How is Current Noise Measured at Wavelength Electronics?

INTRODUCTION

In many sensitive measurement systems, electrical noise produced by a laser driver becomes a limiting performance factor. Current noise can interfere with sensor resolution, especially in Quantum Cascade Laser based chemical sensors. To develop an effective low noise driver, WEI established a noise testing protocol with the assistance of Pacific Northwest National Laboratory (PNNL). This Technical Note describes the protocol and some test results for the QCL1000, 1 A Low Noise Quantum Cascade Laser Driver.

The Wavelength Electronics test system includes an external Stanford Research SR560 low-noise pre-amplifier to bring the Device Under Test (DUT) noise characteristics to an amplitude well above the noise floor of the spectrum analyzer to effectively lower the system noise floor. A Stanford Research SR785 spectrum analyzer is also used for WEI noise tests. It should be noted that a pre-amplifier is not required for spectrum analyzers with internal pre-amplification.

TERMINOLOGY & TEST METHODOLOGY

Most laser drivers list an RMS current noise specification. This noise current consists of two elements. The first is the amplitude of the noise current and is usually denoted in micro-amps (µA). The second specification is the measurement bandwidth. Because of the fundamental way all electrical noise is measured, the bandwidth is key to understanding the performance of the laser driver. A low noise current amplitude may not be representative of the true performance of a driver if the measurement bandwidth is artificially low. However, if the target application has a restricted bandwidth, then noise current measured out to extremely high bandwidths may not be necessary or useful. It is important to know the bandwidth of interest when examining noise performance specifications.

Beyond bandwidth, there are many conditions that affect the noise current specification of a laser driver. These conditions include the following:

- Load impedance
- Load current
- Cable configuration, shielding and length
- Grounding
- Environmental noise

All of these factors must be compared to actual operating conditions in order to judge the applicability of the current noise specification under those conditions.

SPECTRAL CURRENT NOISE DENSITY TESTS

Due to the complexities of measuring noise and the ability to misrepresent actual noise performance over select frequency bands, WEI chose to measure both spectral noise density and root-mean-square (RMS) noise. Both are mathematically related, but give different snapshots of actual performance. Spectral noise density measurements give a detailed look at driver performance at specific frequencies across a measurement bandwidth. With the spectral noise density data, accumulated RMS noise can be determined over any arbitrary bandwidth within this initial measurement bandwidth.

