

# Making Pulse Current Measurements with the Series 2280S Precision Measurement DC Power Supplies

## Introduction

More and more integrated circuits and electronic sub-assemblies today are being designed for use in mobile applications, which means this circuitry will operate on battery power and will have a finite supply of power available to them. To maximize the battery life of the end products into which these circuits are built, it is imperative for device designers to minimize their power consumption. This requires characterizing the power consumption of a device in all states in order to understand where to focus their efforts.

One of the biggest challenges associated with characterizing the power consumption of mobile devices is that their current draw varies greatly depending on the state in which the device is operating. It is common for mobile devices to spend a majority of their time in sleep mode, drawing only microamps of current or less, waking up only periodically to perform a function. While performing these functions, current draw can increase dramatically, jumping to tens, hundreds, or even thousands of milliamps. In many cases, this lasts for as little as a few hundred microseconds, making measuring the device's current consumption during these operations difficult.

Typical power supplies are incapable of measuring the sudden current pulses drawn by a device while it is awake, requiring additional instrumentation to make the measurement. This not only adds to the cost of testing these devices but increases the complexity of the test system. Precision measurement DC power supplies like the Keithley Series 2280S are capable of measuring pulse currents as narrow as  $140\mu\text{s}$  and include the triggering features required to synchronize the measurement with the current pulse.

This application note demonstrates how to use the Keithley Series 2280S Precision Measurement DC Power Supplies to measure the pulse of load current drawn by a wireless transceiver module during its transmission state.

## Test Equipment

This application involves measuring the load current drawn by an 802.15.4 Wireless Transceiver Module when it is in its data transmission state. The equipment used includes:

- Keithley Series 2280S Precision Measurement DC Power Supply

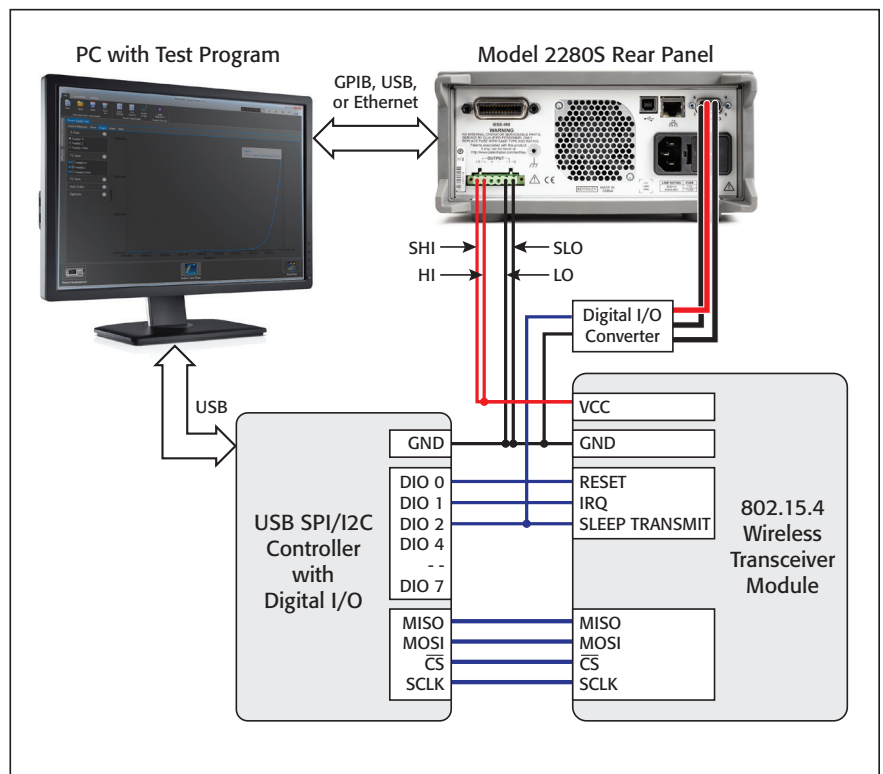
- USB-to-SPI/I2C controller with digital I/O
- PC with custom test program
- Digital I/O converter

The wireless transceiver module is commonly used with the ZigBee network stack for creating products designed for building automation and remote sensor monitoring. This transceiver includes an SPI digital interface for configuration and operation, which allows it to be controlled easily by a microcontroller. However, for device testing purposes, a USB-based SPI/I2C controller with a digital I/O port is used to configure and operate the device from test code running on a PC. This test code also configures and controls the Keithley Series 2280S Precision Power Supply to supply power to the device and make the pulsed current measurement.

