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Power Supply Transient Response Considerations When Testing Portable Wireless Devices

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Introduction

Designers of today’s portable, battery-powered electronic equipment, such as cellular telephones, pagers, two-way radios, personal digital assistants, and other communication devices are constantly striving to provide greater functionality and higher speed in smaller packages. At the same time, they want to offer longer operating periods between recharges. As desirable as these capabilities are from the consumer's perspective, they pose new challenges for device manufacturers' production test engineers.

For example, the trend toward lower voltage circuitry and longer operation between recharges are driving efforts to decrease in the minimum battery voltage at which a device will operate (before it automatically turns itself off to prevent damage.) With device power levels remaining the same or increasing, operating currents are increasing. Therefore, to conserve power, today's portable electronics typically operate in pulse fashion and most devices enter the "idle" mode when not being used. This requires the device to switch quickly into “operate" mode to perform a function and then go back to idle mode when not immediately needed.

For example, a cellular phone that's not being used will be in stand-by mode, then switch itself on to transmit, then switch back to standby. During these transitions from one mode to another, it's not uncommon for the load on the battery to change from tens of milliamps to several amps in just 20 to 50 microseconds. This means that test systems must include power supplies capable of responding quickly to transient load changes.

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Pulse Operation In Cellular Phones

To maximize the cellular phone industry's message capacity (the number of users that can access the system in a particular cellular site), standards require phones to communicate with the system in defined time intervals. Several different standards have been developed around the world. The U.S. digital standard is known as the North American IS-54 Standard. This standard utilizes a combination of frequency division multiple access (FDMA), in which a base station assigns a mobile phone to operate at a specific 30kHz frequency band, and time division multiple access (TDMA), in which three users share the same frequency slot by transmitting at different time intervals. The base station assigns each user a time slot. The IS-54 standard requires that transmissions occur in time slots of 6.67ms.

European digital communications equipment follows the Global System for Mobile communication (GSM) standard. This standard has been adopted within most of Europe as well as in many other countries. The GSM standard is also an FDMA/TDMA system. The assigned frequencies have 200kHz bandwidths; however, eight users can share one frequency allocation. As a result, each transmission time slot is a narrow 576µs.

Thus, power supplies testing cellular phones must respond to load changes that can occur in intervals as short as 576µs. ***Figures 1*** through ***3*** outline current requirements from sample cellular phones and illustrate the magnitude of the load changes involved.

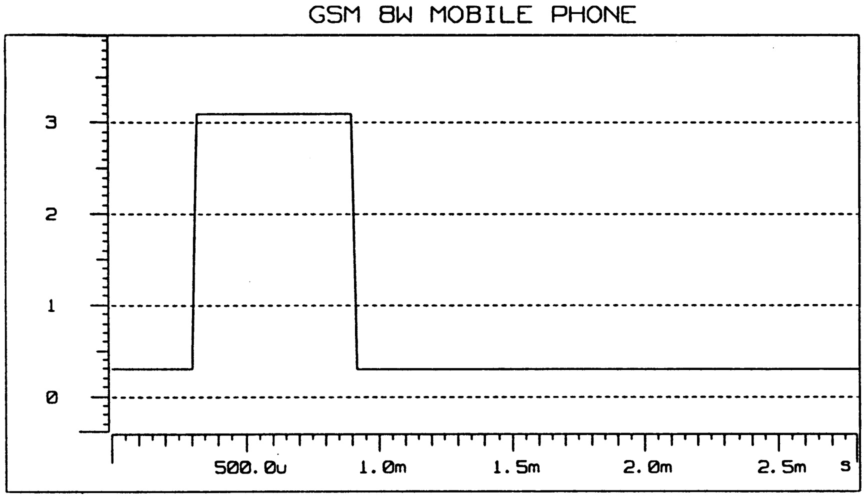

Figure 1.

