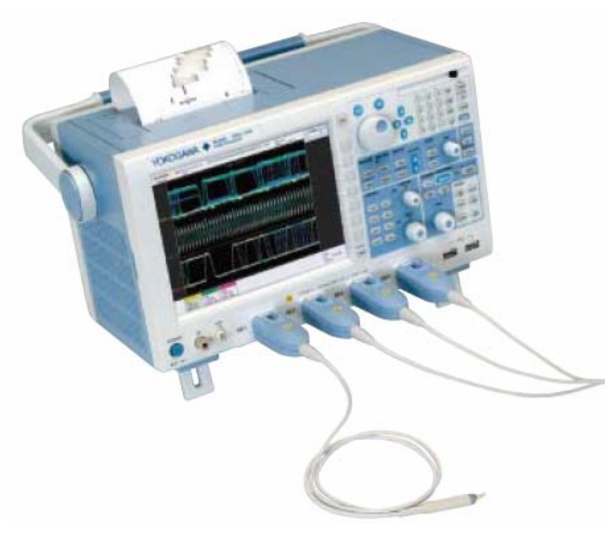
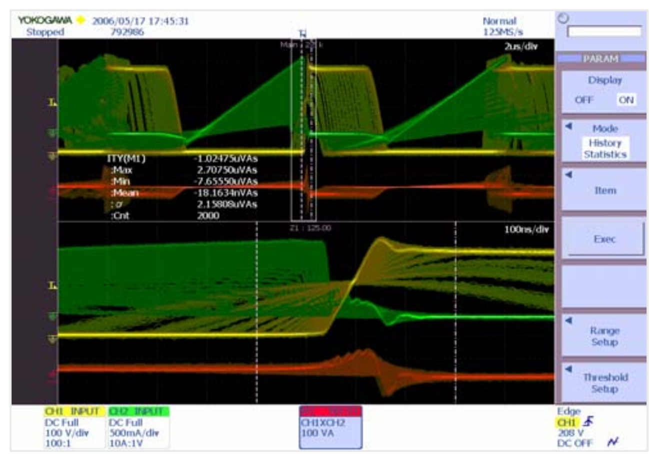
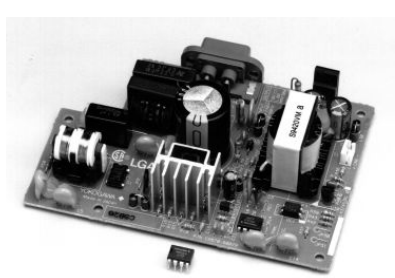
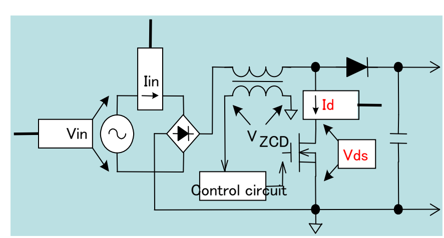
DL9000 Series Power Analysis Application Handbook









Contents

Power Electronics

People's lives are touched by a variety of power electronic products including inverter air conditioners, inverter fluorescent lamps, refreigerators, motors, amplifiers, and UPS. The power control boards for these products contain microcomputers that judge load conditions and allow for optimum control. Aside from the microcomputer, power control boards are made up of capacitors, filters, transformers, power modules, and other components (devices), plus power circuits. Figure 1 provides a technical classification of power circuits.

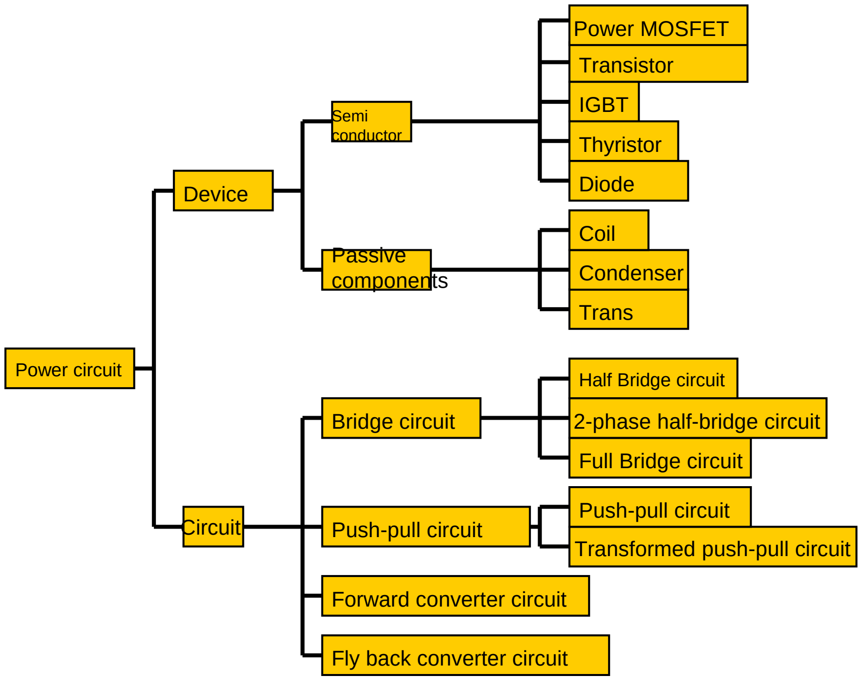


Fig 1 Technical classification of power circuits

As shown in figure 2, power electronics technologies are generally divided into *power circuits* and *control circuits.* Power circuits are composed of power devices such as MOSFETs and inductors and capacitors. The control circuits control the power circuits.

The main target applications for the DL9000 Power Supply Analysis Function are design and evaluation of power devices (semiconductors) and power circuits. Switching power supply technology depends greatly on MOSFET, IGBT, and other semiconductor switching devices. It is by no means an exaggeration to say that switching devices are the determining factor of overall performance in switching power supplies.

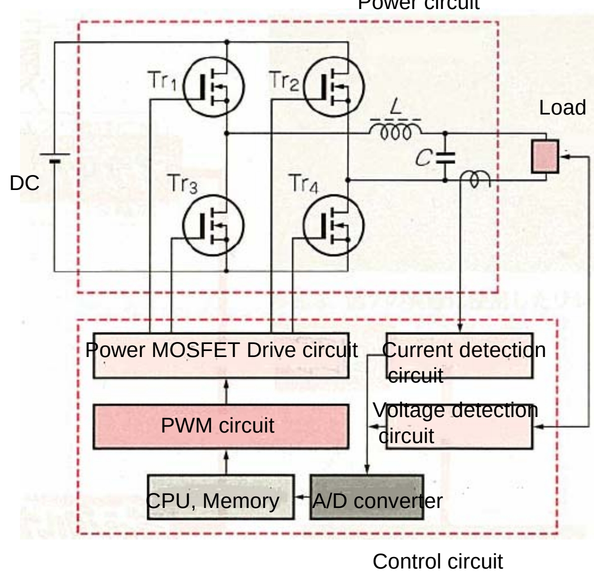


Fig 2 Example of Power Control Circuit

Switching Circuit Characteristics and Design Issues

What is Switching Circuit?

Switching circuits control voltage and current by taking advantage of the high-speed ON/OFF switching action of semiconductor devices. The voltage applied to the switching device can potentially be very high, and can result in "floating voltage" that is not referenced to ground. Such voltage is measured on a digital oscilloscope using a differential probe.

Features of Switching Circuit

Switching circuits have the following characteristics.

