

# Testing RF Power Amplifiers with the Model 2306 Battery/Charger Simulator's Pulse Current Step Function

## Introduction

Typically, production testing of DC RF power amplifiers involves measuring RF power output and drive current consumption. During testing, the power amplifier is programmed to output a series of RF power levels, then load current measurements are taken at each level.

The Keithley Model 2306 Dual Channel Battery/Charger Simulator offers a time-saving pulse current step function that's ideally suited for this application. This pulse current step mode can be used to perform a series of up to twenty current measurements on the same trigger level range. The instrument can be triggered sequentially at twenty different current levels and will return all the readings from a single trigger command. When compared with the time involved in triggering and processing each measurement separately, this approach reduces measurement time significantly.

## Test Setup

The pulse current step mode can be used with either continuous or one-shot current pulse trains. Use one-shot pulses for sequences that rise and fall between steps or that start at a low current level and ramp upwards (see the section titled "False Triggering").

The first step in using the pulse current step function is to configure the integration time, trigger delay, timeout settings, trigger level steps, and trigger level range. With the exception of the trigger level, all settings apply to all steps in the current pulse.

## Pulse Current Step Function Parameters

### Integration Time

The integration time is the interval over which the Model 2306 is measuring the current pulse. The integration time plus any trigger delay must be less than the width of the pulse.

In order to use the pulse current step method, there must be at least 400 $\mu$ s between pulses. This interval is required to process the previous measurement and to arm for the next current level.

### Trigger Level

The 20 different trigger levels are combinations of up and down steps. The total number of active steps (up step plus down step) must be equal to or less than 20. The instrument makes the same number of measurements as the number of active steps.

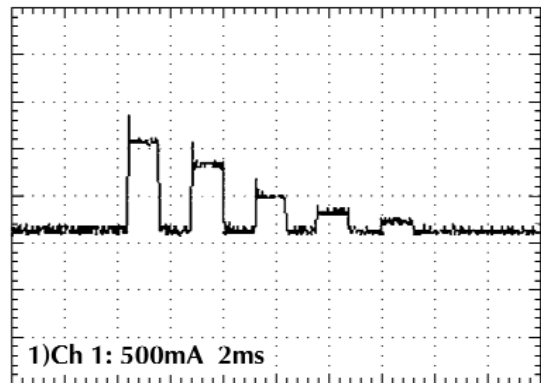


Figure 1. Model 2306 input pulse waveform

Figure 1 illustrates an example of a one-shot test sequence, including five current levels with a 50% duty cycle and a period of 2.5ms. To specify this current pulse, program five up steps and zero down steps. The down steps must be set to zero because the default setting for both up and down steps is one. If down steps are specified instead of up steps, the Model 2306 will measure the standby current.

### Trigger Delay

To allow sufficient time for a pulse overshoot to settle, set an optional trigger delay. The trigger delay starts after pulse detection and before integration begins. The trigger delay is in addition to a built-in 15 $\mu$ s trigger latency (minimum).

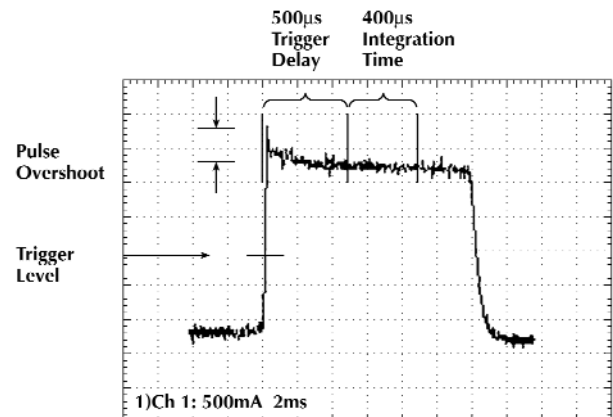
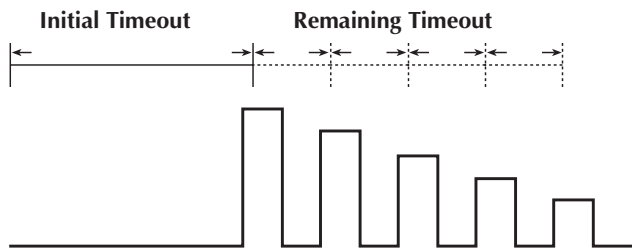


Figure 2. Expansion of 1A current pulse with 0.25A pulse overshoot from Figure 1

*Figure 2* represents a trigger delay and integration interval. After the delay, the current response is in a steady state, resulting in a more stable measurement.

## Timeout Settings

“Timeout” refers to the point when the instrument “times out” or stops looking for the signal to be measured. The pulse current step mode requires two timeout settings: initial and remaining. As *Figure 3* indicates, the initial timeout is before pulse detection, and the remaining timeout is between each step after the initial pulse detection. After an initial or remaining timeout is reached, all successive measurements are returned as an overflow. Measurements taken before a timeout are returned correctly.



