Dynamic Power Analysis Techniques for Low-power Satellite Design

Using high-performance DC sources to characterize and optimize dynamic current

Application Note

Introduction

In satellite development, power optimization is critical in every stage of the design process since it affects: equipment weight, equipment size, thermal management, power consumption, storage systems. Optimizing satellite subsystems for low-power operation requires the ability to accurately analyze dynamic power needs during each phase of development. This spans the beginning stages of the software design for FPGAs, microprocessors, ASICs, and so on, and extends to include the system design of modules and subassemblies.

The major challenge is accurately characterizing the sharp transients and dynamic behavior of a design's current profile. An averaged or integrated view of power demand is not sufficient. Instead, a meaningful characterization requires an accurate, high-resolution picture of the current profile—the highs, the lows and the transitions. As an example, the dynamic current demanded by a transmitter amplifier in a communications subsystem may shift from "sleep" to "transmit" levels in a matter of microseconds. The ideal instrument for this application has three key attributes. First, capturing such transitions requires a wide dynamic range that can seamlessly and accurately measure currents that range from less than 1 mA to more than 1.0 A. Second, the instrument should have sufficient measurement bandwidth to accurately capture the rise and fall times of the current profile transitions. Finally, the instrument would have little or no effect on the circuit or device under test (DUT). Unfortunately, no instrument perfectly satisfies all three of these needs. As a result, engineers must make tradeoffs when characterizing dynamic current.

This application note presents three methods engineers can use to characterize dynamic power and optimize their designs for low power consumption. The description of each method includes pros, cons and tradeoffs as well as helpful tips to ensure accurate characterization of the dynamic current profile of a design.

Agilent Technologies

Understanding dynamic current

Dynamic current refers to the constantly changing current profile of a device. For low-power design in satellite equipment, the dynamic current is typically characterized and optimized during every phase of the design process.

Example devices and subsystems

Dynamic current is an important consideration in the design of devices or subsystems such as RF power amps, integrated circuits (ICs) and microprocessors. Choices of communication format or protocol that require changes in hardware configuration can also affect current requirements. Let's take a closer look at each of these.

RF power amps: Data signals are typically transmitted using an RF power amp. When the power amp is not transmitting it is in a reverse-bias state and may be pulling micro- or nanoamps of leakage current from its power supply. When the amplifier's gate is turned on to transmit, its current-pull quickly transitions from leakage levels to ampere levels in a few microseconds. After a transmission the amplifier is turned off and its current-pull sharply returns to leakage levels.

ICs: Embedded designers conserve power by turning off integrated circuits dynamically (e.g., putting them into sleep or standby modes) whenever they are not in use, and then turning them on again only when needed. When an IC is put into standby or sleep mode it pulls only milli-, micro- or perhaps nanoamps of current. When it is suddenly returned to operating mode its current consumption quickly jumps back up to a "normal" level. This on/off cycle may be predictable, random or a combination, and the on or off periods may last hours, minutes or milliseconds. Whatever the case, each IC will have its own dynamic current profile.

Microprocessors: Two techniques are often used to manage microprocessor power: dynamic voltage scaling and dynamic frequency scaling. In dynamic voltage scaling, the voltage applied to a CPU is varied depending on the processor's workload. This can help conserve power and reduce heat output.

Dynamic frequency scaling or "CPU throttling" is a technique used in embedded design whereby the clock frequency of a microprocessor is automatically adjusted on-the-fly. This can help conserve power or reduce the amount of heat generated by the chip. Dynamic frequency scaling is based on the notion that not every operation requires the same amount of processing speed. From this, it's possible to adjust the clock rate to satisfy the processing needs of each operation.

Formats and protocols: Reconfiguring the hardware to handle any change in communication format or protocol may also require different transmission durations and therefore different power requirements. For example, a complex protocol may require more data processing, leading to a more challenging current profile compared to simpler formats or protocols.

The importance of characterizing dynamic current

As stated in the introduction, simple average-power measurements do not provide enough information to tune a design for low power consumption. The best alternative is an accurate, high-resolution characterization of dynamic current: This sort of detailed characterization will provide the insight needed to optimize the design.

Optimizing IC performance

When programming FPGAs, microprocessors and microcontrollers, there are typically multiple ways to perform the same task. However, even though the performance characteristics may be equal, the total power consumption and dynamic current profiles can be very different. In such cases, an averaged-power profile provides too little information: Methods that have extended periods of high current draw may require additional forms of active and passive cooling, adding to the size, weight, and power needs of the final design. What's more, periods of high current draw necessitate the use of bulkier, less-efficient components in the power-distribution system (e.g., a larger, higher-power DC-to-DC converter). Dynamic current characterization makes it possible to identify and analyze periods of large current consumption, helping designers select the best way to program a task in terms of power optimization and thermal management.