- Compactness, light weight, and high efficiency
- Good accuracy across a broad range of voltages and currents
- Good response to fluctuations in load

In general, series regulators experience a large amount of power loss, and are unable to control power very efficiently. By contrast, semiconductor switches that alternate (switch) between the ON and OFF states have low loss and allow for highly efficient control.

What is Switching Power Supply?

Switching power supplies employ switching circuits that utilize “switching” devices (elements that can turn a portion of the electric circuit ON and OFF, usually MOSFETs). Input transformation can take place in an AC-DC, DC-DC, or DC-AC converter.

Requirements for Switching Power Supply

Generally speaking, switching circuits must be designed to fulfill the following requirements.

1. High power conversion efficiency
   The circuit must convert power efficiently even under changing loads, waveform distortion, and other hindrances.
2. High reliability
   Users demand circuits that can handle sudden changes in peak loads and input voltages, and that have excellent temperature characteristics. It is also essential that they be immune to external noise (that they not experience breakdown or malfunction).
3. Countermeasures against harmonics
4. Low power consumption
   For example, there is demand for technology related to power savings such as PC suspend modes and the low standby powers of AV equipment remote controls.
5. Low price

From the above, we can cite the following issues with regard to the design of switching circuits (power supplies).

1. Reducing switching loss

2. Improving reliability (confirming ASO)

3. EMC (harmonic current suppression and noise reduction)

4. Lowering cost

The DL9000 Power Supply Analysis Function is a powerful testing and evaluation tool that aids with these challenges.

Measuring Switching Waveforms and Computing Loss:

Measurement Points and Waveform Example

Switching power supplies can respond efficiently to load fluctuations. Measurement of switching waveforms and computation of loss are two of the most typical items in evaluation of switching circuits, and are indispensible to making instruments more efficient and lower in power consumption. To improve power conversion efficiency, engineers must evaluate switching (device) loss.

As shown in figure 3 on the right, when measuring and computing switching loss on an oscilloscope, a differential and current probe are used to measure the switching device's:

Drain-to-source voltage (Vds); and
Drain current (Id).

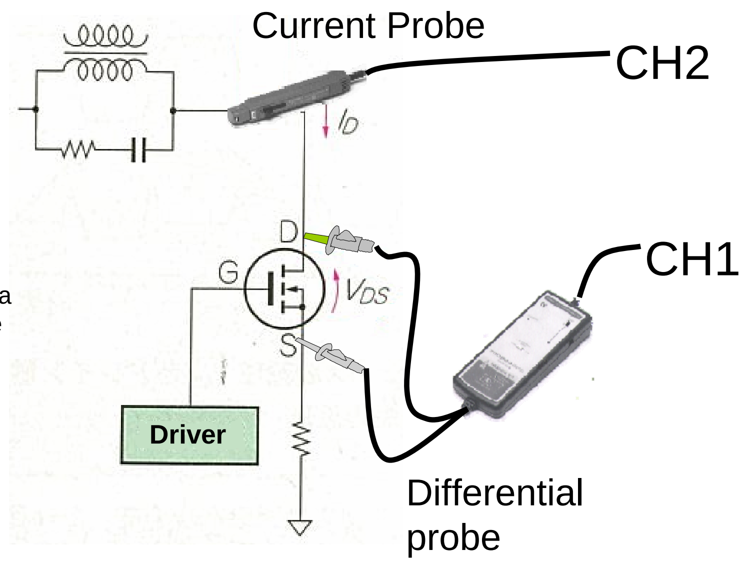


Fig 3 Probing Points

Switching loss can be defined as follows in terms of the switching device's processes:

(1) Power loss during the transition from the OFF state to the ON state — Turn-on loss (T1-T2)
(2) Power loss during the transition from the ON state to the OFF state — Turn-off loss (T3-T4)
(3) Per cycle loss — Total avg. loss (T1-T4)

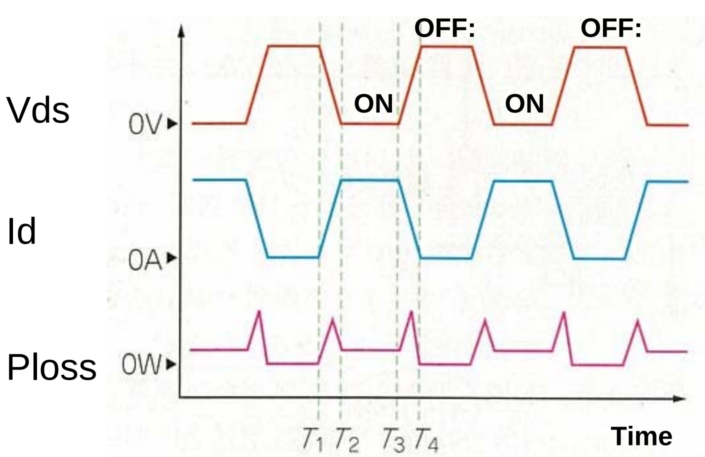


Fig 4 Example of Waveforms

Example)
Turn-on loss is defined by the following formula.

$$P_{loss(on)} : \int_{T1}^{T2} V_{ds}(t) \cdot I_d(t)\ dt$$

Using the DL9000 Power Supply Analysis function, the losses in (1)–(3) above are automatically computed from the measured waveform data. T1-T4 are specified with the range cursors of Measure parameter Wp.

Measuring Switching Loss Waveforms with the DL9000

Figure 5 is an example of measurement and computation of turn-off loss wavefroms using the DL9000. CH1 on the DL9000 measures drain-to-source voltage U (Vds) and CH2 measures drain current I (Id). **The loss waveform power (Ploss) is displayed simply by selecting the dedicated operator (Power). Switching loss (turn-on loss, turn-off loss, and per cycle loss) can be computed numerically using the dedicated parameter operator Wp, P.**

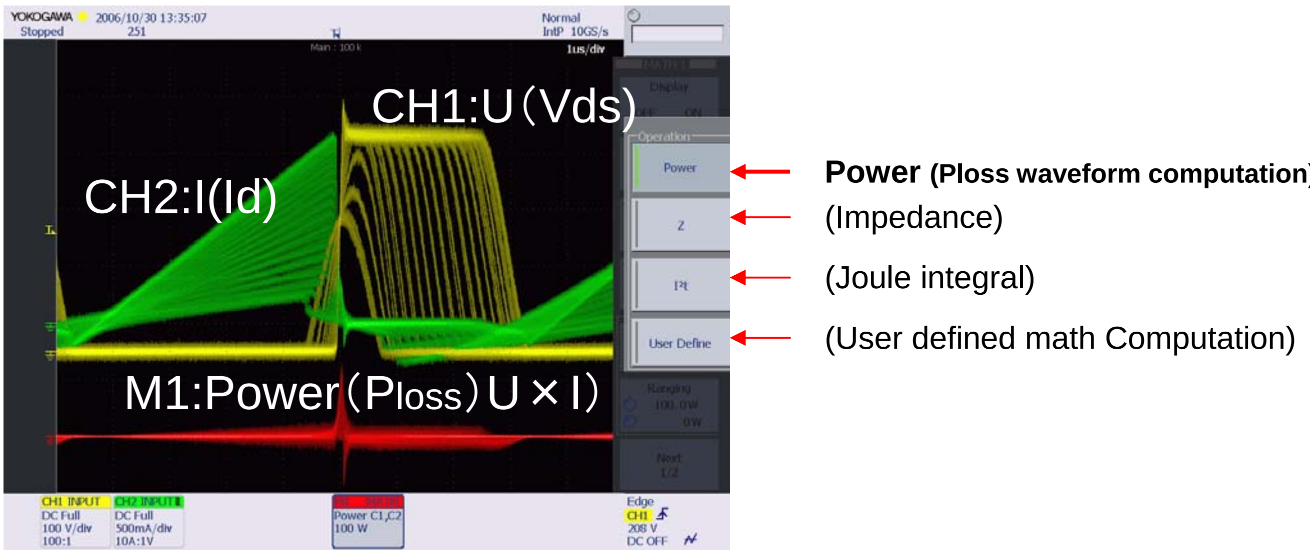


Fig 5 Example of Measurement Results of Turn-off loss
（APFC（Active Power Factor Correction) circuit)

