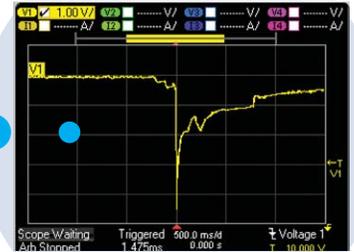


Automotive ECU Transient Testing Using Captured Power System Waveforms

Application Note



Contents

• Introduction	2
• Description	2
• Problem	2
• Solution	2
• Capturing the voltage transient	3
• Adjusting the data	4
• Transfer the data to the N6705A	7
• Playback the waveform	7
• Programmatically starting waveform using SCPI commands	8
• Conclusion	9

Introduction

This application note describes how Automotive Electronic Control Unit (ECU) conducted transient tests can quickly and thoroughly be accomplished using the Agilent Technologies N6705A DC Power Analyzer to playback actual transients seen in your vehicle.

Description

Automotive vehicle power systems are very harsh electrical environments. High current motors, solenoids and other components on the power system cause power system voltage transients and dropouts to occur often. Successful operation of your automotive electronics depends on adequate power transient immunity, and the mission critical nature of automotive electronics make thorough ECU testing a must.

A variety of test standards such as ISO-7637 and ISO-16750 document transient waveform profiles to help you in that effort. But those waveforms represent a best guess at what your ECU will see in the vehicle. This application note describes methods to help you verify your ECU operation in the harsh vehicle power system environment by actually capturing the voltage transients as they occur in the vehicle, and playing back at a later time at your convenience to test your ECU.

Problem

Standard test methods and voltage profiles for automotive power system testing provide a good basis for ECU test. However they may not adequately reflect the actual transients that your ECU will see in the vehicle. Each ECU placement in the vehicle is unique and power system transients present may differ depending on the ECU location. High current motors or solenoids may be placed on the same power branch or proximity as your ECU and alternator and battery performance varies with environmental conditions. As such, the standard profiles used for power system transient testing are not totally representative of the transients that your ECU will experience.

The ultimate test is to actually test the ECU in the vehicle itself under all operating conditions. But unfortunately this is not very practical.

Solution

What if you can record the transients which occur in the vehicle and play them back in your development lab when needed?

Capturing the transients can be done by simply using an oscilloscope. Connect your oscilloscope to the power system where your ECU will be located and then exercise conditions known for generating transients while capturing the transients. Conditions such as engine cranking, compressor activation and cold temperature operation can be exercised, and the resulting power system transients captured.

Once the transients have been captured, load them onto your PC for inspection, modify if needed and download to an arbitrary waveform generator (arb). Playback the output waveform via the arb connected to the ECU via a wide-band power amplifier. This approach can provide excellent insight into how your ECU will perform in the vehicle, and can be repeated multiple times as various ECU prototype revisions are developed. Multiple transient scenarios can be saved and a complete library created to use as needed. The transients can even be run for extended times such as overnight to test for intermittent susceptibility.



Usually this task requires the use of discrete arbitrary waveform generators and power amplifiers which can be cumbersome and time consuming to setup and program. However, the N6705A dc power analyzer can speed this testing by providing the arb and power supply in one convenient package.

The N6705A solution provides up to four channels of clean, high grade power supplies as well as built in standard waveforms such as sine, square and ramp. In addition, user defined waveforms with up to 512 data points of waveform memory can be created as needed. A selection of more than 20 plug-in dc power modules allows you to select the best module for your application. Fast slew rate outputs are available and when driven by the internal arb source can generate the power transients you need. Up to 600 watts of power can be provided by the N6705A. Modules are available that can deliver up to 20 amps. The ergonomically designed, user friendly front panel controls make it ideal for use in design validation, where ease of set-up and ease of use are paramount. The N6705A provides the complete solution, allowing you to focus your valuable engineering time to what matters most... getting your ECU to market fast!

Capturing the voltage transient

A variety of different oscilloscopes can be used to capture the voltage transient. Connect the oscilloscope directly to the automotive vehicle battery terminals and adjust the sample rates, sweep durations and triggering appropriate for the transient to be captured.

To demonstrate, we will capture the power system transients that occur during engine cranking. Once the scope is connected across the battery and properly setup, turning the ignition key to begin cranking the engine starter will trigger the scope and capture the voltage transient. Figure 1 shows a resulting view of the captured waveform and Figure 2 gives a partial tabular listing of the data as saved by the oscilloscope.

