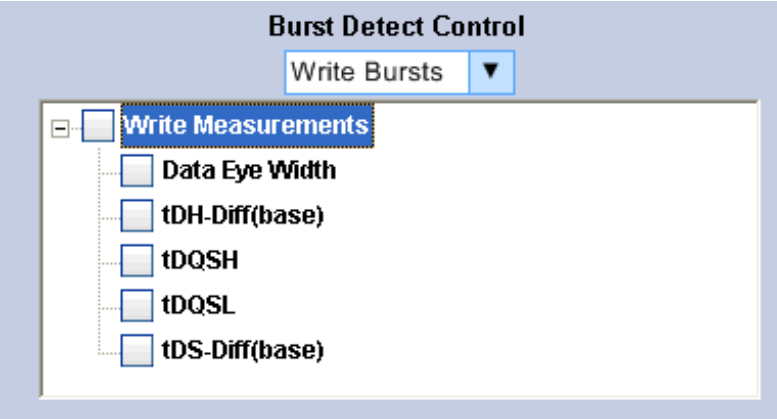
Measurement availability depends on the selected DDR standard. Select the measurement category (Read bursts, Write bursts or Clock bursts) from the drop-down list. A message prompts you to select one or more measurement before moving to the next step.



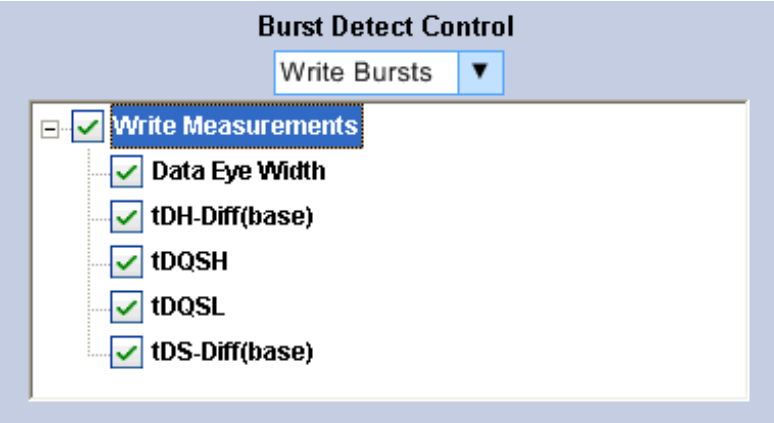
Tree Structure Flow

The measurement tree structure flow is as follows:

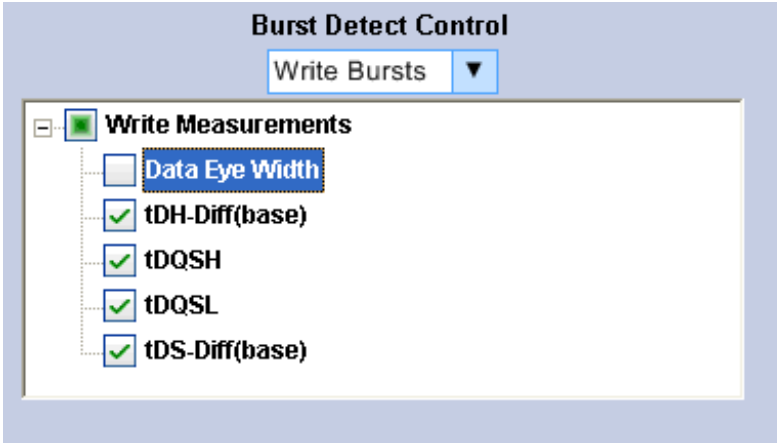
- The tree structure displays only the measurements listed under the current selected measurement type.



- Click ⊞ to expand and show the elements within the parent element.
- Click ⊟ to collapse and hide the elements within the parent element.
- Selecting the parent check box, selects all the children elements. Selecting all the children elements, selects the parent element.



- Clearing the parent check box clears all the children elements.
- When the children include both checked and unchecked elements, the parent element becomes highlighted as shown:



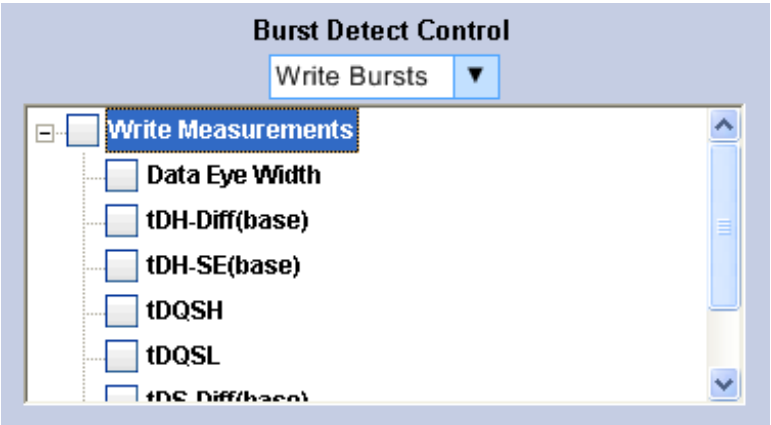
NOTE. *If you move to next step without selecting a measurement, the application displays the message "Please select measurements in Step2".*

Measurement Selection Based on Probe Type

The application adds the suffix SE (Single-ended) or Diff (Differential) for relevant measurements depending on the probe type.

- If your probe type is differential, the measurements with suffix **Diff** should be selected and those with SE should be deselected.
- If your probe type is single-ended, the measurements with suffix **SE** should be selected and those with Diff should be deselected.

For example: For DDR2 800 MT/s, Write burst selection shows both SE and Diff measurements as shown in the following figure. You need to select appropriate measurements based on the probe type to obtain valid results. For measurements with suffix Diff, DQ is SE and DQS is Diff whereas for measurements with suffix SE, both DQ and DQS are SE. Measurements such as Data Eye Width, tDQSH and tDQSL can be used for both Diff and SE measurements.



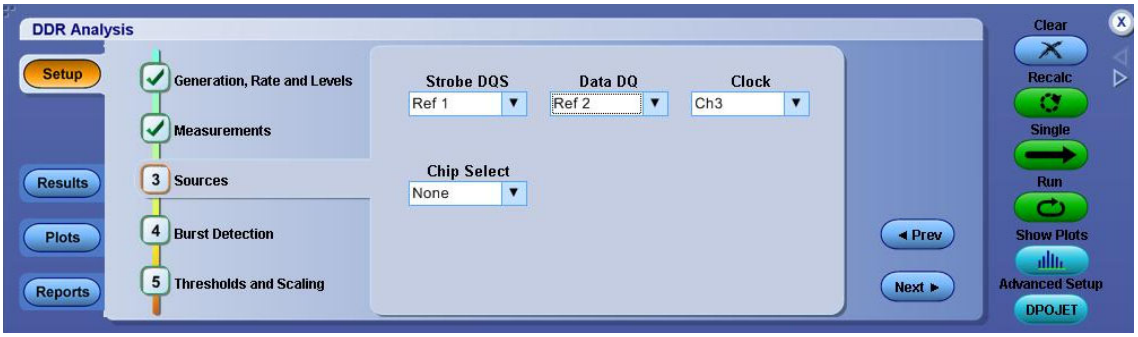
NOTE. *The application displays a hint "Cannot select Diff and SE measurements at the same time" when measurements with suffix SE and Diff are selected together under Write Bursts of DDR2/DDR3 generation.*

Reference

- Hints

Step3: Sources

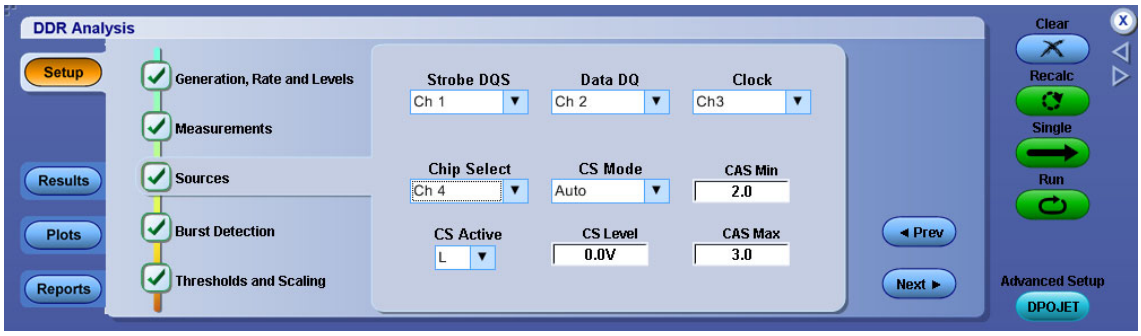
Identify all measurement sources that are required for your set of selected measurements. The sources are mutually exclusive. If Strobe is Ch1 and Data is also Ch1, then Strobe will switch to a different available channel. For more information, refer to Measurement Sources.



NOTE. *If the same channels are used for DQ/DQS/Clock sources (Example: DQ=Ch1, DQS=Ch1), the application displays a hint "Cannot use the same channel for different sources". If live and Ref channels are used together (Example: Ch1 for DQS and Ref2 for DQ), the application displays a hint "Cannot use Live and Ref waveforms together".*

1. Select the appropriate Clock source, Strobe DQS, and Data DQ from the drop-down lists.
2. Select the Chip Select source to set numeric values for CAS Min/CAS Max, and CS Level using the virtual keypad. Select CS Active and CS Mode as shown in the following figure.

NOTE. *If a Chip Select source is selected, CS-Strobe DQS is used for signal separation otherwise Strobe DQS-Data DQ is used. You need to configure DQ source to enable Search and Mark.*



Chip Select Source

Chip select source is used as a logic input to select read or write bursts corresponding to the chip select signal. When a chip-select signal source other than none is specified, reads or writes will only be shown when the chip-select source is active.

CAS Min/CAS Max

These values determine the CAS (Column Address Strobe) range for the memory being tested and specify the time-delay (in clock cycles) from the chip-select signal to the read or write bursts. The configured CAS range allows the user to offset the region where the chip-select logic source is measured for activity.