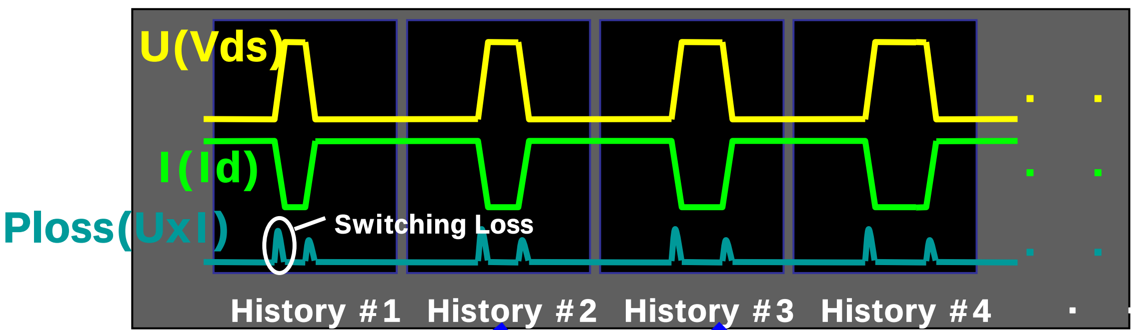
In figure 5, a trigger activates on the falling edge of the turn-off (Id) portion at which point the loss waveform is computed. However, by changing trigger conditions, you can simultaneously trigger on the turn-on portion as well. This allows you to also compute the waveform of the turn-on loss.

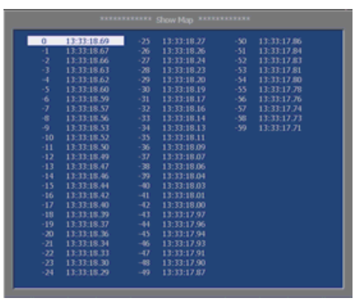
With the DL9000's Power Analysis function, in addition to the active power (Ploss) operation that computes the switching loss waveform in figure 5, you can also compute waveforms of the power supply analysis items of impedance, Joule integral, and user defined math. Whatever the computation, the computed result is displayed as a waveform simply by selecting the relevant operator from the menu.

Measuring Loss Using History Memory

With its high speed acquisition capabilities, the DL9000 offers a History Statistics function that is useful for measuring the turn-on and turn-off switching losses separately. History memory is a mechanism in which, when single screens are captured into short lengths of memory, the captured waveforms are stored in available memory space without any being discarded (stores waveforms of all cycles at **up to 2.5 million waveforms per second)**.

Figure 6 shows a process in which waveforms of each switching cycle are being stored in the DL9000's history memory. All switching cycle waveforms can be stored in history memory without omission because the DL9000 can perform high speed acquisition.





History Time Stamp Display

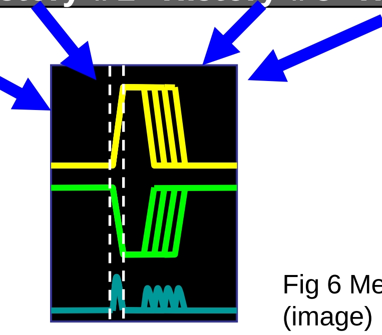


Fig 6 Measuring loss using History Memory (image)

After capture, each of the multiple captured switching cycle waveforms can be checked one at a time as in figure 7. You can also superimpose multiple cycles of waveforms on the display (see figure 5 on the previous page) for easy cycle-by-cycle comparisons.

This means that you can capture multiple cycles of waveforms into the history memory while varying the rated load applied to the switching device in order to evaluate the correlation between switching loss and load.

Furthermore, trends in the switching waveform over time can also be played back on the DL9000 screen for viewing at a later time by using the History Replay function.

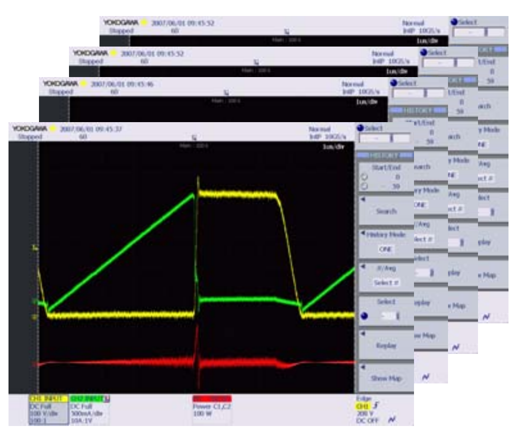
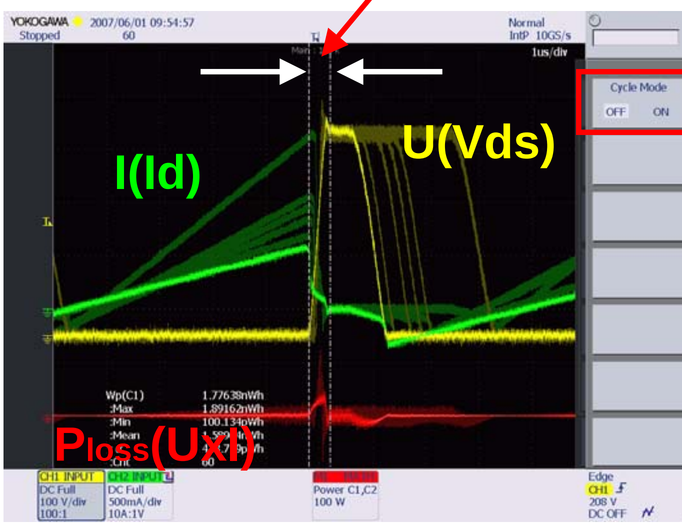


Fig 7

Computing the Total Loss in Multiple Switching Cycles

With the DL9000, you can compute parameter statistics on each waveform in history, therefore you can find statistical values for a specified range in each screen. This gives you the ability to compute statistics on switching loss waveforms that span multiple cycles, as well as the total switching loss for those cycles.

Turn-off loss computation range (can be freely defined by the user)



Set Cycle Mode(See the next page) OFF

<u>Example of computing statistics on turn-off loss over many cycles:</u>
Max: Max. loss
Min: Min. loss
Mean: Ave. loss
Cnt: number of cycles

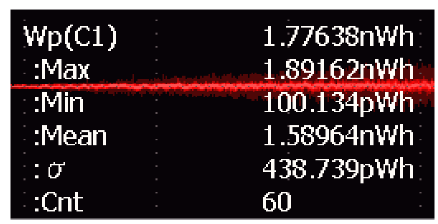


Fig 8 Example of statistical processing of switching loss using History Statistics function

Switching loss (Ploss) can be computed with parameter operator Wp. Figure 8 shows that if you place range cursors in the range that corresponds to T3 and T4 in figure 4, you can automatically measure the loss you wish to determine (in this case, the turn-off loss).

