Battery-powered wireless medical devices have become increasingly prevalent in our daily lives. This can be seen in the explosion of healthcare or medical devices with built-in capability to connect to the internet. Examples of these emerging classes of medical devices include fitness band or smart watch (includes pulse monitor and heartbeat monitor capabilities), blood pressure monitor, pacemaker, pulse oximeter, glucose monitor, thermometer, and hearing aids.

Designers and manufacturers face unique challenges when testing these medical devices as these devices require low-power, small form factor, mobile, lightweight, and support wireless connection with low-power consumption. The biggest challenge for wireless medical devices is the life of the small, on-board batteries. Medical devices such as hearing aid and pacemaker must work for long periods of time without any failure. Failing in these medical devices may cause mild to severe consequences.

Therefore, it is essential to understand the power consumption patterns and battery life of these devices. To maximize the battery life, many of these devices are only active at brief intervals to send or receive data; otherwise, they remain in standby or sleep mode. A device can draw up to hundreds of milliamperes in the active mode, but will only draw microamperes while in the sleep mode. High current spikes and transient effects occur when the device is turned on and off frequently. This means that the equipment used to test these devices must accurately measure over a wide dynamic range, and perform fast measurements continuously to capture these single shot and transient current waveforms.

Traditional Approach and Test Challenges

Design engineers will normally assemble multiple test instruments and external circuitry to analyze the energy requirements of the device to be tested. Typically, an oscilloscope, digital multimeter (DMM), or digitizer is used to make the measurements (usually two channels, one to measure voltage and the other current), a power supply and/or battery to power the medical device, and shunt resistors for current measurements. Design engineers will need to design a test system to control the medical device (to test its different states of operation) as well as to control the test equipment to collect and analyze the desired data (current, voltage, power). This can be accomplished manually, or semi-automatically, by connecting the test equipment to a computer and writing a software to programmatically control the test sequences. This approach is time consuming and requires coding knowledge to program and configure the overall system.

The result is typically a voltage and current waveforms for the different operating states of the device. Design engineers will then use the data to determine the power consumption of the device.

The challenges of this traditional approach are that the information gathered are very limited.

- Limited dynamic range of scopes, digitizers, and most DMMs (8-21 bits), while different shunt resistors are required to measure the peak values (100 mA to Amps) and the sleep mode current values (low microamps).
- Understanding of the medical device’s transient behavior from sleep mode to active mode
- Difficulty in characterizing the dynamic power consumption versus the device mode
Integrated Solution Approach

A source measurement unit (SMU) is the new integrated solution approach in measuring and analyzing medical device power consumption. The benefits of using the SMU are that it allows the following:

- Source a voltage/current and measure a current/voltage back from the device. Hence, an SMU is capable to measuring voltage, current, and power, assuming that the SMU's power rating is sufficient and removes the need for external shunt resistors for current measurement. This eventually eliminates the additional test equipment required to perform the same test.
- Provide data logging feature which allows the capture of voltage, current, and power over time. This is important to capture multiple operating states of the medical device and also calculate the medical device battery capacity (Ah).
- Remove low value-added tasks such as data gathering, equipment integration, and writing test programs.
- Save time and build confidence for designers to analyze their design.

Following are the steps to determine the power consumption of Blip using Keysight DC Power Analyzer.

Seamless Ranging

SMU has recently been developed with dynamic ranging capability to allow measurement of current spikes up to 3 A from the sleep mode current of tens of microamps with resolutions of tens to hundreds of nanoamps, within the same digitization pass. This feature is known as seamless ranging. It is fast to detect quick pulses in power, overload, and any other pulse event. Seamless ranging does not glitch the measurements as compared to the traditional AUTORANGE function in a DMM.

Figure 2. Blip wireless blood pressure cycle: 1) Voltage supplied, 2) Waiting for user’s feedback, 3) BP cuff is inflated, 4) Measuring BP during deflation, 5) Wi-Fi transmitting BP measurement information to internet, 6) Display of BP measurement and return to sleep mode.

Figure 3. Results of the sleep mode current of a Blip wireless blood pressure. An SMU can measure up to 3 A while measuring the μA level with the accuracy of the 1 mA range (100 nA offset error). Every point in the waveform is measured with the highest level of accuracy possible. Unlike a conventional DMM, this new approach provides accurate measurements of the dynamic power transients and eventually have a better understanding of the impact on battery life.
Energy Drain Analysis

SMU can be used as a virtual ammeter to identify where current is used within the subcircuits measurement. Multiple channels can be measured simultaneously and the time correlated on the scope or datalogging screen. Max. sampling rate: 1 GSa/s

Hence, this eliminates the need of analyzing spreadsheets to evaluate the current drain and estimate the approximate battery life. The current drain details can be analyzed with one single acquisition measurement.

Complementary Cumulative Distribution Function (CCDF)

The CCDF feature is able to determine how much current was drawn during a specific percentage of the datalog record (as shown in Figure 9), whereby the horizontal axis is a log scale of current and the vertical axis represents the log scale of percent of time during datalog.

Figure 5. Complementary cumulative distribution function: 1) Sleep mode current, 2) Display result current, 3) BP measurement current, 4) BP cuff pump peak current. Markers show that 7.7% of the datalog record was spent drawing more than 100 mA.

The benefits of the CCDF feature to designers are as follows:

- Gain insight to their design and understand which design draws the most current, and for how long.
- Spend more time to improve the battery power design by comparing the CCDF graph between design iterations.
- Access tools to compare different hardware and firmware releases to document the impact of the changes towards the power consumption of the medical devices.
Summary

With the exponential growth in demand for medical devices in various types, sizes, and wireless connectivity, the need to understand the battery life of medical devices is becoming critical. Conventional testing method provides more challenges to a designer than solving the ultimate question: how long will the battery will last?

With the new integrated SMU approach, designers can shorten the development time with a more accurate and reliable test measurement system. In addition to that, the new SMU features such as the seamless ranging, detailed energy drain analysis, and CCDF allow designers to easily and confidently optimize the battery life of the medical devices or wireless healthcare devices.

Figure 6. Keysight Battery Drain Solution, and Blip, the world's first Wi-Fi blood pressure monitor system
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