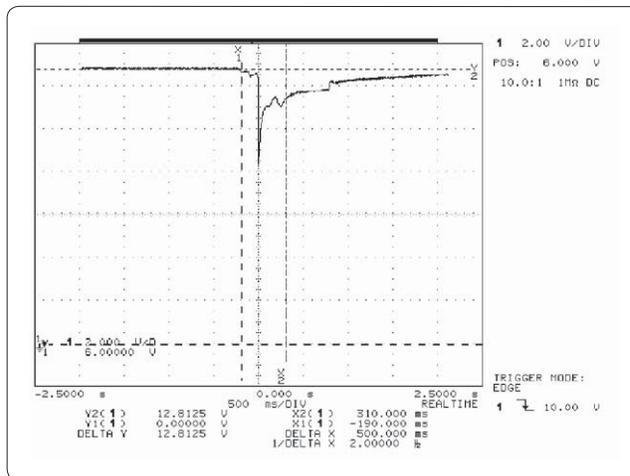


Figure 1. Power system transient due to starter motor crank

Once the waveform has been captured and imported to the PC, the data can be opened with Microsoft Excel and inspected. Adjustments may be made to customize the waveform if desired.

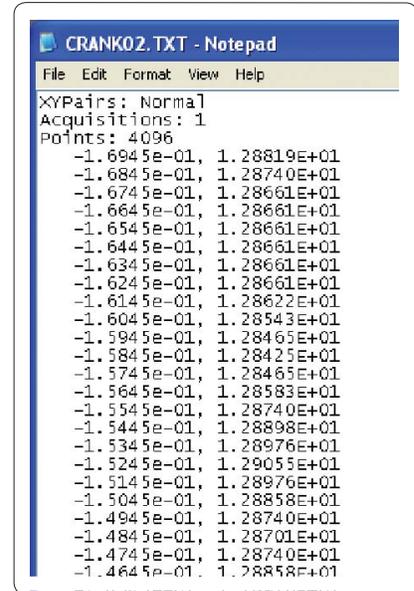


Figure 2. Tabular data

Adjusting the data

The N6705A uses a memory efficient point/dwell programming model to specify user defined arb waveforms. In other words, the waveform is described as a list of voltage (or current) points with a corresponding list of dwell times (one for each point). As an example, the N6705A User Defined Voltage entry window is shown in Figure 3 and shows four points of waveform data

entered. In this case when the User Defined Voltage is started the resulting waveform as displayed by the N6705A front panel is shown in Figure 4.

With this approach, if there is no change in voltage during long durations, it is possible to simply use one memory point with a corresponding long dwell time. Notice in Figures 3 & 4 how four waveform data points can efficiently describe a waveform that lasts 11.2 seconds.

Although this method makes very efficient use of waveform memory, it also means that the waveform data may need to be adjusted to match the format used in the N6705A. The best approach for programming the N6705A User Defined waveforms depends on the number of data points you have.

If the waveform is described with up to 512 data points:

If the complete waveform is contained in 512 memory points or less, simply set the dwell time to a fixed value corresponding to the time/voltage point. For example, if the waveform is 500 ms long, and you have 500 data points, simply set the dwell time per point to 1 ms and enter in the voltage or current data.

If the waveform is described with greater than 512 data points:

If the captured waveform data is initially longer than 512 memory points, you can compress the data and reduce the memory required by selectively adjusting the waveform dwell durations for sections of the waveform that have little or no change. The waveform previously shown in Figure 3 and Figure 4 is a good example of this approach. In this case four data points describe the complete waveform by setting the appropriate dwell time.