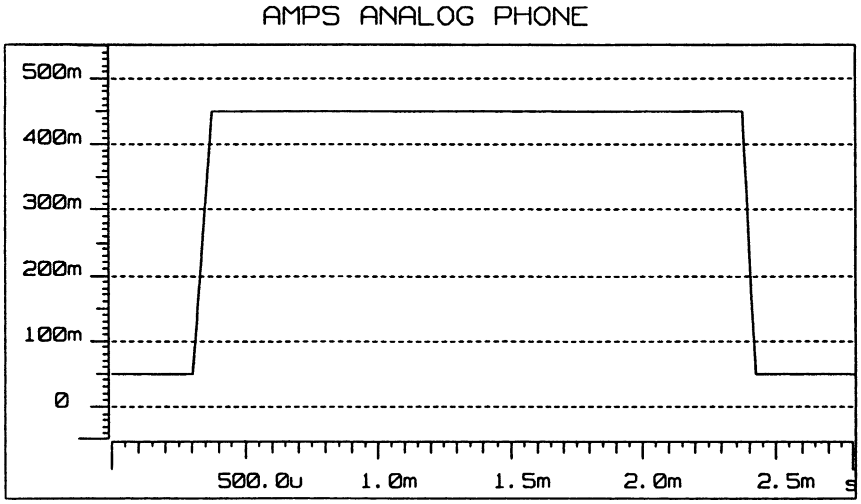

Figure 2.

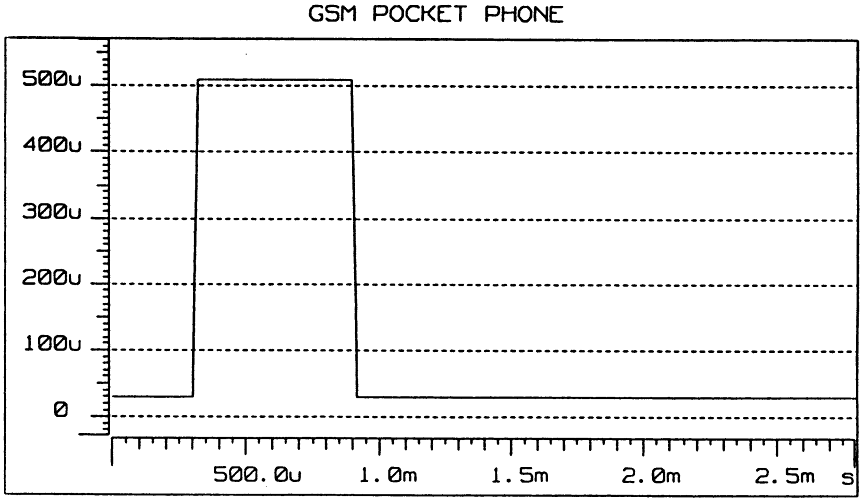

Figure 3.

From the test engineer's perspective, the ideal power supply for a test system would offer a response like a voltage-programmable battery. Unfortunately, the typical power supply has less than ideal load transient recovery response. The voltage will droop and the supply will require some period of time to respond to a new value. This slow response makes it difficult to test the device's pulse operating conditions at the low end of the specified battery voltage. In some types of equipment, an insufficient level of voltage will trip the under-voltage detect circuit, shutting down the device. The test engineer must select a power supply that can be set to this low voltage and respond to the load transient, so that the device under test (DUT) will not shut off and fail the test because of power supply droop and recovery time. A battery is not an ideal device and will display some droop in response to a pulse load (≈ tens to hundreds of millivolts), but the power supply used for the test must respond at least as quickly as a battery.

When most general-purpose, off-the-shelf power supplies are designed, fast transient response to pulse loads usually is not the designer's main concern. In order to be useful for a wide range of applications, the designer must make sure the power supply remains stable under any load condition, including large capacitive or inductive loads. Accordingly, most power supplies are designed to prevent instability problems by accommodating these load conditions, which is done at the expense of transient response. This usually produces less than optimum power supply performance under a resistive load, such as those in cellular phones and many other battery-operated devices with fast pulse loading. What the test engineer needs is a power supply designed for fast transient response to resistive load changes, even at the expense of providing a general-purpose supply that's stable under any load condition.

Power Supply Performance Characteristics

A power supply's ability to respond to load transients is directly related to its open loop response characteristics. The open loop response of a system is a way to measure its stability and transient response; this response is affected by the type of load applied. The power supply designer uses the open loop response measurement to optimize the supply's transient response while ensuring its stability under all possible loads. This usually requires a trade-off between transient performance and stability.

Two important parameters of a system's open loop response are the bandwidth and gain. The greater the bandwidth, the better the supply's ability to respond to rapid load changes. The higher the gain, the less the supply will droop in response to a pulse load. The magnitude of both variables is limited by the supply's stability requirements.

As stated before, the type of load directly affects open loop response. Resistive loading usually produces the greatest bandwidth, while capacitive loading reduces bandwidth and affects stability. The challenge for the test engineer is to select a power supply that will be stable with the device's load characteristics, while having enough gain and bandwidth to respond to device pulse requirements. In most cases, power supplies are specified to operate up to a maximum capacitance value and minimum or no inductance; the open loop response is designed to be stable under these conditions. For a general-purpose power supply, the capacitance specified usually is quite large to cover a wide range of possible loads, resulting in a less than optimum response for pulse loading conditions.

