Power Consumption Solutions for Battery Operated Medical Devices

Battery Life is Key

Characterizing battery life is critical for developers of portable battery-powered medical devices. Advances in semiconductor technology have enabled most components in a medical device to be integrated onto a single chip, or a system-on-a-chip (SoC). Further reductions in size are constrained by powering technologies like energy storage and harvesting elements. Long periods of sleep/idle, wakeup/active, and short RF bursts create a challenging demand on the battery.

The typical peak current for wireless technologies is shown below:

<table>
<thead>
<tr>
<th>Wireless technology</th>
<th>Peak current</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bluetooth® Low Energy</td>
<td>&lt; 15 mA (read and transmit)</td>
</tr>
<tr>
<td>NFC</td>
<td>&lt; 15 mA (read)</td>
</tr>
<tr>
<td>ZigBee</td>
<td>~ 5.9 to 34 mA</td>
</tr>
</tbody>
</table>

Figure 1. Example of current drain profile

Long battery life is critical for portable battery-powered medical devices, especially in emergency and rescue situations. Although implantable devices themselves may last through the patient’s lifetime, periodic surgical replacement may be required for depleted batteries. Therefore, understanding and accurately measuring battery current drain is extremely important in the design and development of medical devices.
Figure 2. A typical wireless, battery-operated medical device module. Keysight’s DC power analyzer and digital multimeter target module-level power consumption, while the device current waveform analyzer, low noise power source, and high-sensitivity current probe address power consumption at the chip-level within the module.
Source and Measurement Solutions
N6705C DC power analyzer and N6781A/N6785A source measurement unit

- Gain insights in your device’s power consumption in minutes
- Visualize current drain from nA to A in one pass
- Performs wide dynamic range current measurements using patented seamless current ranging technology and gapless measurement sweep
- Ideal for battery run-down test

Figure 3. Keysight N6705C DC power analyzer

Figure 4. Battery run-down test results

BV9200B/BV9201B Control and Analysis Software for Advanced Power Supplies

Keysight’s PathWave BenchVue BV9200B and BV9201B Control and Analysis Software for Advanced Power Supplies gives you fast and easy access to the advanced sourcing and measurement functionality of your N6705 DC power analyzer, N7900 Series power supplies, and RP7900 Series regenerative power system without any programming. The software can control up to 16 modules and provides a visualization tool that gives greater insight and guidance into measurement data. It simplifies complex, repetitive tasks, and gets your answers quicker.

Figure 5. Keysight PathWave BenchVue Control and Analysis Software
B2961A/B2962A 6.5 digit low noise power source

Finding a cost-effective power source for precision measurement applications can be challenging. Analog-to-digital (ADC) converter circuits often require power sources with at least 20 bits of resolution. Voltage controlled oscillator (VCO) applications can require noise floors of 10 μV rms or less. While there are existing instruments and measurement techniques that can perform these measurements, these solutions can often run into tens of thousands of dollars. In addition, many low-frequency (10 kHz or less) applications often need voltages and currents greater than typical signal generators can source. Finally, it can be very cumbersome to use a PC to control instruments in a benchtop lab environment, so a self-contained solution with a small profile, interactive GUI and built-in graphing capability is highly desirable.

Keysight’s B2961A/B2962A 6.5-digit low noise power source provides the following features:

- Precision low noise voltage/current sourcing while also monitoring them.
- Best noise floor of 10 μVrms (1 nVrms/√Hz@10 kHz) with the N1294A-020/021 ultralow noise filters outperforms that of even linear power supplies. This satisfies the phase noise requirement for testing medical devices that require precise low-noise voltage supplies/sources for proper characterization.

![Figure 6. B2961A 6½-Digit Low Noise Power Source](image1)

![Figure 7. Observed data with the N1294A-022 low noise filter from oscilloscope at 350 Vrms: 10 Hz to 20 MHz](image2)
Current Measurement Solutions

CX3300 Series device current waveform analyzers

- Industry’s lowest current measurements down to 150 pA to analyze sleep mode abnormalities
- Ideal for low-power medical device measurements
- Maximum bandwidth: 140 MHz, to capture sharp current spikes and quick transient effects
- Current range: 150 pA to 100 A
- High-resolution/high-speed sampling at 14-bit (1GSa/s)/16-bit(75MSa/s)

Figure 8. CX3300 Series device current waveform analyzer

Figure 9. CX3300 enables you to capture the dynamic characteristics of the power rail precisely and quickly.

