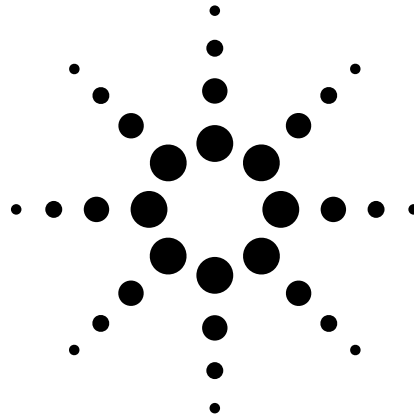


# How to capture, save, and reproduce arbitrary load current waveforms

AN 1480



## Introduction

Many products and circuits today draw a variety of current waveforms from their power source resulting from different modes of operation. That power source could be a battery, a DC power supply, or any other source of DC power. For example, a digital camera will draw different waveforms of battery current depending on whether the camera is initially powering up, taking a photo, or displaying photos in playback mode. During normal use the camera user may access these modes in any sequence, stringing together a multitude of current waveforms to create unique current profiles. Battery design can be fully qualified by both battery and camera manufacturers by checking the effect of these current profiles on the battery. Since a variety of current profiles is possible, the ability to capture current waveforms to create and randomly produce current profiles is beneficial.

This application note provides techniques for capturing, saving, and reproducing current waveforms and profiles. Waveform capture is accomplished with either the combination of a current probe and oscilloscope, or a dynamic measurement DC source. Current reproduction

is accomplished by downloading the captured waveform to a function/arbitrary waveform generator, which drives an electronic load. Using these techniques will help save test setup time and testing time, thereby reducing the time required to gain insight regarding power source design, selection, and use, ultimately leading to lower overall cost of design. Although a digital camera is used as an example, these techniques are equally applicable to the design of cell phones, laptop computers, PDA's, or other similarly powered products, especially those in which power management techniques are used.

## General procedure

There are two methods that will be discussed here for capturing a current waveform, and one method of reproducing the current waveform. More detail on these methods is presented later in the "Detailed Procedure" section.

## Waveform capture – Current probe/scope

The first method to capture the waveform makes use of a current probe and an oscilloscope. See Figure 1a, page 2. The probe is used to sense the current while the scope is used to capture, display, and save the waveform for eventual uploading to the PC.

## Waveform capture – Dynamic measurement DC source

The second method to capture the waveform utilizes a power supply with dynamic current measurement capability, meaning it has a built-in digitizer that can capture a current (or voltage) waveform. Normally, the power supply measures its own output current, so if it is the source of power in a circuit, no other connection considerations are necessary to capture the current. However, in this example a different power source, like a battery, is providing power to the circuit. Therefore, the dynamic measurement DC source must be connected in series with the power source where it acts like a zero ohm shunt and measures



the current from the battery (refer to Agilent Technologies Application Note 1427 for detailed information about this configuration). Figure 1b illustrates this configuration. The power supply digitizes the current waveform and stores it for eventual uploading to the PC. Software is also available to capture and upload the waveform data for viewing with the PC.

### Waveform reproduction

Reproducing the current waveform is accomplished by using a waveform generator driving an electronic load as shown in Figure 2. The previously captured waveform is downloaded from the PC to the waveform generator. Then, the output of the waveform generator is used to drive the external

programming input of an electronic load, thereby superimposing the desired waveform on the current being drawn by the load. When considering the digital camera example, the electronic load/waveform generator combination is simulating the current drawn by the camera.