CS Level

CS Level specifies the logic-level above or below which the chip-select level is considered active and is applicable when CS Mode is set to Manual.

CS Active

Selects whether the chip-select source logic is considered active high or active low.

CS Mode

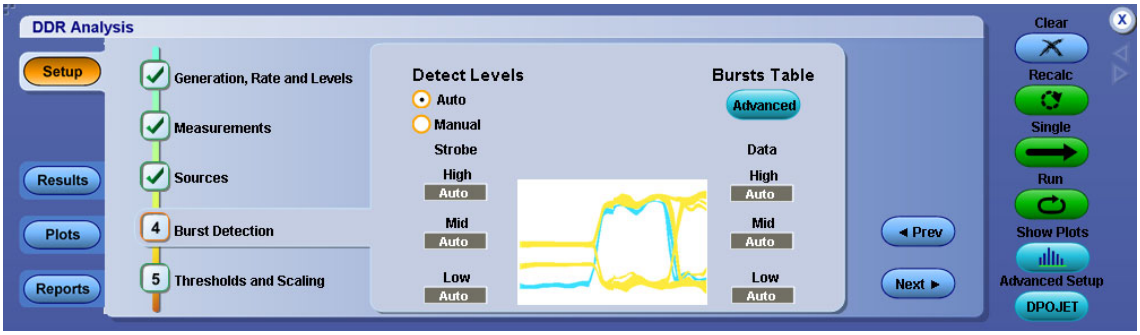
CS Mode consists of two modes– Auto and Manual. CS Auto mode calculates the level automatically for you (as half the peak-to-peak voltage), while manual mode allows you to specify a CS level. In cases where an entire acquisition could occur with no transitions on the chip-select line, you need to select manual mode to set the correct logic level.

Reference

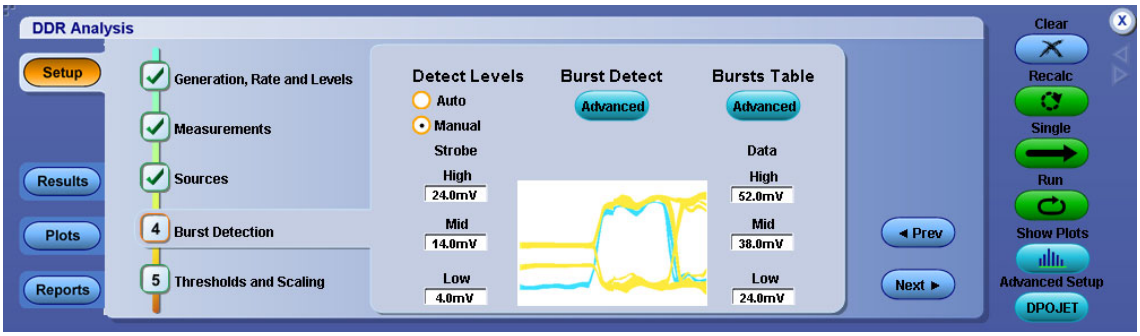
- Hints

Step4: Burst Detection

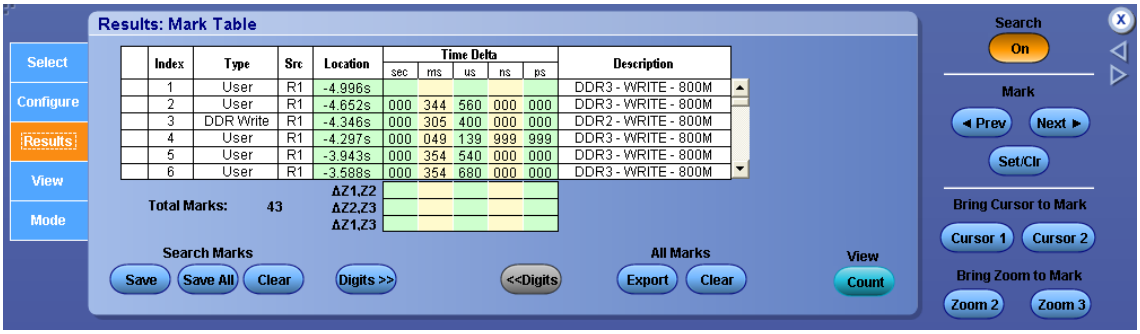
Set the burst detection levels to view the results in the Mark table. For more details on how to view results, refer to the “Search - Results: Mark Table Control Window” in your oscilloscope online help.



1. Select the type of burst level for the search.
   - If you select Auto, the application calculates these levels for you. It is recommended unless you find that manual levels are necessary for reliable detection.
   - If you select Manual, enter both the Strobe and Data reference levels for the signal (High, Mid, and Low). Click Advanced under Burst Detect to set the Edge Detection Hysteresis value, and the Termination Logic Margin in the Advanced Burst Detection window.



2. Click **Advanced** to view the search results in the **Results:Mark table**.



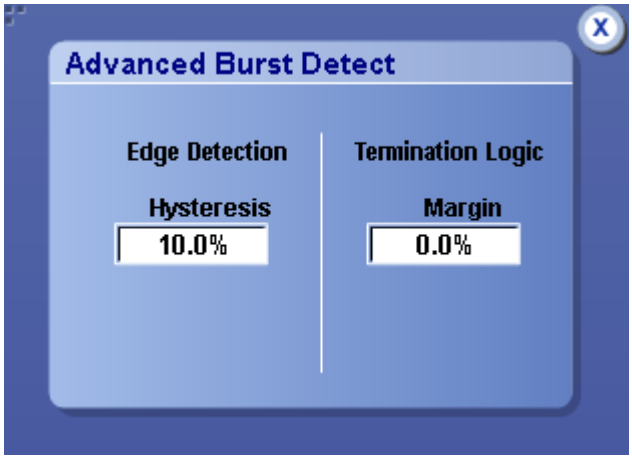
NOTE. *Use the forward and backward arrows at the right corner of the control panel to switch between DDRA and Results:Mark table window.*

Reference

- Hints

Advanced Burst Detection

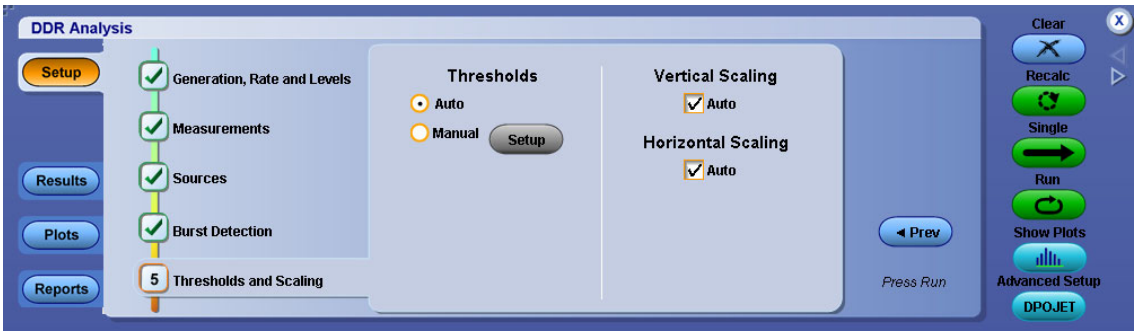
The following advanced burst detection settings need not be changed in most cases:



- **Edge Detection Hysteresis:** This control configures the internal edge finder's hysteresis band which is used to detect read or write bursts. In the event of noisy inputs, it can be increased to correct marks which may be larger than appropriate.
- **Terminator Logic Margin:** This control can be increased to help in terminating marks on back-to-back writes in cases where otherwise a continuous strobe would cause a write-mark to merge two back-to-back writes.

Step5: Thresholds and Scaling

The left half of this panel controls selection of critical voltage thresholds used by the measurement algorithms. The right half determines whether scaling is automatically adjusted each time you sequence.



Thresholds

Select either Auto or Manual as the Threshold type.

- If you select Auto, the application calculates these levels for you. It is recommended to use this option.
- If you select Manual, set the measurements levels by clicking the **Setup** button.

For more details, refer to the topic “Ref Levels” of the DPOJET help.

NOTE. *For every measurement selected in DDRA, appropriate reference levels are set in the DPOJET application. You can change these levels, if needed, from the DPOJET application.*

Vertical Scaling

Selecting Auto performs autoset on the oscilloscope vertical settings only.

For more details, refer to the topic “Source Autoset” of the DPOJET help.

Horizontal Scaling

Selecting Auto performs autoset on the oscilloscope horizontal settings only.

For more details, refer to the topic “Source Autoset” of the DPOJET help.

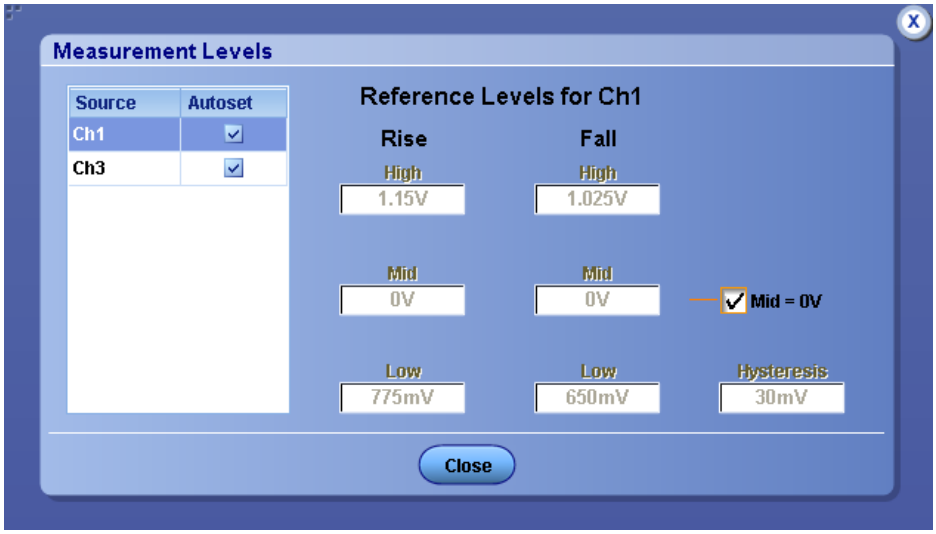
NOTE. *If both Vertical and Horizontal are checked, the application performs autoset on both vertical and horizontal oscilloscope settings when Single/Run is selected.*

Reference

- Hints

Measurement Levels

By definition, edges occur when a waveform crosses specified reference voltage levels. Reference voltage levels must be set so that the application can identify state transitions on a waveform. By default, the application automatically chooses reference voltage levels when necessary.