When working with ICs such as FPGAs that require multiple power supplies, proper on/off power sequencing is often required to avoid latch-up problems. Latch-up can be catastrophic to the chip and possibly the surrounding circuit, or it can cause noncatastrophic current spikes. In the latter case the design will function properly; however, power is wasted and the current spikes at every turn-on or turn-off may lead to long-term problems with parts reliability.

Dynamic current characterization makes it possible to check for short-duration current spikes and ensure latch-up is not occurring. Even if a device is operating normally, latch-up may occur if a sufficiently large voltage differential occurs between the power supply rails of an IC. Here on Earth, the occurrence of a sudden voltage differential high enough to cause a latch-up condition is relatively unlikely. In a satellite, however, this is a very real possibility because with no atmosphere the satellite is exposed to radiation and high-energy particles that can cause momentary voltage changes that may induce latch-up. Such scenarios must be tested and dynamic current characterization is needed to capture the outcome of each test.

Low-level current profiles are important because they can reveal if the various ICs in an embedded design are properly configured for the lowest power consumption in their inactive states. As an example, for a microcontroller to achieve its lowest current levels while in sleep mode, its datasheet typically specifies that all pins must be set as inputs and certain registers must be set to their default states. With the correct settings, a current draw of less than 10 µA is easily achievable; however, with improper settings the current level could reach 1 mA. Also, load levels external to the pins can cause leakage current.

These affects may be dynamic in nature, depending on what is occurring external to the microcontroller. If a device is not properly configured for the lowest-possible current consumption and it experiences long periods of inactivity, it will have a much larger power need and thereby cause reduced battery life during normal operation. Identifying these effects requires the ability to capture the low-level current profile (e.g., microamp level or below) of the IC and circuits in the design.

Optimizing battery life

For battery-powered devices, achieving the lowest average current does not necessarily mean the best battery life. Batteries are specified in amp-hours and typically have multiple amp-hour specifications, each based on an assumed level of constant current draw. The specifications are linked to constant current-drain levels because the efficiency or capacity of a battery changes in real time along with the current level. One reason: During spikes or pulses of high current draw, the chemistry used inside a battery causes its output capacity to drop. Fortunately, a condition known as charge recovery restores some of the battery's capacity during times of extremely low current draw.

Regarding battery life, assume that a task in a battery powered device can be performed two different ways with the same hardware and two different versions of firmware. If both versions yield the same performance and produce identical average power readings, they seem equivalent. If both methods yield the same performance and produce identical average power readings, they may seem equivalent. However, the resulting battery life may be quite different: If one technique inserts periods of low current draw between periods of high draw, it may achieve battery life that is up to 30 percent longer. Thus, in battery-powered designs that demand long battery life, dynamic current characterization is critical for estimating and optimizing battery life.

Challenges in characterizing dynamic current

Because of its constantly varying nature, dynamic current cannot be captured with an averaging or integrating measurement device. Instead, measurements of dynamic current should be performed with a high sample rate device such as an oscilloscope, a digitizer or a dedicated "power analysis" instrument.

As was discussed earlier in the RF power amp example, dynamic current in communication subsystems can have rise and fall times in the microsecond range. Capturing these rapid transitions requires digitizing devices with measurement bandwidths in the tens of kilohertz and sampling rates of more than twice that range. Low-current measurement capability must achieve at least microamp levels to capture sleep, standby and leakage currents. A large dynamic measurement range is needed to make accurate measurements throughout the design's varying current profiles, spanning from microamps to amps. When characterizing dynamic current, the measurement technique should have little or no effect on the circuit and its behavior.

Measuring dynamic current

This section presents three methods used for the analysis of dynamic current: current probes; current shunts; and high-performance DC sources.

Method 1: Current probe

A current probe takes advantage of the magnetic field created when current flows through a conductor (Figure 1). The probe captures a portion of this magnetic field and converts it into an equivalent voltage level that is typically digitized and displayed by an oscilloscope.

Figure 1. With a current probe, characterizing the current profile of a DUT is as simple as clamping the probe around a conductor.

Advantages

The two biggest advantages of this method are its measurement bandwidth and simplicity. Characterizing the current profile of a DUT is as simple as clamping the probe around a conductor. The bandwidth of a current probe can easily extend above 1 MHz (the widest of the three methods described here). An additional advantage comes with the use of a multichannel mixed-signal oscilloscope, which can reveal relationships between current changes and analog or digital signal activity.

Disadvantages

Current probes suffer from four key drawbacks: limited low-end measurement capability; accuracy; circuit loading; and offset drift.

