WAVECREST Corporation

MEASURING DAC OUTPUT GLITCH ENERGY USING THE DTS-2075

Application Note No. 128

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***WAVECREST* Corporation**
A Technologies Company
7275 Bush Lake Road
Edina, Minnesota 55439
(612) 831-0030
(800) 733-7128
www.wavecrestcorp.com

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Introduction

One of the more time consuming and difficult parameters to characterize and test in an ATE environment is the **Glitch Energy** specification. Glitch energy specifications are found on parts such as D to A converters and RAMDAC video driver chips. This specification is also found in the video outputs on the graphics processor chips used on computer video cards. Also, any analog circuit that is switched will produce a glitch on the output as it changes level and settles out. This paper will describe the capabilities of the DTS-2075 hardware to test **Glitch Energy**. It will also outline the software steps to program the DTS-2075 over the GPIB interface in an ATE environment as well as the use of *WAVECREST's Virtual Instruments*™ (Patent pending) waveform capture tool to measure glitch energy in a lab environment.

Specification Measurement Background

Glitch energy is defined as the area under the voltage time curve of a single DAC step measured until the step has settled out to within a specified error band of the step's final value (Linearity Error, Figure 1). Depending on the internal logic of the DAC, the glitch energy can be very low (<50 picovolt seconds) for segmented architectures to values higher than 10 nanovolt seconds. for resistor divider networks. For most DACs, the maximum glitch energy occurs when a transition is made between segments, which have the worst switching current skew. Often, this is where the digital count switches an MSB such as 0111 1111 to 1000 0000 on an 8-bit RAMDAC. This is also where the internal registers are all switched and current sources are turned on and off.

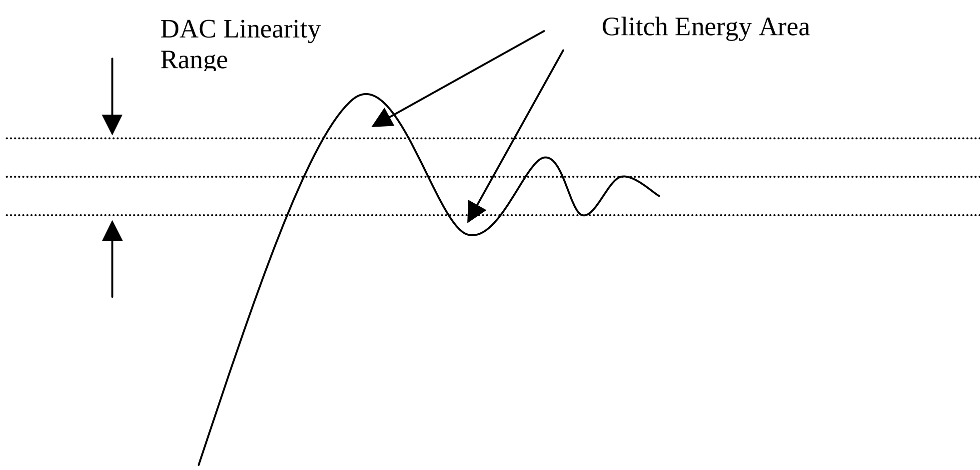

Figure 1 - Glitch Energy Area Definition

It is important that a video part have low glitch energy to avoid pixel color change, blurring pixels across a screen. Since glitch energy is difficult and time consuming to test, often times RAMDACs, video DACs, and graphics processors guarantee the glitch energy spec. by design and leave it up to quality lot screening to capture test failures. The DTS-2075 waveform capture capability enables the test programmer to capture an accurate glitch waveform and perform a go no go test with a minimum of test time impact

Measurement Setup

The experiment used to demonstrate the glitch energy test capabilities was setup as shown in picture 2.