In the example in figure 8, waveforms of the turn-off portions of 60 switching cycles are captured into memory and superimposed on the screen. Using the History Statistics (Statistics) function, you can perform statistical calculations on that data to find the maximum, minimum, and average loss. With these statistics you can determine the total loss of all the captured cycles. Total loss of the turn-on and turn-off portions can be found separately.

From the above history statistics, the total loss of the turn-off portion is calculated as:

total loss (average loss x no. of cycles)

= Mean x Cnt

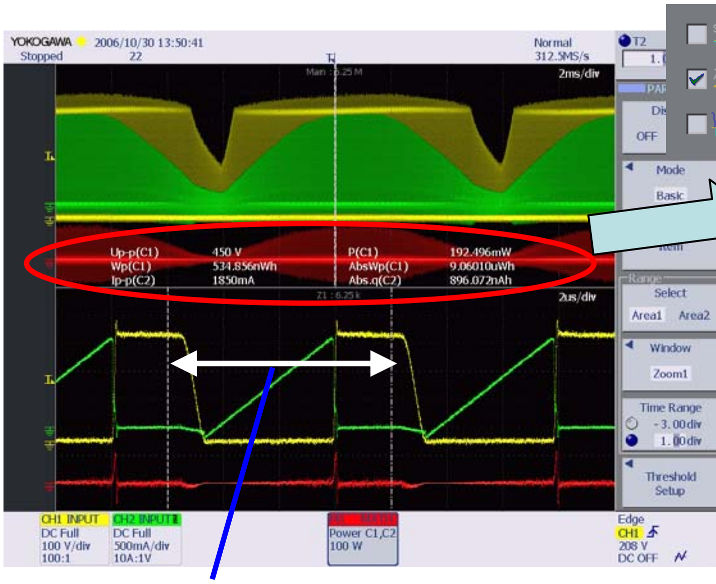
In the above example, this yields the following result.

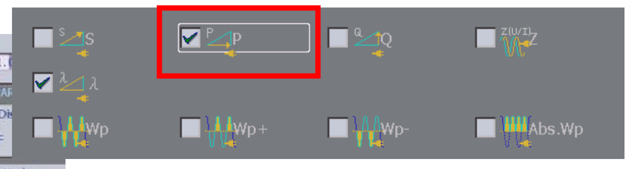
Total (turn-off) loss = 1.59 [nWh] x 60 = 95.4 [nWh]

Computing the Total Loss per Cycle

The total power loss on any given cycle (i.e. the average loss, which equals switching loss + transmission loss) can be automatically computed simply by selecting the parameter operator P. The arbitrary cycle waveform to use for computation is specified with the range cursors that define the computation area for the “statistics over an area parameter computation” function. The DL9000 automatically identifies and extracts one cycle within that area, calculates parameter P (total loss) as shown below, and displays the result. The variable T in the expression below is the time of that one cycle that the DL9000 automatically identifies. In the example in figure 9, a result of 192.496 mW was calculated.

$$P_{loss(Ave)} : \frac{1}{T}\int_0^T V_{ds}(t)\ I_d(t)\ dt$$





Example)

Specify range cursors such that the cycle on which total loss is to be determined lies between them

Note)

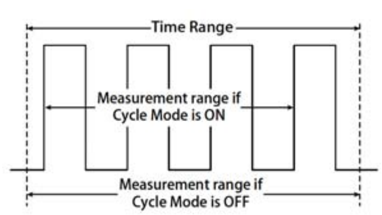
The dynamic range of the voltage applied to the switching device is wide; it can be a few hundred mV upon continuity (when turned ON) as opposed to a few hundred V when turned OFF. These cannot be measured accurately with just a single waveform capture on common 8-bit resolution digital oscilloscopes. Depending on the oscilloscope, loss computation through waveform observation may not be intended as a precise way measure an absolute value, but rather as a simple means of computation.

Fig 9 Example of Computing the Total Loss per Cycle

The DL9000 has a wide variety of dedicated items for power related parameter measurement. Depending on the parameter, the measured range may differ as follows.

Entire measured range: Upk, U-pk, Up-p, I+pk, Ip-p, I^2t
Sections that can be extracted as cycles in the measured range: Other than the above

However, you can select the range under test for the operators used to compute switching loss, Wp, Wp+, Wp-, and Abs.Wp, and the operators of ampere hours q, q+, and q- (switching of the cycle mode ON and OFF).



DL9000 Cycle Statistics

What is Cycle Statistics?

The cycles of the displayed waveform are determined in order from the oldest data, the selected parameters for automated measurement are measured on the data within the cycle, and statistical processing is performed. The cycle statistics function can even use channels other than those targeted for statistical processing as a reference waveform. For example, you could set the commercial power supply waveform on CH1 as the reference cycle, then measure the power consumption on each cycle of the MATH1 power waveform.

Statistical Items

Max: Maximum
Min: Minimum value
Mean: Mean value
σ : Standard deviation
Cnt: Number of measured values used in the statistical processing

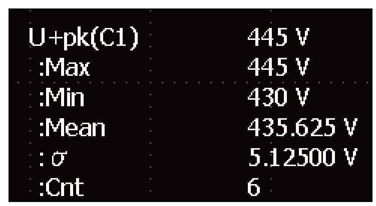


Fig 10 Example of Cycle Statistics

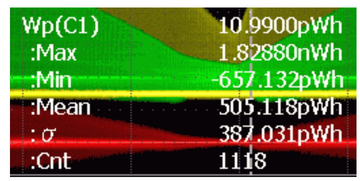
In the example in figure 10, six cycles' worth of the Vds waveform is measured, and cycle statistics for the maximum surge voltage (parameter: U+pk) are computed per switching cycle. The maximum, minimum, and average of the cycles were computed to be 445 V, 430 V, and 435.625 V, respectively.

Displaying Trends in Loss per Cycle

With the DL9000's up to 6.25 MW–long memory, you can continuously acquire multiple cycles of voltage (Vds) and current (Id) data and compute switching loss (Vds x Id) on the M1 waveform. By using the DL9000's Cycle Statistics function, you can perform statistical processing on the computed results of loss (parameter: Wp) for each cycle in a specified range. Furthermore, you can view lists and trend graphs of per cycle changes in loss on the DL9000, making it useful for the following types of applications.

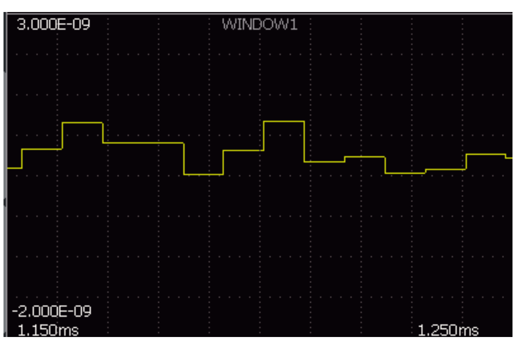
•Check trends in excessive changes per switching cycle from power ON to stable operation
•Capture multiple cycles of waveforms while varying the load applied to the switching device, and check trends in total loss per cycle

Results of statistical computation of switching loss per cycle (Wp) in data of multiple cycles (example: 1,118 cycles)



The computation range for cycle statistics can be arbitrarily assigned with cursors

Fig 11 Example of Cycle Statistics computation



Loss Trend Display of Zoomed Data per Cycle

List Display

In the example in the figure above (Window 1), the computed per cycle loss for the approximately 10 cycles displayed in the zoom area is trend-displayed in a time series. In Window 2, the computed results of loss are displayed in a list by cycle. The maximum and minimum values are marked allowing easy identification of the cycle portion of maximum (or minimum) loss, and that part of the waveform can be displayed in the zoom area.