Low-end current: A typical high quality current probe can measure down to just 5 mA. Low-end measurement capability can be improved by feeding multiple wraps of the power-supply wire through the current probe. For instance, feeding ten wire wraps through the current probe produces a new low-current range that is the old one divided by ten (e.g., 5 mA becomes 500 µA).

Accuracy: Another downside to using current probes is accuracy. Because current probe measurements are derived from magnetic fields, noise will affect both accuracy and resolution. What's more, accuracy may also be sensitive to temperature fluctuation. As a result, even high quality current probes will have amplitude accuracy of no better than 1 percent.

Circuit loading: Current probes often have an effect on the impedance of the circuit under test, adding a few milliohms of impedance at low frequencies and up to 100 mΩ of impedance at frequencies above 100 kHz. The impedance is mainly in the form of inductance.

Offset drift: Figure 2 illustrates the noise and offset drift problems commonly seen with current probes. This example used a high quality current probe specified at 1-percent amplitude accuracy and a lowest measurable current of 5 mA.

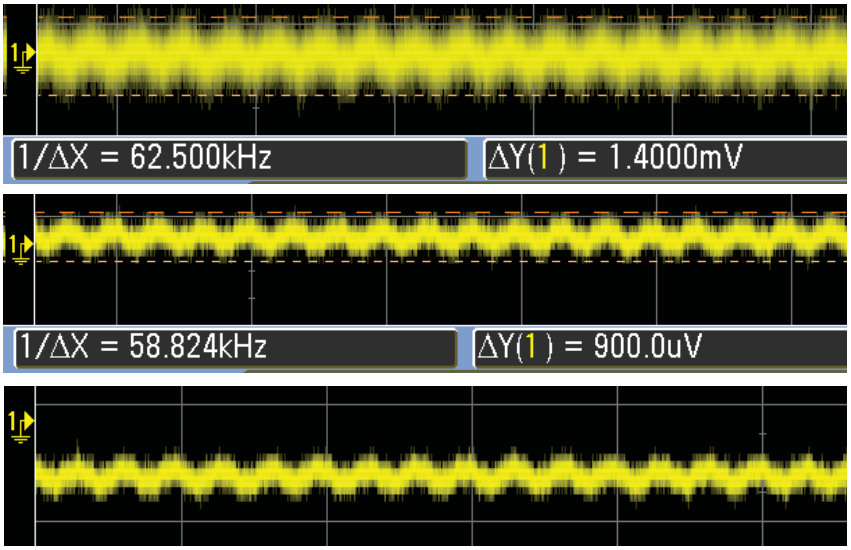


Figure 2. Three views of a current probe signal: probe noise (top); probe noise measured with oscilloscope bandwidth limiting (middle); and zero-offset error after four hours (bottom).

The three images show zoomed-in views of the current probe with no input. The trace scaling is a divide-by-ten view of current in terms of voltage, so 1 mV equals 10 mA. The top trace has noise of 1.4 mV peak-to-peak (14.0 mA); this was captured without the scope's bandwidth-limitation feature. Such high noise levels make it difficult to accurately resolve current readings of 10 mA and below. Applying the scope's bandwidth limitation feature will reduce the noise effects (middle trace), but even so there is still 900 µV (9.0 mA) of peak-to-peak noise. The bottom trace shows approximately 20 mA drift that occurred over a four-hour period.

Compensating for drift typically requires recalibration every few hours, or at the start of each measurement session. Fortunately, the calibration process is simple, requiring only a manual adjustment to achieve proper alignment (as viewed on the screen of a scope). However, the need for manual adjustment may limit the usefulness of probes in automated test systems.

Dynamic currents with wide dynamic range can also cause offset drift. When analyzing current profiles that have large, fast current spikes, it is possible to watch the offset slowly begin to drift on the screen of an oscilloscope. This poses a problem in long-term data acquisition tests, such as battery rundown, and ATE environments in which no one is available to constantly monitor the offset drift of the probe.

Method 2: Current shunt

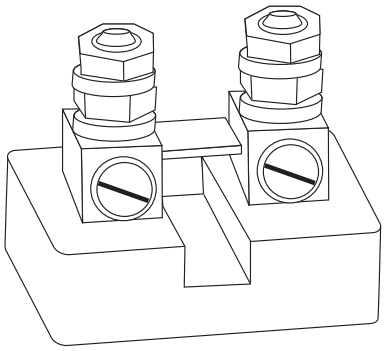


Figure 3. A current shunt offers a low-cost solution, but it has some important drawbacks.

