Application Note

YOKOGAWA

Oscilloscopes DL9000 Series

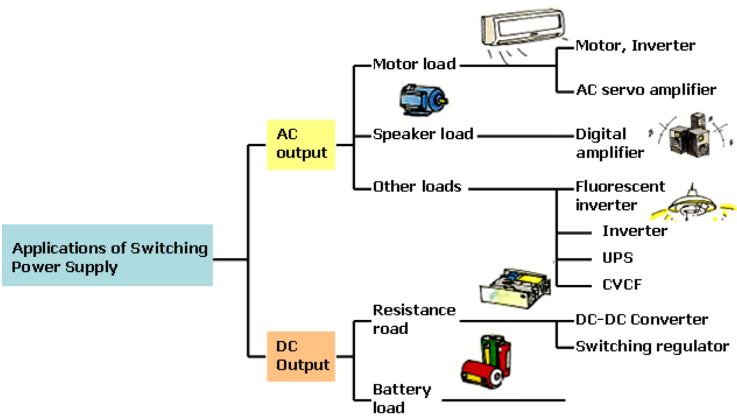
Mixed Signal Oscilloscopes DLM2000 Series

Analysis and evaluation of switching power supplies

1.Introduction

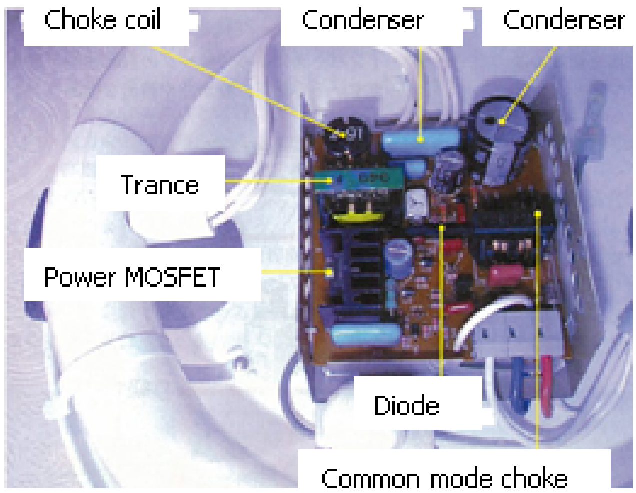
Our lifestyle is surrounded by a variety of power electronic products including inverter air conditioners, inverter fluorescent lamps, refrigerators, motors, amplifiers, and UPSs. The power control boards for these products contain microcomputers that gauge the load conditions to allow optimum control. For example, the microcomputers in air conditioners estimates the current load to perform a quiet and precise temperature control by changing the rotary speed of the motor without any restrictions to the motor inverter. The inverter control panel in fluorescent lamps inhibit the flickering with continuous high-frequency lighting.

Switching power supplies are power supplies with in-built power control panels that perform complex (precise and intelligent) and high-speed control for electrical equipment and products. Switching power supplies are embedded in a variety of power electronic products and are applied in many areas as can be seen in Figure 1.



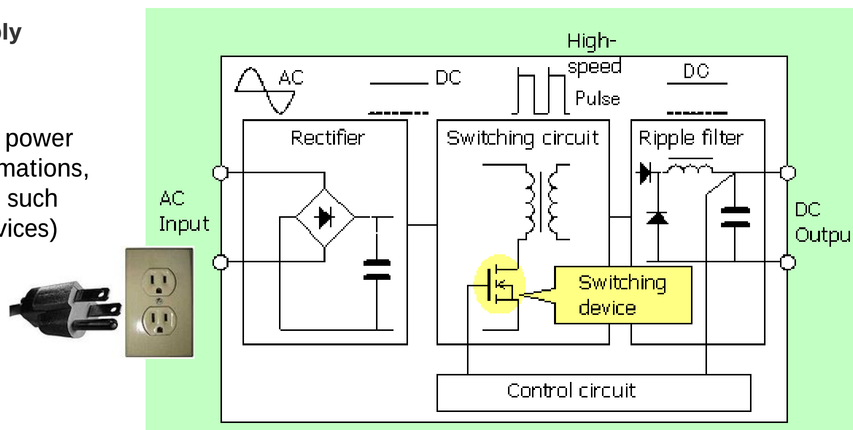
<Figure 1> Applications for Switching Power Supply

The actual switching power supplies are configured with power control panels that conduct controls and output transformations, as shown in Figure 2. Other than microcomputers, items such as condensers, filters, transformers, power modules (devices) are mounted.



<Figure 2> Power Control Panels Embedded in Inverter-type Fluorescent Lamps (Excerpt from Transistor Technology)

Switching power supplies have a built-in device that does the "switching" (an element that can switch ON/OFF part of the electric circuit such as MOSFET and IGBT). The output can be varied without restrictions by carrying out high-speed switching of the input voltage. Input transformation can take place in an AC-DC, DC-DC, or DC-AC converter. 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. Figure 3 is an outline drawing of the switching power supply.



<Figure 3> Outline Drawing of a Switching Power Supply

As seen in Figure 3, the electric power enters from the left and switches from AC →DC →AC → DC and comes out from the right. The switching power supply, applied in various fields as stated in Figure 1, converts from AC-DC, DC-DC, and DC-AC as shown in Figure 3.

Switching power supplies have the following characteristics.

-Compact, lightweight, and high-efficiency
-Good accuracy across a broad range of voltages and currents
-Good response to fluctuations in load

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

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

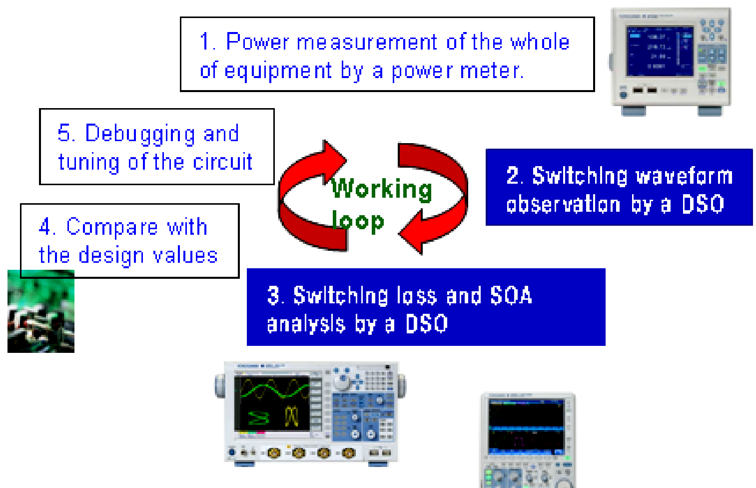
➢**High-power conversion efficiency**
The circuit must convert power efficiently even under changing loads, waveform distortion, and other hindrances.
➢**High-reliability**
Users demand circuits that can handle sudden changes in peak loads, input voltages, as well as excellent temperature characteristics. It is also essential that they must be immune to external noise (to avoid breakdowns or malfunctions).
➢**Countermeasures against harmonics**
AC power supply lines are used to curtail distorted waveforms to prevent damages to other equipment. Regulated under EN standards (EN61000-3-2).
➢**Low power consumption**
Miniaturize equipment by regulating heat as well as pursue low power consumption to protect the environment. To reduce electricity during standby, it is important to be efficient not only during normal output but also during minute outputs.
➢**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 SOA)
3. EMC (harmonic current suppression and noise reduction)
4. Lowering cost

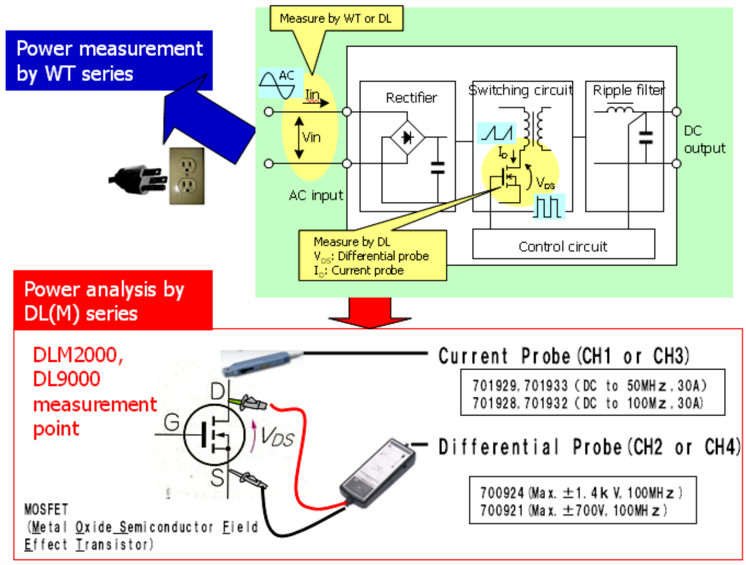
2. Outline of Switching Power Supply

It is easy to evaluate the switching power devices in or built in power supplies by using the power supply analysis function in DLM2000/DL9000 Series digital oscilloscopes. On the other hand, WT Series digital power meters are used to measure the power in the total equipment. Figure 4 is a flow chart of an actual experiment and evaluation.