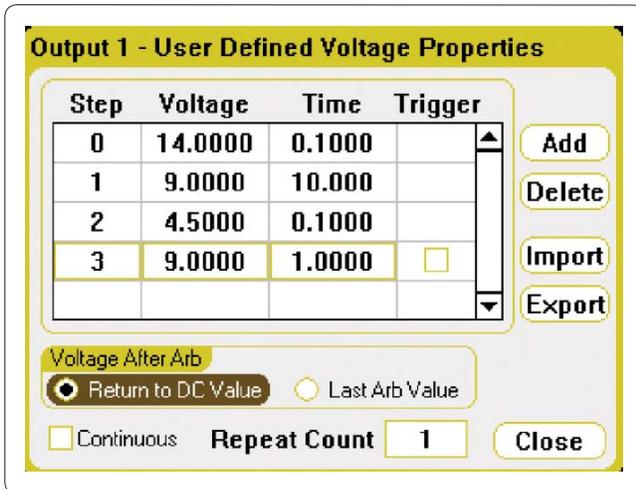


Figure 3. N6705A User Defined Voltage entry screen waveform

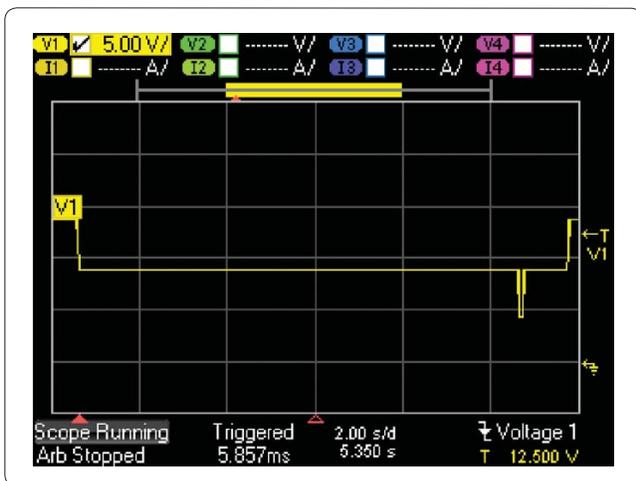


Figure 4. Resulting User Defined

For long waveforms it may be helpful to take a more algorithmic approach to reduce memory requirements. For example, when the scope trace is captured, there is generally a lot of data. An algorithm can be used on long scope data to compress to a point/dwell list format.

An example algorithm that can do this conversion is described below:

1. Choose an initial voltage threshold value, V_{inc} (this will be a small voltage such as 0.02 V).
2. Sort through the *scope data* to create a (1) *voltage list* and (2) *dwell time list*. Create the list values using the following approach:
 - a. Start by setting the first *voltage list* ($ylist(0)$) value equal to the 1st *scope data* value.
 - b. Incrementally sort through the *scope data* until you find the next value whose difference from the previous *voltage list* value is greater than V_{inc} and do the following:
 - i. Create the next *voltage list* point equal to that *scope data* voltage value.
 - ii. Set the *dwell time list* value for the *previous voltage list* point to the time difference from the current *scope data* point time to the previous *scope data* time.
 - c. Step to the next *scope data* value.
 - d. Repeat steps b-c until you run out of list points or scope data.
3. Repeat above while iterating with different V_{inc} values until the number of resulting waveform *voltage list* points is between 450 and 512. Too small V_{inc} and there will be too many compressed data points. Too large V_{inc} and the compressed waveform won't closely follow the scope data.

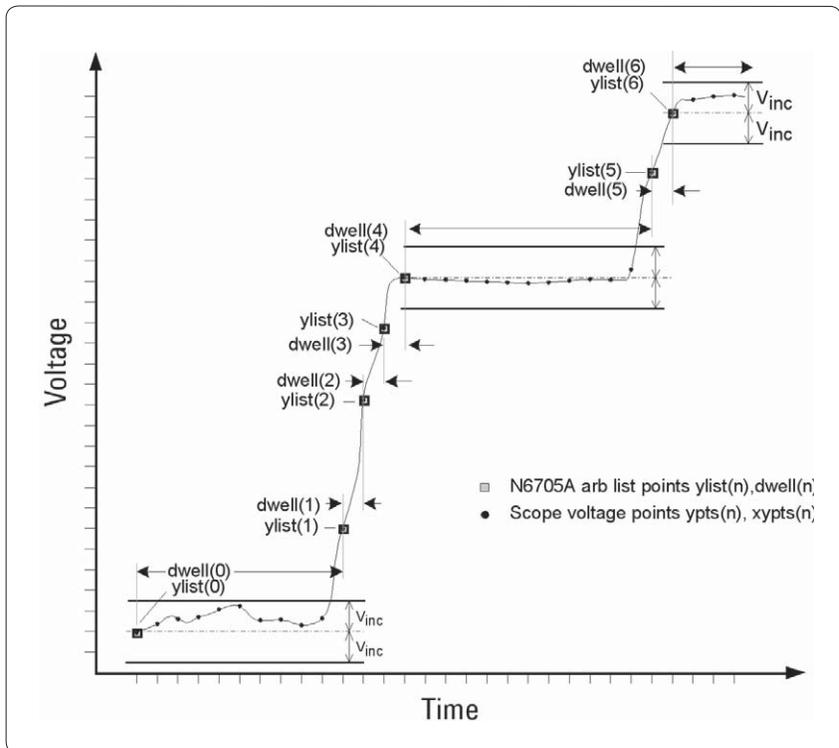


Figure 5. Compress 30 scope data points (ypts, xpts) to 7 voltage/dwell data points (ylist, dwell)

This algorithm can easily be implemented in Microsoft Excel using its built in VBA. Figure 6 shows a small section of code that demonstrates this.