Measuring the Area of Safe Operation (ASO)

To increase the reliability of switching power supply circuits, engineers must consider how to make the power device operate within operating boundaries. To do this, the relationship between voltage and current is plotted on an X-Y graph to evaluate the characteristics of the device's active region. In the case of MOSFET, we confirm that the power device operates within the area of safe operation (ASO) shown in the figure 12(the area under the lines). The points of measurement are the same as those shown in the figure 3.

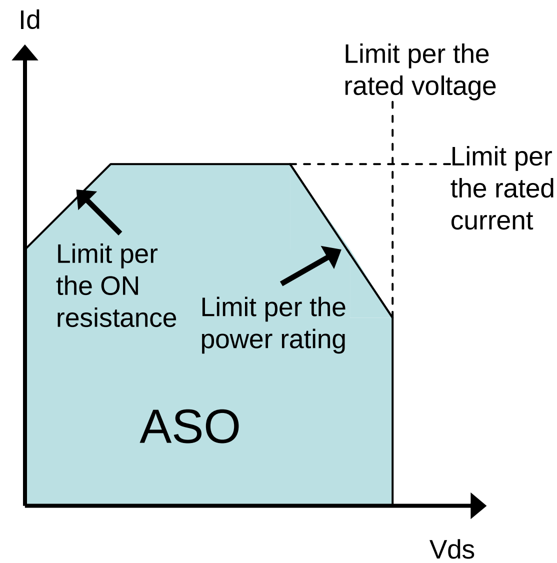


Fig 12 ASO definition

With the DL9000, levels are taken from CH1 (Vds) for the X-axis and the CH2 (Id) waveform for the Y-axis. ASO can be confirmed by looking at the correlation between the two input signal levels. Simultaneous observation of X-Y waveforms and normal T-Y waveforms (waveform display using time axis and level) is possible. Additionally, since you can place the cursor on an arbitrary location on the displayed ASO waveform to read its value, you can easily check whether the level lies within the limit.

Specifying the area from the T-Y waveform and displaying the ASO

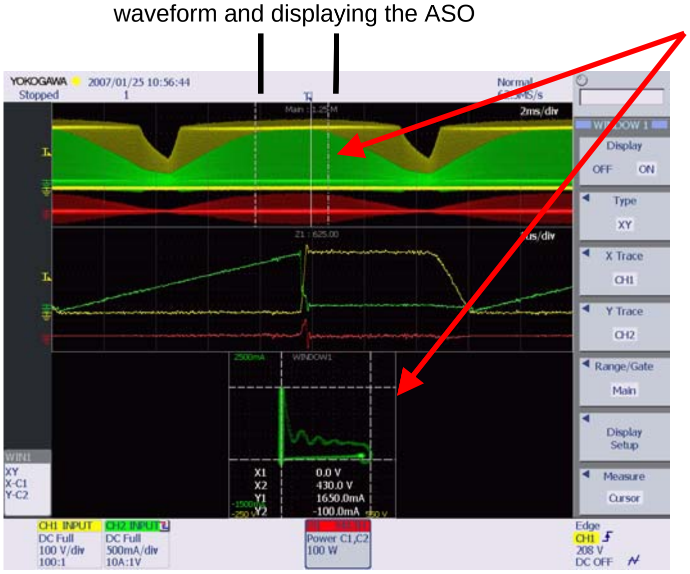


Fig 13 Example of ASO measurement by DL9000

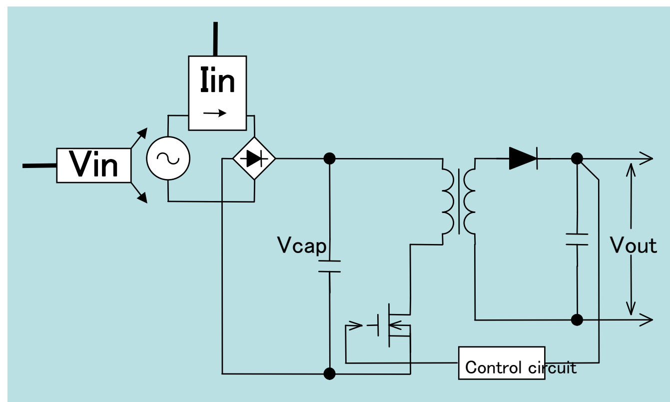
Range cursors are placed on the T-Y waveform, and the X-Y (ASO) waveform of the corresponding range (cycle) is displayed at the same time. Thus, the corresponding ASO can be evaluated in the selection of conditions (points) from the T-Y waveform such as when the power is turned ON or when the load fluctuates.

Also, you can display the cycle waveform (T-Y waveform) for which you wish to view the ASO in the zoom area, and display the X-Y graph (ASO) using the data from the range displayed in that zoom area. By auto-scrolling the zoom area, you can continuously check trends in the cycle-by-cycle ASO in the X-Y screen.

Fig 14 Example of cursor measurement on the ASO waveform

Measuring Inrush Current Using I^2t

Capacitor input–type switching power supplies exhibit large inrush currents on start-up. Inrush current is measured to check whether current in excess of the allowed current value is flowing in the various parts. Also, the key design parameter I^2t (the maximum current squared x time) is checked when selecting fuses.



■Checking I^2t: the Fuse Selection Parameter

When using the dedicated power supply parameters provided with the DL9000 Power Supply Analysis function, you can measure I^2t (current squared x time) directly. And if you also use MATH (computation functions) you can display the I^2t result as a waveform for visual confirmation.

The points of measurement are represented by Vin and Iin in the figure above. To measure the value of a desired portion, you can use cursors on the measured waveform to define a range. As you no longer need to perform a separate calculation using the measured current value as before, reliability is increased, and the time required for evaluations is reduced.

Measuring Line (Power) Quality

Designing a switching power supply requires evaluating the quality of the switching power supply's primary side line power. The actual power line is not an ideal sinewave, but rather includes distortion and other phenomena. Such anomalies affect power consumption, efficiency, and reliability, therefore it is important to measure the line (power) quality.

The DL9000 Power Supply Analysis function comes with a wealth of parameter operators for measuring the line (power) quality such as apparent power, active power, power factor, and other characteristics (see the next page for details on parameter operators).