*Figure 3. Initial and remaining timeout intervals*

## Initial Timeout

For a continuous pulse train, the initial timeout should be set slightly longer than the period of the complete pulse train. This ensures that if the Model 2306 begins to search for the pulse and misses the first trigger level, the instrument will not timeout before the next pulse sequence begins.

For a one-shot pulse train, set the initial timeout to the maximum of 60s. This allows extra time that may be required for triggering the Model 2306 and generating the one-shot pulse train.

## Remaining Timeout

The remaining timeout setting tells the Model 2306 how long to search for the next pulse edge before timing out. For other one-shot or continuous pulses, set the remaining timeout to cover the longest pulse period.

The remaining timeout for the waveform in *Figure 1* must be longer than the 2.5ms pulse period to ensure that the Model 2306 will trigger on the remaining pulse edges.

## Basic Programming Guidelines

The pulse current step mode is available on the Model 2306’s battery channel (#1) when the instrument is operated via the GPIB (sens:pcur:step commands).

This programming example corresponds to the pulse current waveform shown in *Figure 1*:

## Commands to set up Model 2306 (one-shot pulse)

```
:SENS:NPLC .01      ' Specify integration rate
                    ' to .01 PLC
:SOUR:VOLT 3.6      ' Specify output voltage
:SOUR:CURR 2        ' Specify current compliance
                    ' limit
:OUTP ON            ' Enable output
:SENS:FUNC 'PCUR'   ' Select pulse current
                    ' measurement function
:SENS:PCUR:STEP ON  ' Enable pulse current
                    ' step mode
:SENS:PCUR:STEP:UP 5 ' Specify 5 up steps
:SENS:PCUR:STEP:DOWN 0 ' Specify 0 down steps
:SENS:PCUR:STEP:RANGE 1 ' Specify the 1A trigger level
                    ' range
:SENS:PCUR:STEP:TIME .0004 ' Specify 400µs for step
                    ' integration time
:SENS:PCUR:STEP:DEL .0005 ' Specify 500µs for step
                    ' trigger delay
:SENS:PCUR:STEP:TOUT:INIT 60 ' Specify 60s for initial
                    ' timeout
:SENS:PCUR:STEP:TOUT .003 ' Specify 3ms for step timeout,
                    ' except the first one
:SENS:PCUR:STEP:TLEV1 .8 ' Step 1 trigger level value
:SENS:PCUR:STEP:TLEV2 .7 ' Step 2 trigger level value
:SENS:PCUR:STEP:TLEV3 .38 ' Step 3 trigger level value
:SENS:PCUR:STEP:TLEV4 .18 ' Step 4 trigger level value
:SENS:PCUR:STEP:TLEV5 .05 ' Step 5 trigger level value
```

## Commands to trigger and read from Model 2306

Once the Model 2306 has been configured, the following commands will trigger and return a new measurement:

```
:READ:ARRAY?      ' Triggers and returns the
                    ' 5 step measurements
Delay .1 second    ' Insert a delay between
                    ' triggering the 2306 and
                    ' generating a one-shot pulse
                    ' train
"Enter from 2306" ' Enter data into PC from
                    ' Model 2306
```

## Typical Sources of Error

### Windows Operating System Delay

The Model 2306 requires 4ms for trigger setup before taking measurements. This instrument does not have direct hardware synchronization, so a delay must be inserted between the software measurement trigger and the one-shot pulse of the DUT. A GPIB timeout will occur if the delay is too short and the Model 2306 misses the pulse.

A software delay must be added to compensate for the inaccuracy of the Windows® system timer. For example, programming a delay of 100ms produces an actual delay that can vary from 50ms to 100ms. A shorter delay of 50ms may generate an actual delay of less than the required 4ms, resulting in a GPIB timeout. A delay is not required when using a continuous pulse train.

## False Triggering

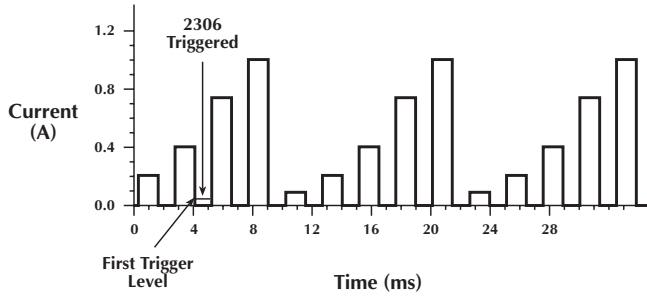


Figure 4a. False trigger generated with a continuous current pulse train

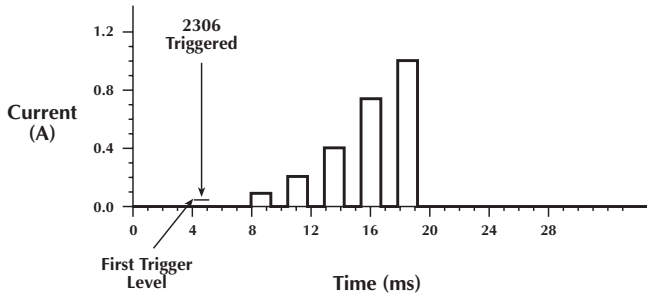


Figure 4b. The Model 2306 triggers on the correct step using a one-shot pulse train