Once the data is compressed to 512 points or less it can be adjusted using Excel to the proper format used in the N6705A. From Excel enter (or copy) the voltage and dwell time columns into a new worksheet with the voltage points in Column A starting at A3 (row's 1 & 2 are reserved for comments). Be sure that Excel represents this data in floating point notation (as opposed to scientific notation). The N6705A expects data in “x.y” format and will not correctly import the file if it is in scientific notation.

Corresponding dwell time's are listed in Column B. Finally, the third column C is used to indicate if a trigger is to be issued at the start of that segment. If set to 1, a trigger will be issued via the external trigger point or digital I/O port at that waveform step. See Figure 7 for proper file format.

Save the file in comma separated variable (.csv) format.

```
'AGORITHM TO COMPRESS WAVEFORM DATA
'FROM LINEAR TIME TO POINT/DWELL FORMAT
*****
'ypts & xpts contain scope results:
' ypts() contains voltage
' xpts() contains time
'yinc contains voltage increment threshold
'ylist() will contain compressed voltage list
'dwell() will contain dwell list
lasty = ypts(0)
lastx = xpts(0)
ylist(0) = lasty
dwell(0) = lastx
lstPts = 1

For n = 0 To WaveformSize
  If (Abs(ypts(n) - lasty) > yinc) Then
    ylist(lstPts) = ypts(n - 1)
    dwell(lstPts - 1) = xpts(n) - lastx - TimeStep
    lasty = ypts(n - 1)
    lastx = xpts(n - 1)
    lstPts = lstPts + 1
  End If
Next n
dwell(lstPts - 1) = xpts(n - 1) - lastx
```

Figure 6. VBA code to demonstrate algorithm

	A	B	C	D	E	F
1	Arb User Defined Waveform					
2	VOLTAGE	TIME	TRIGGER			
3	12.8819	0.008	1			
4	12.8543	0.005	0			
5	12.874	0.024	0			
6	12.8465	0.006	0			
7	12.874	0.003	0			
8	12.9055	0.007	0			
9	12.874	0.039	0			
10	12.9055	0.005	0			
11	12.874	0.047	0			
12	12.9055	0.011	0			
13	12.874	0.051	0			
14	12.9055	0.006	0			
15	12.874	0.016	0			
16	12.8465	0.022	0			
17	12.8189	0.005	0			
18	12.8465	0.008	0			
19	12.874	0.059	0			
20	12.9055	0.007	0			
21	12.874	0.002	0			
22	12.8465	0.014	0			

Figure 7. N6705A User Defined Waveform format

Transfer the data to the N6705A

Once the waveform data is properly format as a .csv file it may be entered into the N6705A using two different methods:

Using a USB flash drive

The simplest method to transfer the .csv file to the N6705A is to use a USB flash drive. Save the previously created .csv file onto your flash drive. Place the flash drive into the N6705A front panel USB connector, and copy the file into N6705A memory to save permanently.

Using the LXI web browser

A second method to move the .csv file to the N6705A is to use the LXI web browser. Open the web browser, enter the N6705A IP address (or hostname) and select the “Get Data” tab. The “Get Data” window will allow you to browse the local files on your PC and transfer them to the N6705A memory.

Playback the waveform

Once the data is loaded into the N6705A memory it can be played back using the N6705A as an Arb User Defined Voltage. See figures 7a & 7b for assistance.

- Select the N6705A **Arb** button twice to get the **Arb Selection** screen to appear.
- Select the channel to be used by pressing the correct color-coded **Select Output** button.
- Use the arrow keys to select **User Defined Voltage** and press **Properties** button.
- Use arrow keys to select **Import**, and use the file browser to find and import your .csv file.
- Be sure to turn the channel on, and then press Arb Run/ Stop to start arb.