A Tektronix MDO4104B Mixed Domain Oscilloscope provides verification and visual representation of the measurement.

## Making Connections

*Figure 1* illustrates the connections required for this test.



**Figure 1. 802.15.4 wireless transceiver test system connections**

The VCC and GND pins of the wireless transceiver are connected to the HI and LO leads of the Series 2280S power supply. To ensure the voltage level applied at the device is accurate, the sense lead jumpers should be removed from the connector on the rear of the instrument and a separate set of sense leads should be run to the device's VCC and GND pins. This will allow the instrument to compensate for any voltage drops in HI and LO leads that may occur due to the device's large current draw during transmission.

The Chip Select ( $\overline{CS}$ ), MISO, MOSI and SCLK lines of the wireless transceiver module's SPI interface are routed to the SPI lines of the USB-to-SPI/I2C controller. The Reset, Interrupt and Sleep/Transmit lines are routed to the USB-to-SPI/I2C controller's digital I/O port.

Note that the wireless transceiver module's Sleep/Transmit line and GND lines are routed not only to the USB-to-SPI/I2C controller but also to the digital I/O port of the power supply. Data transmission for this wireless transceiver can be controlled by toggling this line, making it a perfect trigger source for triggering a measurement on the power supply. However, this line cannot be used directly to trigger it, and an in-line converter is required. Refer to the next section for details on this converter.

The PC controls the entire test system using a custom test program.

## Converting the Digital I/O Signals

The wireless transceiver module and all of its digital signals operate at 1.8V; the power supply's digital I/O port requires at least 3.4V. This 1.8V is not large enough to register as a signal level high on the power supply's digital I/O, so it can't be used directly to trigger the instrument. Furthermore, the signal that starts the transmission on the wireless transceiver is a rising edge, but a falling edge is required to trigger the power supply. In order to use the Sleep/Transmit line of the wireless transceiver as a trigger signal for the power supply, the line must first be level-converted.

A couple of resistors and a small signal NPN BJT (Part No. 2N3904) are all that's needed both to create a simple circuit that will convert the signal from 1.8V to 5V and to invert its polarity, creating a 5V falling edge trigger from the 1.8V rising edge trigger. *Figure 2* illustrates the details of this circuit.

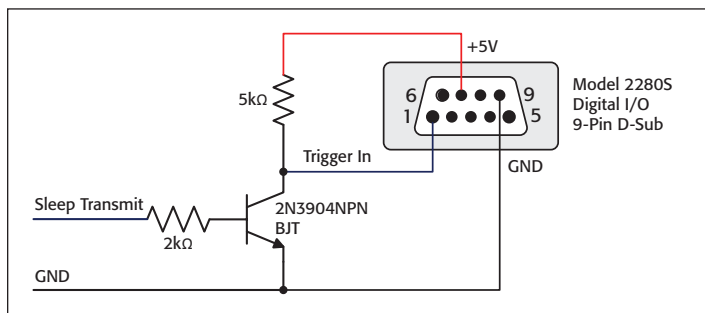


Figure 2. 1.8V to 5V trigger level converter circuit diagram

## Configuring the Instrument

To measure current pulses as small as  $140\mu\text{s}$ , a Series 2280S Precision Measurement DC Power Supply must be configured for fast, synchronized measurements by following these steps:

- Reset the instrument to Power On Defaults.
- Change the Measure Function to Current (default is Concurrent, measuring both voltage and current).
- Turn the Averaging Filter off.
- Change the NPLC to 0.002, the fastest measurement time.
- Change the Measure Range to a fixed 1A or 10A range depending on the current level drawn by your device.
  - Note: 100mA and 10mA ranges can be used for pulses lasting 2ms or longer.
- Turn off Auto-Zero
  - Auto-zero will automatically measure an internal reference to zero the instrument for each triggered measurement. This will extend the length of the measurement interval and result in the measurement missing the pulse. Turn auto-zero off to ensure proper measurement timing.
- Configure the Trigger Layer Trigger Source as External.
- Configure the Source Delay to delay the start of the measurement from the input trigger and place the measurement at the flat top of the current pulse.

Using these settings, the instrument makes a fast current measurement every time it receives a trigger on its digital I/O port. Using the Sleep/Transmit line of the wireless transceiver module as a trigger source, this measurement is aligned with the top of the current pulse.