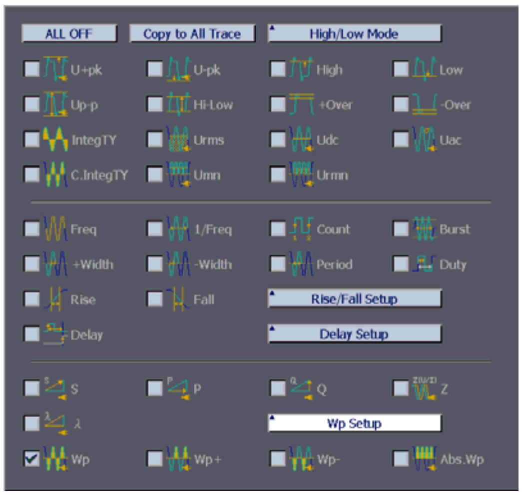


Fig 15 Measurement items for voltage channel(CH1, CH3)

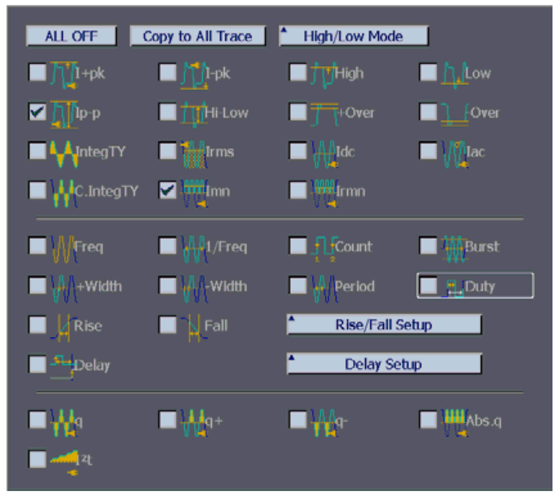


Fig 16 Measurement items for current channels(CH2、CH4)

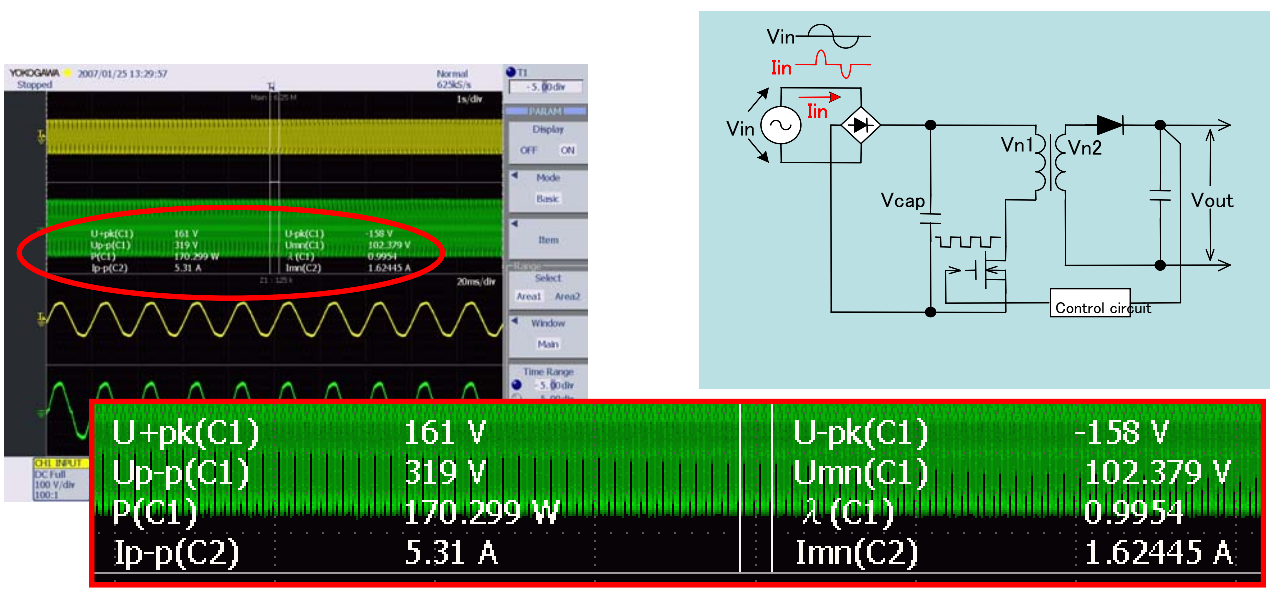


Fig 17 Example of measuremnt and computation by DL9000

Performing Automated Measurement of Parameters with the DL9000 Power Supply Analysis Option

The following are the dedicated power supply analysis parameter operators shown in figures 15 and 16 on the previous page.

Parameters for Voltage

$U\ [V]\quad U_{rms} : \sqrt{\frac{1}{T}\int_0^T u(t)^2 dt}$

$U_{mn} : \frac{\pi}{2\sqrt{2}}\frac{1}{T}\int_0^T |u(t)|\,dt$

$U_{rmn} : \frac{1}{T}\int_0^T |u(t)|\,dt$

$U_{dc} : \frac{1}{T}\int_0^T u(t)dt$

$U_{ac} : \sqrt{U_{rms}{}^2 - U_{dc}{}^2}$

U_{+pk} : *Maximum value*

U_{-pk} : *Minimum value*

U_{p-p} : *Peak to Peak value*

Parameters for Current

$I\,[A]\quad I_{rms} : \sqrt{\frac{1}{T}\int_0^T i(t)^2 dt}$

$I_{mn} : \frac{\pi}{2\sqrt{2}}\frac{1}{T}\int_0^T |i(t)|\,dt$

$I_{rmn} : \frac{1}{T}\int_0^T |i(t)|\,dt$

$I_{dc} : \frac{1}{T}\int_0^T i(t)dt$

$I_{ac} : \sqrt{I_{rms}{}^2 - I_{dc}{}^2}$

I_{+pk} : *Maximum value*

I_{-pk} : *Minimum value*

I_{p-p} : *Peak to Peak value*

Other Parameters

Active power	$P[W]$	$\frac{1}{T}\int_0^T u(t)\cdot i(t)\ dt$
Apparent power	$S[VA]$	$U_{rms}\cdot I_{rms}$
Reactive power	$Q[\mathrm{var}]$	$\sqrt{S^2 - P^2}$
Power factor	λ	$\frac{P}{S}$
Impedance	$Z[\Omega]$	$\frac{U_{rms}}{I_{rms}}$
Watt hour	$W_p, W_{p+}, W_{p-}[Wh]$	$\int_0^T u(t)\cdot i(t)\ dt$
Ampere hour	$q, q_+, q_-[Ah]$	$\sum_{N=0}^{n} I$
I2t (Joule integral)	I^2t	$\int_0^T i^2(t)\ dt$

Analyzing Harmonics

Normally when a load is connected to a power supply, the flowing current is continuous and contains a large amount of distortion. The voltage waveform also distorts according to the harmonic current. As this can cause problems with equipment, a "Guideline for Reduction of Harmonic Emmission" has been put in place.

The DL9000 allows you to analyze harmonics emitted from a DUT for each applicable class (A–D). We recommend that you use our digital powermeters and harmonic measurement software (model 761921) to perform precise measurements that conform to the standard, but the DL9000 series' harmonic analysis functions are affective tools for rough evaluations of the characteristics.

Electrical and electronic equipment having an input current up to 16 A per phase

Class A

- Balanced 3-phase equipment
- Household appliances, excluding equipment identified as Class D
- Tools excluding portable tools (portable tools are Class B)
- Dimmers for incandescent lamps
- Audio equipment
- Equipment not specified in 1 of the other 3 classes (B, C, and D)

Class B

- Portable tools
- Non-commercial arc welders

Class C

Lighting equipment

Class D

Television receivers, personal computers (PCs), and PC monitors with a rated power of 600 W or less

Target equipments and classification

With the DL9000, you can compute the harmonics emitted from the DUT determined by the IEC61000-3-2 standard for each applicable class (A–D), and display the results on a bar graph or list that allows you to compare the harmonic current limit values with the computed values.