<Figure 4> Flow of Experiment and Evaluation

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.

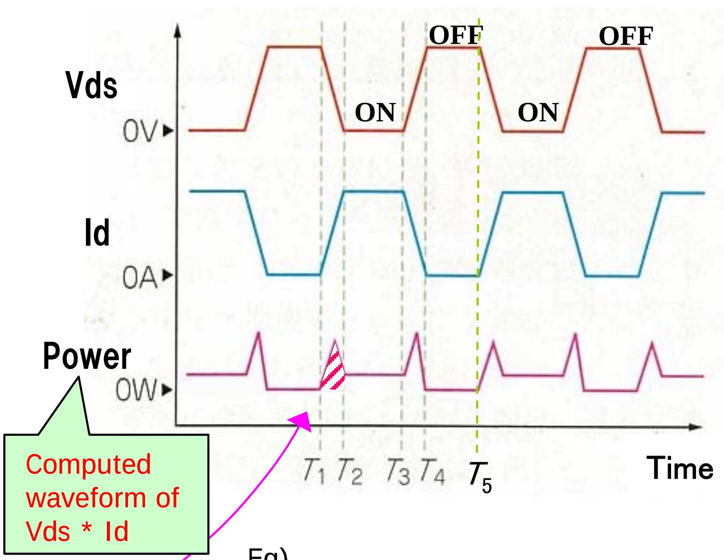


<Figure 5> Measurement Areas

The voltage applied to the switching device can potentially be very high, and can result in a "floating voltage" that is not grounded. Under these circumstances, differential probes are used when making measurements of the voltage with digital oscilloscopes. When measuring and computing the switching loss with an oscilloscope, the Drain-to-source voltage (Vds) and drain current (Id) of the switching device are measured with a differential and current probe as shown in Figure 5.

Switching loss is a loss of wasted electricity consumed as heat derived when switching the device ON/OFF. Switching loss can be defined in the following terms during the operation of the switching device:

1) Power loss during the transition from the OFF state to the ON state - Turn-on loss (T1-T2)
2) Power loss during ON state: conduction loss (T2 – T3)
3) Power loss during the transition from the ON state to the OFF state - Turn-off loss (T3-T4)
4) Cyclic loss including conduction loss T2 – T3 : Total average loss (T1 – T5)



Eg)
Turn-on loss is defined by the following formula.
(Please refer to the following remarks.)

$$Wp_{(on)} : \int_{T_1}^{T_2} V_{ds}(t) \cdot I_d(t) \; dt$$

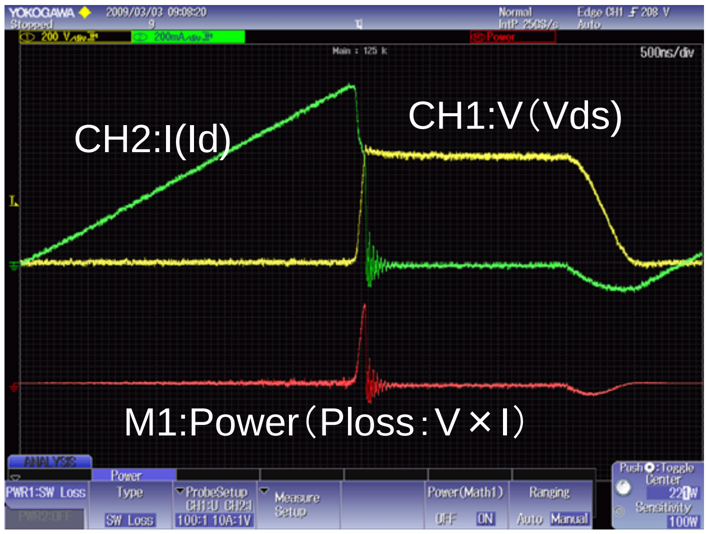
The hatched area

<Figure 6> Waveform Measurement

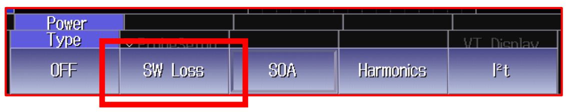
Switching loss is computed as the area (integral) of multiplied waveforms of Vds and Id as shown in Figure 6. For example, the computing results for Turn-on loss (T1 – T2) is the hatched area in Figure 6.
Using the DLM2000/DL9000 power supply analysis function, the losses in (1)–(3) above are automatically computed from the measured waveform data. Figure 7 is an example of a measurement and computing done by DLM2000.

3. Switching Loss Analysis with DLM2000 and DL9000

Figure 7 is an example of a measurement and computation of turn-off loss waveforms using the DLM2000. CH1 on the DLM2000 measures drain-to-source voltage V (Vds) and CH2 measures drain current I (Id). Oscilloscopes execute multiplication and integration of V*I (Power).



Special parameter computation is carried out just by selecting the items (SW Loss) that want to be analyzed from the menu.



<Figure 7> An Example of Turn-off Loss Waveforms with DLM2000

Measurements of loss 1) to 4) is computed by the following formula to calculate the loss parameters Wp and P.

Turn ON/OFF, conduction loss 1), 2) and 3):

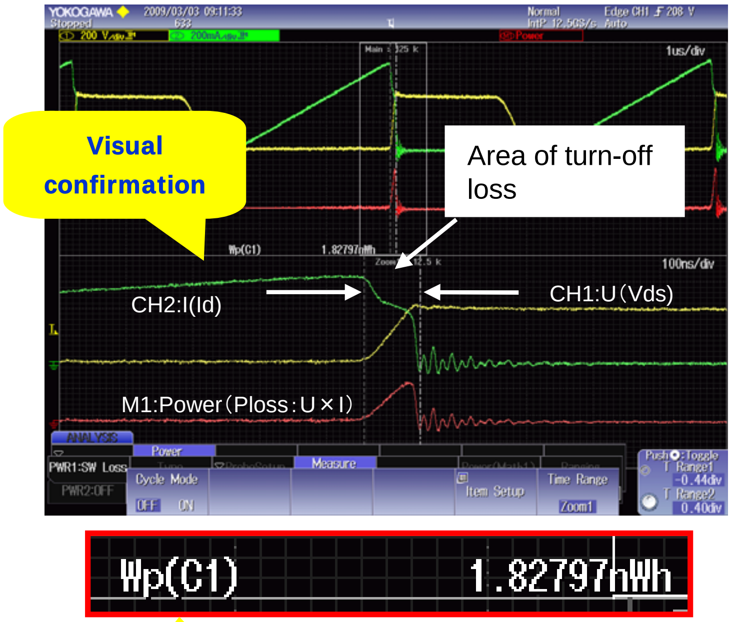
$$Wp[Wh] \; : \int_{T_1}^{T_2} V_{ds}(t) \cdot I_d(t) \; dt$$

Total cyclic loss 4):

$$P[W] \; : \frac{1}{T} \int_{T_1}^{T_5} V_{ds}(t) \cdot I_d(t) \; dt$$

The scope of loss (integral scope) is specified with the computing range cursor (range cursor). T1 to T5 is specified with the cursor when the dedicated parameter Wp or P is selected.

The loss (Wp) unit derived from the formula will be Wh or J (selectable). In case the W unit loss is to be calculated, use parameter P and not Wp.



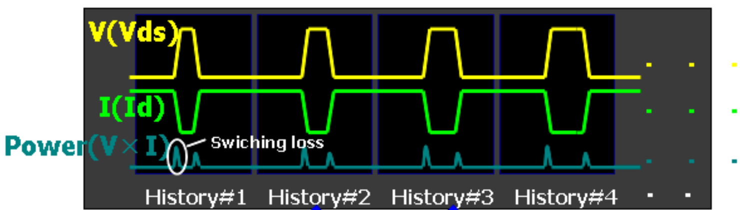
Quantitative confirmation

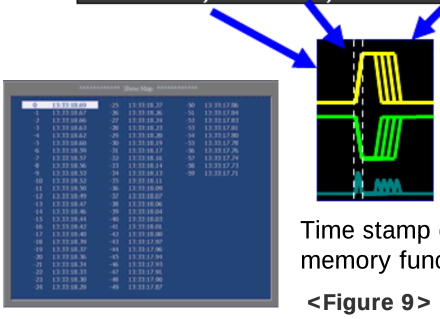
Parts control can be carried out over a short time by computing with DLM2000/DL9000 Series in real time. With the dedicated analysis function, GO/NG judgment can be adjusted visually and quantitatively.

