APPLICATION NOTE

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.

Battery life is important for any IoT device manufacturer, but it is especially critical in the Healthcare IoT, where premature product failure can have serious negative consequences for both the patient and the device manufacturer.

The typical peak current for wireless technologies is shown below:

Wireless technology	Peak current
Bluetooth® Low Energy	< 15 mA (read and transmit)
NFC	< 15 mA (read)
ZigBee	~ 5.9 to 34 mA

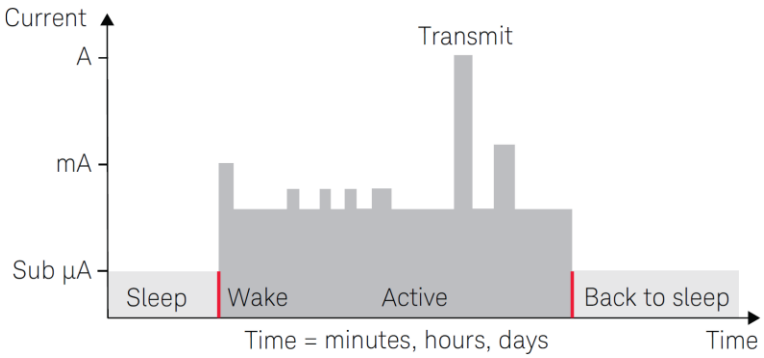

Figure 1. Example of current drain profile

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.

KEYSIGHT TECHNOLOGIES

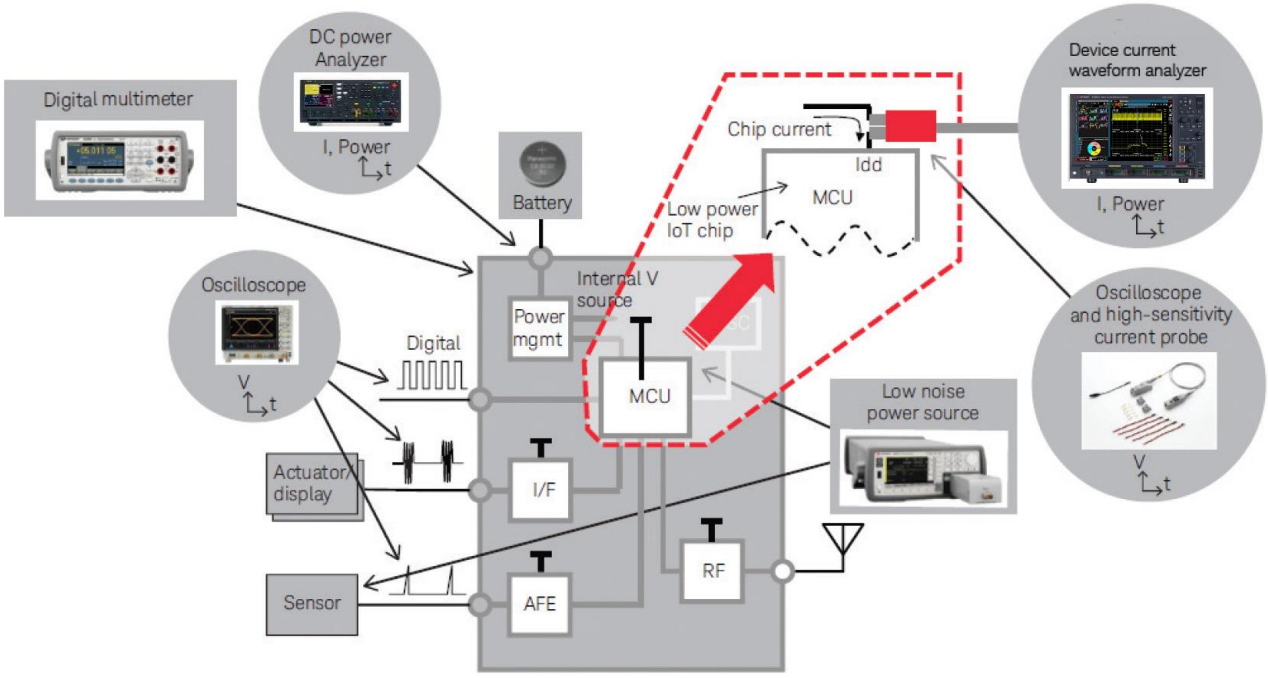

Figure 2. A typical wireless, battery-operated medical device module. Keysight's DC power analyzer and digital multimeter target module-level power consumption, while the device current waveform analyzer, low noise power source, and high-sensitivity current probe address power consumption at the chip-level 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 6 ½-Digit Low Noise Power Source

