APPLICATION NOTE

Double Pulse Testing Using a Keysight Function Generator

KEYSIGHT

Introduction

Double pulse testing is a standard method used to characterize the dynamic switching performance of power transistors or power stages in integrated circuits (ICs). This technique is widely used to measure switching losses, voltage overshoots, recovery characteristics, and overall transient behavior under specific conditions. It plays a critical role in designing and optimizing power electronics, especially for high-performance applications such as insulated gate bipolar transistors, metal-oxide-semiconductor field-effect transistors (MOSFETs), and advanced materials like silicon carbide (SiC) and gallium nitride (GaN).

Technically, the double pulse test focuses on analyzing the behavior of power devices during critical switching events: turn-on and turn-off. These events are fundamental in understanding energy losses, thermal stress, and reliability in high-performance applications. For a DC-DC converter IC with integrated MOSFETs, as an example, the double pulse test measures switching losses and evaluates voltage spikes during turn-on and turn-off transitions. In addition to the semiconductor industry, electric vehicles, renewable energy systems, industrial automation, aerospace, and other industries depend heavily on insights from design pulse tests for the design and optimization of their systems.

The purposes of the double pulse test include the following:

- Dynamic analysis to capture real-time behavior during fast transitions.
- Efficiency evaluation to quantify the switching losses to enhance power efficiency.
- Reliability testing to identify vulnerabilities like voltage overshoots or diode recovery issues.
- Material comparison to facilitate the comparison of different material technologies and select the best case.

The double pulse test involves applying a controlled sequence of two pulses to the device under test (DUT). The waveform generated simulates real operational conditions, enabling detailed performance characterization. The first pulse magnetizes the load inductor to a target current level for simulating realistic operation. A recovery period follows the first pulse to prevent an incomplete recovery that could distort measurements or damage the DUT. Following the brief off period, the second pulse measures how the device behaves under nominal current flow, capturing critical switching parameters like switching losses, peak voltages, and recovery times.

To run the double pulse test, a function generator is required to supply the gate drive signals. For this application note, we use the Keysight FG33532A function / arbitrary waveform generator along with the 33503B BenchLink Waveform Builder Pro application to generate the double pulse signal.

The function generator used for this double pulse test is part of the Keysight Smart Bench Essentials Plus suite of instruments. This elevated set of basic instruments — power supply, waveform generator, digital multimeter, and oscilloscope — comes with proven pro-level measurement technologies designed to minimize measurement errors resulting from real-world factors to provide the accuracy and precision required for this application. The instruments include large color screen displays and graphical interfaces to visualize, analyze, and share test results quickly.

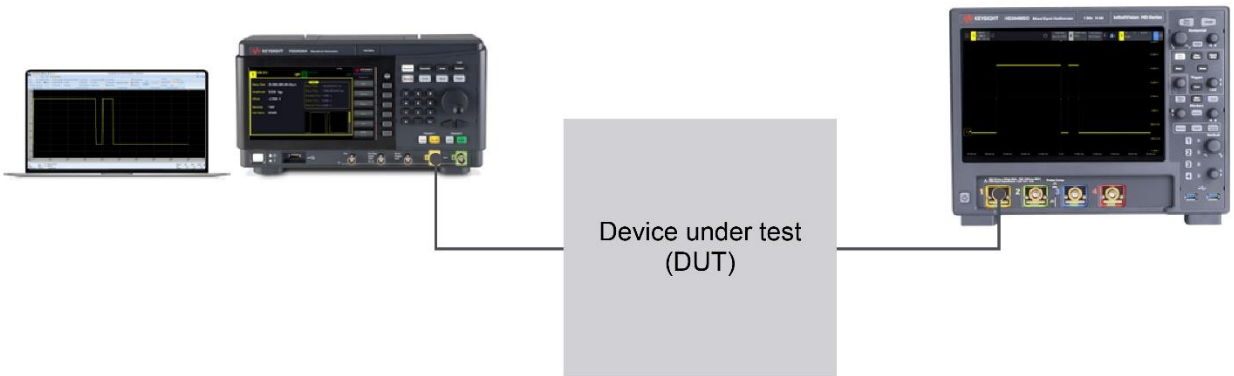

Figure 1. Instrument setup for double pulse testing

Double Pulse Test Setup

The following steps outline how to create a double pulse waveform using the BenchLink Waveform Builder Pro application. After generating the waveform, we import it directly into the Smart Bench Essentials Plus function generator. Finally, we observe the created pulses using an oscilloscope.