<Figure 8> Measurement of Turn-off Loss Waveforms and Examples of Loss Computing (DLM2000)

● Transient Response Evaluation of Turn-On Loss

When there are changes in the conditions such as start ups, the switching pulse changes dynamically. In these circumstances, it is vital to grasp the transient conditions of the operations when evaluating the Turn-On and Turn-Off loss that changes per switching pulse. The history memory function of DLM2000/DL9000 Series with a built-in long memory can capture all the switching pulses that change dynamically with the high speed acquisition. It can also measure the switching pulses per each pulse.
Figure 9 is an image of a loss measurement using the history memory function.





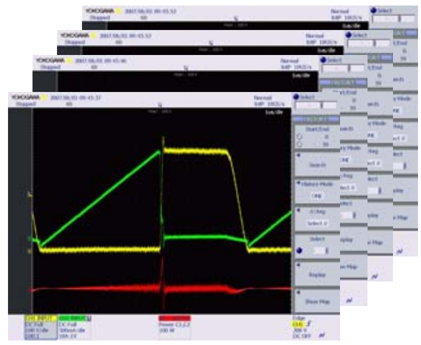
Time stamp display of the history memory function.

<Figure 9> Measuring Loss Using the History Memory Function (Image)

Display after capturing each of the multiple captured switching cycle waveforms can be checked one at a time as in Figure 10. Multiple cycles of waveforms can also be superimposed on the display (see Figure 7) for easy cycle-by-cycle comparisons.

This means that multiple cycles of waveforms can be captured 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, the History Reply function can replay trends in the switching waveform over time on the DLM2000/DL9000 screen to view at a later time.

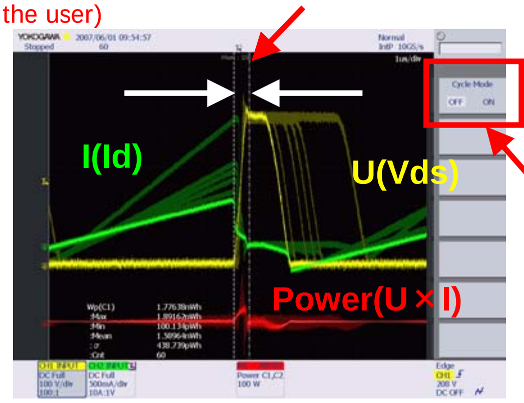


<Figure 10>

● Computing Total Loss in Multiple Switching Cycles

Circuits with cyclic variations such as AC input power supplies and motor inverters need to measure the total loss of one cycle of AC power supplies and one motor rotation to find the correlation with the measurement values of the power meter. To do so, use the measured value of each history memory waveform to calculate the statistics of the switching loss waveform over multiple cycles and the total switching loss.

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



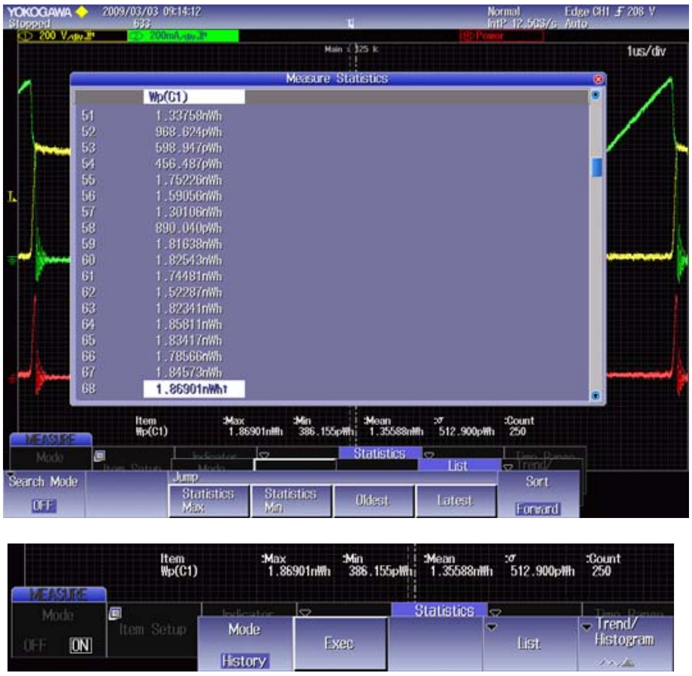
Set Cycle Mode OFF (an example of DL9000)

Max: Max. loss
Min: Min. loss
Mean: Ave. loss
Cnt: number of cycles

Wp(C1)	1.77638nWh
:Max	1.89162nWh
:Min	100.134pWh
:Mean	1.58964nWh
:σ	438.739pWh
:Cnt	60

Example of DL9000

<Figure 11> An Example of Computing Turn-Off Loss Statistics over Multiple Cycles (History Statistics)



<*Figure 12*> An Example of Loss Trend Displays for Each Cycle (DLM2000)

As stated before, operator Wp is used to find the parameters for the switching loss (1 and 2).

Wp : Sum of both plus/minus electric energy
Wp+ : Sum of plus electric energy
Wp- : Sum of minus electric energy
Abs.Wp : Sum of absolute value of Wp+ and Wp-

Figure 11 shows that by placing the range cursors in the range that corresponds to T3 and T4 in Figure 6, the required loss (in this case the turn-off loss) can be measured automatically.

In Figure 11 (an example of DL9000), waveforms of the turn-off portions of 60 switching cycles are captured into the history memory and superimposed on the screen. Using the History Statistics (Statistics) function, the statistical calculations of that data such as the maximum, minimum, and average loss can be found. With these statistics, the total loss of all the captured cycles can be determined. Total loss of each turn-on and turn-off can be calculated by capturing waveforms under different trigger conditions. From the above history statistics, the total turn-off loss is calculated as: Total loss (average loss x no. of cycles) = Mean x Cnt

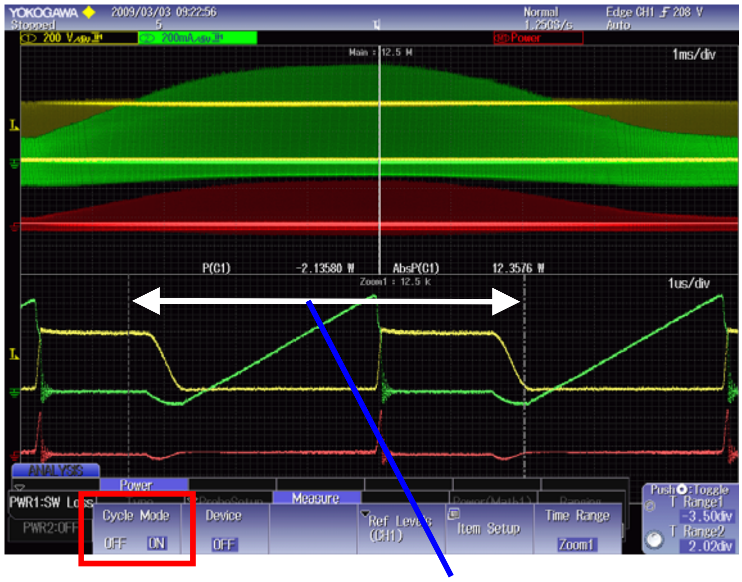
In the above example,
Total (turn-off) loss = 1.59 [nWh] x 60 = 95.4 [nWh]

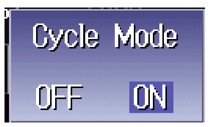
Computing the total loss is used to check whether there is no abnormal rise in the junction temperature of the switching device when it is in the transient condition during start up.