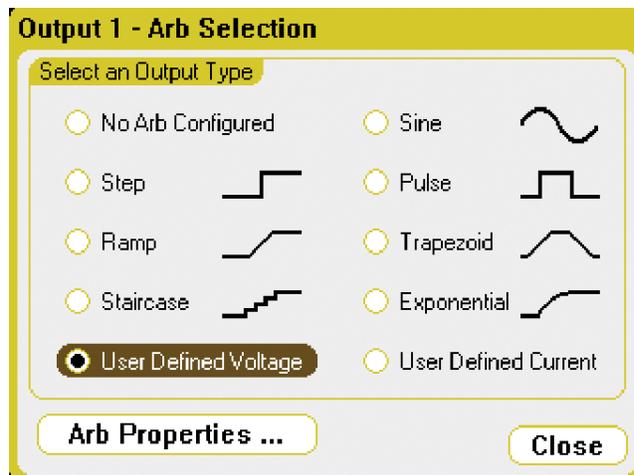


Figure 7a. Arb Selection Screen

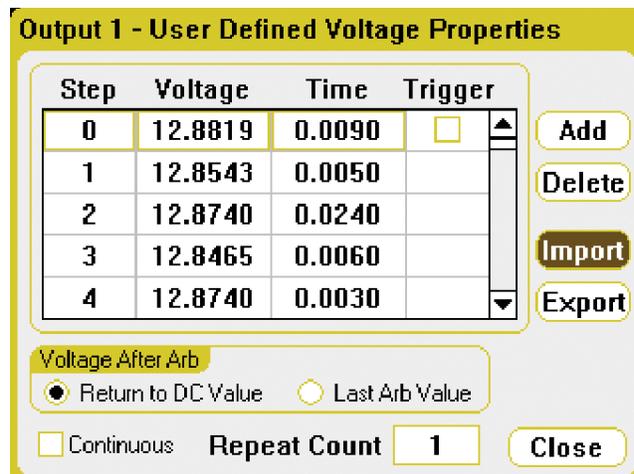


Figure 7b. User Defined Properties Screen

Below is the original waveform (Figure 8) and the waveform as played back by the N6705A (Figure 9).

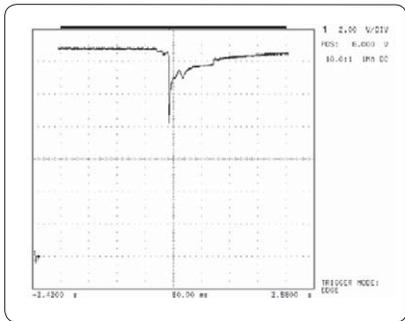


Figure 8. Original transient captured by scope

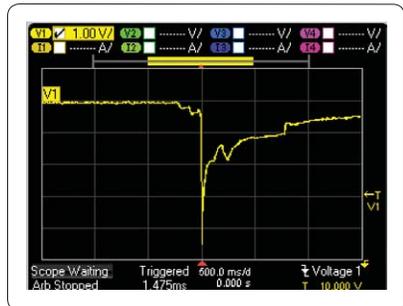


Figure 9. Transient played back by N6705A

Programmatically starting waveform using SCPI commands

The method described previously to transfer and start up the .csv waveform file works very well in a lab bench-top environment. However in some cases it is desirable to automate waveform download and start-up. An alternate method exists in the event that you want to programmatically download and start-up the transient

waveform. The N6705A provides multiple SCPI commands to assist in download and setup of the user defined waveform. See Table 1 for a short list of some of these commands, and see the programming reference for a complete list of commands, as well as detailed information on programmatically setting up and running arb waveforms.

Source Commands	
[SOURCE:]	
ARB	(ARB commands only on N6705A)
:COUNT <Nrf+> INFINITY, (@chanlist)	Sets the ARB repeat count
:FUNCTION STEP RAMP STAIRcase SINusoid PULSe TRAPezoid EXPonential UDVoltage UDCurrent, (@chanlist)	Selects the ARB function
:TERMinate:LAST <Bool>, (@chanlist)	Sets the ARB termination mode
:VOLTage	
:UDEFined	
:BOSTep[:DATA <Bool> {,<Bool>}, (@chanlist)	Generate triggers at the Beginning Of Step
:POINTS? (@chanlist)	Returns the number of BOST points
:DWELl <Nrf> {,<Nrf>}, (@chanlist)	Sets the user-defined dwell values
:POINTS? (@chanlist)	Returns the number of dwell points
:LEVel <Nrf> {,<Nrf>}, (@chanlist)	Sets the user-defined voltage values
:POINTS? (@chanlist)	Returns the number of voltage points

Table 1. Key ARB User Defined waveform SCPI commands. See programming reference for complete list.

Conclusion

The automotive vehicle power system is a very harsh electrical environment. Successful operation of automotive electronics depends on adequate power transient immunity, and the mission critical nature of automotive electronics makes thorough ECU testing a must.

To aid in that effort, the N6705A dc power analyzer reduces your test time and improves your ECU test coverage by allowing you to easily capture and re-play power system transients. Create your own portfolio of transient waveforms and play them back

at your convenience with the N6705A. Libraries of transient cases can be developed and archived for future use as well as for long term support and ECU re-qualification.

See the Agilent Technologies website at **www.agilent.com/find/n6705a** for more information on how the N6705A dc power analyzer can help you succeed with your testing needs.



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