Step 1: Configure parameters using BenchLink Waveform Builder Pro

BenchLink Waveform Builder Pro enables you to create a customized waveform, including the double pulse signal. To create a double pulse waveform, set up the arbitrary waveform using the following configuration:

- **First pulse:** Ensure it is long enough to ramp the load current to a steady state.
- **Off-time / recovery period:** Allows freewheeling current through the diode to fully de-energize before the second pulse. This step is important to prevent incorrect readings or potential device failure caused by incomplete recovery.
- **Second pulse:** Capture turn-on behavior during switching transitions or nominal current conditions, tailored to the DUT’s requirements.

The duration of the first pulse is always longer than that of the second pulse to ensure that the DUT reaches a steady state, allowing for accurate measurement of its switching characteristics. The shorter duration of the second pulse ensures that the current through the DUT does not reach levels high enough to damage the device.

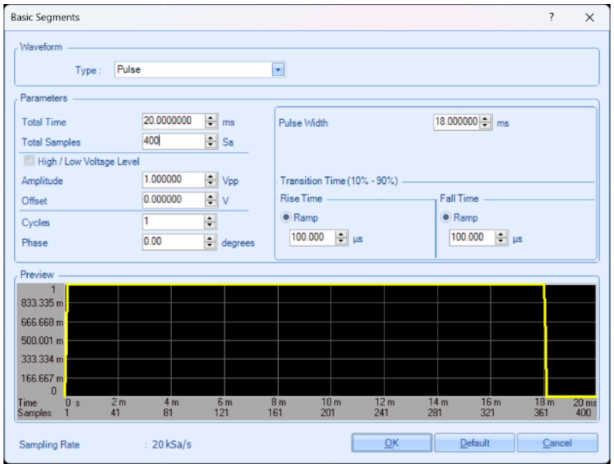

Figure 2. First pulse configuration and off-time setting

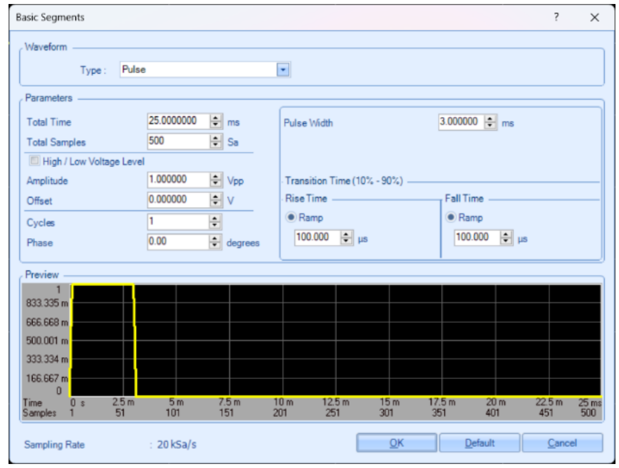

Figure 3. Second pulse configuration

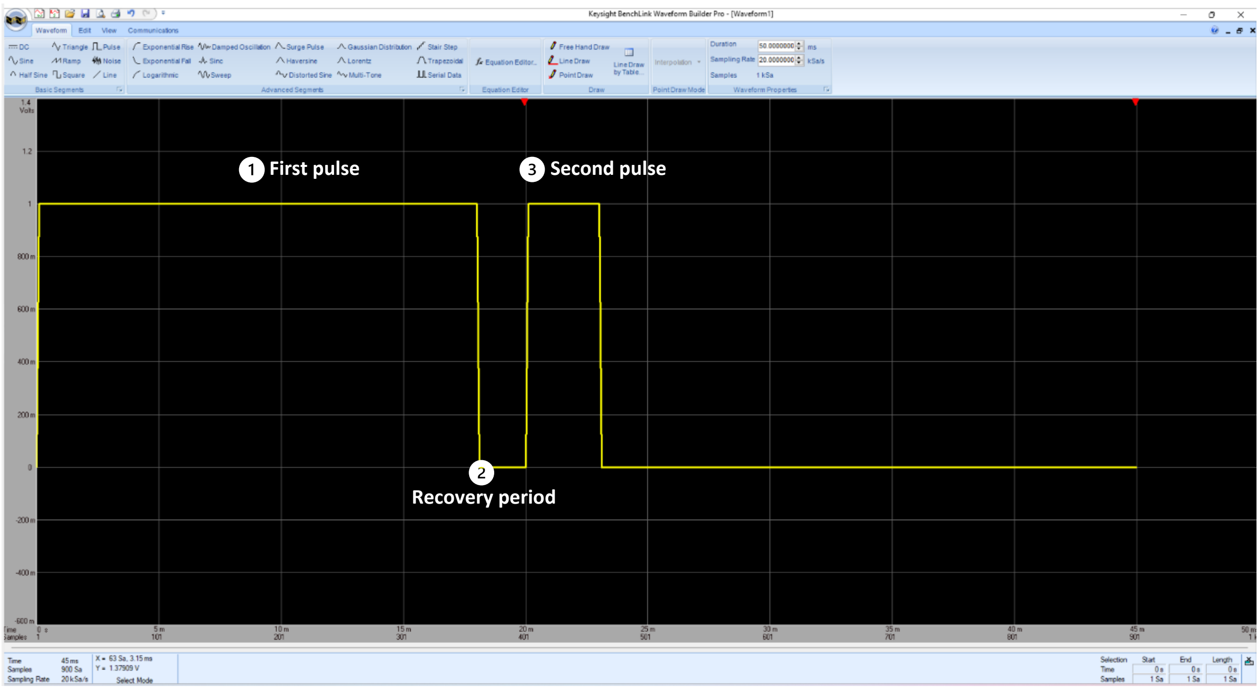

Figure 4. Double pulse signal display in the Keysight BenchLink Waveform Builder Pro application

Step 2: Import double pulse signal into a function generator

You can use the BenchLink Waveform Builder Pro software to connect your function generator to directly import the double pulse signal into the Smart Bench Essentials Plus function generator. In this application note, the function generator is connected as a signal source to the DUT. On the Communications tab, press **Connect** to make sure your function generator is connected before importing the data. Then, press **Send Data to Instrument** to import the double pulse waveform into the function generator.

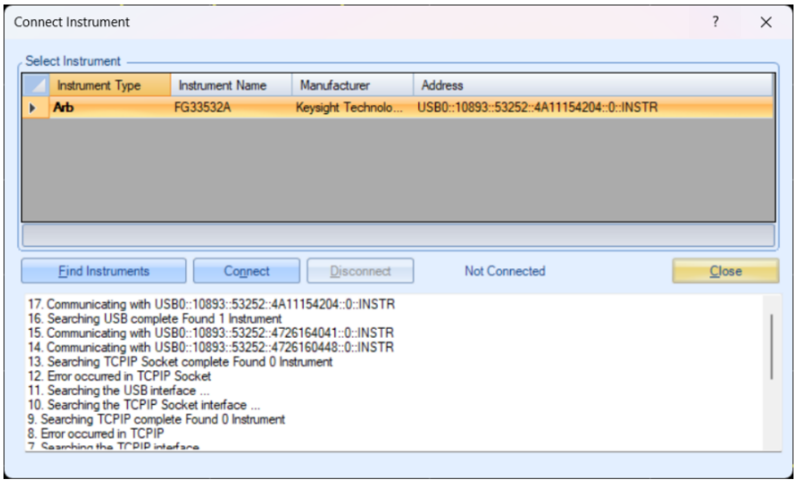

Figure 5. Connect the Keysight FG33532A function / arbitrary waveform generator before importing the waveform data