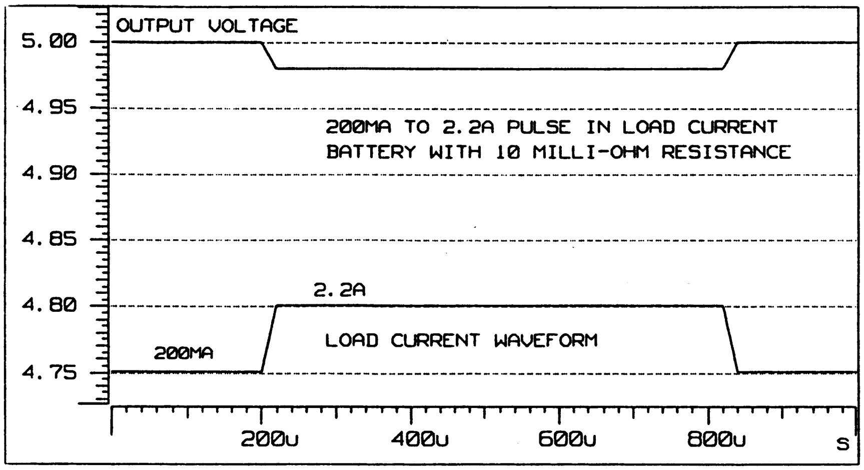

Figure 4.

A battery's response, which is not ideal, can be measured and modeled as one resulting from a resistance in series with an ideal voltage source. The resistance will change with the type of batteries and their level of charge. The response is equivalent to one produced in a power supply with an infinitely large bandwidth and a finite gain. ***Figure 4*** shows the response of a 5V battery with a 10mΩ series resistance. The load pulse is from 200mA to 2.2A, with a rise time of 20µs, which is typical of a cellular phone. Notice the voltage droop is proportional to the current step due to the series resistance.

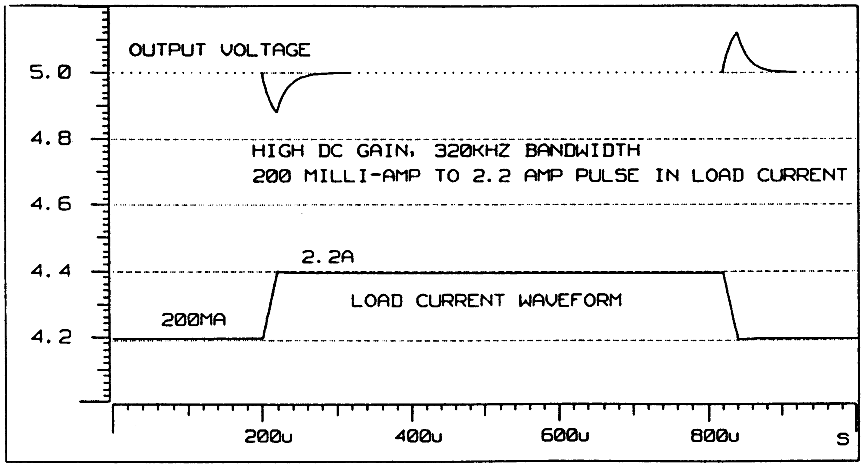

Figure 5.

Figure 5 shows the response of a power supply with 320kHz bandwidth and a high DC gain. The pulse load is the same as for the battery — 200mA to 2.2A. The droop in output voltage is 100mV and it recovers to near its original value in less than 60µs. This response is not as good as a battery's, but it does recover quickly to the drop in voltage. The test engineer would need to determine if this recovery time is sufficient to avoid adversely affecting the DUT.

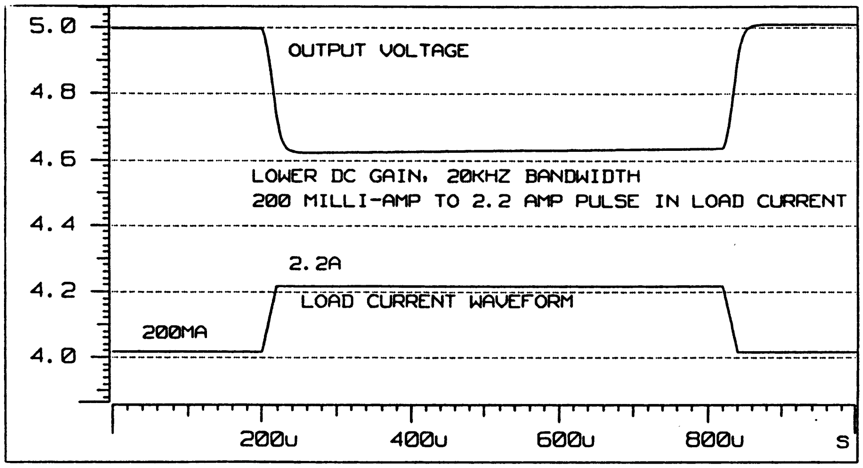

Figure 6.