The DDRA application uses three basic reference levels: High, Mid and Low. In addition, a hysteresis value defines a voltage band that prevents a noisy waveform from producing spurious edges. The reference levels and hysteresis are independently set for each source waveform, and are specified separately for rising versus falling transitions.

Item	Description
Measurement Reference Levels Setup (one level per source) †	
Rise High	Sets the high threshold level for the rising edge of the source.
Rise Mid	Sets the middle threshold level for the rising edge of the source.
Rise Low	Sets the low threshold level for the rising edge of the source.
Fall High	Sets the high threshold level for the falling edge of the source.
Fall Mid	Sets the middle threshold level for the falling edge of the source.
Fall Low	Sets the low threshold level for the falling edge of the source.
Hysteresis	Sets the threshold margin to the reference level which the voltage must cross to be recognized as changing; the margin is the relative reference level plus or minus half the hysteresis; use to filter out spurious events.

† Default setting are 90% (High), 50% (Mid), 10% (Low), and 3% (Hysteresis).

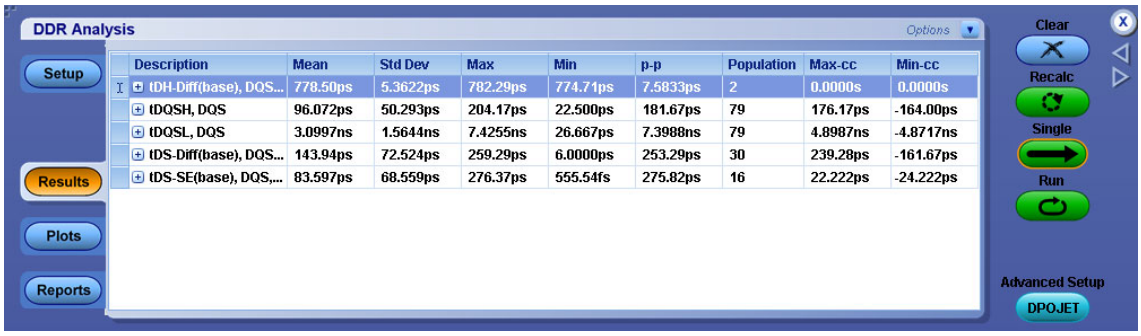
Hints

The DDRA application displays the following hints at different steps:

Hint	Step	Description
Read Measurements require a clock signal	2 or 3	Displayed when a read measurement that requires a clock source is selected. Example: DDR3, 800 MT/s data rate, select tDQSCK-Diff under Read bursts.
Select a standard data rate in DDRA	1	Displayed when data rate is None. When you select a non standard data rate in ASM, the data rate is set to None in DDRA.
GDDR3 not completely supported. Some features may not function.	1	Displayed on selecting GDDR3 standard, which does not have standard data rates. Only Data Eye Width measurement is available for both Read and Write bursts.
Please provide a Limits file under Jitter and Eye > Limits	1	Displayed for custom data rates for which limits are not defined. You need to manually configure the limits.
You have selected manual control of measurement thresholds in Step 5. Please verify that they are appropriate for these settings.	1	Displayed when Vdd or Vref values are set to Manual in Step 1 after thresholds are set to Manual in Step 5.
Cannot use Live and Ref waveforms together.	2 or 3	Displayed on selecting both Live and Ref waveforms as source for DQ and DQS. Example: Data Eye Width measurement with sources as Ch1 for DQ and Ref1 for DQS.
Cannot use the same channel for different sources.	2 or 3	Displayed on selecting the same source for DQ and DQS. Example: Data Eye Width using Ch3 for both DQ and DQS.
Cannot select Diff and SE measurements at the same time.	2	Displayed on selecting measurements with suffix SE and Diff. Example: DDR2, Write bursts, tDH-Diff and tDH-SE measurements.
Use unique sources that are either Live or Ref.	2 or 3	Displayed on selecting measurements which require DQ, DQS and Clock sources. Example: DDR3, 800MT/s, select all Read burst measurements.

Results as Statistics

Result statistics for most of the measurements show **Population** in terms of UI or transitions. According to the JEDEC specification, the analysis for most of the clock measurements is done for a 200-cycle moving window. However, for clock measurements such as tCL(avg) and tCH(avg), the population is shown as tCK(avg) units. For some measurements such as Data Eye Width, exactly one measurement occurs per acquisition. For such measurements, the population increases by one for each acquisition independent of the number of UI in the acquisition.

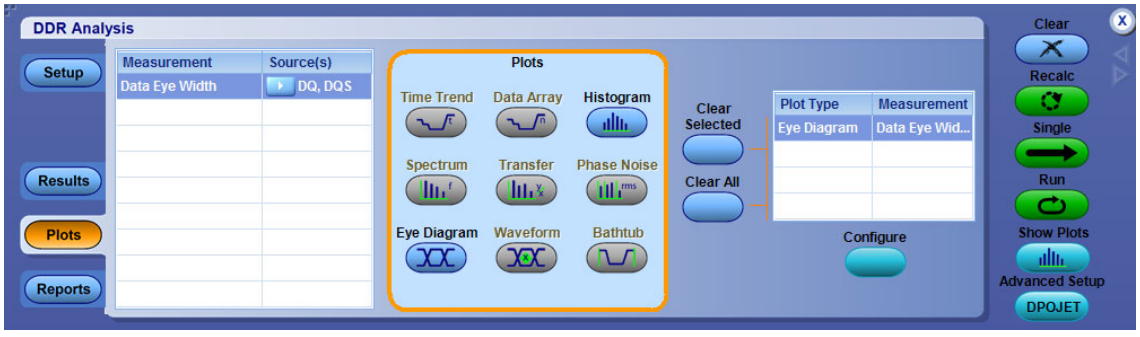


For more details, refer to the topic “Viewing Statistical Results” of the DPOJET help.

Plots

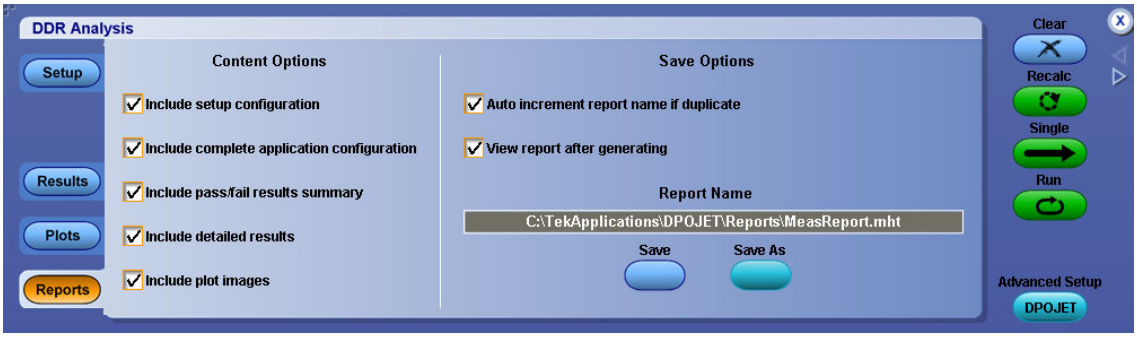
The only measurement for which a plot is automatically configured is Data Eye Width, which is available for both Read and Write bursts. However, plots may be added for other measurements through the plot panel. The plot selection and configuration methods are identical to those used for DPOJET. For more details, refer to the DPOJET help.

For acquisitions containing more than one read or write burst, time trend plots connect together all measurements within each burst with a continuous line, but do not draw lines between bursts. If a vertical cursor is placed where it does not intersect a line, the cursor annotation will read "NaN" (Not a Number).



For more details, refer to the topic “About Configuring Plots” of the DPOJET help.

Reports



For more details, refer to the topic “About Reports” of the DPOJET help.

Switching between the DDRA and DPOJET Applications

For advanced analysis, click 

to switch to the DPOJET application. Likewise, click 

in the DPOJET application to revert to the DDRA application.

The transition behaves as follows:

- The application name in the title bar switches between **DDR Analysis** and **Jitter and Eye Diagram Analysis Tool**.
- Measurement name remains unchanged while traversing from DDRA to DPOJET.
- Within DPOJET, more measurements may be added to those automatically configured in DDRA. These measurements must be configured manually.
- Once in DPOJET, measurements automatically configured by DDRA may be reconfigured. (The measurements will generally no longer be JEDEC-compliant in this case.)
- Upon returning to DDRA, new or non-standard measurements will be retained.
- Measurement sequencing, results analysis and report generation can be done from either application.
- Any change in generation and burst detect control in the DDRA deselects all the currently selected measurements.
- Switching back from DPOJET to DDRA, always resets focus to the Setup panel.
- DPOJET or DDRA application is always accessible from the oscilloscope menu bar, as an alternative to the quick navigation buttons.

Introduction to the Tutorial

This tutorial teaches how to set up the application, take measurements, and view results as plots or statistics.

Before you begin the tutorial, perform the following tasks:

- Set up the oscilloscope.
- Start the application.
- Recall the tutorial waveform.

Setting Up the Oscilloscope

The steps to set up the oscilloscope are:

- Click **File > Recall Default Setup** in the oscilloscope menu bar to recall the default settings.
- Press the individual CH1, CH2, CH3, and CH4 buttons as needed to add or remove active waveforms from the display.

Starting the Application

Click **Analyze > DDR Analysis** to open the application.