A false trigger may occur when using a continuous pulse train and a low trigger level, as shown in *Figure 4a*. After the Model 2306 is triggered, measurements begin with the first step that satisfies the trigger level. As a result, overflow readings and/or out-of-sequence values may be returned. In the example shown in *Figure 4a*, the Model 2306 begins measuring with the fourth step. To ensure the Model 2306 will begin triggering on the correct step, use a one-shot pulse train, as shown in *Figure 4b*.

## Measurement Timing Error Analysis

Using a programmed delay of 100ms and a one-shot pulse train, the average time required to take the five current measurements shown in *Figure 1* is 137ms. The measurement time begins at the point a `:read:arr?` command is sent and ends when the current measurements are returned over the bus.

The results in *Table 1*, which are based on 75 samples, show that the delay generated by the Windows system timer causes some inconsistency in the total test time.

Table 1. Summary of pulse current step test time for five current measurements

	Total Time	Delay Time
Average	137ms	73ms
Standard Deviation	14.3ms	13.6ms
Minimum	112ms	51ms
Maximum	165ms	101ms

## Single Measurement Solutions

The Model 2306 offers the standard technique for making a series of current measurements in which the 2306 will trigger each new measurement and then read in the result. It takes 3.5ms to send the Model 2306 the trigger command `:sens:pcur:sync:tlev .8`. This method will not work when measuring a one-shot pulse train similar to the one shown in *Figure 1* because the time between pulses is less than 3.5ms. This approach will work when using pulses with a longer off time.

Another possible solution requires making each load current measurement from successive pulse trains. For example, it's possible to measure the first current level from the first pulse train, then measure the second current level from the second pulse train and continue until all measurements are taken. This method depends upon knowing the pulse train characteristics exactly and having a repeatable pulse train. This method does not actually trigger on each level separately; it is based on triggering the first current level of the pulse train, then delaying until the pulse train reaches the desired current level.

The following sample code can be used to measure the first two current levels from *Figure 1*.

```
:sens:pcur:sync:tlev .8      ' Trigger on the first
                             ' current level
:sens:pcur:sync:del .0005   ' Delay for 500ms
:read?
Enter from 2306              ' Read in the first
                             ' current measurement

:sens:pcur:sync:tlev .8      ' Trigger on the first
                             ' current level
:sens:pcur:sync:del .003    ' Delay 3ms until the
                             ' second current level
                             ' is reached

:read?
Enter from 2306              ' Read in the second
                             ' current measurement
```

Using this approach with a continuous pulse train as shown in *Figure 1*, the measurement takes an average of 700ms—five times longer than the pulse current step method for the same measurements. The data in *Table 2* is based on 75 samples.

Table 2.

	Total Time
Average	703ms
Standard Deviation	27.5ms
Minimum	663ms
Maximum	766ms

In conclusion, the pulse current step method is the fastest, most reliable way to make a series of current measurements.

## Equipment List

1. Keithley Model 2306 Dual Channel Battery/Charger Simulator or Keithley Model 2302 Battery Simulator
2. PC with KPCI GPIB Interface Card
3. Model 7007 IEEE Interface Cable

## Test System Safety

Many electrical test systems or instruments are capable of measuring or sourcing hazardous voltage and power levels. It is also possible, under single fault conditions (e.g., a programming error or an instrument failure), to output hazardous levels even when the system indicates no hazard is present.

These high voltage and power levels make it essential to protect operators from any of these hazards at all times.

Protection methods include:

- Design test fixtures to prevent operator contact with any hazardous circuit.
- Make sure the device under test is fully enclosed to protect the operator from any flying debris. For example, capacitors and semiconductor devices can explode if too much voltage or power is applied.

- Double insulate all electrical connections that an operator could touch. Double insulation ensures the operator is still protected, even if one insulation layer fails.
- Use high-reliability, fail-safe interlock switches to disconnect power sources when a test fixture cover is opened.
- Where possible, use automated handlers so operators do not require access to the inside of the test fixture or have a need to open guards.
- Provide proper training to all users of the system so they understand all potential hazards and know how to protect themselves from injury.

It is the responsibility of the test system designers, integrators, and installers to make sure operator and maintenance personnel protection is in place and effective.

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