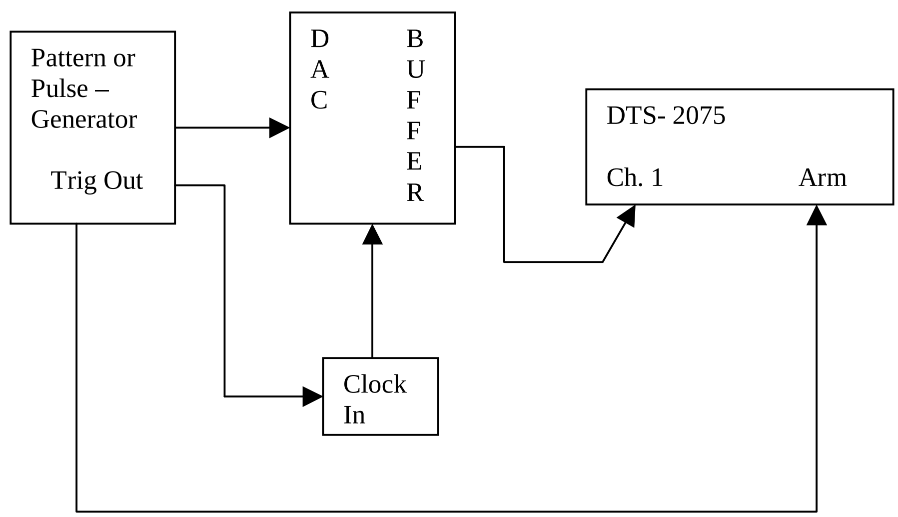

Figure 2 - Experiment Setup

The key to this setup is that the observer has control over the timing that the DAC outputs switch. The DTS-2075 can be triggered on a repetitive DAC output waveform or from the pattern or pulse generator input. The optimum test speed is obtained when we asynchronously trigger on the waveform at the DAC output. The DAC is programmed to repeat a worst case switch (0111 1111 to 1000000) and the glitch energy measurement is made using the DTS-2075 waveform capture capabilities to measure the area of the glitch. A repetitive switching waveform is all that is required by the DTS-2075 to acquire the glitch waveform. The existence of the arming signal is to demonstrate correlation with an oscilloscope and acquire waveforms from signals that are not repetitive.

Comparison of DTS-2075 Waveform Capture Capabilities

In waveform capture mode, the DTS-2075 operates like a random sampling or equivalent time sampling oscilloscope. In addition to the DTS-2075's time measurement system, the instrument has a strobing voltmeter that can be used to plot the Voltage/Time waveform. This is precisely the capability that a glitch energy test requires. What makes the DTS-2075 a good method to test glitch energy is that it has the following capabilities:

Voltage Resolution 150µv
Timing Step Resolution .... 10ps minimum
Capture Range 100µs
Trigger Capability CH1, CH2, ARM1, ARM2
Analog Comparator Bandwidth .... >2GHz
System Noise Floor .... <6ps RMS

This measurement is typically made with a sampler or digitizer on an ATE system, or an oscilloscope in a lab environment. What do these specifications mean and how do they compare to ATE or an oscilloscope?

To achieve the type of voltage sensitivity in an ATE environment of the DTS-2075 has often requires a buffer or amplifier on the DUT board. This would allow a receiver on a sampler that typically has 2-5mv resolution to receive low level or finer stepped voltages. The DTS-2075 has much less of a need to use DUT board amplifier designs because of its voltage sensitivity. Eight and twelve bit DACs can usually be tested directly and 14 bit and above can often be tested with much simpler amplifier designs. The DTS-2075 has the voltage resolution, and accuracy required for measuring glitch energy specifications below 20pv-sec.

A very good Digital Sampling Scope such as a Tektronix CS803 or a HP 83480 communications analyzer has a vertical sensitivity of 1mv/div and accuracy of 1% of the voltage.[1,2] Dividing each division by five and you have a measurement ***capability*** of approximately 200µv. This assumes that the glitch in question can fit on the Oscilloscope screen with this voltage setting. A general purpose HP Infinium 54845A model has a vertical sensitivity of 2mv/div[2]. The DTS-2075 thus has an equivalent or better operation in the vertical axis.

The timing resolution on the DTS is very important to measuring glitch energy. The timing resolution necessary to accurately measure the energy in high speed glitches should be at least ten times the time duration of the glitch being measured. This ensures a fairly accurate integration of the glitch area calculation. The DTS-2075 can place ten measurements inside a 100ps glitch. Since the glitches on DACs are usually of much longer duration (500ps or greater), the 10ps timing resolution of the DTS-2075 waveform capture provides very good area calculation capability.