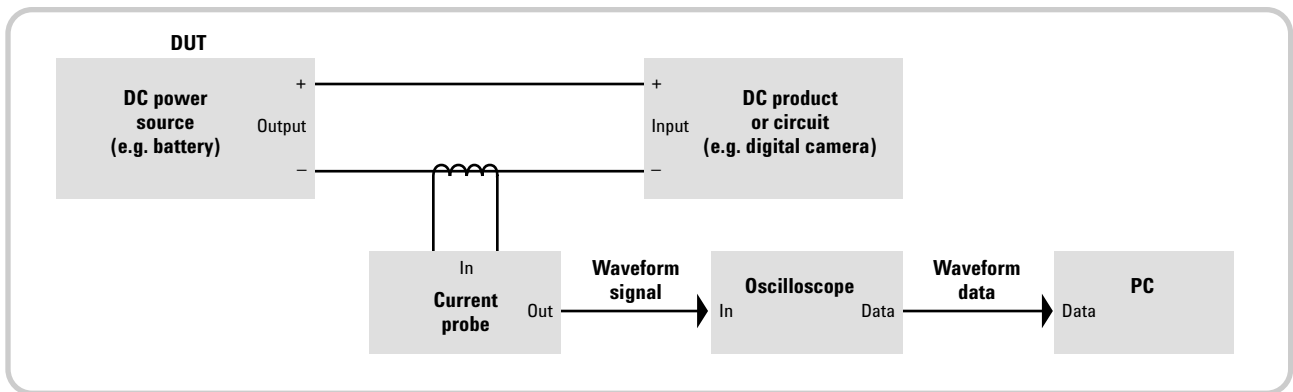


Figure 1a. Current waveform measurement setup using current probe and scope

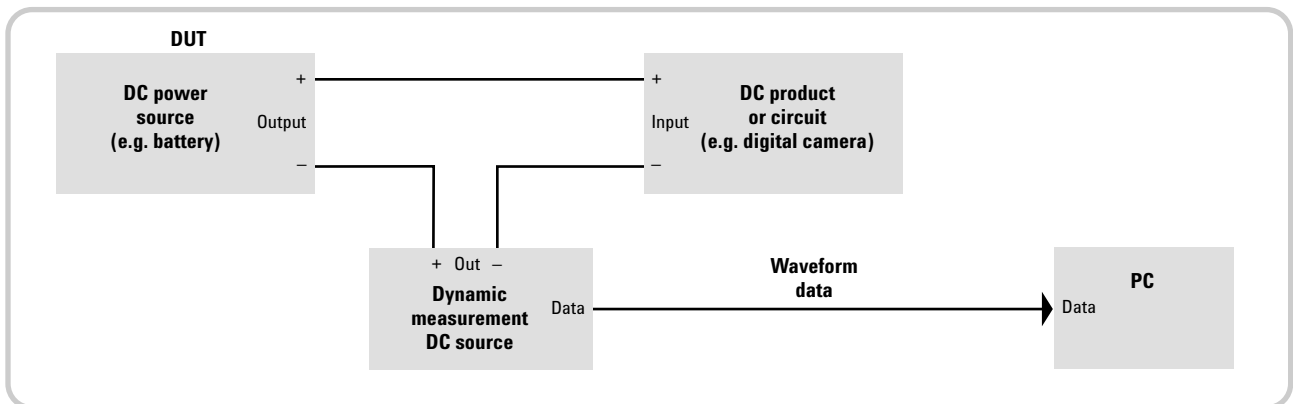


Figure 1b. Current waveform measurement setup using dynamic measurement DC source in pass-through configuration

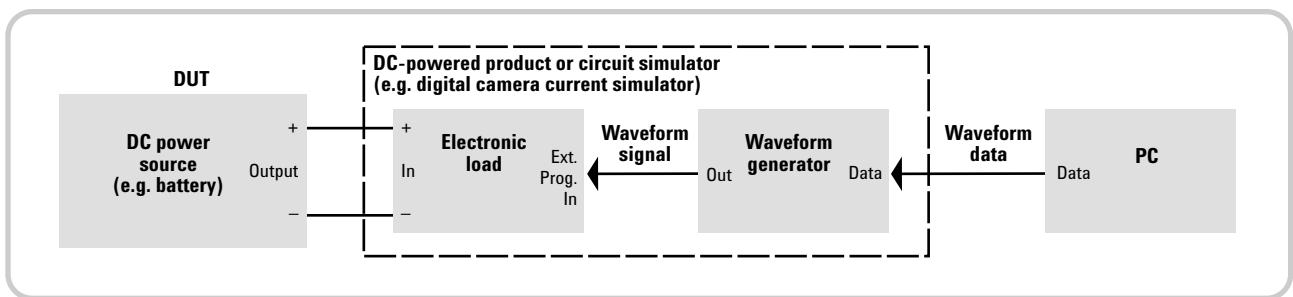


Figure 2. Current waveform simulation setup

## Recommended equipment

Table 1 shows the recommended instruments that should be used for this current waveform capture and reproduction application.