Precision current shunts offer good measurement accuracy at any current level, enabling readings at nanoamp levels. Any device with a known resistance can be used as a shunt, including readily available resistors with 5-percent tolerances. For highly accurate current measurements, precision wire-wound resistors are typically used. One example is a high quality four-wire shunt supplied with a calibrated temperature table.

Advantages

This method has three noteworthy advantages: low-current measurement capability; good accuracy in specific current ranges; and low cost. The cost is low if a scope or digitizing device is readily available. This is especially true if a high level of measurement accuracy is not needed. In such cases, low-cost 5-percent resistors can be used as shunts. Also, as in Method 1, if a multi-channel mixed-signal oscilloscope is available, current-shunt measurements can be used to observe relationships between current levels and the activities of analog and digital signals.

Disadvantages

The use of current shunts has four important disadvantages: circuit loading; setup complexity; bandwidth limitations; and temperature effects.

Circuit loading: Because shunts are placed in series with a circuit they add impedance, altering circuit behavior and thereby the dynamic current profile. For instance, when measuring a standby current of 1 mA, a 10-Ω shunt would provide a measurable 10 mV drop. However, when the circuit switches to full operation its current draw will ramp up and the 10-Ω shunt would drop 1 V at a current of just 100 mA. When working with a 3.3-V system, a 1-V drop would be enough to cause an IC to reset.

Approaching the problem from the opposite direction, a 10 mΩ shunt would produce a drop of only 10 mV when the circuit is drawing 1 A. This voltage is measurable and there is very little loading on the circuit. Unfortunately, a 1-mA standby current would produce a voltage drop of just 10 µV, which cannot be measured accurately with most digitizing measurement devices.

Taking these methods together suggests using the 10-Ω shunt for standby-level measurements and the 10 mΩ shunt for full-operation measurements. Making this work would require pausing of the measurement in midstream, switching between shunts, and continuing. In general this approach is not feasible.

Another consideration is the shunt interacting with circuit capacitance. Circuits that have fast current transients, such as amplifier-based circuits, often have capacitance in parallel with the circuit's power supply line. The purpose of this capacitance is to help the power supply keep up with fast current transients caused by sudden changes in circuit loading. When the load current demand suddenly jumps, the capacitance begins to discharge to compensate and give the power supply time to catch up. Adding a current shunt to the circuit increases the series resistance of the circuit, increasing the charge and discharge time constants of the capacitance in the circuit. This will distort the circuit current during sharp transitions in the dynamic current profile, possibly changing the circuit's behavior or performance.

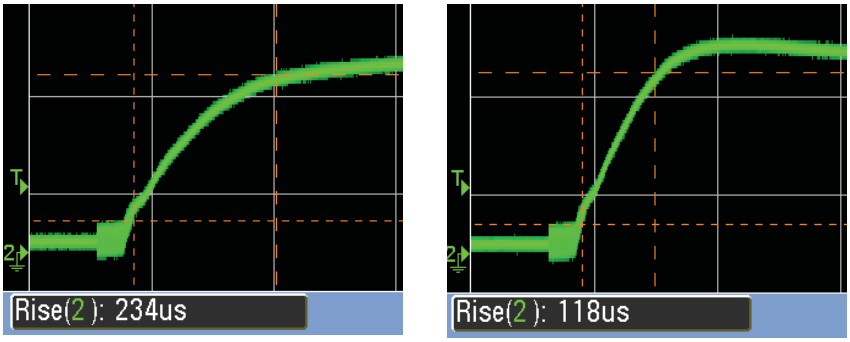


Figure 4. In this example, removing a 100 mΩ shunt (lower trace) halved the rise time of the current transient.

Figure 4 shows an example. Two current transients were captured from a circuit that had an input capacitance of 100 µF. For the measurement on the left, a 0.1 Ω low-side current shunt was added to the circuit. The current profile shows that the transient had a rise time of about 234 µs. The trace to the right shows the same test when repeated without the shunt: after removing the 0.1 Ω resistance, the rise time fell to half that of the shunt-based measurement. Such an effect gives a distorted representation of the circuit's actual current profile and can affect the performance or behavior of the circuit during testing.

Complexity: Shunts add time and complexity to test setup because they must be placed into the circuit. Also, it often requires multiple shunts to handle a current profile with high variance, and this will benefit from the assembly of a simple breadboard that enables switching between shunts. This leads to another complication: The use of multiple shunts usually means multiple setups and multiple measurements for each shunt and its specific current range. In an automated test system, this can be done with a switch matrix. Depending on the requirements, this could be either an off-the-shelf solution or a custom configuration.

Bandwidth limitations: For high-accuracy current measurements, precision wire-wound resistors are typically used. Although these offer high accuracy, they have bandwidth limitations that must be considered when characterizing current transients with sharp rise and fall times.