In comparison, ATE instrumentation that uses a digitizer cannot capture more than a point or two on a glitch since the best digitizers have a 4 to 8GS/s capability. This would be a 125ps or 250ps time step. ATE digital timing systems can provide 10-20ps edge strobe time resolution but the edge placement accuracy and timing vernier linearity often precludes accurately measuring glitch energy.

In the oscilloscope arena, the timing resolution on a Tektronix CS803 has a timing resolution of 1 ps[1]. Digitizers with 8GS/s rate can observe 250ps glitches. Digitizers with 4GS/s rate can observe 500ps glitches. The DTS-2075 waveform capture has a much better resolution for capturing glitches while a sampling scope like a CS803A can acquire more points on the glitch than the DTS-2075.

One of the most important specs to review when choosing an instrument to measure glitch energy is the input bandwidth. A CS803 or a HP 83480 can accept plug-ins that can achieve 50GHz bandwidth. A common plug-in is 20MHz. Compared to a 20GHz bandwidth, the DTS-2075 with a 2GHz bandwidth will appear to attenuate the peak amplitude of a glitch while also slowing down the glitch rise times. Comparing the glitch energy measured with a 20GHz plug-in and a 2GHz instrument, the DTS-2075 will slightly understate the glitch energy. Compared to what’s available in the ATE environment, the DTS-2075 has much better bandwidth. Typical instruments that can be used on commercial ATE to measure glitch energy have a bandwidth of 500MHz to 1GHz.

Using *Virtual Instruments*™ to Measure Glitch Energy

The *Virtual Instruments*™ software that can be used to program the DTS-2075 has a tool that makes the DTS-207x into an oscilloscope. This tool can be used to measure the glitch energy using the following steps:

1) Capture the glitch waveform in question
2) Pass the Voltage points to a Spread Sheet
3) Calculate the area under the glitch waveform.

** *At present, the software version of Virtual Instruments™ (patent pending) that is used in this paper is version 3.20. The oscilloscope function does not contain an automatic mode to measure the glitch energy. Future versions of the software may contain this feature.*

Correlating the glitch energy on the DAC is done between a CS803A oscilloscope using the Area+ and Area- measurement routines and a DTS-2075 using the three steps above. Picture 3 on the following page is a print out of the CS803A's view of the waveform glitch energy.