Waveform Files

The DDRA application provides the following waveforms at `C:\TekApplications\DDRA\Waveforms`:

- DDR2_800_DQS_Write.wfm
- DDR2_800_DQ_Write.wfm
- DDR2_800_CLK.wfm

NOTE. *These waveforms have to be used only for Write bursts and CLK.*

Recalling a Waveform File

To recall a waveform file, follow these steps:

1. Click **File > Recall** in the oscilloscope menu bar to display the Recall dialog box.
2. Click Waveform icon in the left of the Recall dialog box.
3. Select Ref1, Ref2, Ref3, or Ref4 as the Destination option.
4. Browse to select the waveform. Use the keypad to edit the waveform file name.
5. Click **Recall**. The oscilloscope recalls and activates the Reference Waveform control window.
6. Click **On** to display the waveform.
7. Click  to return to the application. Alternatively, DDRA can also be accessed from **Analyze > DDR Analysis**.

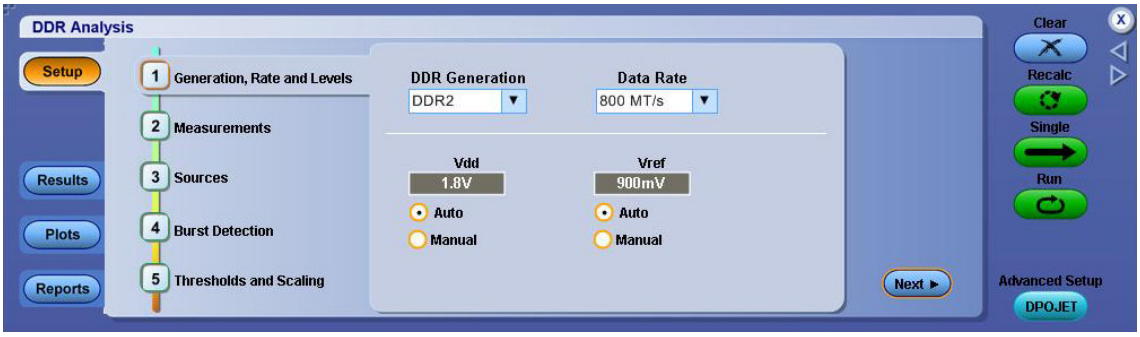
Taking a Measurement

In this tutorial, we are taking the following example:

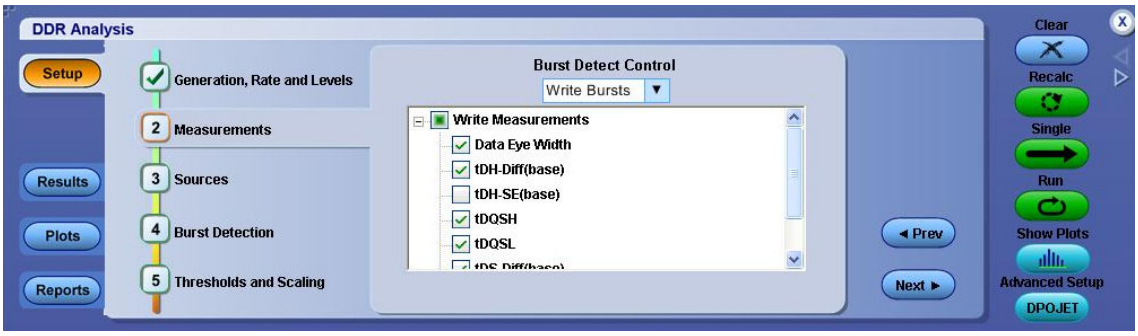
DDR2 800MT/s, Write bursts - Differential measurements

Waveforms Used: DDR2_800_DQS_Write.wfm and DDR2_800_DQ_Write.wfm

1. To set the application to default values, click **File > Recall Default Setup**. This is not necessary if you have just started the application.
2. To view the DDRA application, select **Analyze > DDR Analysis**.
3. At Step 1, select the DDR2 standard and the data rate as 800 MT/s. The default voltage settings are retained as shown:

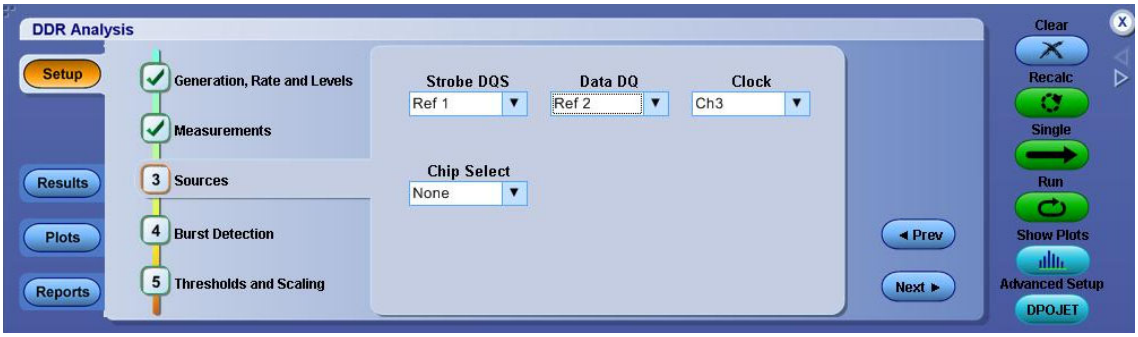


4. At Step 2, select all the measurements except tDS-SE(base) and tDH-SE(base) under Write bursts as shown. This is because the reference waveform is differentially probed.

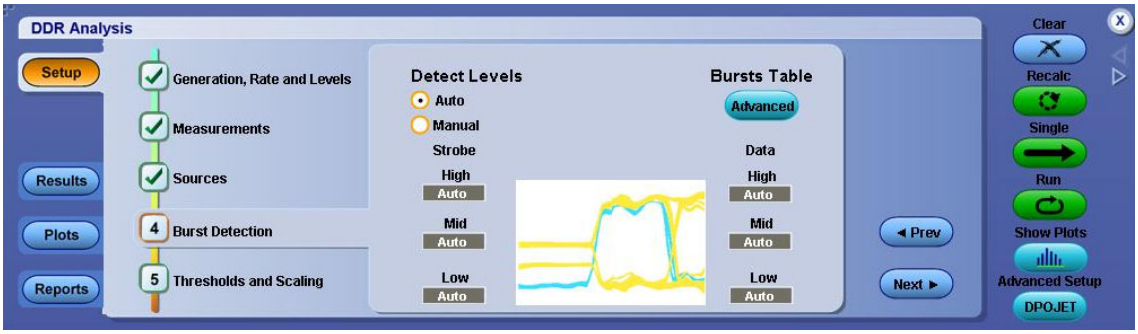


5. At Step 3, select the sources. In this example, DQS is recalled as Ref1 and DQ as Ref2 as shown. Since none of the selected measurements requires the clock, the clock source selection will be ignored.

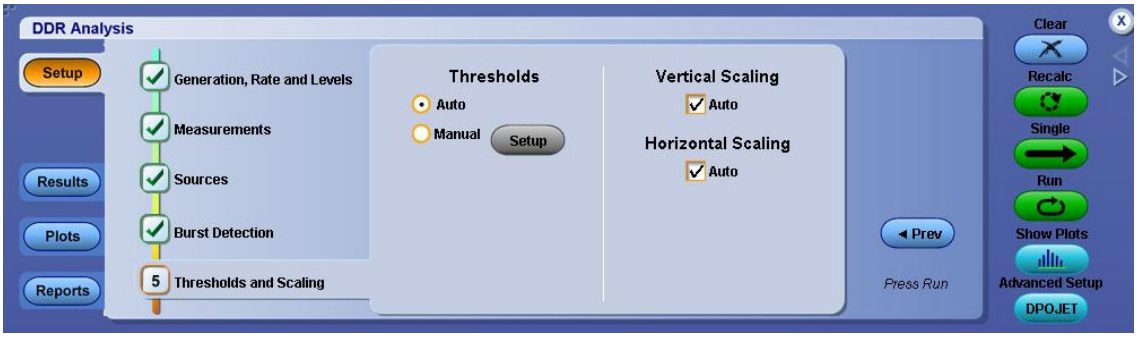
NOTE. *Alternatively, you could simply click Single from step 3 since no more configuration changes will be made.*



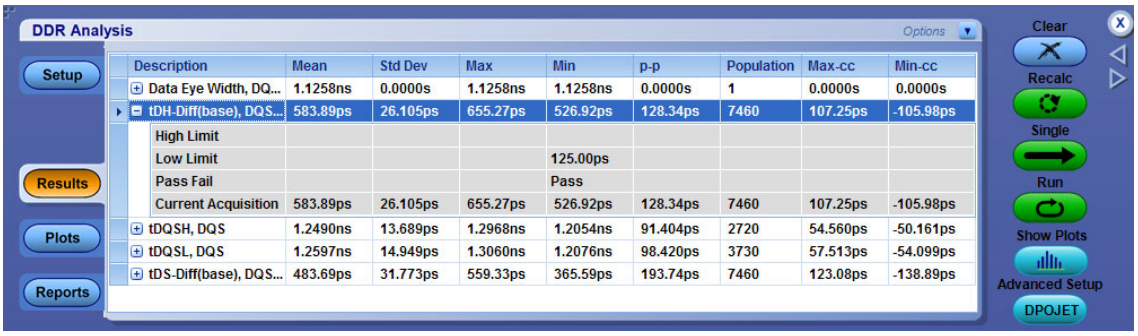
6. At Step 4, retain the default settings as shown:



7. At Step 5, retain the default settings as shown:

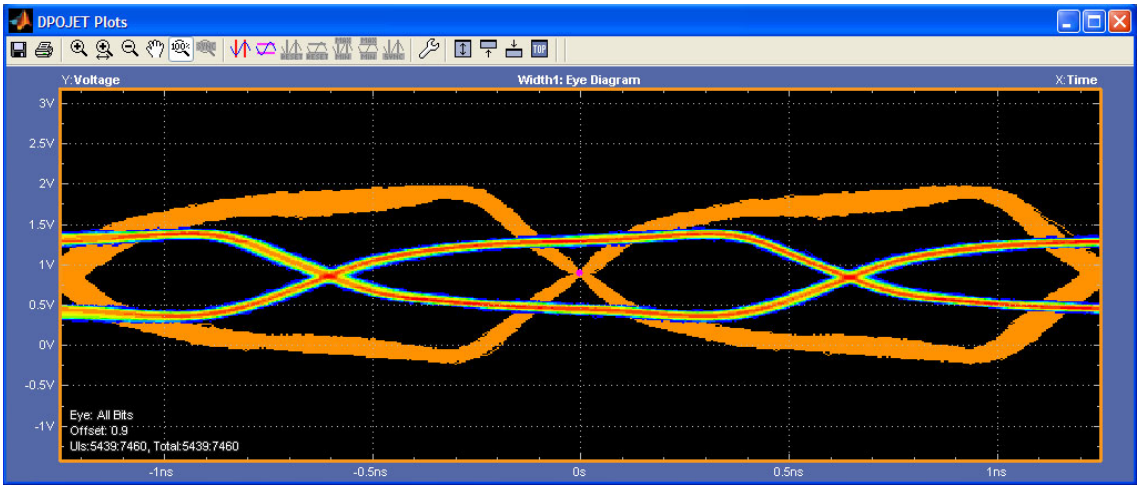


8. Click **Single** to run the application. When complete, the result statistics with limits are shown in the results tab.