## Waveform capture comparison

As mentioned earlier, there are two methods for capturing a current waveform: one using a current probe and scope, and the other using a dynamic measurement DC source. The pros and cons of each solution are summarized in Table 2.

As can be seen from the table, both methods have equal numbers of advantages and disadvantages. The current probe/scope method may have more appeal simply because of the ease with which the waveforms can be viewed. However, the choice of method is a matter of preference and equipment availability.

**Table 1.** Recommended equipment

Instrument Type	Agilent Model	Use
Oscilloscope + GPIB interface	54621A + N2757A	Waveform capture and display
Current probe	1146A	Waveform capture
Power supply	66321B (or any 663xx)	Waveform capture
Device characterization software (optional)	14565A	Waveform capture and display showing power supply data
Waveform generator	33220A	Waveform reproduction
Electronic load mainframe	N3300A or N3301A	Waveform reproduction
Electronic load module	N3302A – N3307A	Waveform reproduction

Note that the bandwidth of the external programming input on the Agilent N3302A-N3307A electronic loads is DC to 10kHz when operating the load input at or above 3V, and is DC to 1kHz when operating below 3V.

**Table 2.** Comparison of waveform capture methods

Evaluation criterion	Current probe/scope		Dynamic measurement DC source	
	Pros	Cons	Pros	Cons
Ease of setup	–	Multiple instruments	Single instrument	–
Accuracy	–	Undefined; multiple additive errors	Well defined	–
Current range	Virtually unlimited	–	–	Limited to maximum current capability
Calibration	–	More complex	Single instrument	–
Triggering system	Can be done by hand	–	–	Must be done via GPIB
Waveform capture	–	Time may be coarsely quantized	15.6us resolution from 1 to 4096 points	–
Waveform display	Visible on scope	–	–	Need software* to display waveform
Data collection (availability)	Data available directly from scope	–	–	Need software* to collect data
Data collection (units)	–	Binary data returned needs to be scaled	Data returned directly in amperes	–
Waveform verification	Easy display of multiple waveforms	–	–	Need software* to display multiple waveforms

\*Provided by Agilent 14565A software package or can be developed by user

## Detailed procedure

### 1. Capture waveform

There are two basic current waveform parameters that must be known to properly capture the current: waveform amplitude and time span. The amplitude affects the trigger level needed to start the measurement process, and the time span affects the duration of data captured. Using the current probe/scope, attention must be given to properly scale the data displayed on the screen so that current is shown (e.g., in amperes). When using the dynamic measurement DC source, the current is captured directly in amperes.

### 2. Transfer waveform to PC

Simple commands are used to upload the waveform data to the PC from either the scope or power supply. When using the Agilent 54621A scope, the command is

```
“:WAVEFORM:DATA?”.
```

### 3. Prepare data for reproducing waveform

Since the power supply returns data directly in amperes, no scaling is necessary. However, the scope data may be returned in a different format (e.g. binary) that needs to be scaled.

Next, each element of the resultant current data array, now in amperes, must be checked to ensure that the electronic load can produce the desired current waveform. Two criteria are evaluated: 1) no negative values are allowed since the load can only draw positive current, and 2) no values can exceed the maximum current for the selected load range. At this point, the data can also be scanned for the maximum and minimum current values. These values will be used next to normalize the data. Additionally, the maximum and minimum values will also be used to calculate the high and low voltage values for the waveform generator, which correspond to the high and low current values to be produced by the load.

Once the data has been validated, it must then be normalized for the waveform generator. The recommended Agilent 33220A waveform generator's arbitrary waveform mode requires data between -1 and +1. Therefore, the current values representing the waveform must be normalized to values from -1 to +1.

### 4. Transfer waveform to waveform generator

The data is now in the proper format to be sent to the waveform generator using simple commands. When using the Agilent 33220A waveform generator, the command is

```
“DATA VOLATILE, <value>, <value>,...”.
```

### 5. Adjust waveform generator parameters (amplitude and frequency)

**Amplitude:** 0 to +10V on the external programming input of Agilent electronic loads corresponds to 0 to full-scale input current for the current range selected on the load. Therefore, to produce the correct load current amplitude, the 33220A high and low voltage values must be calculated using the maximum and minimum current values found in Step 3 and then sent to the waveform generator. For example, a load with a current range of 0-60A requires +10V at its external programming input to draw 60A. 3V would be required to draw 18A. Therefore, if the maximum and minimum values were 60A and 18A respectively, the high and low voltage values on the 33220A must be 10V and 3V.