Figure 6 shows a power supply with a 20kHz bandwidth and the resulting slower response. Notice that the voltage response to the current pulse is poor. The droop is nearly 400mV and the voltage does not recover to its original value before the pulse has ended. This type of response might be slow enough to trip the DUT's under-voltage circuitry and cause the device to fail the test.

Power supply data sheets typically do not specify open loop response data directly. While it may not be specified in a data sheet, most power supplies do have high DC gain to achieve good DC voltage regulation, and the maximum DC voltage change of the output usually is specified. Still, high gain at high frequencies also is important for pulse load response. Again, this is unlikely to be specified in power supply data sheets due to the difficulty in collecting this data.

If available, high frequency gain and bandwidth data are typically specified as dynamic transient response. While it would be ideal if this could be specified as a maximum voltage droop and recovery time to any load change, manufacturers typically specify it in terms of a recovery time and (sometimes) maximum droop to a specific load change, often a 50% load change. However, a device such as a cellular phone could change from 200mA to 2.2A, which is a load change of 1000%. In other words, a single data point (e.g., 50% change) on the data sheet does not make it clear how a supply would respond to a different load change. Therefore, test engineers need to review data sheets carefully to find response information. If not included, they should query the power supply manufacturer and/or run a benchmark test with an actual device.

Power Supply Choices

There are two basic types of power supplies from which to choose: linear and switch mode. Both types can achieve high speeds under resistive loading, enabling them to respond quickly to fast (pulse) load changes. Both types can also achieve high open loop gains. Linear supplies may have bandwidths of several megahertz, while switching supplies are limited to low tens of kilohertz values. (However, this is changing as new component developments are allowing higher frequency switch mode supplies to be developed.)

There are a number of trade-offs that must be considered when choosing the most appropriate type of supply for a specific application. Linear supplies can be inefficient and are generally much larger with bulky heat sinks and fans. A switch mode supply, on the other hand, can be highly efficient and much smaller, but will typically have a slower response. In designing a text fixture, a test engineer must balance the power supply's response requirements with the amount of rack space it will occupy.

Another factor to consider is the output noise generated by the power supply. Batteries used in portable devices provide inherently low noise power. In order to test a battery-operated device with a power supply, the test engineer should make certain the noise generated by the supply will not affect testing or operation of the device. Power supply noise usually consists of some voltage ripple and could also contain some higher frequency ringing and/or spikes. In general, linear supplies generate less noise than switching power supplies. However, some linear supplies can be quite noisy if their internal power conversion circuitry creates noise. While switching supplies are inherently noisy because of high frequency switching, they can be made less noisy through careful design, good layout, and the use of appropriate output filters.

Noise information is not always specified in a power supply's data sheet. When listed, the data usually is specified as a maximum peak-to-peak and/or rms noise voltage. If the test engineer is concerned that excessive noise may affect the DUT's testability, it's advisable to contact the power supply manufacturer for more complete information, or to run an actual test with the unit.

Conclusion

Testing today's high performance, battery-operated equipment requires power supplies designed to respond quickly to pulse loads. This requires supplies optimized to operate with resistive loads, not general-purpose supplies designed to operate under a large range of load types. To pick the right supply, the test engineer must first determine the type of load pulses the DUT will have, their magnitude, rise and fall times, and frequency. Then, acceptable power supply voltage droop and recovery must be determined, based on the amount that will cause the DUT to fail the test or shut off. Also, the DUT's tolerance for noise must be specified. Even the amount of rack space occupied by a supply can be important in a production test environment where test space is limited.

Attention to these details is crucial to selecting the proper power supply. Picking a suitable supply will prevent unnecessary false failures and the need to modify a test system later to stabilize the power supply's output during load changes. In other words, selecting a power supply can no longer be an afterthought in portable device testing. The wrong supply can slow production throughput significantly and inflate test development expenses.

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