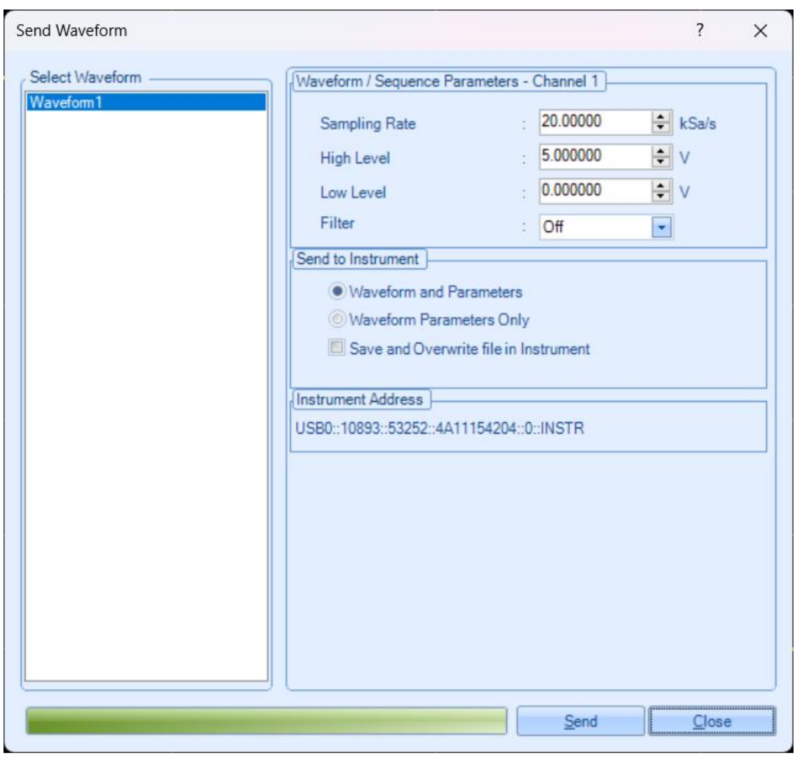

Figure 6. Send the waveform data to FG33532A

After importing the waveform data into the Smart Bench Essentials Plus function generator, you will see the ARB display, as shown in Figure 7. Set the amplitude to match the gate drive voltage specified by the DUT manufacturer.