Description	Mean	Std Dev	Max	Min	p-p	Population	Max-cc	Min-cc
Data Eye Width, DQ...	1.1258ns	0.0000s	1.1258ns	1.1258ns	0.0000s	1	0.0000s	0.0000s
tDH-Diff(base), DQS...	583.89ps	26.105ps	655.27ps	526.92ps	128.34ps	7460	107.25ps	-105.98ps
High Limit								
Low Limit				125.00ps				
Pass Fail				Pass				
Current Acquisition	583.89ps	26.105ps	655.27ps	526.92ps	128.34ps	7460	107.25ps	-105.98ps
tDQSH, DQS	1.2490ns	13.689ps	1.2968ns	1.2054ns	91.404ps	2720	54.560ps	-50.161ps
tDQSL, DQS	1.2597ns	14.949ps	1.3060ns	1.2076ns	98.420ps	3730	57.513ps	-54.099ps
tDS-Diff(base), DQS...	483.69ps	31.773ps	559.33ps	365.59ps	193.74ps	7460	123.08ps	-138.89ps

The eye diagram plot is displayed as shown:



About Parameters

This section describes the DDRA application parameters and includes the menu default settings. Refer to the user manual of your oscilloscope for operating details of other controls, such as front-panel buttons.

The parameter tables list the selections or range of values available for each option, the incremental unit of numeric values, and the default selection or value.

Step1: Generation, Rate and Levels Parameters

Step1 includes the following parameters:

Option	Parameters	Default setting
DDR Generation	DDR, DDR2, DDR3, LPDDR and GDDR3	DDR3
Data Rate †	**DDR:** 200 MT/s, 266 MT/s, 333 MT/s, 400 MT/s, Custom and None **DDR2:** 400 MT/s, 533 MT/s, 667 MT/s, 800 MT/s, 1066 MT/s, Custom and None **DDR3:** 800 MT/s, 1066 MT/s, 1333 MT/s, 1066 MT/s, Custom and None **LPDDR:** 200 MT/s, 266 MT/s, Custom and None **GDDR3:** 500 MT/s, 600 MT/s, 700 MT/s, 800 MT/s, 900 MT/s, 1000 MT/s, 1200 MT/s, Custom and None	200 MT/s for LPDDR and DDR 400 MT/s for DDR2 800 MT/s for DDR3 500 MT/s for GDDR3
Vdd	Auto, Manual	Auto
Vref	Auto, Manual	Auto

† Data rate varies for different DDR standards.

Step2: Measurements Parameters

Step2 includes the following parameters under Burst Detect Control:

- Read Bursts
- Write Bursts
- Clock

Step3: Sources Parameters

Step3 includes the following parameters:

Table 7: Source Parameters

Option	Parameters	Default setting
Strobe DQS	Ch1-Ch4, Ref1-Ref4, Math1-Math4	Ch1
Data DQ	Ch1-Ch4, Ref1-Ref4, Math1-Math4	Ch2
Clock	Ch1-Ch4, Ref1-Ref4, Math1-Math4	Ch3
Chip Select	None, Ch1-Ch4, Ref1-Ref4, Math1-Math4	None
CS Mode *	Auto, Manual	Auto
CAS Min *	0–1k	2.0
CS Active *	High, Low	Low
CS Level *	Left, Right	0.0
CAS Max *	0–1k	3.0

* **Available only when Chip select source is selected.**

Step4: Burst Detection Parameters

Step4 has the following parameters:

Table 8: Burst Detection Parameters

Option	Parameters	Default setting
Detect Levels	Auto, Manual	Auto
Advanced Burst Detection †		
Edge Hysteresis	0–50%	10%
Termination Logic Margin	0–100%	0%

† **Available only for Manual Burst detection.**

Step5: Thresholds and Scaling Parameters

Step5 has the following parameters:

Option	Parameters	Default setting
Thresholds	Auto, Manual	Auto
Vertical Scaling	Set, Clear	Clear
Horizontal Scaling	Set, Clear	Clear
Measurement Levels		
Rise High	–20 V to 20 V	1 V
Rise Mid	–20 V to 20 V	0 V
Rise Low	–20 V to 20 V	–1 V
Fall High	–20 V to 20 V	1 V
Fall Mid	–20 V to 20 V	0 V
Fall Low	–20 V to 20 V	–1 V
Hysteresis	0 to 10 V	30 mV

Measurement Sources

The sources required for analysis are Data Strobe (DQS), Data (DQ) and Clock (CK/$\overline{CK}$). DQ and DQS can be either Single-ended (SE) or Differential (Diff).

The following table lists the sources required for each measurement:

DDR measurements	DPOJET base measurement	Performed on	Additional required sources
Write Measurements			
Data Eye Width	Eye Width	DQS and DQ	None
tDH-Diff(base)	DDR Hold-Diff	DQS-Diff and DQ-SE	None
tDH-SE(base)	DDR Hold-SE	DQS-SE and DQS-SE	None
tDQSH	Pos Width	DQS-Diff and DQ-SE	None
tDQSL	Neg Width	DQS-Diff and DQ-SE	None
tDS-Diff(base)	Setup	DQS-Diff and DQ-SE	None
tDS-SE(base)	Setup	DQS-SE and DQS-SE	None
Read Measurements			
Data Eye Width	Eye Width	DQS and DQ	None
tDQSCK-Diff	Skew	DQS and CK	DQ *
tDQSQ-Diff	DDR Setup-Diff	DQS and DQ	None
tAC-Diff	DDR Setup-Diff	DQ and CK	DQS *
Clock Measurements			
tCH(abs)	Pos Width	CK or $\overline{CK}$	None
tCH(avg)	DDR tCH(avg)	CK or $\overline{CK}$	None
tCK(abs)	Period	CK or $\overline{CK}$	None
tCK(avg)	DDR tCK(avg)	CK or $\overline{CK}$	None
tCL(abs)	Neg Width	CK or $\overline{CK}$	None
tCL(avg)	DDR tCL(avg)	CK or $\overline{CK}$	None
tERR(11–50per)	DDR tERR(m–n)	CK or $\overline{CK}$	None
tERR(2per)	DDR tERR(n)	CK or $\overline{CK}$	None
tERR(3per)	DDR tERR(n)	CK or $\overline{CK}$	None
tERR(4per)	DDR tERR(n)	CK or $\overline{CK}$	None
tERR(5per)	DDR tERR(n)	CK or $\overline{CK}$	None
tERR(6per)	DDR tERR(n)	CK or $\overline{CK}$	None
tERR(7per)	DDR tERR(n)	CK or $\overline{CK}$	None
tERR(8per)	DDR tERR(n)	CK or $\overline{CK}$	None
tERR(9per)	DDR tERR(n)	CK or $\overline{CK}$	None
tERR(10per)	DDR tERR(n)	CK or $\overline{CK}$	None
tERR(11per)	DDR tERR(n)	CK or $\overline{CK}$	None

DDR measurements	DPOJET base measurement	Performed on	Additional required sources
tERR(12per)	DDR tERR(n)	CK or $\overline{CK}$	None
tERR(6–10per)	DDR tERR(m–n)	CK or $\overline{CK}$	None
tERR(13–50per)	DDR tERR(m–n)	CK or $\overline{CK}$	None
tJIT(cc)	CC–Period	CK or $\overline{CK}$	None
tJIT(duty)	DDR tJIT(duty)	CK or $\overline{CK}$	None
tJIT(per)	DDR tJIT(per)	CK or $\overline{CK}$	None
tHP	Period	CK or $\overline{CK}$	None

* Required for Opt.ASM

Different DDR Speed Grades

As per JEDEC (JESD79E) specifications, few measurements of DDR generation have limit values defined for both TSOP and BGA packages. The DDRA application supports limits only for BGA package. You need to change the limit values to run the measurements for a different package type.