Anomalous Waveform Analytics

The anomalous waveform analytics feature uses data logging and machine learning to quickly capture and analyze signals for anomalies in the current and voltage waveform data, which can exceed one terabyte. This lets you find unexpected or abnormal behaviors in data collected up to 100 hours at maximum 10-MSa/s high sampling rate, with higher sensitivity than an oscilloscope, and these abnormal behaviors can potentially pose risks to medical device users and manufacturers. The fast 10-MSa/s sampling rate lets you validate the circuit and component margin against the peak and inrush current, optimize power consumption, and characterize the power rail impedance for power integrity.

Figure 10. CX3300 Data logger mode enables long duration measurement up to 100 hours without dead-time.
Waveform Analytics group the triggered segment by similarity with the number of occurrences. It is easy to find the unique anomaly.

Playback only the selected trigger pattern in the entire waveform for a quick deep dive analysis.

Figure 11. Waveform Analytics enables you to identify anomalies quickly.
Keysight N2820A/N2821A high sensitivity, high dynamic range current probes

- Measure wide range of current from 100 nA to 120 A
- Probing with the Make-Before-Break connector
- Compatible to InfiniiVision 3000 TX-Series/ 4000 X-Series/ 6000 X-Series/ Infinium S, and Infinium 9000A Series.
- Essential troubleshooting tool for any engineer or technician

34465A/34470A Truevolt digital multimeter

- Most basic tool to measure current consumption and voltage
- Measure high active mode current and ensure current drops below a certain level during sleep mode
- Cost-effective
- Current range: 1 µA to 10 A
## Specifications at a glance

<table>
<thead>
<tr>
<th>Source / measurement solutions</th>
<th>Current measurement solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>N6705C/N6781A¹</td>
<td>B2960 Series²</td>
</tr>
<tr>
<td><strong>Display size</strong></td>
<td><strong>High Speed</strong></td>
</tr>
<tr>
<td>5.9”</td>
<td>14.1”</td>
</tr>
<tr>
<td><strong>Effective Bandwidth, sample rate</strong></td>
<td>29 kHz, 200 kSa/s</td>
</tr>
<tr>
<td><strong>Measurement resolution</strong></td>
<td>18 bits</td>
</tr>
<tr>
<td><strong>Min. measurable static current</strong></td>
<td>800 nA</td>
</tr>
<tr>
<td><strong>Min. measurable dynamic current (10 kHz BW)</strong></td>
<td>2.4 µA</td>
</tr>
<tr>
<td><strong>Max. measurable current</strong></td>
<td>3A</td>
</tr>
<tr>
<td><strong>Burden voltage</strong></td>
<td>0 mV</td>
</tr>
<tr>
<td><strong>Price</strong></td>
<td>$$$</td>
</tr>
</tbody>
</table>

¹. Using N6700 frame with N6781A SMU in manufacturing, N6705C frame with N6781A SMU in R&D and N6785A for 20-V, 8-A application solutions.
². 1 pA is RMS noise (NBW = 0.1 Hz to 10 Hz)
³. 150 pA is RMS noise (NBW = 10 Hz to 20 MHz)
⁴. With Infiniium S-Series oscilloscopes
⁵. With the N2825A user-defined head installed on the N2820A
⁶. When measuring 10 mA on the appropriate range, the N6781A sources current, so the burden voltage is always 0 mV.
⁷. Using 100-mΩ, 0.5-W sense resistor.
Literature
N6705C DC power analyzer
Implantable Medical Devices Customer
Emulate the Battery for More Realistic Mobile Device Test Results

Keysight B2961A/B2962A 6.5-digit low noise power source
Product Fact Sheet
Data Sheet

KeysightCX3300 Series Device Current Waveform Analyzer
Device Current Waveform Analyzer Speeds Medical Device Evaluation and Validation Time by 50 Percent
Data Sheet

Keysight N2820A/N2821A high sensitivity, high dynamic range current probes
How to Select the Right Current Probe
Data Sheet

Keysight Truevolt Series 6.5- & 7.5-digit multimeters
Data Sheet
Brochure

Learn more at: www.keysight.com

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