Temperature effects: These are important factors to consider in applications that require high accuracy. With a widely varying dynamic current profile, a shunt's internal temperature and therefore its resistance may also vary widely. An example is a current profile that is relatively flat but has short bursts of high current. The bursts will cause an increase in both the internal temperature and the resistance of the shunt. This will make it appear as if the current slowly ramps up during a high-current burst when it actually remains constant. At the end of the burst it may seem that the current is slowly rolling off until it returns to its pre-burst level; in reality, it returned to its original value immediately after the burst.

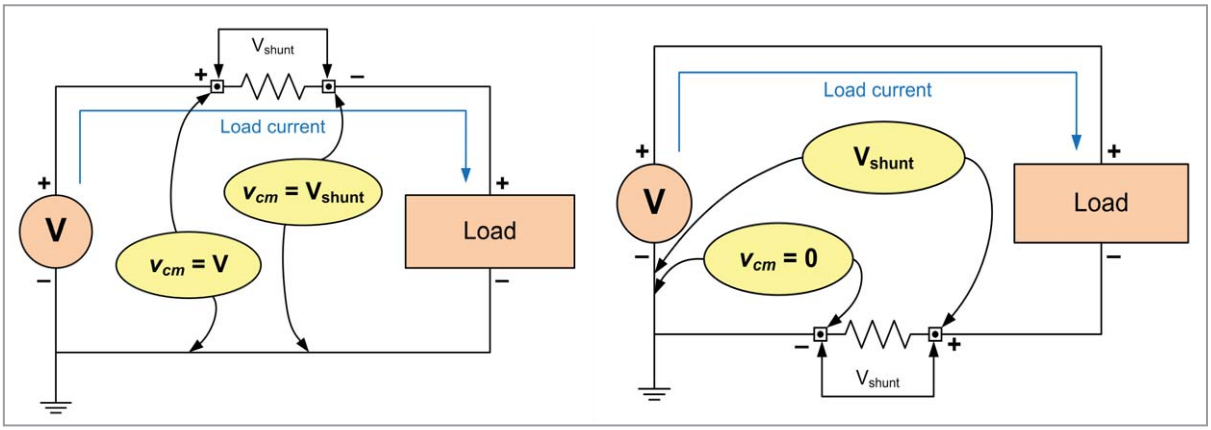


Figure 5. These diagrams show the placement of high-side (left) and low-side (right) shunts relative to the circuit load.

Hints: High-side vs. low-side shunts

When making current measurements with a shunt, the shunt can be placed on either the "high side" or "low side" of the circuit (Figure 5). If the direction of current flow is defined as positive to negative, a high-side shunt is placed before the load in the circuit. Similarly, a low-side shunt is placed after the load in the circuit.

The low-side may seem to be the better place to make these measurements. Unfortunately, it isn't always possible to access the low side of the circuit. As a result, high-side measurements tend to be more common.

When making high-side current shunt measurements, the measurement instrument must have either an isolated single-ended input (floating common) or a differential input. This is an important point: Never use an instrument with its common input tied to ground because this creates a short to ground immediately after the shunt and risks damage to the measurement instrument and the DUT.

One alternative is to use two single-ended input channels to measure the voltage differential across the shunt. Of course, this requires two measurement channels and accuracy is reduced due to the cumulative errors from each channel.

A measurement channel with a floating common can be used. However, when working with higher voltages it is important to pay close attention to the common mode rejection (CMR) specification. The safest and most accurate way to make high-side shunt measurements is with differential-input devices because they offer high CMR, delivering high accuracy and resolution.

When low-side measurements are possible, they can be made with a single-ended measurement channel. However, the best accuracy will be produced by a differential-input measurement channel. This avoids errors caused by ground loops and parasitic resistances between ground and the shunt.

Method 3: High-performance DC sources

The third approach is to use a "high-performance DC source" for dynamic current characterization. This type of instrument has the following characteristics:

- Fast transient response
- Fast down-programming capability
- Accurate, high-resolution measurements
- Built-in digitizer for current measurements
- Low-current measurement capability

These advanced capabilities are dramatically different from those of typical past-generation DC sources. For example, older DC sources are capable of little more than providing power at a constant voltage level. The accuracy of these sources is questionable so output levels may be monitored with an external instrument—and in some cases a capacitor will be connected to the output to improve transient response.

The remainder of this section presents advantages, disadvantages and two measurement examples. The examples provide a closer look at two specific models of high-performance DC sources and two specifications—measurement bandwidth and transient response—that are especially relevant to dynamic current characterization.