The following table lists various timing parameters by different DDR speed grades:

Measure-ments	Units	DDR–200		DDR–266		DDR–333		DDR–400	
		Min	Max	Min	Max	Min	Max	Min	Max
Write Measurements									
Data Eye Width	–	–	–	–	–	–	–	–	–
tDH-Diff	ps	600	–	500	–	450	–	400	–
tDS-Diff	ps	600	–	500	–	450	–	400	–
Read Measurements									
Data Eye Width	–	–	–	–	–	–	–	–	–
tDQSCK-Diff	ps	–800	+800	–750	+750	–600	+600	–600	+600
tDQSQ-Diff	ps	–	600	–	500	–	450	–	400
tAC-Diff	ps	–800	+800	–750	+750	–700	+700	–700	+700
Clock Measurements									
tCH	ns	4.5	6.6	3.375	6.6	2.703	6.6	2.25	4.125
tCK	ns	10	12	7.5	12	6	12	5	7.5
tCL	ns	4.5	6.6	3.375	6.6	2.703	6.6	2.25	4.125
tHP	ns	4.5	–	3.375	–	2.703	–	2.25	–

Different DDR2 Speed Grades

The following table lists various timing parameters by different DDR2 speed grades:

Measurements	Units	DDR2–400		DDR2–533		DDR2–667		DDR2–800	
		Min	Max	Min	Max	Min	Max	Min	Max
Write Measurements									
Data Eye Width	–	–	–	–	–	–	–	–	–
tDH-Diff(base)	ps	275	–	225	–	175	–	125	–
tDH-SE(base)	ps	25	–	–25	–	–	–	–	–
tDQSH	ps	1750	–	1325	–	1050	–	875	–
tDQSL	ps	1750	–	1325	–	1050	–	875	–
tDS-Diff(base)	ps	150	–	100	–	100	–	50	–
tDS-SE(base)	ps	25	–	–25	–	–	–	–	–
Read Measurements									
Data Eye Width	–	–	–	–	–	–	–	–	–
tDQSCK-Diff	ps	–500	+500	–450	+450	–400	+400	–350	+350
tDQSQ-Diff	ps	–	350	–	300	–	240	–	200
tAC-Diff	ps	–600	+600	–500	+500	–450	+450	–400	+400
Clock Measurements									
tCH(abs)	ps	2500	4400	4400	1687.5	1315	4285	1100	4260
tCH(avg)	tCK(avg)	–	–	–	–	0.48	0.52	0.48	0.52
tCK(abs)	ps	5000	8000	3750	8000	2875	8125	2398	2598
tCK(avg)	ps	–	–	–	–	3000	8000	2500	8000
tCL(abs)	ps	4400	2250	4400	1687.55	1315	4285	1100	4260
tCL(avg)	tCK(avg)	–	–	–	–	0.48	0.52	0.48	0.52
tERR(11–50per)	ps	–	–	–	–	–450	+450	–450	+450
tERR(2per)	ps	–	–	–	–	–175	+175	–150	+150
tERR(3per)	ps	–	–	–	–	–225	+225	–175	+175
tERR(4per)	ps	–	–	–	–	–250	+250	–200	+200
tERR(5per)	ps	–	–	–	–	–250	+250	–200	+200
tERR(6–10per)	ps	–	–	–	–	–350	+350	–300	+300
tJIT(cc)	ps	–	–	–	–	–250	+250	–200	+200
tJIT(duty)	ps	–	–	–	–	–125	+125	–100	+100
tJIT(per)	ps	–	–	–	–	–125	+125	–100	+100
tHP	ps	2250	–	1687.5	–	1499	–	1100	–

Different DDR3 Speed Grades

The following table lists various timing parameters by different DDR3 speed grades:

Measure-ments	Units	DDR3–800		DDR3–1066		DDR3–1333		DDR3–1600	
		Min	Max	Min	Max	Min	Max	Min	Max
Write Measurements									
Data Eye Width	–	–	–	–	–	–	–	–	–
tDH-Diff(base)	ps	150	–	100	–	65	–	45	–
tDH-SE(base)	ps	–	–	–	–	–	–	–	–
tDQSH	ps	1125	1833	843.8	1833	675	1833	562.5	1833
tDQSL	ps	1125	1833	843.8	1833	675	1833	562.5	1833
tDS-Diff(base)	ps	75	–	25	–	30	–	10	–
tDS-SE(base)	ps	–	–	–	–	–	–	–	–
Read Measurements									
Data Eye Width	–	–	–	–	–	–	–	–	–
tDQSCK-Diff	ps	–400	400	–300	300	–255	255	–225	225
tDQSQ-Diff	ps	–	200	–	150	–	125	100	–
tAC-Diff	ps	–	–	–	–	–	–	–	–
Clock Measurements									
tCH(abs)	ps	1075	–	882	–	645	–	537.5	–
tCH(avg)	tCK(avg)	0.47	0.53	0.47	0.53	0.47	0.53	0.47	0.53
tCK(abs)	ps	2400	3423	1785	3423	1420	3413	1180	3370
tCK(avg)	ps	2500	3300	1875	3300	1500	3300	1250	3300
tCL(abs)	ps	1075	–	806.25	–	645	–	537.5	–
tCL(avg)	tCK(avg)	0.47	0.53	0.47	0.53	0.47	0.53	0.47	0.53
tERR(11–50per)	ps	–366.0176	366.0176	–329.4158	+329.4158	–292.8141	+292.8141	–	–
tERR(2per)	ps	–147	+147	–132	+132	–118	+118	–103	+103
tERR(3per)	ps	–175	+175	–157	+157	–140	+140	–122	+122
tERR(4per)	ps	–194	+194	–175	+175	–155	+155	–136	+136
tERR(5per)	ps	–209	+209	–188	+188	–168	+168	–147	+147
tERR(6per)	ps	–222	+222	–200	+200	–177	+177	–155	+155
tERR(7per)	ps	–232	+232	–209	+209	–186	+186	–163	+163
tERR(8per)	ps	–241	+241	–217	+217	–193	+193	–169	+169
tERR(9per)	ps	–249	+249	–224	+224	–200	+200	–175	+175
tERR(10per)	ps	–257	+257	–231	+231	–205	+205	–180	+180
tERR(11per)	ps	–263	+263	–237	+237	–210	+210	–184	+184
tERR(12per)	ps	–269	+269	–242	+242	–215	+215	–188	+188

Measure-ments	Units	DDR3–800		DDR3–1066		DDR3–1333		DDR3–1600	
tERR(6–10per)	ps	–257	+257	–231	+231	–205	+205	–180	+180
tJIT(cc)	ps	–200	200	–180	180	–160	+160	–140	140
tJIT(duty)	ps	–	–	–	–	–	–	–	–
tJIT(per)	ps	–100	+100	–90	+90	–80	+80	–70	70
tHP	–	–	–	–	–	–	–	–	–

NOTE. *Limits are not defined for tERR(13–50per) measurement.*

Different LPDDR Speed Grades

The following table lists various timing parameters by different LPDDR speed grades:

Measurements	Units	LPDDR–200		LPDDR–266	
		Min	Max	Min	Max
Write Measurements					
Data Eye Width	–	–	–	–	–
tDH-Diff(base)	ns	1.1	–	0.8	–
tDQSH	ns	4	–	4	–
tDQSL	ns	4	–	4	–
tDS-Diff(base)	ns	1.1	–	0.8	–
Read Measurements					
Data Eye Width	–	–	–	–	–
tDQSCK-Diff	ns	2	7	2	6.5
tDQSQ-Diff	ns	–	0.7	–	0.6
tAC-Diff	ns	2	7	2	6.5
Clock Measurements					
tCH	ns	4.5	5.5	3.375	4.125
tCK	ns	10	–	7.5	–
tCL	ns	4.5	5.5	3.375	4.125
tHP	ns	4.5	–	3.375	–

DDR Standards and their Specifications

Various DDR standards and the supported specfication versions are as follows:

- **DDR** - JESD79E, May 2005
- **DDR2** - JESD79-2E, April 2008
- **DDR3** - JESD79-3B, April 2008
- **LPDDR** - JESD79-4A, April 2007

Measurement Range Limits

The following table lists the measurement range limits of DDR measurements for different standards and data rate:

NOTE. *Measurement Range Limits are provided for each measurement under the General configure tab of the DPOJET application. These range limits are always ON (OFF is disabled) for two source measurements such as Skew, Setup, Hold etc. The range limits are used by the algorithms to associate valid edge of first source to the valid edge of the second source.*

Generation	Data rate	UI=1/CK speed	Measurement range			
			Read measurements		Write measurements	
			Max=+ UI/2	Min=-UI/2	Max= UI	Min=0
LPDDR	200 MT/s	5 ns	2.5 ns	– 2.5 ns	5 ns	0
	266 MT/s	3.76 ns	1.88 ns	–1.8797 ns	3.76 ns	0
DDR	200 MT/s	5 ns	2.5 ns	– 2.5 ns	5 ns	0
	266 MT/s	3.76 ns	1.88 ns	–1.8797 ns	3.76 ns	0
	333 MT/s	3 ns	1.5 ns-	–1.5015	3 ns	0
	400 MT/s	2.5 ns	1.25 ns	–1.25 ns	2.5 ns	0
DDR2	400 MT/s	2.5 ns	1.25 ns	–1.25 ns	2.5 ns	0
	533 MT/s	1.88 ns	0.938 ns	–0.938086 ns	1.88 ns	0
	667 MT/s	1.5 ns	0.75 ns	–0.749625 ns	1.5 ns	0
	800 MT/s	1.25 ns	0.625 ns	–0.625 ns	1.25 ns	0
	1070 MT/s	0.938 ns	0.469 ns	–-0.469043 ns	0.938 ns	0
DDR3	800 MT/s	1.25 ns	0.625 ns	–0.625 ns	1.25 ns	0

Generation	Data rate	UI=1/CK speed	Measurement range			
	1070 MT/s	0.938 ns	0.469 ns	–-0.469043 ns	0.938 ns	0
	1333 MT/s	0.75 ns	0.375 ns	–0.375094 ns	0.75 ns	0
	1600 MT/s	0.625 ns	0.313 ns	–0.3125 ns	0.625 ns	0

Error Codes and Warnings

Code	Description
W410	Number of edges are not sufficient for a measurement: Positive Width.
E1001	Vertical Autoset Failed: Signal on Source x has extreme offset.
E1002	Vertical Autoset Failed: Amplitude of Source x is too small.
E1003	Vertical Autoset Failed: Amplitude or DC offset of Source x is too high.
E1004	Vertical Autoset Failed: No signal on Source x.
E1005	Vertical Autoset Failed: Signal on Source x exceeds top of scale.
E1006	Vertical Autoset Failed: Signal on Source x exceeds bottom of scale.
E1007	Vertical Autoset Failed: Signal on Source x is clipped on top.
E1008	Vertical Autoset Failed: Signal on Source x is clipped on bottom.
E1009	Vertical Autoset Failed: Measurement error (ISDB error code = 6) on Source x.
E1010	Vertical Autoset Failed: Measurement error (ISDB error code = 7) on Source x.
W1011	A change to Source x vertical settings caused overload disconnect. Original settings are restored and Source x is reconnected. Ignore oscilloscope message.
E1012	Vertical Autoset Failed: None of the selected measurements use live sources (Ch1-Ch4). Horizontal autoset works for live sources only.
E1013	Vertical Autoset Failed: Invalid signal on Source x.
E1020	Horizontal Autoset Failed: None of the selected measurements use live sources (Ch1-Ch4). Horizontal autoset works for live sources only.
E1021	Horizontal Autoset Failed: On Source x, cannot determine resolution of rising/falling edges.
E1022	Horizontal Autoset Failed: Horizontal resolution is at the maximum.
E1035	Oscilloscope has gone into invalid state. Please restart the system.
E1040	Autoset Failed: None of the live sources (Ch1-Ch4) selected.
W1051	Ref Level Autoset: Waveform for the source x is clipped.
W1053	Ref Level Autoset: Source amplitude is extremely low.
E1054	Ref Level Autoset: Error in setting reference levels.
E1055	Ref Level Autoset Failed: No waveform to measure.
E1056	Ref Level Autoset: Unstable Histogram for waveform on source x.
E1057	Ref Level Autoset: No selected source.
E1058	Ref Level Autoset Failed: Invalid signal on source x.

