Affordable and Portable Real-Time Spectrum Analysis

by Signal Hound

The presence of high-performance commercial off-the-shelf (COTS) components is opening new doors in the Test and Measurement industry. The need for large, bulky, and expensive measurement equipment is being challenged by new low-cost, high-performance, compact products. These products are made possible by advances in readily available COTS components. The Signal Hound® BB60A Real-Time Spectrum Analyzer (BB60A), manufactured by Test Equipment Plus, Inc. (TEP), is an excellent example of what can be achieved with thoughtful engineering and careful parts and materials selection. The BB60A is small (~ 19.4cm long), lightweight (~310g), affordable (less than $3k USD), tunes from 9 kHz to 6 GHz, and is powered and operated over USB 3.0 link and a PC. TEP's hallmark is to maximize performance while minimizing cost. This is demonstrated by their line of USB based narrow band spectrum analyzers, tracking generators, and now a true real-time broadband spectrum analyzer, the BB60A.

The BB60A was launched in February 2013 and its primary feature is the ability to stream 80 million samples per second of digital IF data to a PC via USB 3.0. This data pipe is the backbone of the BB60A and enables real-time spectrum analysis of any 20 MHz segment of RF spectrum, from 9 kHz up to 6 GHz. USB 3.0, with its 5 Gbps data rate, has enabled USB peripherals to transfer data in excess of 140 MB/s. Cypress, a world leader in USB peripherals, created the FX3 series of USB 3.0 ICs to take advantage of this technology. The FX3 chip was a critical enabling component and, when combined with TEP's USB-based spectrum analyzer experience, the Signal Hound BB60A was created.

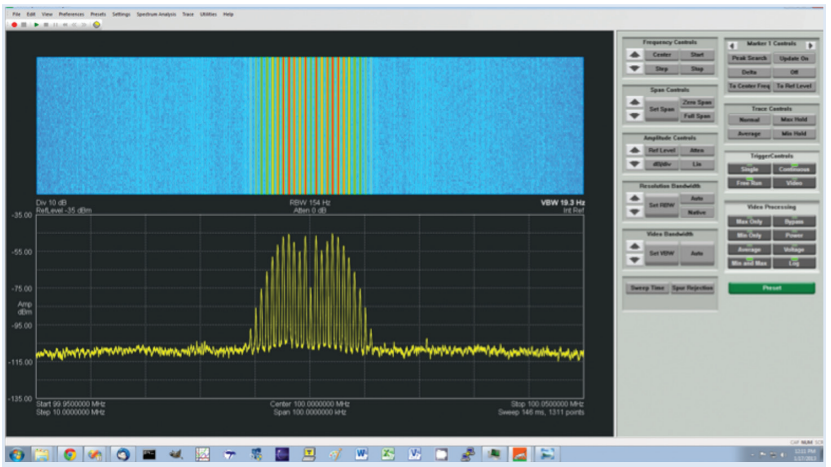

Figure 1: Normal sweep with 2D waterfall history view of a FM modulated signal

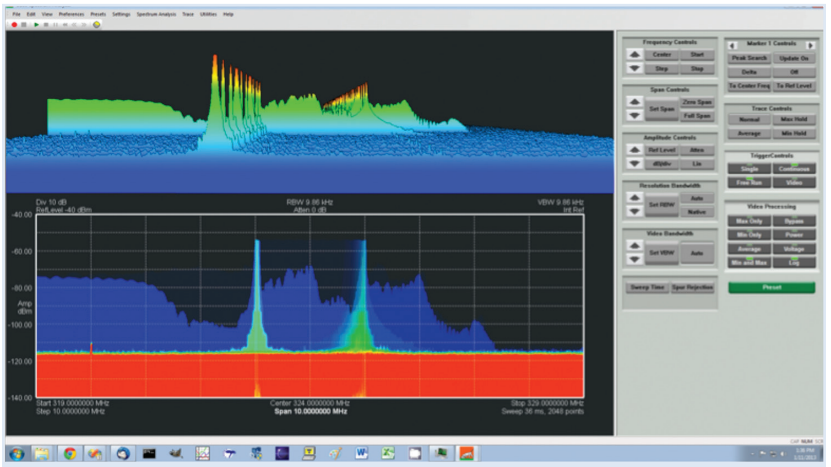

Figure 2: Persistence view and 3D waterfall history view of a tone that is changing frequencies

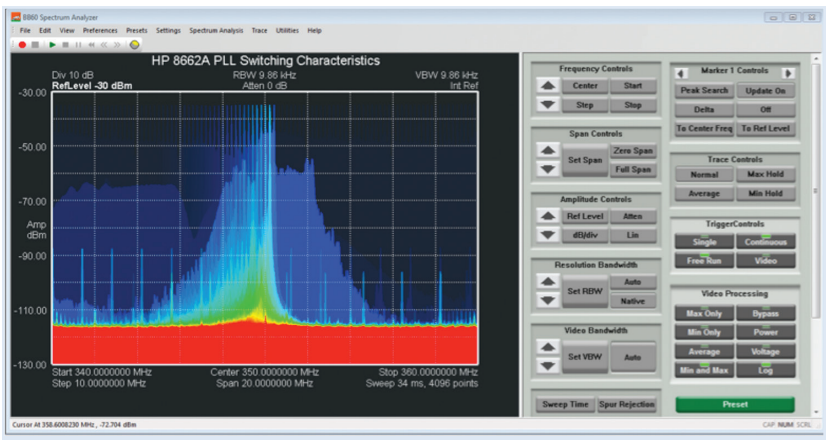

Figure 3: Real-time mode with persistence showing the settling of a PLL in an HP8662A Signal Generator