Advantages

Compared to Methods 1 and 2, high-performance DC sources simplify dynamic current characterization by offering an all-in-one solution. Other advantages include no circuit loading; wider dynamic measurement range compared to current shunts; and better resolution, accuracy and low-current measurement capability compared to current probes.

High-performance DC sources typically perform measurements using a single internal shunt. The voltage output of the DC source is regulated after the internal measurement shunt so the shunt adds no impedance to the circuit. To achieve high accuracy over widely ranging dynamic currents, a high-performance DC source will typically employ more than one measurement range. This can be accomplished with a single shunt by feeding the voltage across the shunt to an adjustable amplifier, which feeds into the measurement analog-to-digital converter (ADC). The amplifier gain is based on whichever current range is set in the DC source. The key advantage: Even if the current exceeds the selected measurement range, output voltage and current are not affected—unlike what occurs when using an in-circuit current shunt.

Disadvantages

Compared to the other two methods, high-performance DC sources provide less measurement bandwidth: between 2 to 50 kHz versus 1 MHz which is typical for current probes. Kilohertz of bandwidth seems low compared to today's wide bandwidth scopes and digitizers used to measure high-speed communication signals, but it can be adequate in the realm of current transients.

Examples with high-performance DC sources

This section provides a closer look at two of Agilent's high performance DC sources with an emphasis on two important specifications: measurement bandwidth and the output transient response.

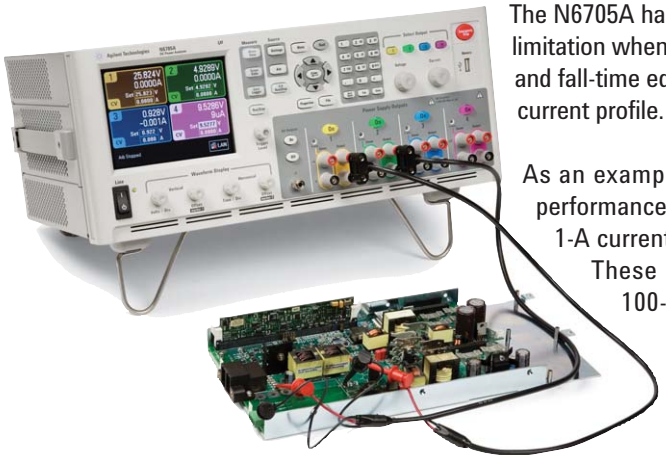
Measurement bandwidth is a function of the internal measurement sampling rates, and output conditioning of the DC source. These two factors must be accounted for when determining a DC source's actual measurement bandwidth. For example, it's easy to (incorrectly) assume that a measurement sampling rate of 50 kSa/s simply equates to a measurement bandwidth of nearly 25 kHz (using the Nyquist sampling theorem). However, this must be tempered by factoring in the specifications for measurement filtering and output conditioning.

Transient response specifications represent the output bandwidth of the DC source—and this is quite different from measurement bandwidth. Said another way, the transient response is the time it takes a DC source to return to a given output-voltage setting in response to a sudden change in load current. High performance DC sources have transient response times that are typically less than 150 µs. This specification is important for dynamic current characterization because the DC source should have a transient response time equal to or better than that of the DUT's intended final power source. If not, the DUT may behave differently, invalidating any current-profile measurements.

Example 1: Agilent N6705A power analyzer

The N6705A provides tremendous productivity gains for sourcing and measuring DC voltage and current into a device under test (DUT). It does this by integrating, in a single instrument, four advanced power supplies with a digital multimeter (DMM), a digitizing oscilloscope, an arbitrary waveform generator and datalogger functionality (Figure 6). The N6705A eliminates the need to gather multiple pieces of equipment and create complex test setups with current probes or current shunts. Specific to the characterization of dynamic currents, it offers five key attributes:

- Three ranges for current measurements
- Accurate current measurement capability down to 1 µA
- Scope-like display for voltage, current, and power measurements
- Datalogging capabilities
- On/off output sequencing



The N6705A has a current measurement bandwidth of 10 kHz. This can be a limitation when characterizing dynamic current profiles that have fast rise- and fall-time edges because the measurement may not capture the actual current profile.

As an example of the current measurement bandwidth of a high performance DC source, an N6705A was used to capture two separate 1-A current pulses with rise times of 10 µs and 100 µs, respectively These rise times were verified using a current probe with a 100-MHz bandwidth.

Figure 6. The Agilent N6705A DC power analyzer simplifies current characterization by providing DC sourcing and a variety of measurement capabilities in a single instrument.