**Frequency:** When using the scope to capture a waveform, the duration of data saved is the duration of the entire scope screen. When using the power supply to capture a waveform, the duration of data saved is determined by the sampling rate and the number of points captured. In order to produce the correct duration of load current, the 33220A frequency must be set to the reciprocal of the duration of the captured data. When the waveform generator frequency is set, it simply repeats the data at the specified frequency indefinitely. Alternately, the 33220A's burst mode can be used instead to output a specified number of cycles.

## Results

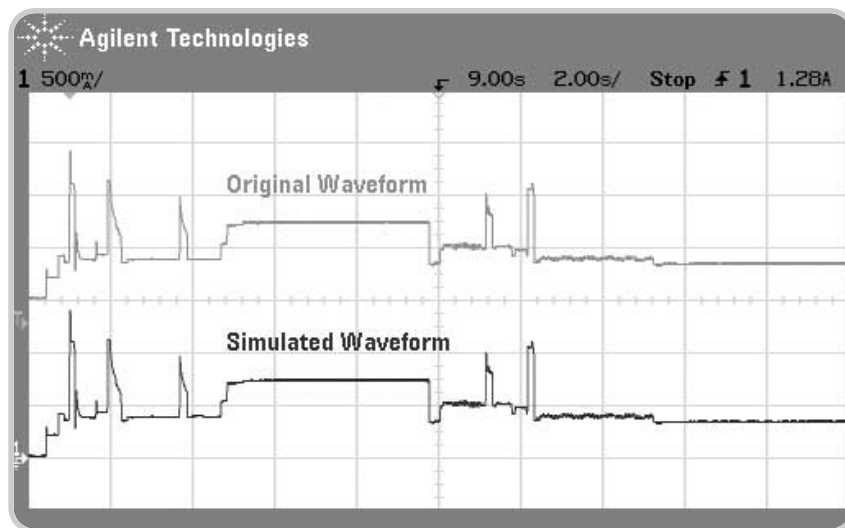
Figure 3 shows the actual results when using the techniques described here. The top waveform in the figure is the original digital camera battery's current waveform captured by a current probe and scope when a picture is taken. The bottom waveform shows the battery current waveform reproduced by the Agilent 33220A function/arbitrary waveform generator driving an Agilent N3303A electronic load. Clearly, the original waveform and reproduced waveform are virtually identical. This demonstrates how the 33220A and the N3303A can be used to simulate the current drain of a digital camera in a test system.

## Summary

When working on the design of a product such as a digital camera that draws current from a DC power source like a battery, having the ability to use electronic instrumentation to reproduce current waveforms instead of using the product itself can help save test time and design time. In evaluating the digital camera design or selecting a battery manufacturer, the camera designers could repetitively press buttons on the camera to draw a variety of currents from the battery. However, this is time consuming and tedious. The solution is to capture and reproduce these waveforms electronically.

As discussed, either a current probe and scope, or a dynamic measurement DC source can be used to capture the current waveform. Downloading the waveform data to a waveform generator and then using its output to drive an electronic load accurately reproduces the waveform. These techniques enable the designers to capture waveforms, and then reproduce them without the actual DC powered product or circuit, thereby freeing up prototypes and other critical resources especially when availability is limited during the early stages of the design process. Having the ability to set up and leave the test, automating the process, saves time. The actual product needs to be used only once to capture the waveforms that can then be simulated by the load multiple times later on for testing. One example of using these techniques is to capture and save several different events individually, and then string them together in any order enabling the ability to create waveform profiles without the use of the actual product.

Utilizing these techniques will ultimately lead to faster design time by making better use of limited resources, eliminating tedious, slow, manual processes, and improving accuracy and repeatability through automation.



**Figure 3.** Comparison of battery current waveforms. Top waveform is current drawn by digital camera; bottom waveform is current reproduced by waveform generator and electronic load.

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