True Real-Time Spectrum Analysis

It is important to define the meaning of Real-Time Spectrum Analysis (RTSA) because some vendors use the 'real-time' verbiage without ever explaining what it is, which makes it unclear if their products actually offer the functionality of an RTSA. The key characteristics of an RTSA are:

- Gapless spectrum coverage through overlapping Fourier analysis
- Display modes that convey this information to the user (Persistence)
- 100% probability of intercept (POI) for events exceeding a minimum specified duration

The Signal Hound BB60A is an RTSA because it has the above features. The gapless spectrum coverage/100% POI is achieved for the entire 20 MHz of IBW (Instantaneous Bandwidth) either by streaming RF to disk using the API (Application Programming Interface) or by using 75% overlapping FFTs (Fast Fourier Transforms) with the resultant spectrums being communicated to the user through the BB60A's spectrum analysis persistence display. This high-level of computational analysis is performed, through the ability of a PC to process 80 million samples per second, producing a full 20 MHz real-time bandwidth. A block of time-domain, digitized IF is processed by the PC through an FFT. Another block of digitized IF is then processed that overlaps by 75% with the first block. This process is performed continuously so that any single event is processed by at least four FFTs which mean that no less than 320 million data points must be processed and transformed every second. Advances in Single Instruction Multiple Data (SIMD) instructions allow a PC, equipped with a third generation Intel Core-i7 quad-core processor, to perform up to 32 multiplies per clock cycle, while still having threads free for other tasks. This computational power combined with the BB60A hardware and software application/API result in 16K to 1 million FFTs per second which, when combined with a persistence plot, allows users to accurately visualize spectral events as short as × 1 µs with 100% POI over a 20 MHz real-time bandwidth.

Enabling Hardware and Technology

After several possible RF front-end architectures were considered, TEP settled on a double-conversion superheterodyne receiver architecture, rather than an I/Q demodula-

tor approach. This gives the user a full 20 MHz of spectrum without having to worry about spurious signals from I/Q balancing. Of course, for users who need I/Q data, digitally mixing inside the PC produces I/Q data which is free from the artifacts that an analog I/Q demodulator would introduce.

The RF input is first attenuated by a user-controlled attenuator, and then low pass / band pass filtered to attenuate image frequencies. The first conversion mixes the incoming RF to one of two intermediate frequencies, approximately 2440 MHz and 1268 MHz, which are then band-pass filtered using a surface acoustic wave (SAW) filter bank. A single mixer, used in two different modes, performs this conversion for all frequencies. To cover 9 kHz to 6 GHz with one mixer, a switch capable of reversing the RF and IF ports was utilized, enabling the BB60A to upconvert frequencies as low as 9 kHz, or downconvert frequencies as high as 6 GHz. The first IF is then down-converted during the second conversion, band pass filtered using a 140 MHz SAW, and finally amplified and digitized. An FPGA packetizes this data, and then sends it to the PC via the FX3 USB 3.0 peripheral controller. By simply handing off the data to the PC for processing, a small FPGA was sufficient, saving cost, power, and heat.

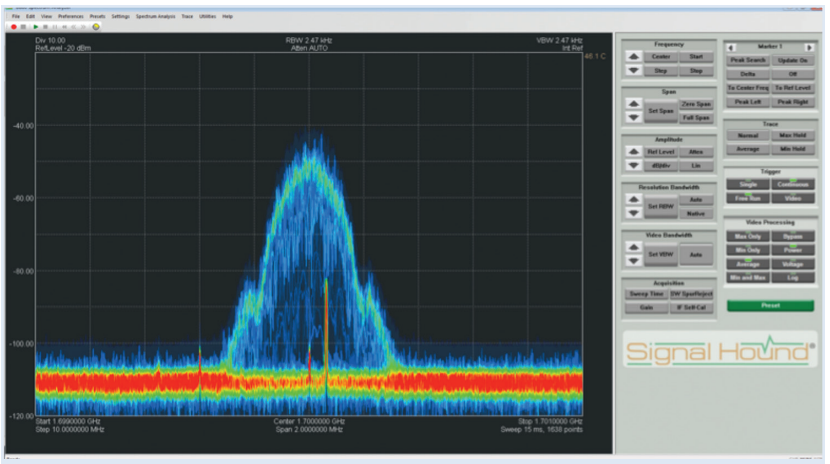

Figure 4: A CW tone hidden under a GSM signal demonstrating the ability of the BB60A to detect Signal-in-Signal