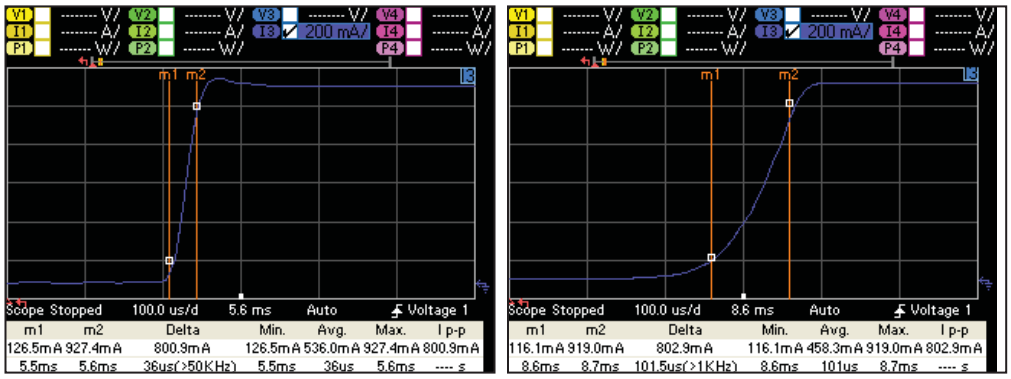


Figure 7. Limited measurement bandwidth can obscure the actual rise time of a pulse. Actual rise time for the trace on the left was 10 µs but it was measured as 36 µs. The right pulse was within the instrument's measurement bandwidth and the rise time was calculated to be 101.5 µs versus the expected value of 100 µs.

In Figure 7, the scope-like display of the N6705A shows the rising edges of each pulse. For the current pulse on the left N6705A measured the rise time as 36 µs. The error is due to the instrument's limited measurement bandwidth, which obscured the actual rise time data of the pulse.

The measured rise time for the pulse on the right was 101.5 µs, which is much closer to the expected rise time of approximately 100 µs. In this case the N6705A's measurement bandwidth was able to measure the actual rise time of the second set of pulses; no measurement data was lost due to limited current measurement bandwidth.

When using a high-performance DC source for dynamic current characterization, it's important to fully understand the DUT's expected rise and fall times as well as the limitations caused by measurement bandwidth. This will help avoid misinterpretation of the measured current profile.

Figure 8 compares the transient response time of the N6705A (left trace) to that of a basic DC source (right trace). This test used the same sharp 1-A current pulses used in the measurement bandwidth example.

The left trace shows the effect of the 1-A pulse on the voltage level of the N6705A and the right figure shows the effect of the pulse on the voltage level of a basic DC source. As shown, the N6705A's voltage level did not droop as much as the basic DC source, 117 mV versus 176 mV. Also, N6705A recovered from the load change more quickly than the basic DC source.

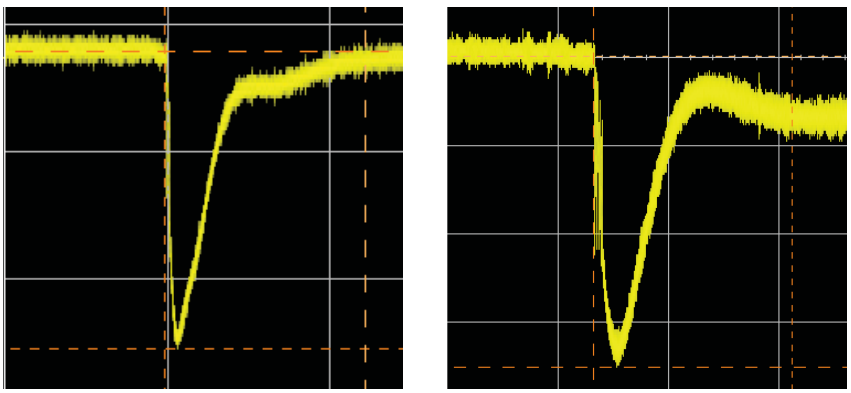


Figure 8. The N6705A offers a faster transient response than a basic DC supply (both traces are 50 mV/div vertical and 100 µs/div horizontal).

Figure 9. The 66300 Series addresses the unique challenges of simulating batteries and battery packs, and measuring the current drawn by the DUT.

Example 2: Agilent 66300 Series mobile communications DC source

This specialized family of DC power sources offers DC sourcing, current sinking and fast transient response as well as measurement capabilities that address the unique challenges of simulating batteries and battery packs, and measuring the current drawn by the device under test (Figure 9). It has four key features that are relevant to the characterization of dynamic current profiles:

- Optional auxiliary DC source channel
- Optional DVM
- Output-resistance simulation
- Available device characterization software

The 66300 Series has a measurement bandwidth of approximately 30 kHz. It was used to characterize only the 10 µs current pulse measured with the N6705A because the 66300 Series has a 3x wider measurement bandwidth. As shown in Figure 10, the rise time measured with the 66300 Series DC source was 13.6 µs, which means it can provide a more accurate picture of higher-rate current pulses.