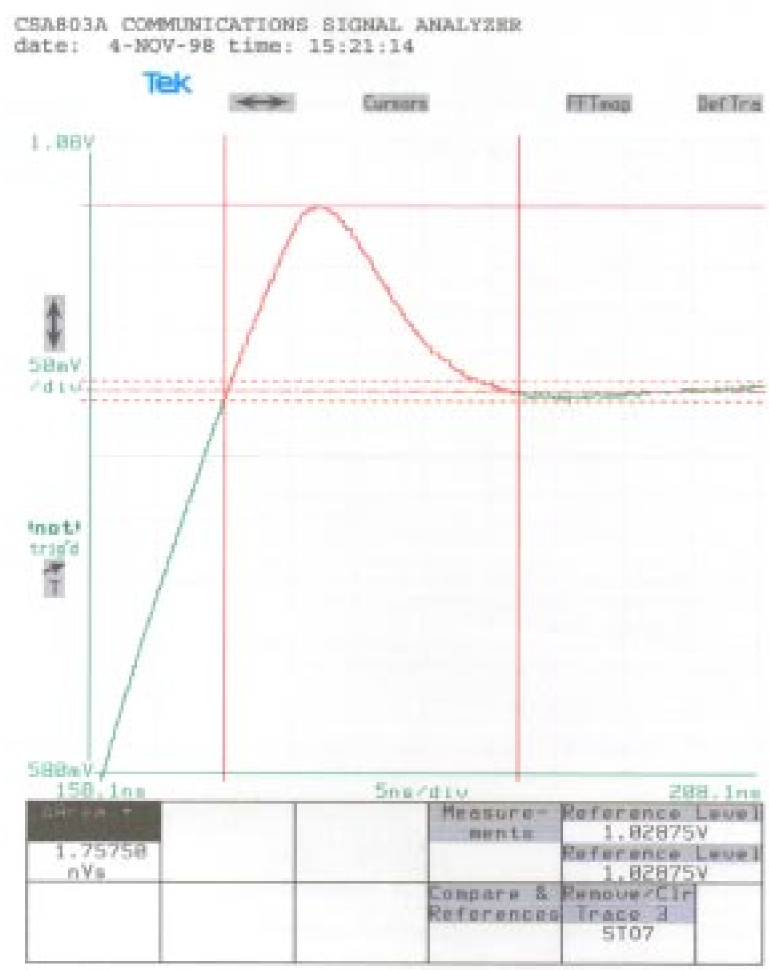

Figure 3 - CS803A Glitch Waveform

The glitch energy measured in this picture is 1.76nv-sec. This is the Area+ of the waveform between the start and stop markers on the horizontal access and the peak and baseline markers on the vertical axis. Note the voltage peak is 1.028v.

The DTS-2075 produces the waveform seen in Figure 4.

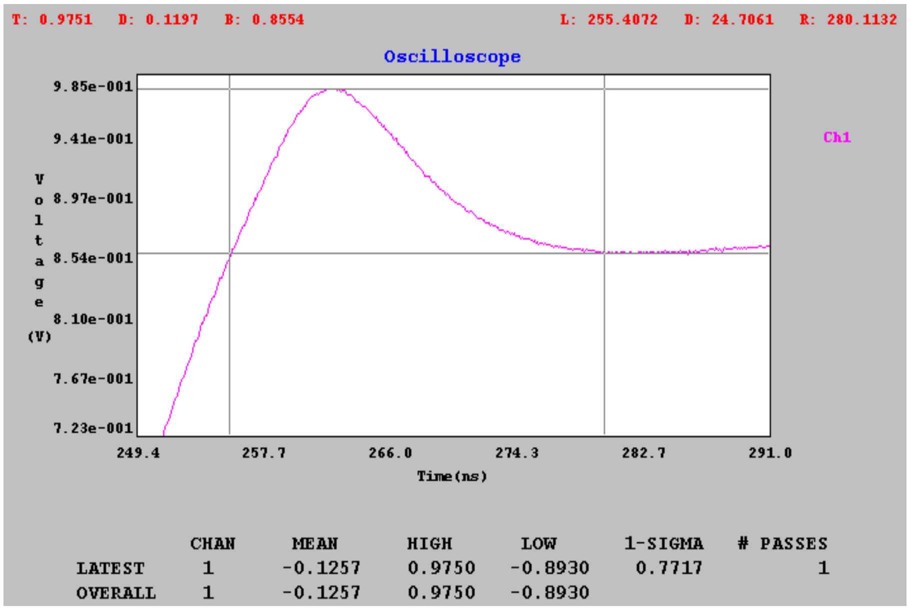

Figure 4 - Glitch Waveform Taken with VI Oscilloscope

This picture is taken using the Oscilloscope tool in *Virtual Instruments*™. The horizontal and vertical markers enabled under the Screen pull down menu frame the glitch energy. The **`Grid`** option in the **`Screen`** pull down is turned off. The following selections in the Oscilloscope **`Options`** menu are used:

Start Time........................ 249ns
Stop Time........................ 291ns
Increment......................... 0.01ns

Trigger Channel............... CH1

Show Plot CH1
Show Measurement......... CH1

In order to capture only the points that we need for calculating the glitch energy, we set the `Options` menu `Start Time` to 255.400ns and the `Stop Time` to 280.110ns. These numbers were taken from the marker values labeled L and R shown in the upper right hand corner of Figure 4. These values produced Figure 5.