● Computing the Total Loss per Cycle

The total power loss on any given cycle (the loss corresponding T1 – T5 in Figure 6) can be automatically computed simply by selecting the parameter operator P. The arbitrary cycle waveform used for computation is specified with the range cursors that defines the computation area for the "statistics over an area parameter computation" function. DLM2000/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 one cycle that the DLM2000/DL9000 can automatically identify. The example in Figure 13, the calculation resulted in 12.3576W(absolute value).

$$P_{loss(Ave)} : \frac{1}{T}\int_{T1}^{T2} V_{ds}(t)\cdot I_d(t)\ dt$$

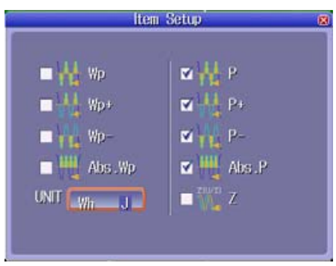




Specify the range cursor within the determined total loss cycle

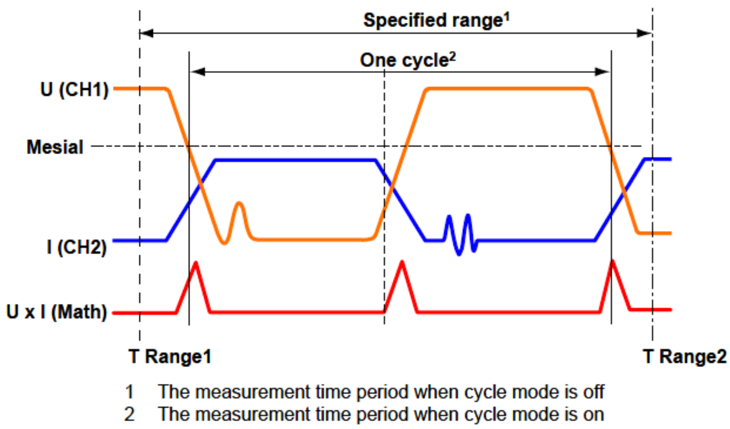
As in Figure 14, one cycle (time "T") is automatically determined from the point where the mesial and the voltage waveform interchanges within the specified range cursor.

Compute the total (average) loss of one cycle



Eg)

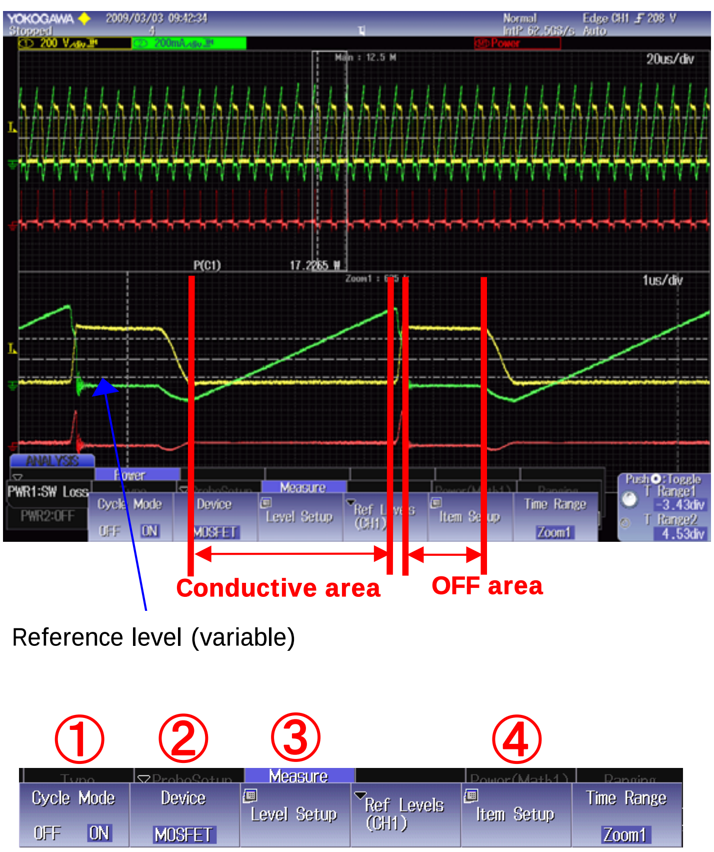
<*Figure 13*> An Example of a Total Loss of One Cycle. (DLM2000)



<Figure 14> Definition of One Cycle

●Error Correction During Conduction Loss

The dynamic range of the voltage applied to the switching device is wide; it can be a few hundred mV when continuous (when turned ON) as opposed to a few hundred V when turned OFF. These cannot be measured accurately with just a single waveform captured on a common 8-bit resolution digital oscilloscope. To correct the measurement errors due to the lack of dynamic range (Figure 16, voltage and current error), DML2000/DL9000 can calculate the errors by entering the fixed value when the conduction is ON and OFF [the ON resistance RDS (on) of the device or the saturated voltage between the collector/emitter Vce (sat)]. Corrections are made by entering zero to the current when the conduction is OFF.

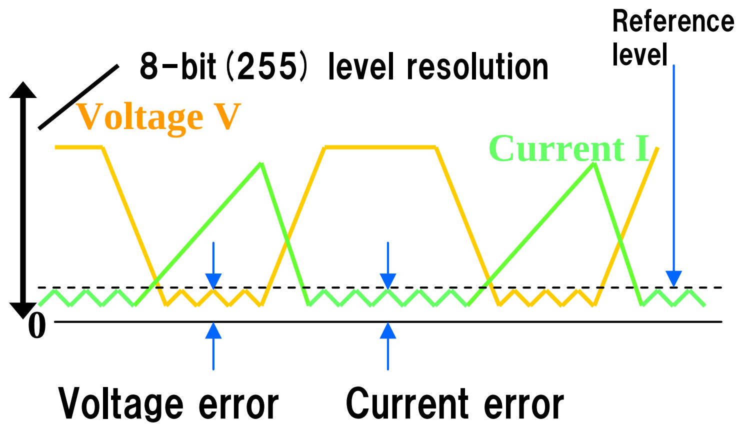


<Figure 15> An Example of Corrections to Loss Errors of OFF and Conduction Area

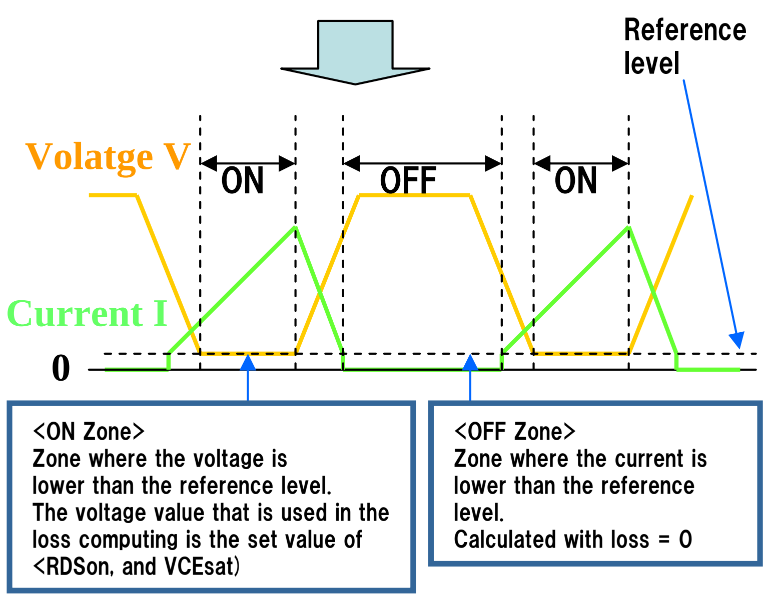
Analysis Method by Device Specification (Error Correction)

1) Switch ON the cycle mode
2) Select the type of device
   Enter RDS (on) for MOSFET and Vce (sat) for BJT/IGBT
3) Set the conduction level
4) Select the analysis item (Wp, P and such)

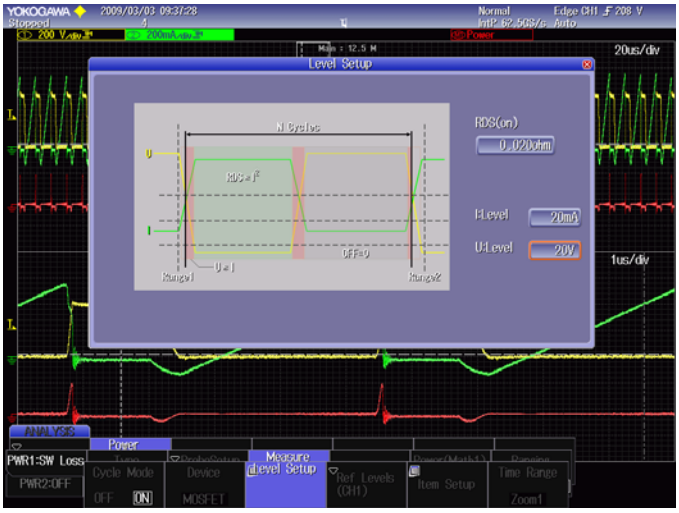
By setting the voltage and current level, the conduction ON and OFF is automatically acknowledged. Select the type of device for the conductive area and enter RDS (on) for MOSFET and Vce (sat) for BJT/IGBT to automatically calculate the conduction loss. The results are reflected during the loss computing (Wp). The current value is corrected to zero as the current is logically zero when OFF. Figure 16 shows when there is no error correction and Figure 17 shows when there is error correction.