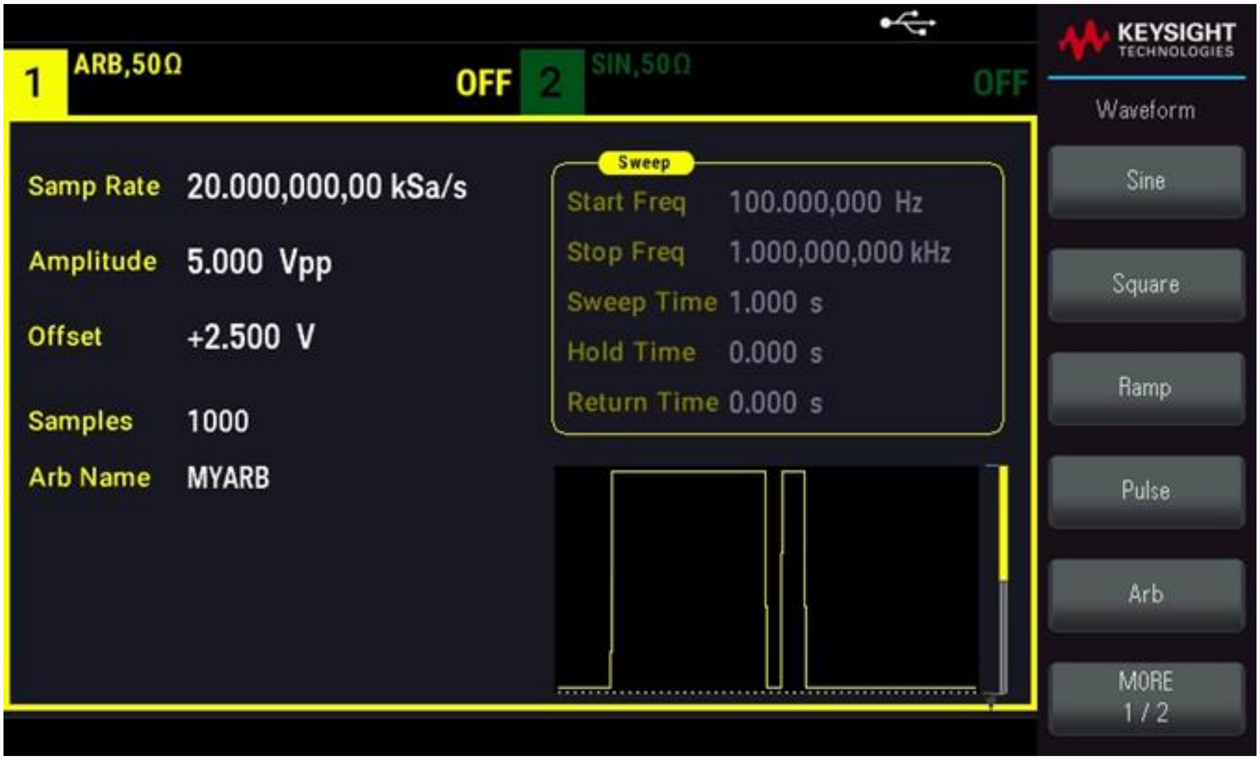

Figure 7. Waveform preview and parameters display on FG33532A

Step 3: Display your double pulse signal using an oscilloscope

To verify the created double pulse waveform from the function generator, connect an HD3 oscilloscope or a similar scope to the output channel of the FG33532A function generator. The high-resolution oscilloscope used in this application is also part of the Smart Bench Essentials Plus instruments. It comes with a custom ASIC and 14-bit ADC built-in to provide very high vertical display resolution and low noise floor to capture the pulse for this application. In this case, set the x-axis scaling to 3.4 ms / div and the y-axis scaling to 1 V / div on the oscilloscope to capture a clear display of the output waveform.