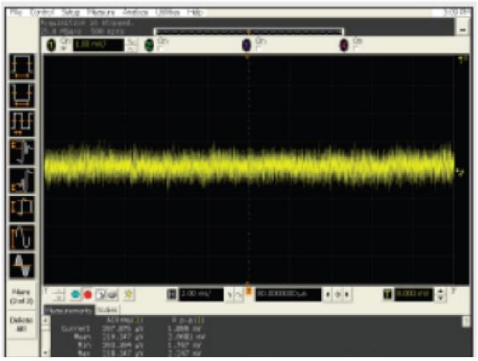

Figure 7. Observed data with the N1294A-022 low noise filter from oscilloscope at 350 Vrms: 10 Hz to 20 MHz

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

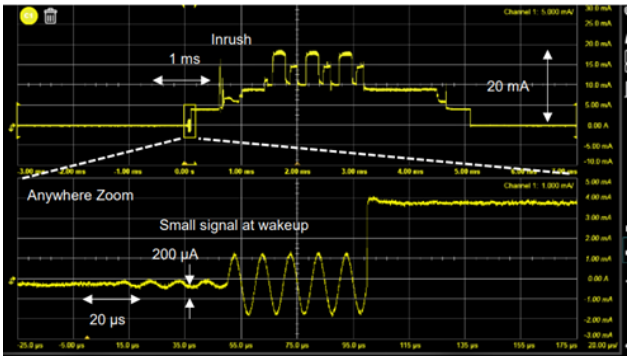

Figure 9. CX3300 enables you to capture the dynamic characteristics of the power rail precisely and quickly.

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.

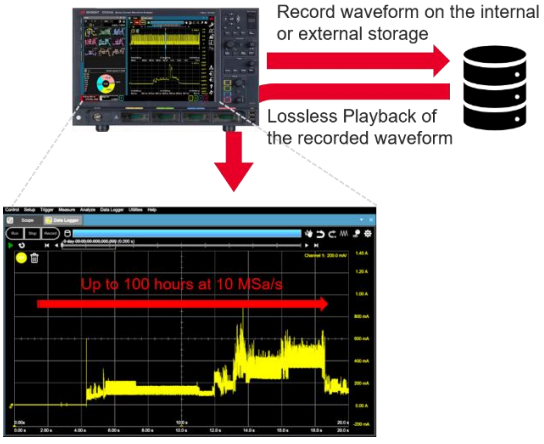

Figure 10. CX3300 Data logger mode enables long duration measurement up to 100 hours without dead-time.