The actual measured value of each harmonic order is displayed along with the limit values, and any data exceeding the limit is marked.

Fig 18 Example of List Display

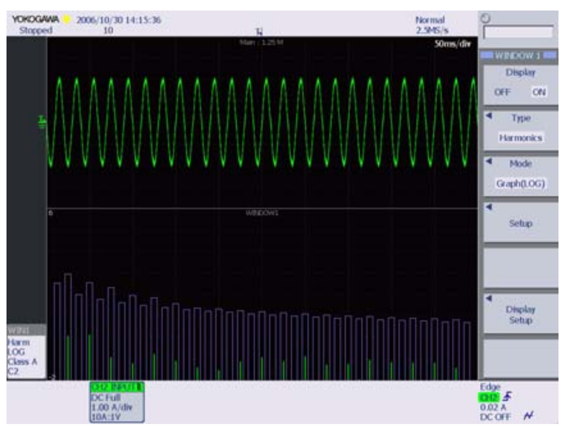


Fig 19 Example of Graph Display

Correcting (Auto-Deskewing) the Difference in the Transfer Time of Analyzed Signals

As described up to now, switching loss is computed by multiplication of Vds and Id. Delay occurs in the output because differential and current probes have built in amps. This delay is different for every probe. Along with the increasing speeds of switching frequencies, the effect that probe-specific propogation delay has on switching loss computation results is becoming a bigger and bigger problem.

It is necessary to adjust the unique signal transmission delay (skew) that is present in the various types of probes used for power supply measurement. This ensures accurate measurement and computation of switching loss.

With the DL9000 you can automatically adjust the skew with a simple operation. After connecting the probe, simply select a reference signal for the adjustment (voltage or current), and press the Auto Deskew Exec key.

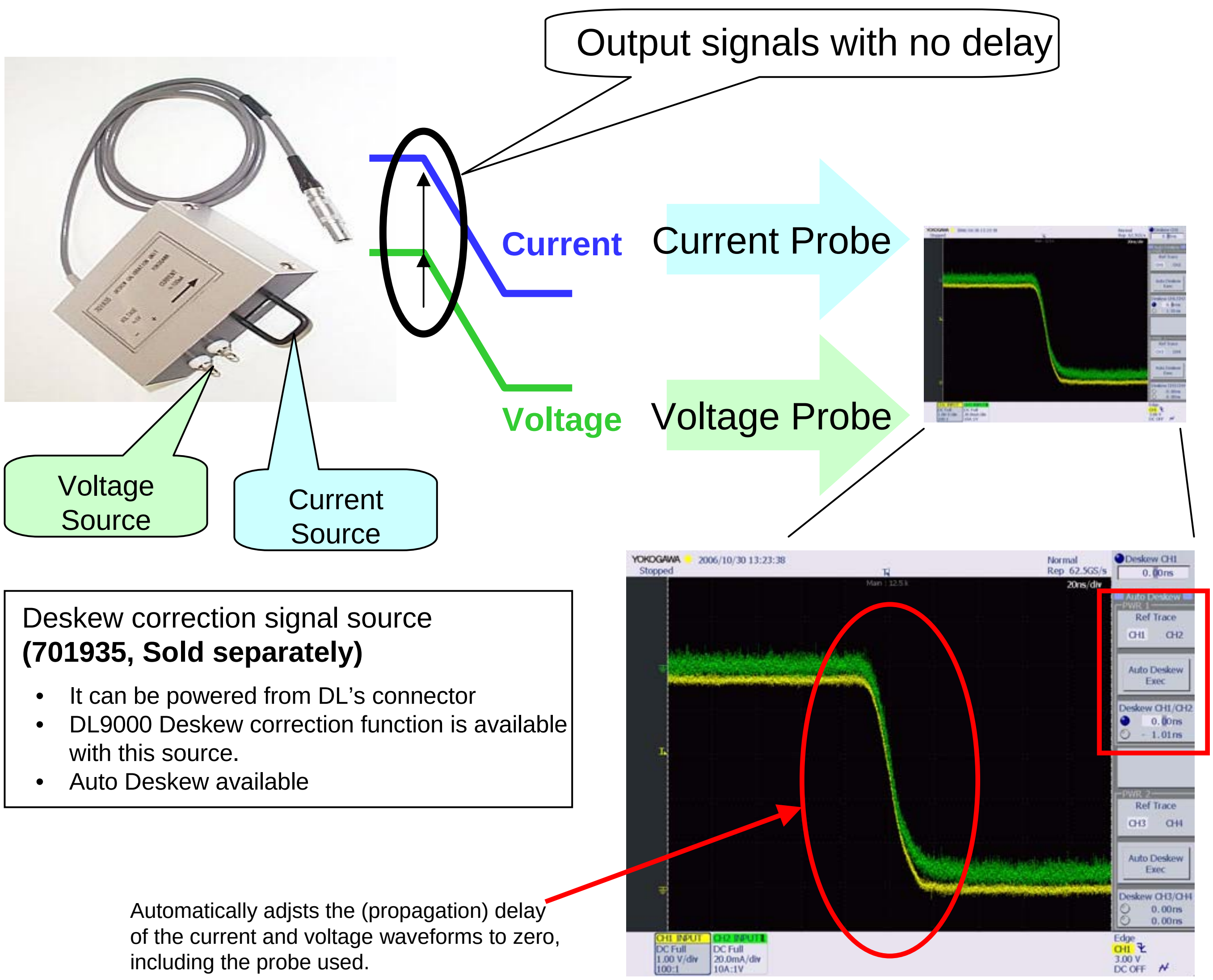


Fig 20 Auto Deskew

Evaluating Power Supplies Using the DL9000: Summary of Key Points

The following is a summary based on the information presented up to now that highlights the key points in using the DL9000 to analyze and evaluate power supplies.

<Key Points>
Observing circuit-internal waveforms, checking operating status, and confirming the safety of, and loss in, the devices used.

(1) Observing Waveforms and Measuring Parameters
Observation of I/O waveforms, control signals, waveforms during excessive operations, and various types of waveforms that occur during abnormalities and in other situations, and measurement of parameters

(2) Measuring Switching Loss
Power measurement using integrals of voltage and current of the switching device

(3) Confirming the the Area of Safe Operation (ASO)
The operating status of the voltage, current, and power values of the switching device

(4) Harmonic Analysis
Distortion in the input current waveform

Summary of Functions of the DL9000 Series Power Supply Analysis Option

The functions and specifications of the DL9000 series Power Supply Analysis Option (/G4) that perform the power supply analysis and evaluation tasks shown on the previous page are summarized below.

- **Correcting Differences in Transfer Times between Signals under Analysis (Deskew)**
  After connecting the probe and deskew adjustment signal source, you can correct (deskew) the difference in transfer time between the signals either automatically or manually, and measure power supply analysis items. Use the model 701935 Deskew Correction Signal Source.

- **Automated Measurement and Statistical Processing of Power Supply Analysis Items**
  Of the waveform data acquired into acquisition memory, you can automatically measure the waveform parameters of the displayed waveforms (within the display record length) that are required for power supply analysis such as switching loss, power factor, impedance, watt-hours and ampere-hours. The DL9000 also supports display of history and cycle statistics, and trends.