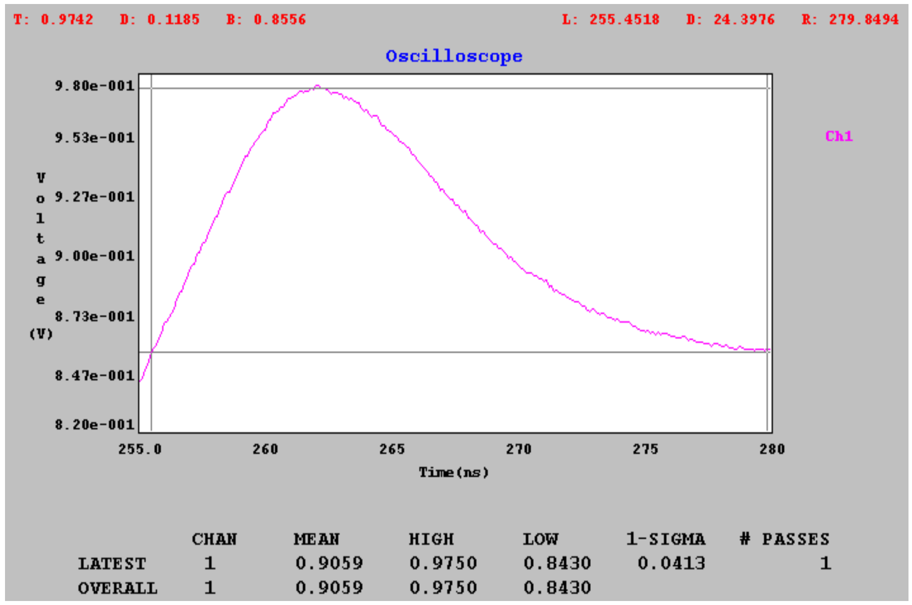

Figure 5 - Glitch Capture Data

This data is saved to a file using the **Save Data** option in the **File** menu pull down in the Oscilloscope tool. This file is ASCII text and is suitable to load into a Microsoft Excel spreadsheet. An abbreviated example of this file looks like:

```
2.57e-007      0.7706
2.571e-007     0.7738
2.572e-007     0.7755
2.573e-007     0.7787
2.574e-007     0.7823
2.575e-007     0.7828
2.576e-007     0.7863
2.577e-007     0.7873
2.578e-007     0.7901
2.579e-007     0.7928
2.58e-007      0.7958
2.581e-007     0.7974
2.582e-007     0.7998
2.583e-007     0.8039
```

The time value is in the left-hand column and the voltage value is on the right

Calculating Area for Glitch Energy

The CS803A uses this equation for calculating Area+[3]:

$$\text{Area+} = \sum_{j=m}^{n-1} \frac{\text{ABS}[W(j+1)-R]+\text{ABS}[w(j)-R]}{2} \times T$$

where:

m= index of left-most measurement sample
n= index of right most measurement sample
W(j) = input sample voltage point
R= reference voltage level
T=time interval between samples
ABS = the absolute value function

This equation describes a discrete integration of the captured curve. A macro can be programmed in the spreadsheet to perform this exact calculation. This macro uses every even voltage cell to calculate a discrete rectangular area for each discrete step and adding the area of the rectangles. Figure 6 shows this algorithm.