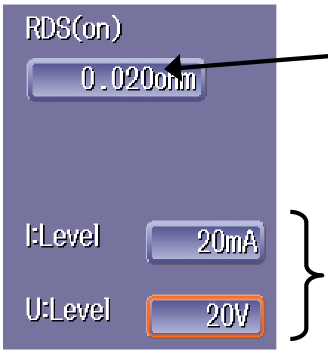


<Figure 16> No Loss Error Correction



<Figure 17> With Loss Error Correction





Enter the set value of the selected type of device:
For MOSFET: RDS (on)

For BJT/IGBT: Vce (sat)

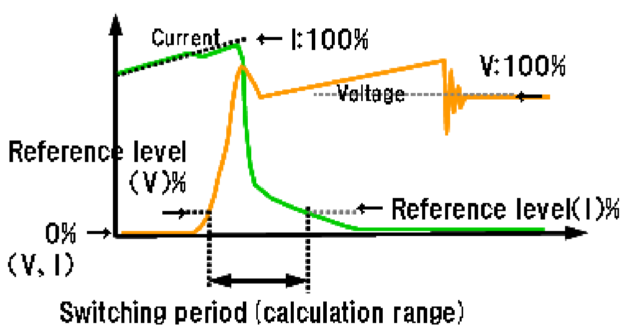
Set reference level of correction in each ON and OFF zone

<Figure 18> Level Setting Screen (DLM2000)

The setting items for corrections in DLM2000, as stated in the previous page, is easy to read as it has a graphical menu as can be seen in Figure 18.

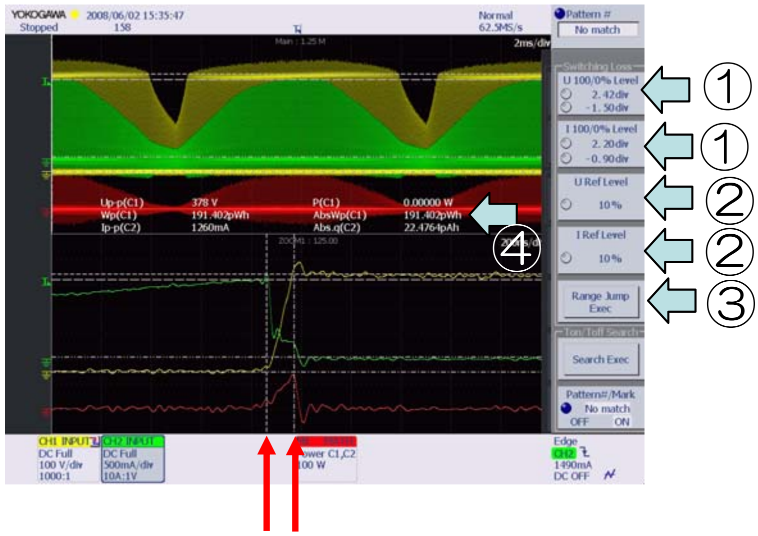
● Automatic Setting of Computing Zone for Switching Loss

The vibration is brought about by the wiring inductance (L load) that appears as ringing and such on waveforms in the switching zone. This must be assessed by separating it from the real loss. The DL9000 Series can automatically set up the switching operational zone (the computing zone of the loss in Turn-On or Off) that is subject to analysis.



<Figure 19> Definition of Switching Operation Zone

Furthermore, it is easy to calculate the loss of Turn-On or Turn-Off by combining with the switching zone (Ton/Toff) search.



Zone range cursor [Switching operation (integration)]

<Figure 20> An Example of an Automatic Setting of the Computation Range

Analysis Method by Specifying the Switching Zone

1) Specify the 100% and 0% voltage and current with cursor
2) Set the standard V and I level (Vref% and Iref%) that determines the switching operation zone.
3) Automatically detect the switching zone from the setting contents in 1) and 2) and move the zone cursor
4) Automatically calculate the loss (Wp) and display on screen

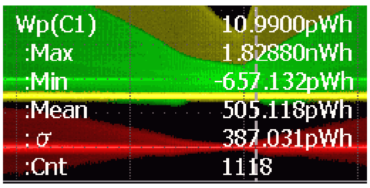
Set V100% and I100% to a level without the vibration onto the measured waveform. Set the ref level that determines what level should be measured for each voltage and current. By conducting a Range Jump, the Range cursor moves to the ref level set on the Turn-On or Turn-Off. The loss (Wp) at that point is automatically calculated. Also, by conducting a Ton/Toff Search, it can search the required Turn-on and Turn-off conditions to compute the loss at that point.

●Displaying Trends in Loss per Switching Cycle

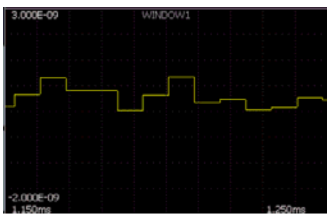
With its 6.25 MW–long memory, DL9000 can continuously acquire multiple cycles of voltage (Vds) and current (Id) data and compute the switching loss (Vds x Id) on the M1 waveform. By using the Cycle Statistics function in DL9000, statistical processing can be performed on the computed loss results (parameter: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

- Check trends in excessive changes per switching cycle from when the power is entered until it reaches a stable operation
- Capture multiple cycles of waveforms while varying the load applied to the switching device, and check trends in total loss per cycle

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



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



Loss Trend Display of Zoomed Data per Cycle

List Display

<Figure 21> An Example of an Statistical Processing of Loss per Cycle (DL9000)

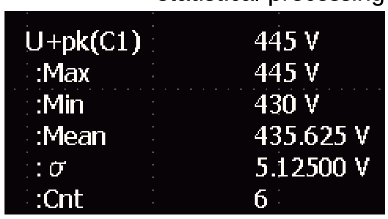
In the example in the above Figure (Window 1), the computed loss per cycle for the 10 + cycles displayed in the zoom area is a trend displayed in time series. In Window 2, the computed loss results are displayed in a list per cycle. The maximum and minimum values are marked allowing easy identification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

What is a Cycle Statistics Function?

Cycle statistics automatically acknowledges the cycles of the displayed waveform in a time sequence. It measures and statistically processes the items in the automatic parameter measurement, which is selected from the data within that cycle. 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



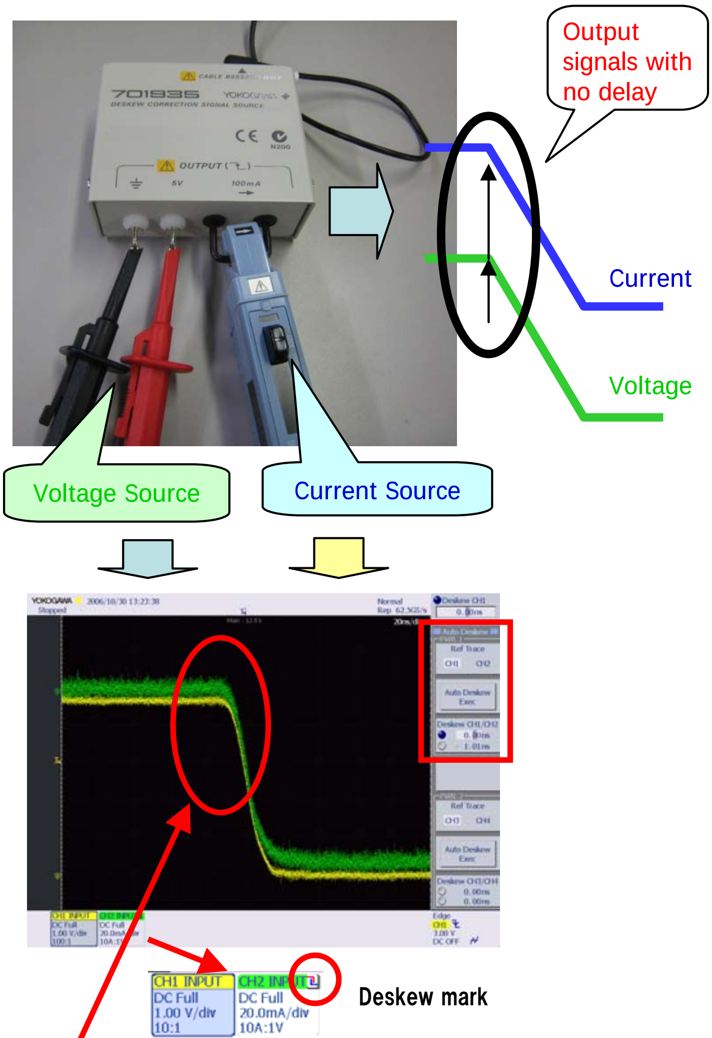
<Figure 22> Example of Cycle Statistics (DL9000)

In the example in Figure 22, six of the Vds waveform cycles 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.