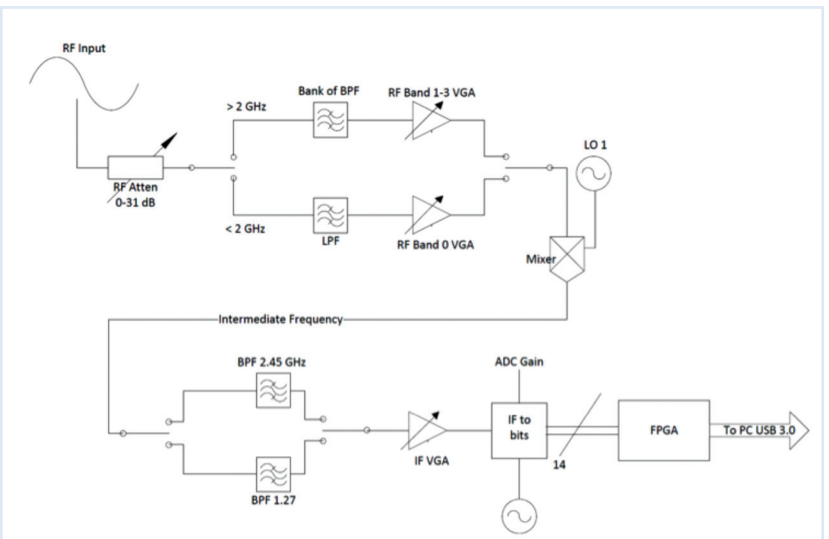

Figure 5: Schematic of the Signal Hound BB60A RF Front-End

Usability and Programmability

The Signal Hound BB60A ships with a Windows based spectrum analyzer software application. The software has all the features that would be expected in a traditional benchtop spectrum analyzer such as span / center frequency control, start / stop frequency, resolution bandwidth, video bandwidth, configurable traces, and markers. Some newer features that add greater value to the product include: two dimensional 'waterfall history' and three dimensional topographical spectrogram plots, allowing the user to see a short history of spectral events; recording sessions, allowing the user to capture a series of sweeps to be played back and analyzed at a later date; and a persistence display.

The BB60A ships with a fully documented API written in C/C++. This provides a tool for users to create their own custom software applications to harness all the spectrum analysis capabilities of the BB60A, from spectral sweeping and real-time analysis, to retrieving the digital IF samples or streaming raw I/Q data. Every functional aspect of the BB60A is exposed and can be controlled through the API.

Possible Applications of an RTSA

The Signal Hound BB60A lends itself well to some specific applications due to its RTSA capability. Some key examples include: intermittent interference hunting, spread spectrum signal analysis, and signal-in-signal detection.

Intermittent interference hunting is a challenging job for any experienced engineer, especially at installed sites and remote locations. The job's difficulty is often magnified by the environments that engineers must deal with and the bulky gear they are forced to travel with to perform their job. The BB60A's ability to detect, capture, and display interference signals with gapless spectrum coverage and 100% POI is invaluable in detecting and identifying hard-to-find and intermittent signals. The worst case scenario for an engineer can be getting to a site to debug an issue only to find they are using an analyzer that is not up to the task or simply very inefficient at measuring short duration interference signals (requiring large amounts of data accumulation and time). This task is greatly facilitated by the BB60A's 2D/3D spectrogram plots, available to all users, which are excellent in visualizing intermittent signals. The advantages of the BB60A's weight and size over traditional bulky benchtop spectrum analyzers are obvious. A single travel bag or road case can carry the BB60A, antenna, laptop PC, and any additional cables, probes, or adapters needed to complete the job.

Spread spectrum (SS) signals are signals which use a modulation type that spreads the frequency of transmission over a much wider bandwidth than is required by the data being transmitted. The value of this approach is to add security, robustness, and reliability to communications. Common SS types include Direct-Sequence spread spectrum (DSSS), Frequency Hopping spread spectrum (FHSS), and Chirp spread spectrum (CSS). The BB60A is capable of capturing and analyzing SS signals up to 20 MHz in total bandwidth. No other commercially available USB-powered spectrum analyzer has the required bandwidth to work with SS. No other products can do this analysis for the cost of the BB60A.

Signal-in-signal (SiS) analysis is a task that can only be done with an RTSA. SiS is when there is an 'unwanted' signal or interference source transmitting in the same band as another communications protocol or 'host signal', such as GSM, ISM, CDMA, etc. This is very difficult for a traditional spectrum analyzer to detect because the unwanted signal cannot be adequately resolved for positive identification. The result is that the performance of the host signal is degraded with no clear explanation or evidence why, leading to problems such as a high bit error rate. When the BB60A is operating in real-time mode, the persistence display can clearly resolve SiS scenarios due to the way that data is processed and displayed by the software application.

Future improvements on the BB60A and where to buy

TEP is currently developing the next generation RTSA which is built on the success of the Signal Hound BB60A RTSA. The forthcoming product will have orders of magnitude better performance in spurious-free dynamic range (SFDR) and will have a wider real-time bandwidth of 27 MHz. For inquires about all Signal Hound products, including the Signal Hound BB60A RTSA, TEP can be contacted at (800) 260-TEST in the USA, (360) 263-5006 for international calls, or by visiting their website at www.signalhound.com.