LeCroy Applications Brief No. L.A.B. 742

Measuring Energy

Verifying Energy Measurements Using Capacitor Discharge

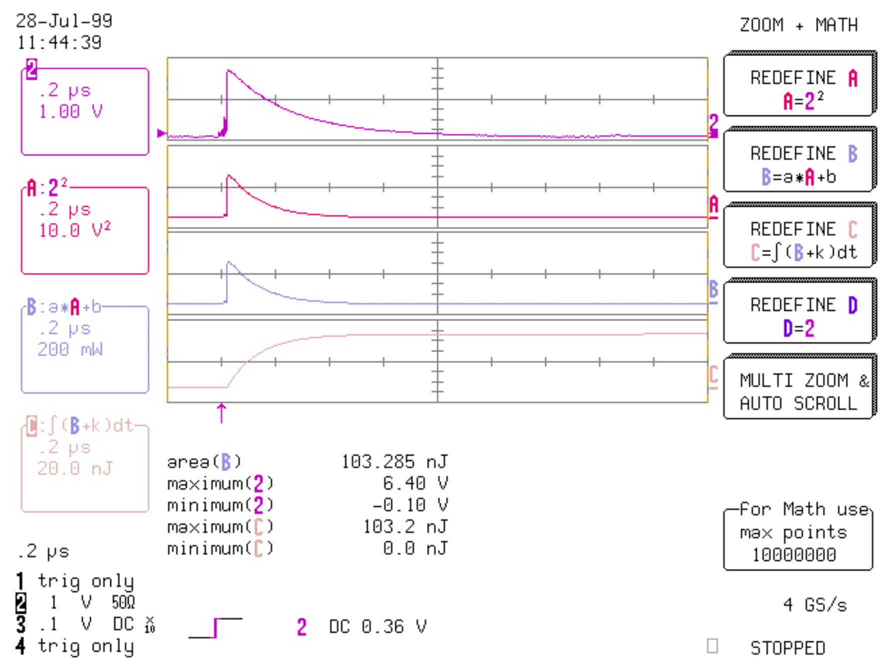

Figure 1 – A simple experiment which will verify energy measurements

Some electro-static discharge (ESD) measurements require the measurement of discharge energy. In many of these experiments the oscilloscope can measure the discharge current or voltage but often both may not be available simultaneously. This means that the determination of energy is dependent upon knowledge of the load impedance into which the energy is discharged. Figure 1 shows the measurement of a simple capacitive discharge which is used to confirm assumptions concerning the nature of the load impedance.

In this example the capacitor is charged to a fixed DC voltage and then discharged into the measurement system. The energy stored on the capacitor can be determined form the capacitance value and the initial volt age across the capacitor.

In this example the capacitor was discharged into a coaxial probe which, has an assumed characteristic impedance of 50 Ohms.

To verify this assumption we use the math traces to calculate energy based on the measured voltage waveform of the discharge. This is shown as the top trace (ch 2) in figure 1. The voltage waveform is squared (trace A), scaled to divide by the assumed characteristic impedance (Trace B) yielding the power in Watts, and finally integrated (trace C). The resultant measured power is displayed using two parameters. The first Area of trace B measures the area under the instantaneous power curve (trace B). This reports an energy level of 103.285 nanoJoules (nJ). The maximum of trace C reads the highest value of the integral of instantaneous power which is energy and it reports a value of 103.2 nJ.

The calculated energy initially stored on the capacitor is based on the measured value of the capacitor (0.00491 µF) and the initial voltage difference across the capacitor as measured on trace 2 using the Maximum and minimum parameters for trace 2. This works out to be 6.5 Volts. The energy is calculated as:

$$\mathbf{E = \tfrac{1}{2}\, C\, V^2}$$

$$= \tfrac{1}{2}\,(4.91 * 10\text{-}9)(\,6.5)^2$$
$$= 103.72 \text{ nJ}$$

This calculation has a probable error of ±9 nJ based on the accuracy of the voltage and capacitance measurements.

The measured and theoretical values for the energy discharged from the capacitor are very close, justifying the assumption of a 50 Ohm impedance for the coaxial probe.