- **Waveform Computation of Power Supply Analysis Items**
  Of the waveform data acquired into acquisition memory, you can perform waveform computations of the displayed waveforms (within the display record length) such as active power, switching loss, impedance, and Joule-integral, and then display the computed results as waveforms (computed waveforms).

- **Harmonic Analysis**
  The harmonics generated by the equipment under test*2 as defined by the IEC Standard*1 can be analyzed for each applicable class (A through D). Bar graphs and lists can be displayed for making comparisons between the limits of the harmonic current and the analyzed values.

1.
   • The harmonic current emissions “IEC 61000-3-2 (Electromagnetic compatibility (EMC) - Part 3-2: Limits - Limits for harmonic current emissions (equipment input current [less than or equal to] 16 A per phase)) Edition 2:2.

• EN6100-3-2 (2000)
• IEC 61000-4-7 Edition 2

2.
   Electrical and electronic equipment having an input current of up to 16 A per phase and connected to public low-voltage distribution systems. The figure below shows the description of the applicable equipment. However, the DL9000 can only compute the harmonics of singlephase equipment. It cannot compute the harmonics of three-phase equipment.

DL9000 Series Power Supply Analysis Option, Top Menu

The DL9000 power supply analysis function option provides a dedicated menu so that you can quickly set the voltage and current measurement channels (see figure 21).

Settings for the voltage and current channels can be entered on screen, and you can confirm all of the settings for each channel. Also, this screen is the entry point for the power supply analysis function, and it includes a shortcut menu for jumping to the various functions.

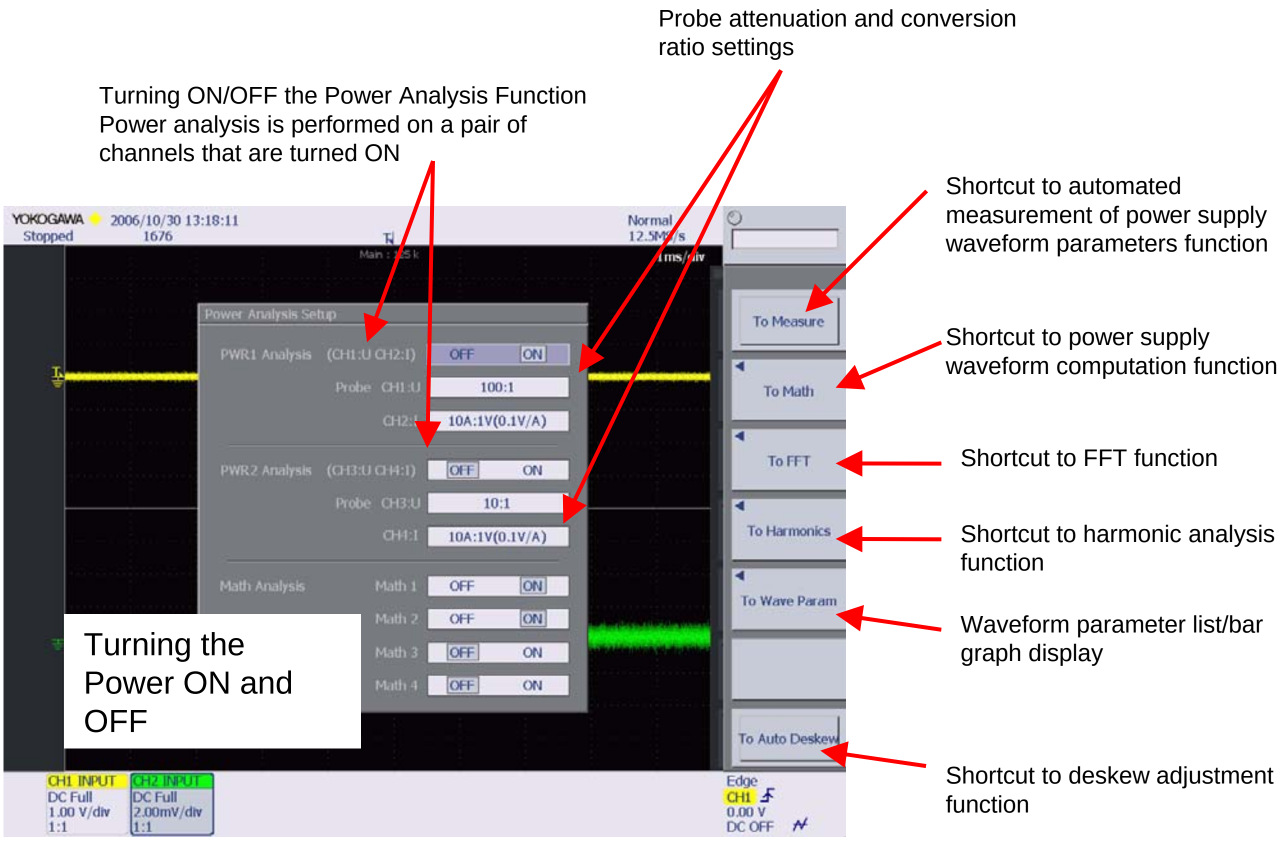


Fig 21 Power Supply Analysis Option, Top Menu

Comparison of Power Supply Analysis Functions in Different Brands of Digital Oscilloscopes and the Strengths of the DL9000 Series

The following shows the characteristics of the power supply analysis functions used with various other manufacturers' digital oscilloscopes.

	DL9000 (/G4)	LeCroy(PMA2)	Tektronix (DPOPWR)
Features	・Easy-to-use dedicated analysis menu (easy switching loss and total loss computation, verification of waveforms and parameter values at each switching occurrence, and extraction of abnormal waveforms). ・High speed cycle statistics computation and statistics computation, trend display, and a total of approximately30 analysis parameters including Joule integral.	・Differential amp (sold separately) for accurate measurement of switching loss at turn-ON. ・Facilitates modulation analysis (analysis of response characteristics during load fluctuations). ・ASO measurement using mask test software.	・Enables harmonic analysis (total harmonic distortion), measurement of loss in magnetic devices, and transformer/core evaluation. ・ASO mask test di/dt, dv/dt measurement. ・Creation of customizable reports using Windows.

Yokogawa's dedicated power analysis functions are based on the DL9000's superior basic characteristics.

In the measurement of switching waveforms, the DL9000 is also strong in its effective high screen update rate, high speed computation, history memory, and its wealth of standard-equipped effective noise-rejecting input filters.

Given these, the points shown below are the strengths of the DL9000 in the performing of power supply analysis.

- ✓ **Supports computation of switching ON/OFF loss, average loss, and total loss**
- ✓ **Makes it easy to verify waveforms and parameter values at each switching occurrence, and extract abnormal waveforms**
- ✓ **Wealth of dedicated analysis parameters and statistical computations**

(1) Captures each switching pulse with no omissions (N-Single), and computes total loss at high speed (History Statistics).

(2) Each switching waveform captured without omission in N-Single mode is automatically saved to history memory. Supports per cycle waveform comparisons (accumulate), power supply analysis parameter statistical computation (history statistics), extraction of abnormal waveforms (dot density display and history search), and other operations.

(3) With the long memory, performs waveform capture at high speed sampling even over the relatively long time when the power supply starts up. Observe changes in switching waveforms in detail.

(4) High speed cycle statistics computation and statistical computation, and trend display: Enables high speed computation of loss at each switching cycle and statistical computation of power supply parameter values within each specified interval (cycle).

(5) Wealth of analysis parameters including Joule integral.

End