## Automating the Pulse Current Measurement

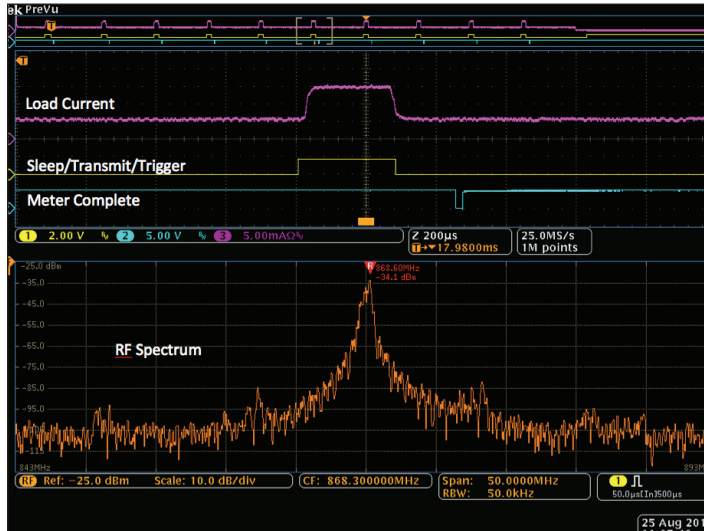
The process of configuring the instrument for fast current measurements and collecting the data can be automated by sending the instrument the following SCPI commands:

*RST	Reset the instrument to defaults.
:VOLT:PROT:LEV 3.3 :VOLT:LIM 2.2 :CURR:PROT:LEV 0.1	Configure the Over Voltage Protection, 3.3V, Voltage Limit, 2.2V and Over Current Protection, 0.1A, to protect both the operator and the device.
:SENS:FUNC "CURR"	Change the measure function to Current only.
:SENS:CURR:AVER:STAT OFF	Turn off the averaging filter.
:SENS:CURR:NPLC 0.002	Change the NPLC setting to 0.002 for a $33\mu\text{s}$ measurement aperture.
:SENS:CURR:RANG 1	Set the current measurement range to a fixed 1A range.
:SYST:AZER OFF	Turn off auto-zero.
:INIT:CONT OFF	Turn off continuous initiation of the trigger model.
:TRIG:SOUR EXT	Set the trigger source to External (Digital I/O Trigger in).
:TRIG:SEQ:COUN 1	Set the trigger count to match the number of pulses being measured in the test. Note: you will need a Digital I/O Trigger in for each count.

:TRIG:SAMP:COUN 1	Set the sample count to 1 to take a single measurement during the pulse. If the pulse being measured is long enough, you can set this to a larger number to take more measurements per pulse.
:DEL:STAT ON :DELAY 60e-6	Turn the source delay on and set the delay value long enough to place the measurement at the top of the current pulse. For this DUT, the delay is set to 60 $\mu$ s.
:DATA:CLEAR	Clear the buffer.
:VOLT 1.8	Set the proper output voltage, 1.8V, for the device.
:CURR 0.1	Set the current limit ,0.1A, to protect the device.
:OUTP ON	Turn the output on
:INIT	Initiate the trigger model to get it ready for the trigger and take the measurement.
*OPC?	This will return "1" after all measurements are complete.
:TRAC:DATA? "READ"	Read back the measurement data from the buffer.

## Test Results

**Figure 3** is a screen shot from the Tektronix MDO4104B Mixed Domain Oscilloscope. The purple waveform at the top is the load current waveform from the DUT. The yellow waveform is the Sleep/Transmit Trigger signal. The blue waveform is the Meter Complete out signal from the instrument, indicating that the instrument is ready for another trigger. The bottom half of the screen is the RF spectrum generated during one of the wireless transceiver's transmissions.



**Figure 3.** Test system signals and device RF spectrum during transmission captured with a Tektronix MDO4104B-6 Mixed Domain Oscilloscope

**Table 1** lists the current readings from the precision measurement power supply.

**Table 1.**

Sample	Current (A)
0	14.552E-3
1	14.854E-3
2	15.189E-3
3	15.156E-3
4	14.955E-3
5	14.921E-3
6	14.921E-3
7	15.022E-3
8	15.055E-3
9	15.022E-3
Average	14.965E-3

These readings were taken from 10 separate current pulses during which the same data was transmitted each time. Note the high precision with which the current can be measured, with up to 6½ digits of resolution. Averaging can be used for even greater precision. The Series 2280S's built-in measurement capabilities greatly simplify test system design by eliminating the need for additional instrumentation.

With Series 2280S Precision Measurement Power Supplies, design and test engineers can make reliable, high quality measurements on narrow load current pulse waveforms, allowing them to characterize and verify device power consumption so that their portable devices' battery operating life targets can be achieved.

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