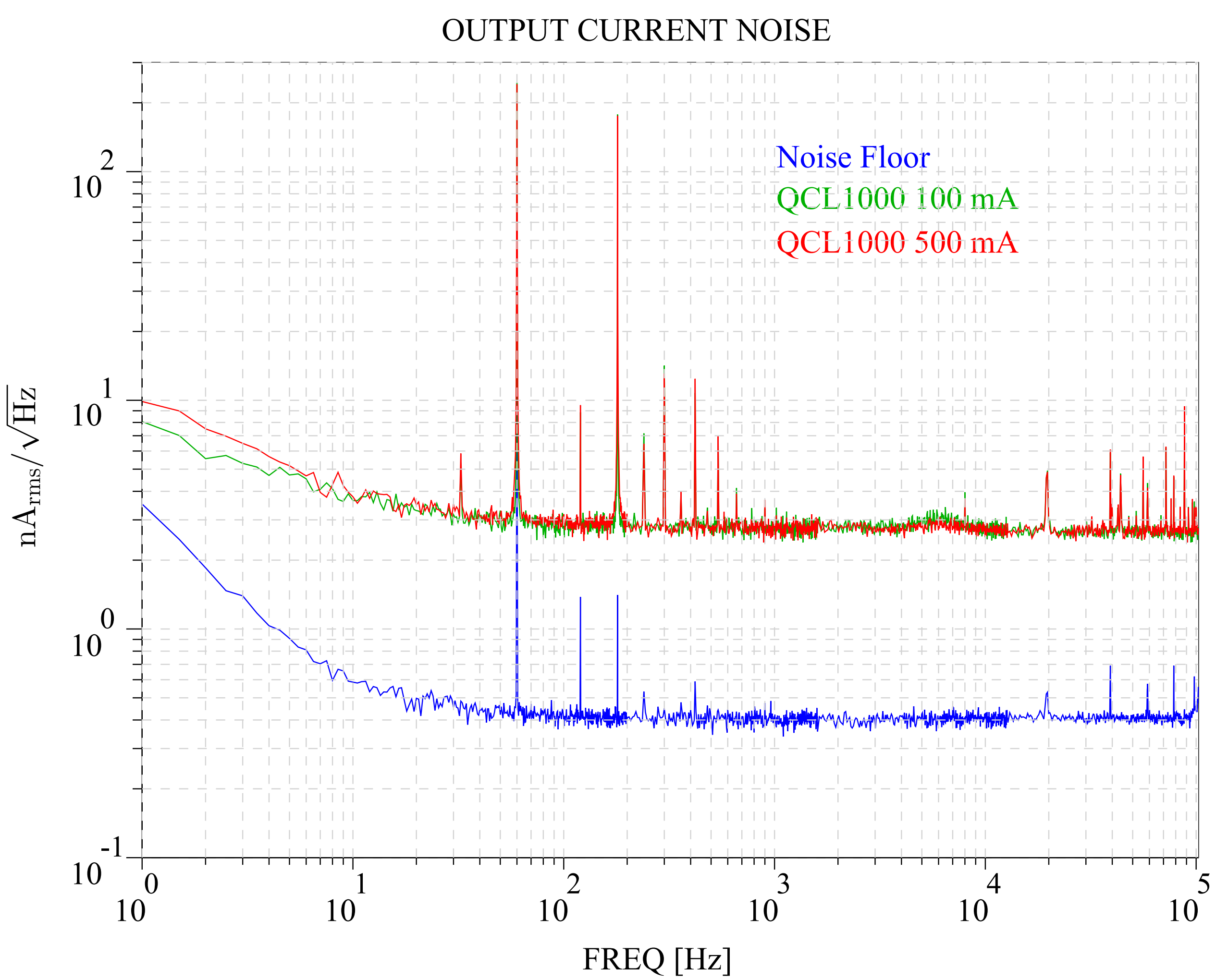
For measurement frequencies below 100 kHz, a Fast Fourier Transform (FFT) analyzer records the noise density performance. For frequencies above 100 kHz, an RF spectrum analyzer is used to measure spectral noise density. Mathematical software is then used to process the two types of data.

INTERPRETING THE DATA

A typical low-noise WEI laser driver will have spectral noise densities that follow the general shape found in Figure 1. All drivers will have some 1/f noise present at low frequencies. This is an unavoidable consequence of using semiconductors. The intensity of the 1/f noise can be reduced by using high quality components in suitable circuit topologies. The spike at 60 Hz is interference from the AC used to power the system. The amplitude of the 60 Hz, 120 Hz (2nd harmonic) and 180 Hz (3rd harmonic) spikes can be controlled with circuit design, chassis grounding and isolation from the upstream AC.