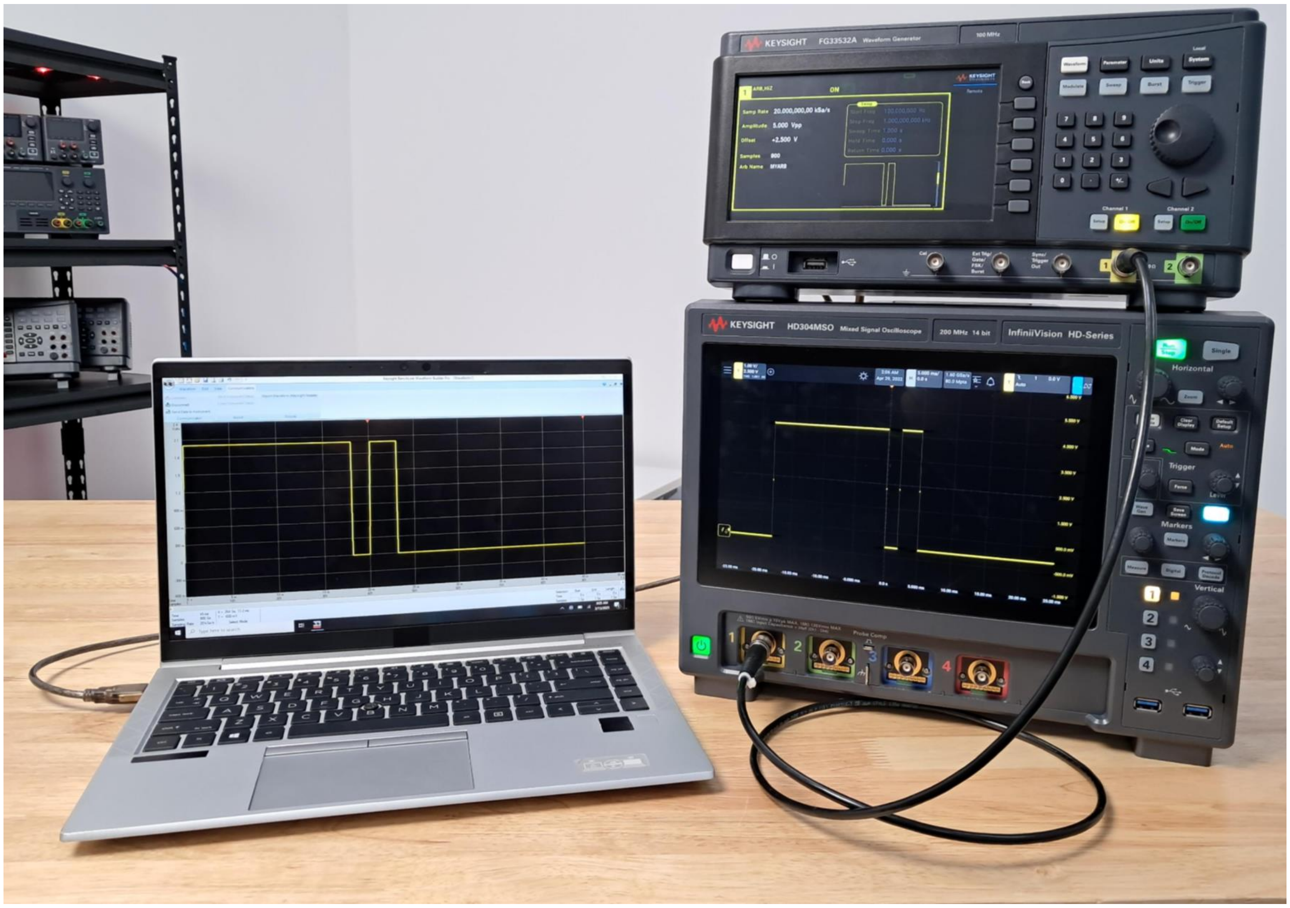

Figure 8. Double pulse signal captured by a scope

Step 4: Analyze turn-on and turn-off characteristics of your DUT

By connecting an oscilloscope to the output of your DUT, you can evaluate its performance under real-world conditions and enhance the reliability of your power electronics design. Optimizing turn-on and turn-off losses is crucial for improving switching efficiency and managing heat dissipation. Turn-on energy (E_{on}) indicates the energy dissipated when the switch turns on, while turn-off energy (E_{off}) represents the energy dissipated when the switch turns off. You can obtain these measurements from the output signal of the DUT using an oscilloscope.

According to the IEC 60747-8 standard for switching times and energies, the turn-on and turn-off characteristics are calculated as follows:

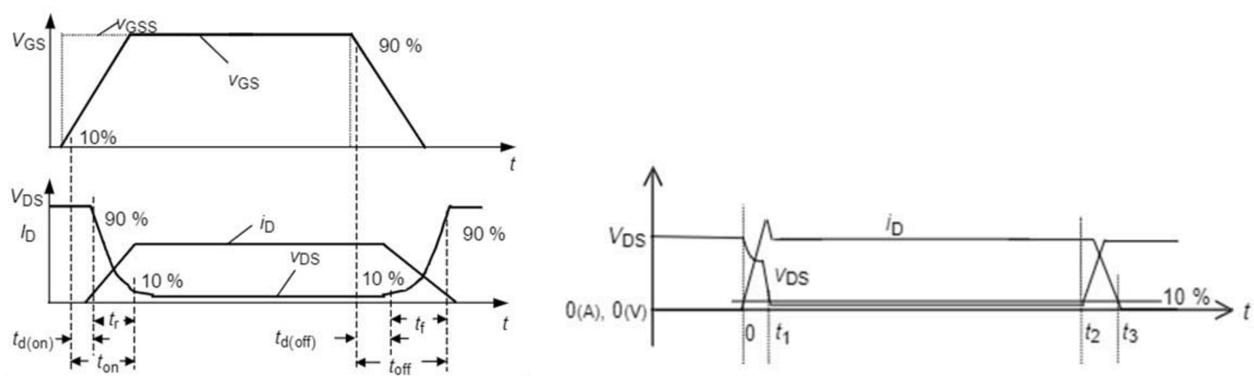

Figure 9. Waveforms and positions of switching times extractions according to IEC 60747-8

Table 1. Turn-on characteristics

Parameter	Description
Turn-on delay, td(on)	Time between 10% VGS → 90% VDS
Turn-on rise time, tr	Time between 90% VDS → 10% VDS
Turn-on time, ton	ton = td(on) + tr
di / dt(on)	Plot the derivative of the current between 10% and 90% of ID. Report the maximum.
dv / dt(on)	Plot the derivative of the voltage between 90% and 10% of VDS. Report the maximum.

Turn-on energy, $E_{on} = \int_0^{t1} i_D \cdot v_{DS} \cdot dt$

Table 2. Turn-off characteristics

Parameter	Description
Turn-off delay, td(off)	Time between 90% VGS → 10% VDS
Turn-off fall time, tf	Time between 10% VDS → 90% VDS
Turn-off time, toff	toff = td(off) + tr
di / dt (off)	Plot the derivative of the current between 90% and 10% of ID. Report the maximum.
dv / dt (off)	Plot the derivative of the voltage between 10% and 90% of VDS. Report the maximum.

Turn-off energy, $E_{off} = \int_{t2}^{t3} i_D \cdot v_{DS} \cdot dt$

In short, optimizing turn-on and turn-off energy is crucial for enhancing the efficiency and reliability of power electronics systems. Lowering these energy losses during switching directly improves overall efficiency, reducing unnecessary power dissipation. This efficiency gain is particularly important in high-frequency applications where frequent switching occurs. Additionally, minimizing E_{on} and E_{off} helps manage heat generation, which is vital for thermal management. Effective heat dissipation ensures that components operate within safe temperature ranges, thereby extending their lifespan and reliability.

Furthermore, efficient switching contributes to better performance by allowing for faster and more precise control of power flow. By carefully measuring and optimizing E_{on} and E_{off}, designers can achieve a balance between performance, efficiency, and thermal management, leading to more robust and reliable power electronics design.

Conclusion

Double pulse testing provides critical insight into the switching behavior of power devices, enabling designers to optimize efficiency, reliability, and thermal performance. By using the Keysight Smart Bench Essentials Plus function generator, you can generate a standard double pulse signal to characterize your DUT instead of investing in a high-cost pulse generator. This approach makes the double pulse test more accessible and cost-effective while providing precise and reliable measurements.

With up to 100 MHz bandwidth, low jitter and total harmonic distortion, and Keysight Trueform waveform generation technology, Smart Bench Essentials Plus function generators deliver high signal integrity. Featuring 16-bit arbitrary waveform generation, advanced waveform sequencing, and a proprietary virtual variable clock with advanced filtering, they generate true representations of the waveforms you require.

Unlike other general-purpose test instruments, Keysight function generators deliver reliable quality, stability, and safety. They consistently meet or exceed industry and safety standards to safeguard the integrity of your products. Certified to ISO / IEC 17025, UL, and CSA standards for testing and calibration, these instruments ensure reliable, repeatable test results. Each device undergoes rigorous testing to ensure user safety.

Using the Keysight BenchLink Waveform Builder Pro application, you can easily create customized waveforms — including double pulse signals — saving you time and enabling precise signal generation with just a few clicks.