Code	Description
E1059	Ref Level Autoset Error: Source x is not defined.
E2002	All the refs are used as sources by the measurements. Export to Ref is not possible.
E2003	Ref 'x' is already used as a measurement source.
E2004	Ref 'x' is already used as a destination for other measurement.
E2005	No measurement(s) are selected. Export to Ref is not possible.
E2006	No results available to export to ref.
E2007	There are no time trend results for the selected measurement(s).
E2008	No ref destination is selected. Results will not be exported to ref.
E3001	Could not open or create a log file. Please ensure that you have read/write permission to access log folders and files.
E3002	The specified path is invalid (for example: The specified path is not mapped to a drive).
E3003	The specified path, file name or both exceed the system defined length. For Example: On Windows-based platforms, the path name must be less than 248 characters and file names less than 260 characters.
E3004	The specified path directory is read-only or is not empty.
E3005	Please ensure that the file is currently not in use by other process and/or has not exceeded the file size limit.
E3006	Invalid filename: Check whether the file name contains a colon (:) in the middle of the string.
E3007	Select at least one measurement from the table before you save.
E3008	There are currently no results to save. Please run a measurement.
E3010	Access to file/directory denied. Please ensure that the file/directory has read/write permissions.
E3012	Folder does not exist.
E4000	Not enough data points. Unable to render plot(s).
E4001	Internal Measurement Error. Please remove a measurement and try again.
E4002	Not enough data points for spectrum computation.
E4003	Low Memory. The entire waveform was not processed and the measurement results are for part of the waveform.
E4004	Edge Extraction failure.
E4005	Qualifier: Horizontal parameters do not match across waveforms.
W4006	A maximum of 10 qualifier zones are supported. The entire waveform will not be processed and hence partial measurement results are available.

About Algorithms

The DDRA application can take measurements by selecting either Clock, Strobe, Data or Chip Select as sources. The number of waveforms used by the application depends on the type of measurement being taken.

Oscilloscope Setup Guidelines

For all measurements, use the following guidelines to set up the oscilloscope:

- The signal is any channel, reference, or math waveform.
- The vertical scale for the waveform must be set so that the waveform does not exceed the vertical range of the oscilloscope.
- The sample rate must be set to capture sufficient waveform detail and avoid aliasing.
- Longer record lengths increase measurement accuracy but the oscilloscope takes longer to measure each waveform.

Search and Mark Algorithms

DDR search algorithms look for patterns in data (DQ) to determine start and end of bursts. All searches use histogram analysis around edges found in the waveform, where edges are determined using the supplied min/max/mid levels. These levels and the speed grade are configurable in the DDRA application's first and fifth steps.

DDR search operates by scanning through both DQ and DQS and measuring peak to peak voltage and mid-levels. The mid-level detected on DQS is then used with a 10% hysteresis band to extract the edges from the DQS signal. These edges are stored and are then used for bit rate estimation.

All DDR searches use waveform shape expectations to determine start or stop of a Read and Write burst. The application will scan for first the start of any burst, followed by that burst's termination condition. Once a start condition has been found, only the termination condition will be searched for until the end-of-record.

Data Eye Width

Data Eye Width is common for both Read and Write bursts. The type of burst is determined by the ASM settings. If a waveform contains multiple bursts of the same kind, the Data Eye Width is calculated and respective Eye Diagram rendered for all bursts within one acquisition. Its uses the DPOJET measurement, Eye width with eye diagram plot enabled. Set DQ to Data signal and DQS to explicit clock edge.

If an explicit clock is used the DQS eye will be superimposed onto the Data Eye diagram. The superimposed eye can be turned off from Eye diagram plot configuration panel. For Write bursts, the DQS eye is offset from the Data eye (crossing in the center), whereas eye diagrams overlap for Read bursts. The position of eye diagrams can be controlled using the Ref Clock alignment property on the Eye diagram plot configuration panel. The left and center options indicate where the DQS crossing shall be located so

that Data Eye will maintain its normal position. Left is suitable for Read bursts and center for Write bursts. Use Auto to automatically determine the offset property.

For more details, refer to the topic “Eye Width” of the DPOJET help.

tDH-Diff(base)

tDH-Diff(base) is defined as the input hold time between Data (DQ) and Differential Strobe (DQS) signal. It uses the DPOJET measurement, DDR-Hold-Diff. This measurement requires you to set up correct reference levels for DQS and DQ signals for different speeds. The DDRA application will set up these levels automatically when “Auto” mode is selected. When manual mode is selected, then these reference levels are calculated based on your input for Vref and Vdd.

For more details, refer to the topic “DDR-Hold-Diff” of the DPOJET help.

tDH-SE(base)

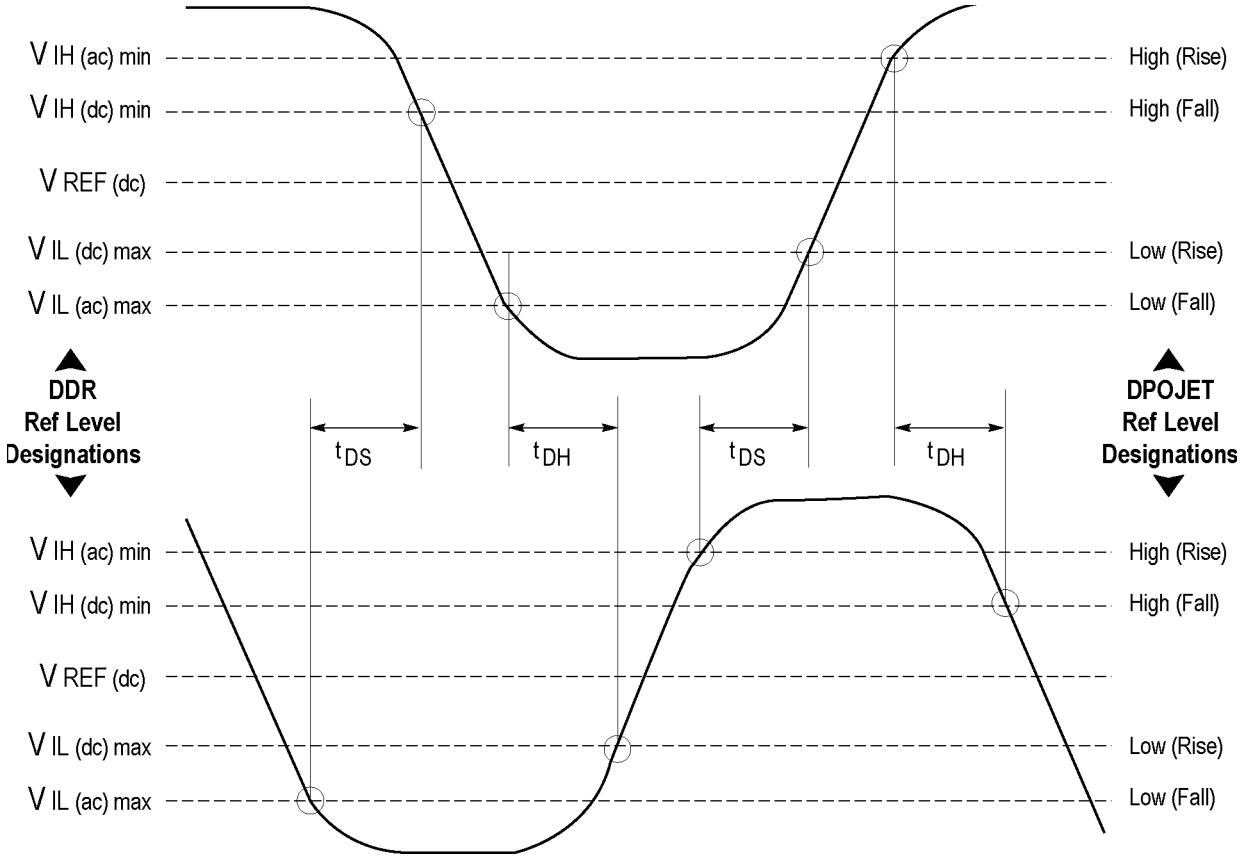
tDH-SE(base) is defined as the input hold time between Data (DQ) and Single-ended Strobe (DQS) signal. It uses the DPOJET measurement, DDR-Hold-SE. The base measurement does not support derating specified in JEDEC specifications based on slew rate of the signals measured.

For more details, refer to the topic “DDR-Hold-SE” of the DPOJET help.

tDS-Diff(base)

tDS-Diff(base) is defined as the input setup time between Data (DQ) and Differential Strobe (DQS) signal. It uses the DPOJET measurement, Setup. The base measurement does not support derating specified in JEDEC specifications based on slew rate of the signals measured.

For more details, refer to the topic “DDR-Setup-Diff” of the DPOJET help.



The configured values of Vdd and Vref are used to calculate $V_{IH(ac)}$min $V_{IH(dc)}$min, $V_{IL(dc)}$max and $V_{IL(ac)}$max, which are applied on the input signal. These levels are further used for calculating Setup and Hold measurements.

The relationship between Vdd and Vref for DDR2 standard is as shown in the following tables. For other DDR standards, please refer to their JEDEC specifications.