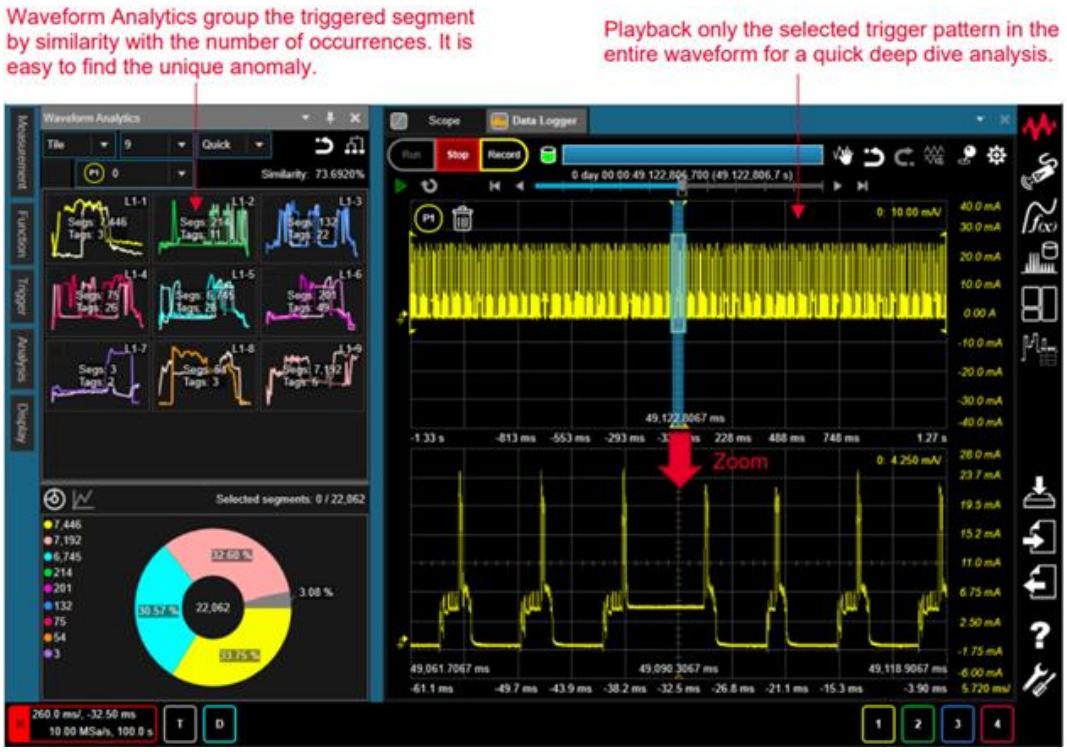

Figure 11. Waveform Analytics enables you to identify anomalies quickly.

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/ Infiniium S, and Infiniium 9000A Series.
- Essential troubleshooting tool for any engineer or technician

Figure 12. N2820A/N2821A high sensitivity, high dynamic range current probes

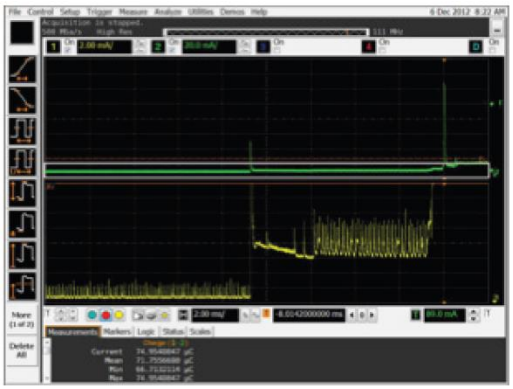

Figure 13. Infinium oscilloscope and N2820A current probe measure the area under the

34465A/34470A True*volt* 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

Figure 14. 34465A Digital multimeter

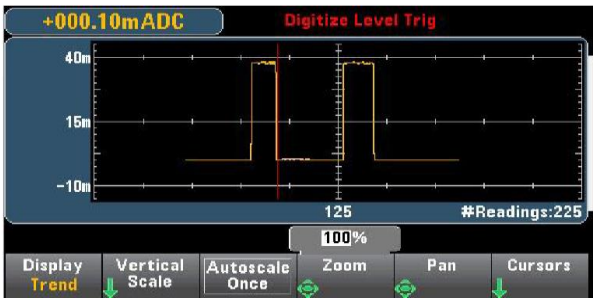

Figure 15. Operating current captured with the 34465A DMM.

Specifications at a glance

	Source / measurement solutions		Current measurement solutions			
	N6705C/N6781A[1]	B2960 Series[2]	CX3300 Series[3]		34470A	N2820A/21A[4,5]
			High Speed	High-Res		
Display size	5.9”	4.3”	14.1”	14.1”	4.3”	N/A
Effective Bandwidth, sample rate	29 kHz, 200 kSa/s	10 kHz, 100 kSa/s	140 MHz, 1 GSa/s	15 MHz, 75 MSa/s	10 kHz, 50 kSa/sec	3 MHz, 20 GSa/sec
Measurement resolution	18 bits	20 bits	14 bits	16 bits	14 bits	14 bits
Min. measurable static current[6]	800 nA	10 fA	150 pA		10 pA	100 nA
Min. measurable dynamic current (10 kHz BW)	2.4 µA	1 pA	150 pA (at 20 MHz nose BW)		10 nA	100 nA
Max. measurable current	3A	3A	100 A		10 A	120 A[5]
Burden voltage[7]	0 mV	N/A	4 mV	4 mV	27 mV	1 mV[8]
Price	$$$	$$$	$$$$	$$$$	$	$$

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. Accounts for typical noise with 1% error and quasi-DC current measurement
7. When measuring 10 mA on the appropriate range, the N6781A sources current, so the burden voltage is always 0 mV.
8. 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 True*volt* Series 6.5- & 7.5-digit multimeters

Data Sheet

Brochure

Learn more at: www.keysight.com

For more information on Keysight Technologies' products, applications or services, please contact your local Keysight office. The complete list is available at: www.keysight.com/find/contactus