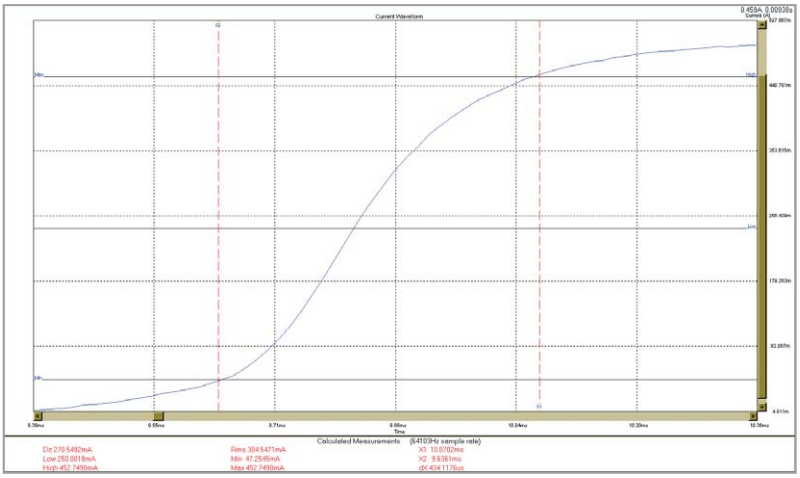


Figure 10. The 66300 Series addresses the unique challenges of simulating batteries and battery packs, and measuring the current drawn by the DUT.

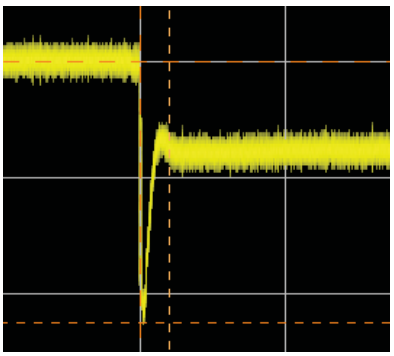


Figure 11. The 66300 Series also offers a faster transient response than a basic DC supply (trace is 50 mV/div vertical and 100 µs/div horizontal).

In a separate test, a 66300 Series DC source had a transient response time of 35 µs (Figure 11). Compared to a basic DC source, the 66300's programmed voltage level dropped 60 mV less and recovered six times faster. Thus, the 66300 Series can be expected to provide a highly stable output voltage levels during fast load-current changes.

Conclusion

This application note presented three ways to characterize and analyze dynamic current: current probe, current shunt and high-performance DC source. Table 1 summarizes the strengths and weaknesses of each approach.

Table 1. Comparison of the strengths and weaknesses of the three methods

Method	Strengths	Weaknesses
Current probe	• Wide bandwidth • Easy setup • Little effect on DUT circuitry	• Limited low-current measurement capability • Insufficient accuracy • A poor fit with automated applications
Current shunt	• Low-current measurement capability • Resolution • Accuracy • Cost	• Difficult to set up • Limited dynamic range • Adds impedance to circuit • Can cause RC time constant
High-performance DC source	• All-in-one solution • Resolution • Accuracy • Measurement dynamic range • Easy set up • Easily automated	• Measurement bandwidth • Cost

The answer to, "Which method is best?" depends on the attributes of the DUT and the desired measurements: bandwidth, resolution, accuracy, current level and susceptibility to loading will help determine which method is most appropriate. In some cases a combination of these methods may be necessary to fully characterize the dynamic current profile of the low-power systems in a satellite. As an example, pairing a DC source with a current probe will provide good measurement accuracy, wide dynamic range, and sufficient measurement bandwidth to capture fast rise and fall times.

In an overall sense, the DC sources are often the most complete single approach. The N6705A and 66300 Series DC sources do cost more than the current-probe or current-shunt approaches if an oscilloscope or digitizer is readily available. However, these DC sources simplify measurement set-up and device testing by including a power source for the DUT, calibrated current measurements and the ability to store and display results. These instruments provide current measurements with high resolution, great dynamic range and excellent accuracy. They are also equally efficient and effective in manual or automated testing.

For detailed information about the N6705A and the ATE-friendly N6700B, please visit **www.agilent.com/find/N6705**. To learn more about the 66300 Series, please visit **www.agilent.com/find/66300**.

For more information about Agilent's broad range of solutions for aerospace and defense applications, please see **www.agilent.com/find/ad**.

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- *www.agilent.com/find/N6705A*
- *Product overview, publication 5989-6319EN*

Agilent 66300 Series mobile communications DC sources

- *www.agilent.com/find/66300*
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