Table 9: Input DC logic Level

Symbol	Parameter	Min	Max	Units
$V_{IH(dc)}$	DC input logic high	Vref+0.125	–	V
$V_{IL(dc)}$	DC input logic low	–0.3	Vref–0.125	V

Table 10: Input AC logic Level

		DDR2–400, DDR2–533		DDR2–667,DDR2–800		Units
Symbol	Parameter	Min	Max	Min	Max	
$V_{IH(ac)}$	AC input logic high	Vref+0.250	x	Vref+0.200	–	V
$V_{IL(ac)}$	AC input logic low	–	Vref–0.250	–	Vref+0.200	V

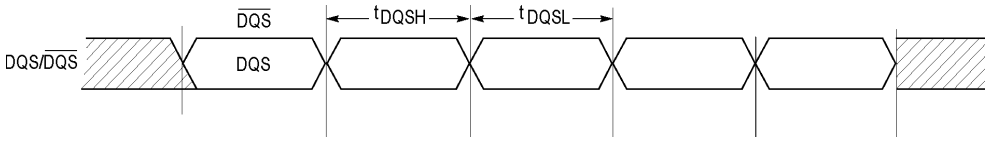
tDS-SE(base)

tDS-SE(base) is defined as the input setup time between Data (DQ) and Single-ended Strobe (DQS) signal. It uses the DPOJET measurement, DDR-Setup-SE. The base measurement does not support derating specified in JEDEC specifications based on slew rate of the signals measured.

For more details, refer to the topic “DDR-Setup-SE” of the DPOJET help.

tDQSH

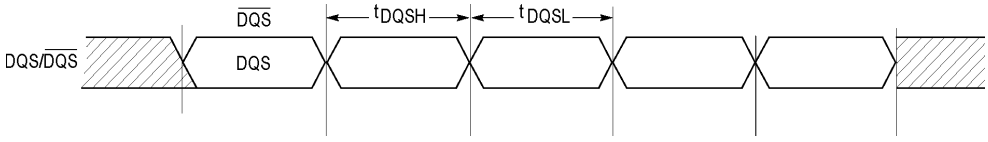
tDQSH is the high pulse width on the Strobe DQS input. It uses the DPOJET measurement, Pos Width.



For more details, refer to the topic “Positive and Negative Width” of the DPOJET help.

tDQSL

tDQSL is the low pulse width on the Strobe DQS input. It uses the DPOJET measurement, Neg Width.



For more details, refer to the topic “Positive and Negative Width” of the DPOJET help.

tCH(abs)

tCH(abs) is the High pulse width on the clock signal. It uses the DPOJET measurement, Pos Width.

For more details, refer to the topic “Positive and Negative Width” of the DPOJET help.

tCH(avg)

tCH(avg) is defined as the average high pulse width and is calculated across a 200-cycle window of high pulses. It uses the DPOJET measurement, DDR tCH(avg).

The application calculates this measurement using the following equation:

$$tCH(avg) = \left(\sum_{j=1}^{N} tCH_j \right) / \left(N \times tCK(avg) \right)$$

Where:

N=200, which is configurable.

tCK(abs)

tCK(abs) is the absolute clock period. It uses the DPOJET measurement, Period.

For more details, refer to the topic “Period” of the DPOJET help.

tCK(avg)

tCK(avg) is calculated as the average clock period across a 200-cycle window of low pulses. It uses the DPOJET measurement, DDR tCK(avg).

The application calculates this measurement using the following equation:

$$tCK(avg) = \left(\sum_{j=1}^{200} tCK_j \right) / N$$

Where:

N=200, which is configurable.

Range: 200≤N≤1M

tCL(abs)

tCL(abs) is the Low pulse width on the clock signal. It uses the DPOJET measurement, Neg Width.

For more details, refer to the topic "Positive and Negative Width" of the DPOJET help.

tCL(avg)

tCL(avg) is defined as the average LOW pulse width calculated across 200-cycle window of consecutive low pulses. It uses the DPOJET measurement, DDR tCL(avg).

The application calculates this measurement using the following equation:

$$tCL(avg) = \left(\sum_{j=1}^{N} tCL_j \right) / (N \times tCK(avg))$$

Where:

N=200, which is configurable.

Range: 200≤N≤1M

tHP

tHP is the minimum of the absolute half period of the actual input clock. It is similar to DPOJET's Period measurement where the edge type is clock with edges selection set to both. Only the minimum result statistics will be compared with the limit values for PASS/FAIL status.

The application calculates this measurement using the following equation:

$$tHP = Min(tCH(abs), tCL(abs))$$

Where:

tCH(abs) is the minimum of the actual instantaneous clock high time.

tCL(abs) is the minimum of the actual instantaneous clock low time.

tERR

tERR (Timing error) is defined as the cumulative error across multiple consecutive cycles from tCK(avg). The application calculates this measurement using the following equation:

$$tERR(nper) = \left(\sum_{j=1}^{i+n-1} tCK_j \right) - n \times tCK(avg)$$

Where:

For tERR(nper):

n=2 for *tERR(2 per)*

n=3 for *tERR(3 per)*

n=4 for *tERR(4 per)*

n=5 for *tERR(5 per)*

n=6 for *tERR(6 per)*

n=7 for *tERR(7 per)*

n=8 for *tERR(8 per)*

n=9 for *tERR(9 per)*

n=10 for *tERR(10 per)*

n=11 for *tERR(11 per)*

n=12 for *tERR(12 per)*

For tERR(m-nper):

$6 \leq n \leq 10$ for *tERR(6–10 per)*

$11 \leq n \leq 50$ for *tERR(11–50 per)*

$13 \leq n \leq 50$ for *tERR(13–50 per)*

tJIT(cc)

tJIT(cc) is defined as the difference in clock period between two consecutive clock cycles. It uses the DPOJET measurement, CC–Period.

The application calculates this measurement using the following equation:

$$tJIT(cc) = Max\ of\ |tCK_{i+1} - tCK_i|$$

tJIT(duty)

tJIT(duty) is defined as the cumulative set of the largest deviation of any single tCH from tCH(avg) and the largest deviation of any single tCL from tCL(avg). It uses the DPOJET measurement, DDR tJIT(duty).

The application calculates this measurement using the following equation:

$$tJIT(duty) = Min/max\ of\ \{tJIT(CH), tJIT(CL)\}$$

Where:

$tJIT(CH) = \{tCHi - tCH(avg)\}$

$tJIT(CL) = \{tCLi - tCL(avg)\}$

Where:

i=1 to 200

tJIT(per)

tJIT(per) is defined as the largest deviation of any single tCK from tCK(avg). It uses the DPOJET measurement, DDR tJIT(per).

The application calculates this measurement using the following equation:

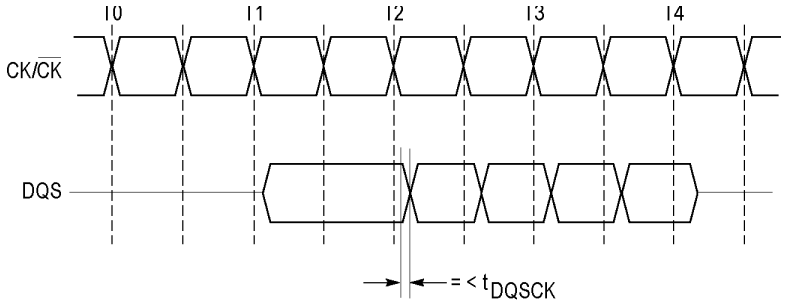
$$tJIT(per) = Min/max\ of\ \{tCK_i - tCK(avg)\}$$

Where:

i=1 to 200

tDQSCK-Diff

tDQSCK-Diff is the DQS output access time from CK or $\overline{CK}$.



The application calculates this measurement using the following equation:

$$Skew = T_n - T_{DQS(n)}$$

for mid level

Where:

T_n specifies the clock edges.

$T_{DQS(n)}$ specifies the DQS edges.

The edge locations are determined by the mid-reference voltage levels. This is a skew measurement between the rising edge of DQS and the rising edge of clock.

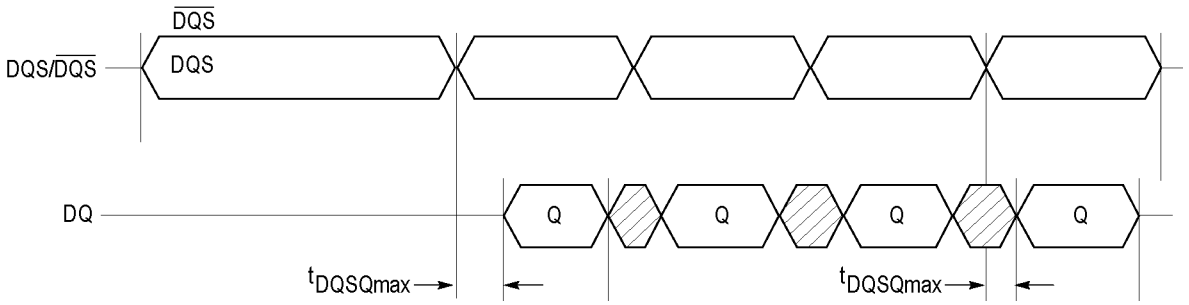
For more details, refer to the topic "**Skew**" of the DPOJET help.

NOTE. *The JEDEC standard specifies that tDQSCK is the actual position of a rising strobe edge relative to CK, $\overline{CK}$. Hence, DQS should be in phase with CK. When DQS and CK are not in phase, there could be possibility of probe polarity interchange. You can overcome this by changing the edge direction to "Opposite as From" under edges configure tab for Skew measurements.*

For more details, refer to the topic "Configuring Edges for Skew Measurement" of the DPOJET help.

tDQSQ-Diff

tDQSQ-Diff is the DQS-DQ skew for DQS and associated DQ signals. It uses the DPOJET measurement, Setup. Set JEDEC standard reference levels for DQ.



For more details, refer to the topic "**Setup**" of the DPOJET help.

tAC-Diff

tAC-Diff is the DQ output access time from CK or $\overline{CK}$. It uses the DPOJET measurement, DDR-Setup-Diff. Set DQ as the clock source and DQS as the differential source. Set appropriate reference levels for DQ.

For more details, refer to the topic "**DDR-Setup-Diff**" of the DPOJET help.

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