4. Cautions when Analyzing Switching Loss

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

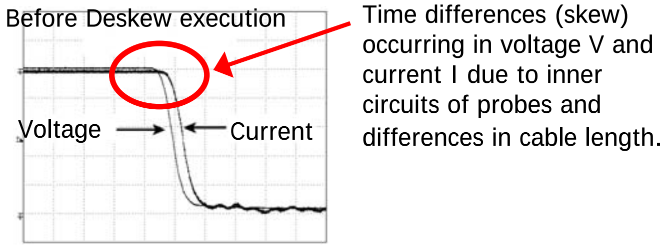
As described heretofore, switching loss is computed by the product of Vds and Id. Delays occur in the output due to the inner circuit of the differential or current probes and the cable length of the probe. This delay differs from each probe. Along with the increasing speeds in switching frequencies, the effect that the probe-specific propagation delay has on switching loss computation results is becoming an increasingly bigger problem. It is very important to calculate the switching loss accurately to adjust the time difference (skew) due to the propagation delay of the voltage and current probe used in measuring power supplies. With DLM2000/DL9000 you can automatically adjust the skew with a simple operation. After connecting the probe, simply select an adjusted reference signal (voltage or current), and press the Auto Deskew Exec key.



Automatically adjsts the (propagation) delay of the current and voltage waveforms to zero, including the probe used.

<Figure 23> Auto Deskew(DL9000)

(reference)

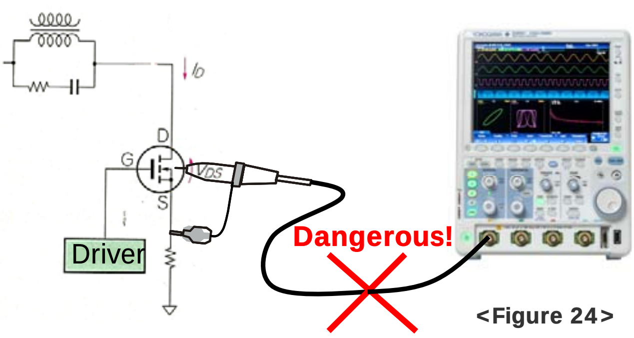


Signal Source Deskew Correction (701935, Sold separately)

- Power supplied by DL connector
- DLM2000/DL9000 Deskew correction function
- Supports Auto Deskew

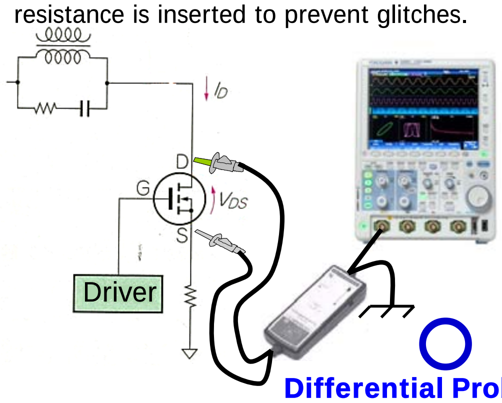
● For a Safe Measurement

Differential probes are necessary when measuring voltage Vds between drain sources with oscilloscopes as switching elements have floating connections.
The ground of oscilloscopes are the same as the ground used in the chassis. It is dangerous when connecting the probe ground lead to either terminal in the MOSFET as it will short circuit to the ground via the oscilloscope.



<Figure 24>

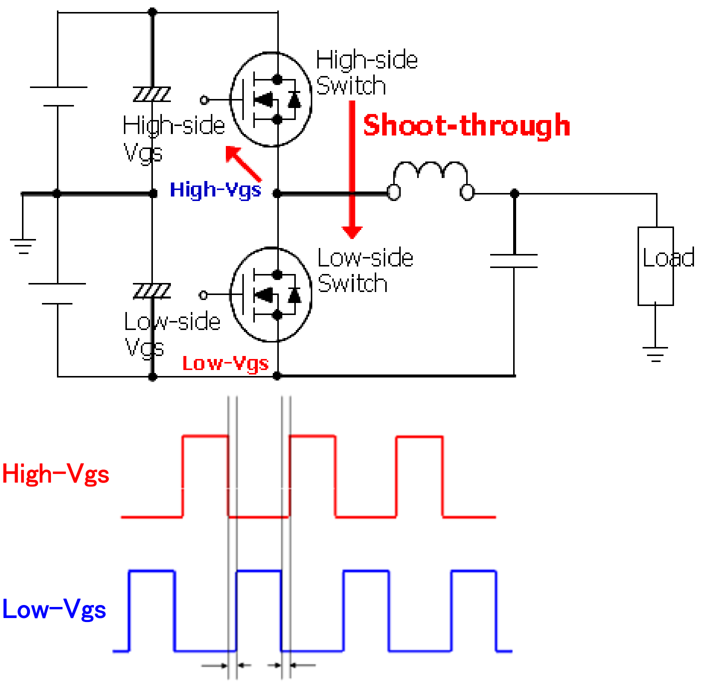
By using differential probes, it is possible to isolate the ground under test and the oscilloscope and to measure the voltage of the switching element safely.
Please use differential probes when measuring gate voltages Vgs of inverter circuits.
As gates have high impedance, it is recommended that damping resistance is inserted to prevent glitches.



<Figure 25>

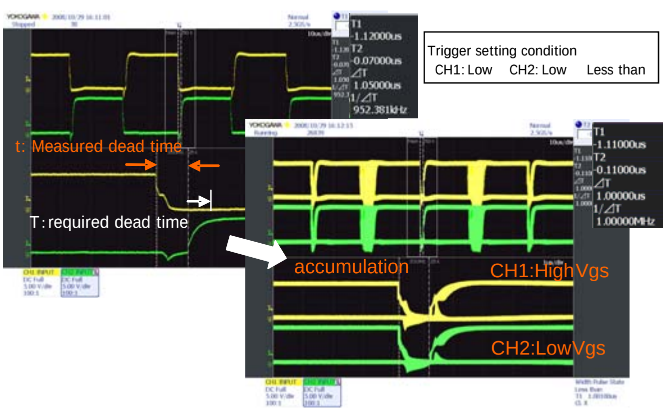
5. Switching Timing Analysis

Inverters have high side and low side switches. When both switches are ON at the same time, electrical loss occurs with the flow of large shoot through currents. The switches are switched ON alternatively during dead time. Shorter dead time can reduce the amount of loss, however, the dynamic margin decreases which will increase the risk of generating shoot through currents. DLM2000/DL9000 Series observe high side and low side Vgs waveforms to check whether the dead time is abnormal.



<Fig 26 Shoot-through and dead time

Within the many trigger functions in DLM2000/DL9000, the state width trigger * is used to trigger the areas that lack dead time. It is possible to retain data, even if the phenomena is infrequent, by overlapping waveforms.



<Figure 27> An example of a State Width Trigger Measurement (DL9000)

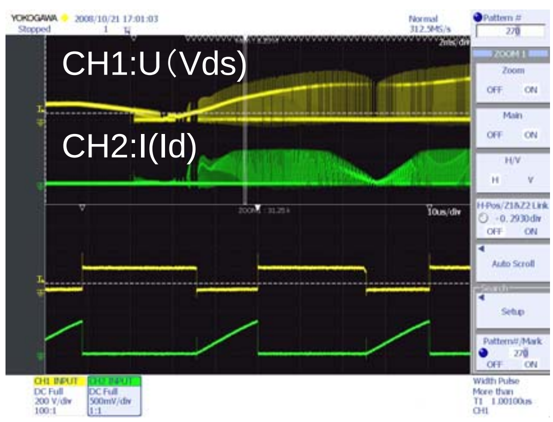
By setting the trigger condition to t<T where "t" is defined as when both CH1 and CH2 are in low time and "T" is the setting time, triggers can be activated when the setting is abnormal.

Each of the overlapped waveform is recorded in the DLM2000 and DL9000 history memory. Thus past waveforms can be tracked back to find the waveform in need.

*1. Definition of State Width Trigger
Trigger when the relationship of the set state time width "t" and the designated time "T" is established.

6. Check the Transient of the Switching Dynamics

It is necessary to check the transient of the switching dynamics when starting up, during shut down, state of load shorts and off loads, and abrupt changes in load. It is possible that the circuits may breakdown when pulse blocks and miss switching occurs. To check the transient, the switching waveform is captured in long term and high sampling conditions and enlarged per switching pulse to check if there are any abnormal waveforms. Abnormal waveforms can be searched instantaneously with the rich waveform search function. Also, pulse errors can be found by statistically processing the major parameters (pulse width) using the cycle statistical function. Furthermore, it is a convenient function as the area can be enlarged automatically time wise to display by scrolling to confirm and evaluate.