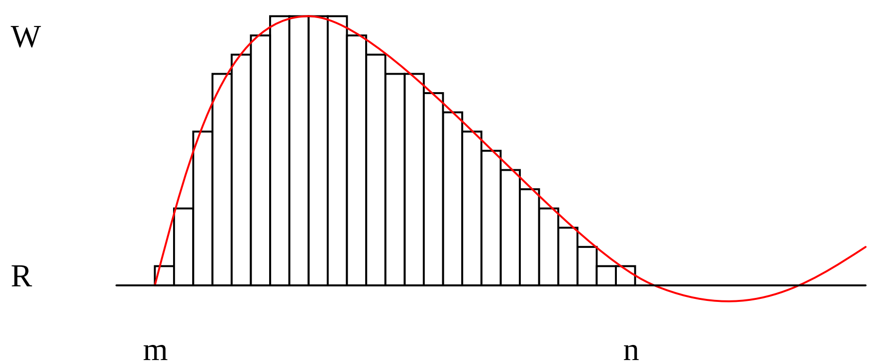

Figure 6 - DTS-2075 Discrete Area Calculation Algorithm

The spread sheet calculation from the waveform capture data is **1.71nv-sec**, an understatement of 40pv-sec, or 4%. This is good correlation. There are two reasons for the difference. First, the difference in amplitudes obtained by the two instruments. The CS803A measures a peak amplitude of 1.028v, the DTS-2075 peak amplitude of 0.988v. This is due to the higher bandwidth (20GHz) of the CS803A than the DTS-2075 (2GHz). Second, the DTS does a discrete measurement at linear steps of 10ps, while the CS803A is making dot to dot measurements at linearity of 6ps and a resolution of 1ps[1]. This difference will produce a larger integration error on the DTS measurement than on the CS803A.

Measuring Glitch Energy in an ATE Environment

In a production environment, the speed of test is paramount. With this in mind, the DTS-2075 provides the test programmer with a firmware macro that can be used to capture the waveform. The command is executed in two parts

1) Acquire the waveform by setting the start, stop and time increment. This can be executed quickly using the GPIB command **`ACQ:WIND/start/stop/increment.`**[4]

   where:

   start = start time in picoseconds
   stop = stop time in picoseconds
   increment = step time resolution

2) Download the voltage and time data using the Wavecrest GPIB command **`MEAS:VDATA?`**. This command returns the voltage measurement points acquired in the previous **`ACQ:WIND`** command. The data returned is a five-digit voltage value at each time point referenced from the start time.

The glitch energy algorithm should be designed to provide the best time/accuracy trade-off between the time resolution and the time it takes to complete the measurement. A single voltage acquires takes approximately 20µs. A 1000 point measurement will take 20ms with an additional 10-20ms for the data to be downloaded over the GPIB 488 bus. Add a couple of milliseconds for calculation and the total time to make a glitch energy test on a production ATE system is less than 50ms.

Example C program skeleton:

```
Void perform_glitch_energy()

{
double data

Send (0,5,”:ACQ:WIND/250000/280000/10”,26,EOI);
Send (0,5,”:MEAS:VDATA?”,12,EOI);
Receive(0,5,data,3000,EOI);
}
```

This code returns 3000 data points to the variable data.

Conclusion

In addition to its jitter and time measurement capability, the DTS-2075 and Virtual Instrument software is a very good waveform capture tool. It does not suffer from the inherent resolution issues that high-speed samplers and digitizer designs have and closely matches the capabilities of High speed DSOs such as the Tektronix CS803. Because the instrument acquires are executed quickly and the instrument does not have to display a waveform, it can be used on production ATE in applications that require precise waveform measurements. Test applications that can take advantage of this capability include DACs, RAMDACs and Video processors.

It is suggested here that future enhancements to the capabilities of the DTS software should include automatic calculations of glitch energy and edge linearity for both production test GPIB code and characterization using *Virtual Instruments*™. Throughput improvement through the creation of a firmware macro is also urged. Typical improvements in other cases of firmware code migration have resulted in 10 to 30 times speed improvements over executing from the GPIB bus.

Please refer questions or comments on this paper to:

rlesniko@wavecrestcorp.com

References

1. Tektronix Web Site Address:

   http://www.tek.com/Measurement/cgi-bin/framed.pl?Document=/Measurement/Products/catalog/csa803c/index.html&FrameSet=old_meas

2. HP Web Site Address

   http://www.tmo.hp.com/tmo/datasheets/English/HP83483A.html

3. Tektronix CS803A User Manual pg. D-13

4. DTS-2077/2075 GPIB Programming Guide, pg. 40, Section 6-12

WAVECREST Corporation
World Headquarters
7275 Bush Lake Road
Edina, MN 55439
(612) 831-0030
FAX: (612) 831-4474
Toll Free: 1-800-733-7128
www.wavecrestcorp.com

WAVECREST Corporation
West Coast Office:
1735 Technology Drive, Suite 400
San Jose, CA 95110
(408) 436-9000
FAX: (408) 436-9001
1-800-821-2272

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