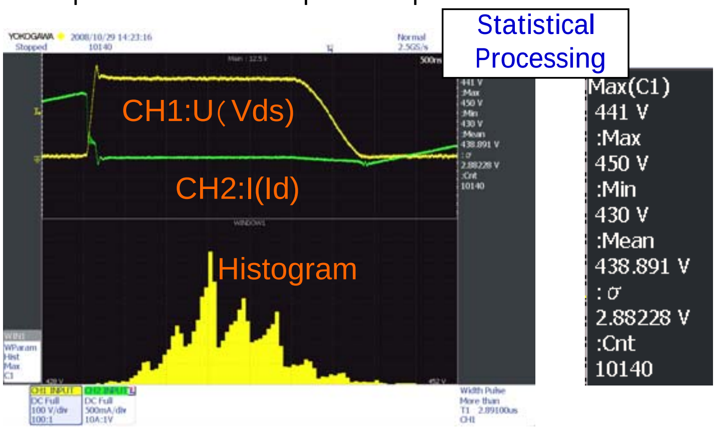


Normal: An example of a cyclic pulse

Abnormal: An example of an irregular pulse

<Figure 28> An Example of Confirming Transient (DL9000)

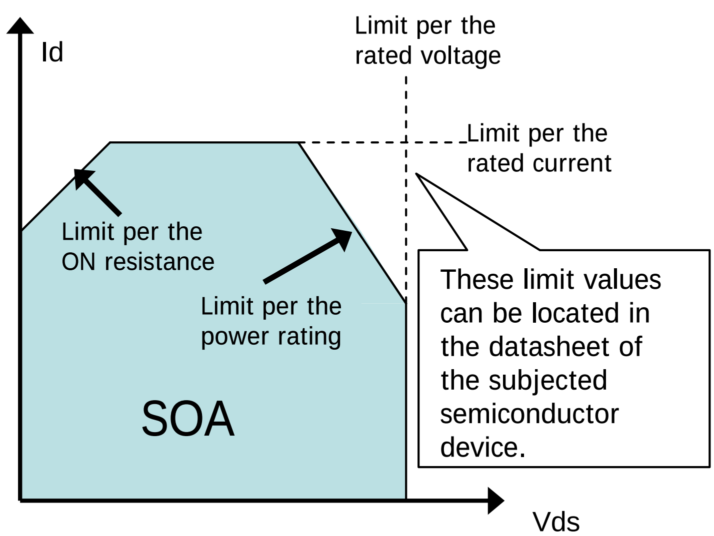
Surge voltage that is generated by switching elements must leave a margin against the rated voltage. To suppress the surge voltage, engineers will adjust the parts while observing the waveforms and the loss at the same time. The DLM2000/DL9000 Series observes the switching waveforms to measure the peak of the surge voltage. The maximum, minimum, average, and standard deviation is calculated by using the statistical function. Regarding its distribution, it is possible to check the scattering on the histogram. Also, the long memory has sufficient time resolution for commercial frequencies and can capture even the infrequent low peak values.



<Figure 29> An Example of a Histogram Display of Surge Voltage (DL9000)

7. Measuring the Safety Operation Area (SOA)

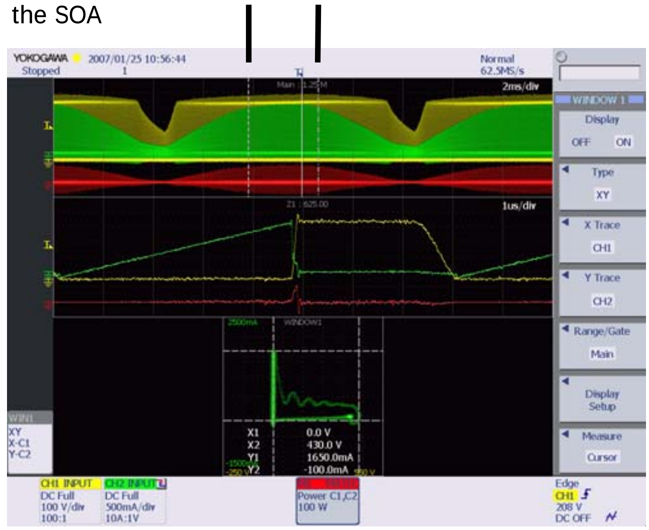
To increase the reliability of switching power supply circuits, engineers must consider how to make the power device operate within operating boundaries. To do this, the relationship between the voltage and current is plotted on an X-Y graph to evaluate the characteristics of the device's active region. In the case of MOSFET, the power device operates within the Safety Operation Area (SOA) shown in the Figure 30 (the area under the lines). The points of measurement are the same as those shown in the Figure 5.



<Figure 30> Definition of SOA

With the DLM2000/DL9000, levels are taken from CH1 (Vds) for the X-axis and the CH2 (Id) waveform for the Y-axis. SOA 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 SOA 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 SOA

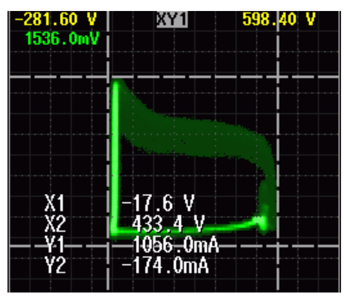


<Figure 31> An Example of SOA Measurement by DL9000

Range cursors are placed on the T-Y waveform, and the X-Y (SOA) waveform of the corresponding range (cycle) and displayed at the same time. Thus, the corresponding SOA 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.

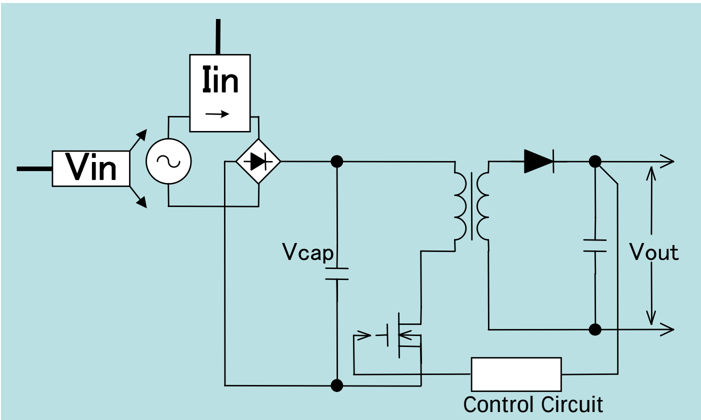
Also, the cycle waveform (T-Y waveform) can be displayed in the SOA zoom area, and the X-Y graph (SOA) using the data from the range can be displayed in that zoom area. By auto-scrolling the zoom area, the SOA cycle-by-cycle trends can continuously be confirmed in the X-Y screen.

<Figure 32> An Example of Cursor Measurement on the SOA Waveform



8. Measuring In-rush Current Using I^2t

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



<Figure 33> I^2t Measurement

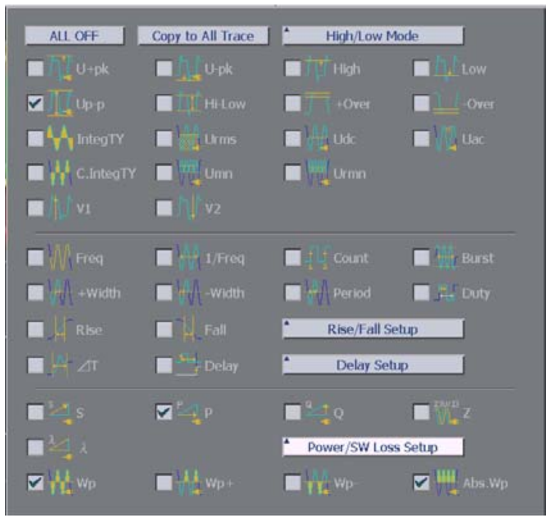
●Checking I^2t: The Fuse Selection Parameter

I^2t (current squared x time can be measure directly by using the dedicated power supply parameters provided with the DLM2000/DL9000 Power Supply Analysis function. If the MATH (computation functions) is used, the I^2t results can be displayed as a waveform for visual confirmation. The points of measurement are represented by Vin and Iin in the above Figure. To measure the value of a desired portion, place the cursors on the measured waveform to define a range. This increases reliability and reduces the evaluation time as there is no need to perform a separate calculation using the measured current value.

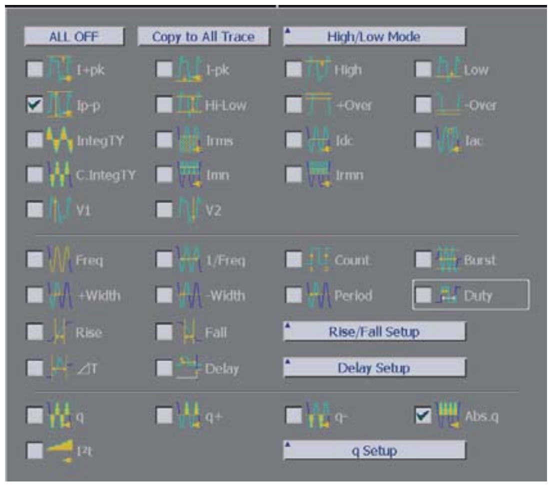
9. Measuring Line (Power) Quality

Designing a switching power supply requires evaluating the quality of the switching power supply's primary side line power. The actual power line voltage and current waveforms are not ideal sine waves, 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.

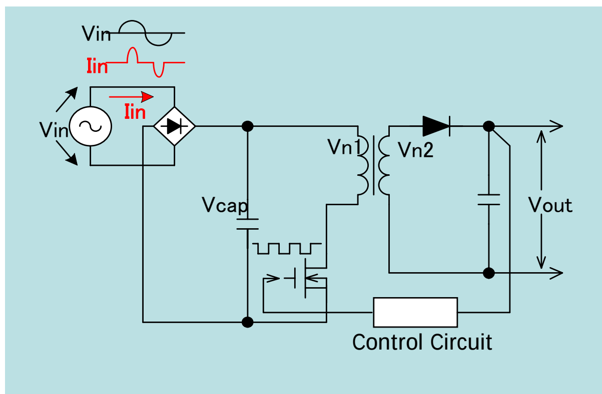
The DL9000 Power Supply Analysis function comes with a wealth of parameter operators for measuring the line (power) quality such as apparent power, active power, power factor, and other characteristics.

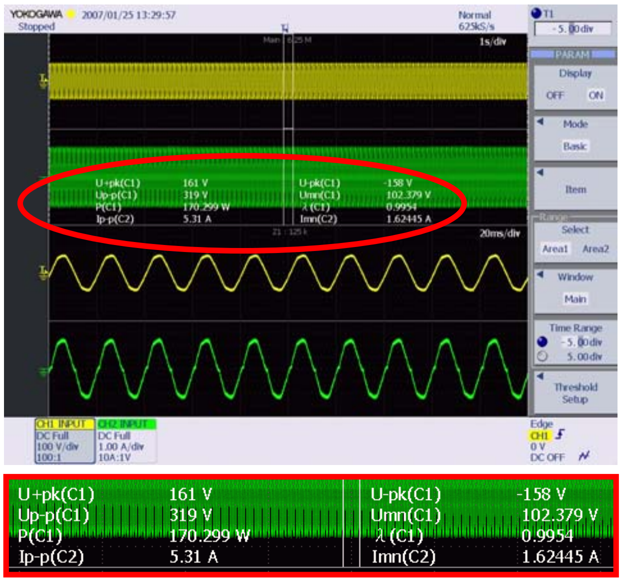


<Figure 34>
Measurement items for voltage channels(CH1, CH3)



<Figure 35>
Measurement items for current channels(CH2、CH4)





<Figure 36> An Example of Line Parameter Measurements

● Details of automatic measurement parameters (DL9000)

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

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

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

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

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

U_{+pk} : *Maximum value*

U_{-pk} : *Minimum value*

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

Parameters for Voltage

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

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

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

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

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

I_{+pk} : *Maximum value*

I_{-pk} : *Minimum value*

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

Parameters for Current

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	$W_p, W_{p+}, W_{p-}, Abs.Wp[Wh]$	: $\int_0^T u(t)\cdot i(t)\ dt$
Ampere hour	$q, q_+, q_-, Abs.q[Ah]$	: $\int_0^T i(t)\ dt$
I2t (Joule integral)	I^2t	: $\int_0^T i^2(t)\ dt$

Other Parameters

10. Analyzing Harmonics

When a load is connected to a power supply, it is normal to have a continuous flowing current and contain large amounts of distortion. The voltage waveform is also distorted according to the harmonic current. A "Guideline for Reduction of Harmonic Emission" was introduced as this can cause problems with the equipment. It is possible to analyze harmonics emitted for a DUT for each applicable class (A-D) with the DLM2000/DL9000. It is recommended to use our digital power meters and harmonic measurement software (model 761921) to perform precise measurements that conform to the standard. The harmonic analysis functions of the DLM2000/DL9000 Series are, however, affective tools for rough evaluations of the characteristics.

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

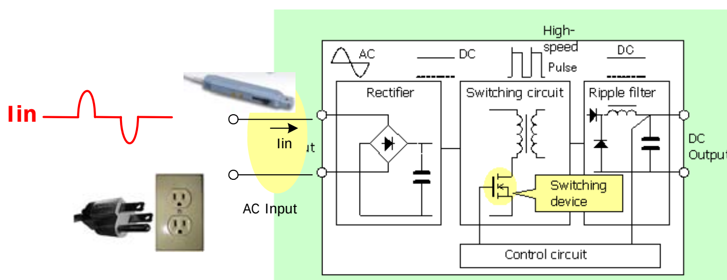
Class C

Lighting equipment

Class D

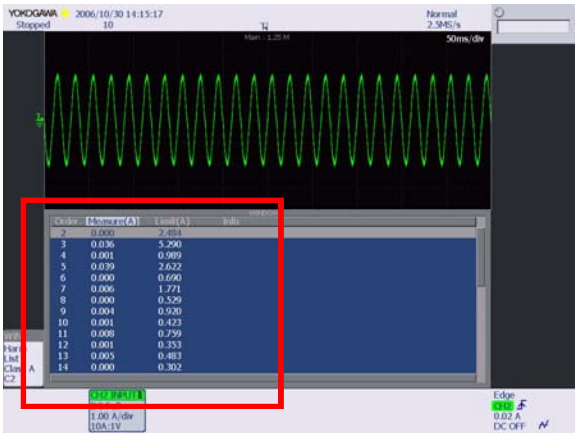
Television receivers, personal computers (PCs), and PC monitors with a rated power of 600 W or less

<Target equipments and classification>



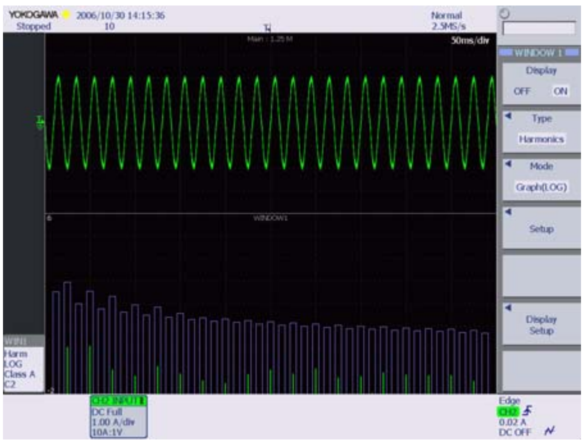
<Figure 37> Measuring Point

With the DLM2000/DL9000, the harmonics emitted from the DUT determined by the IEC61000-3-2 standard for each applicable class (A–D) can be computed, and the results can be displayed on a bar graph or list that compares the harmonic current limit values with the computed values.
While checking the compatibility of the standards, it can be used to debug the high harmonic circuit (PFC: Power Factor Correction).



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

<Figure 38> An Example of List Display(DL9000)



<Figure 39> An Example of Graph Display(DL9000)

11. Evaluating Power Supplies: Summary of Key Points

<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. Has loss error correction function.

(3) Confirming the Safety Operation Area (SOA)
The operating status/margin of the voltage, current, and power values of the switching device

(4) Harmonic Analysis
Distortion in the input current waveform. EMC support.

12. Summary of Functions of the DLM2000/DL9000 Series Power Supply Analysis Option

The functions and specifications of the DLM2000/DL9000 Series Power Supply Analysis Option (/G4) that perform the power supply analysis and evaluation tasks 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.

●Calculating Switching Loss

Can measure the total loss (electrical loss) and switching loss (electricity loss during switching) of the device. It also has a built-in computing error correction (reduction) function and an automatic set up function for computing range. It also supports statistical computing for multiple switching cycles captured by long memory.

●Safety Operation Area (SOA) Analysis

Can evaluate the SOA using the X-Y display function. Place the cursor on the SOA to read the values. Can make judgment by comparing with the values on the device spec sheet.

●Harmonic Analysis (EMC support)

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 DLM2000/DL9000 Series, however, can only compute the harmonics of single-phase equipment. It cannot compute the harmonics of three-phase equipment.

● Measurement of Rush Current with I^2t

Compute I^2t (the maximum current squared x time) to display the waveform and the computed value. It is possible to evaluate the rush current at start up for condenser input type switching power supplies and to evaluate the guidelines for fuse selection.

(End of Document)