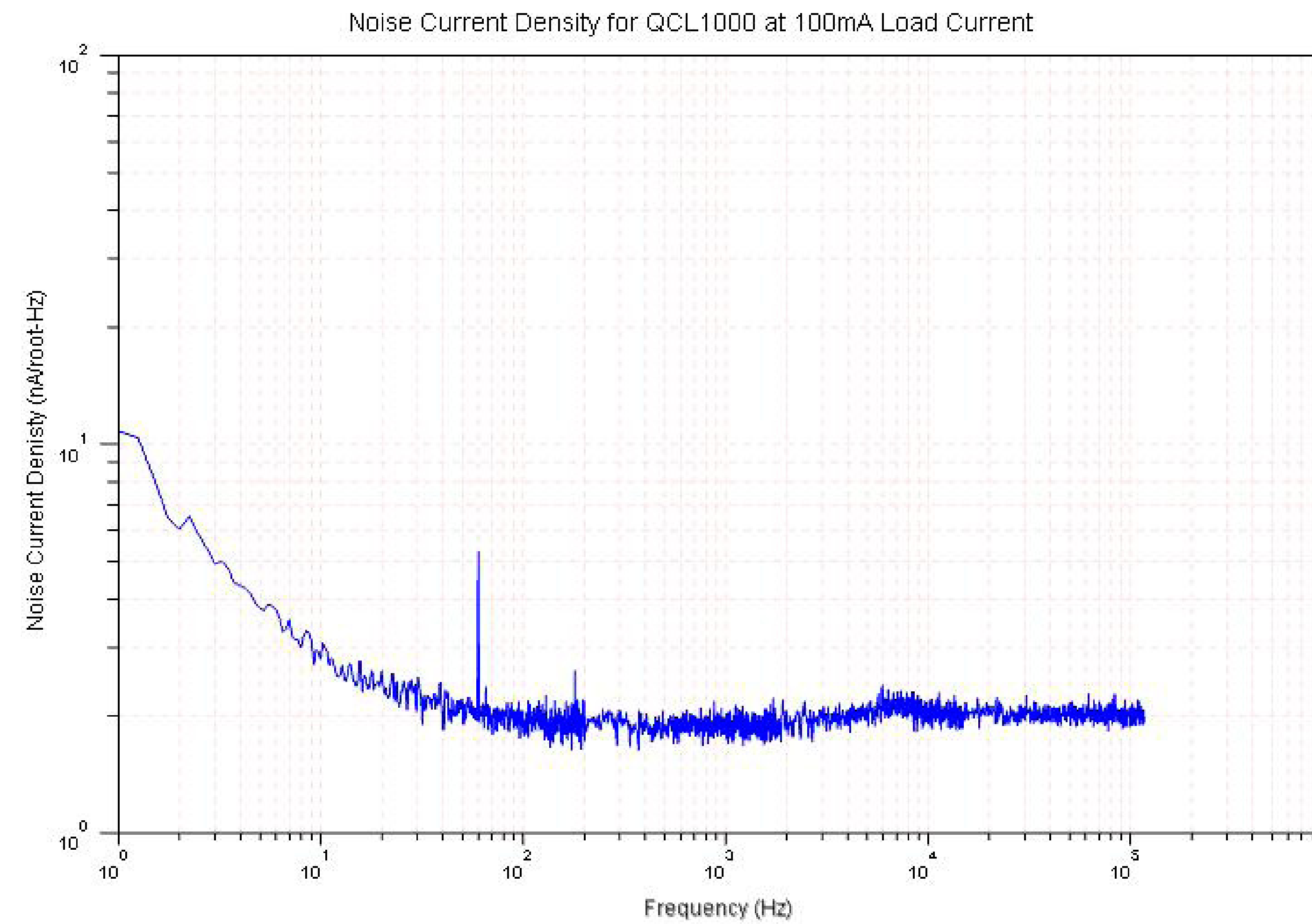
Beyond the AC noise, the noise density amplitude maintains a flat profile out to the limit of the measurement system. This is the baseline spectral noise density and is determined by internal components and the load impedance. Higher current models will have higher spectral noise density levels. Any spikes that occur at the higher frequencies are results of electromagnetic interference (EMI) and are dependent on both the internal circuitry and the shielding/grounding configurations. In certain environmental situations, EMI can only be attenuated but not removed. For example, if operation requires close geographical proximity to an AM radio station, then the powerful radio waves will be very difficult to eliminate.

Figure 1a. Example Spectral Noise Density with long cables, AC interference, various current levels



Data courtesy Dr. Matthew Taubman, PNNL

Figure 1b. Example Spectral Noise Density with short cables and minimal AC interference



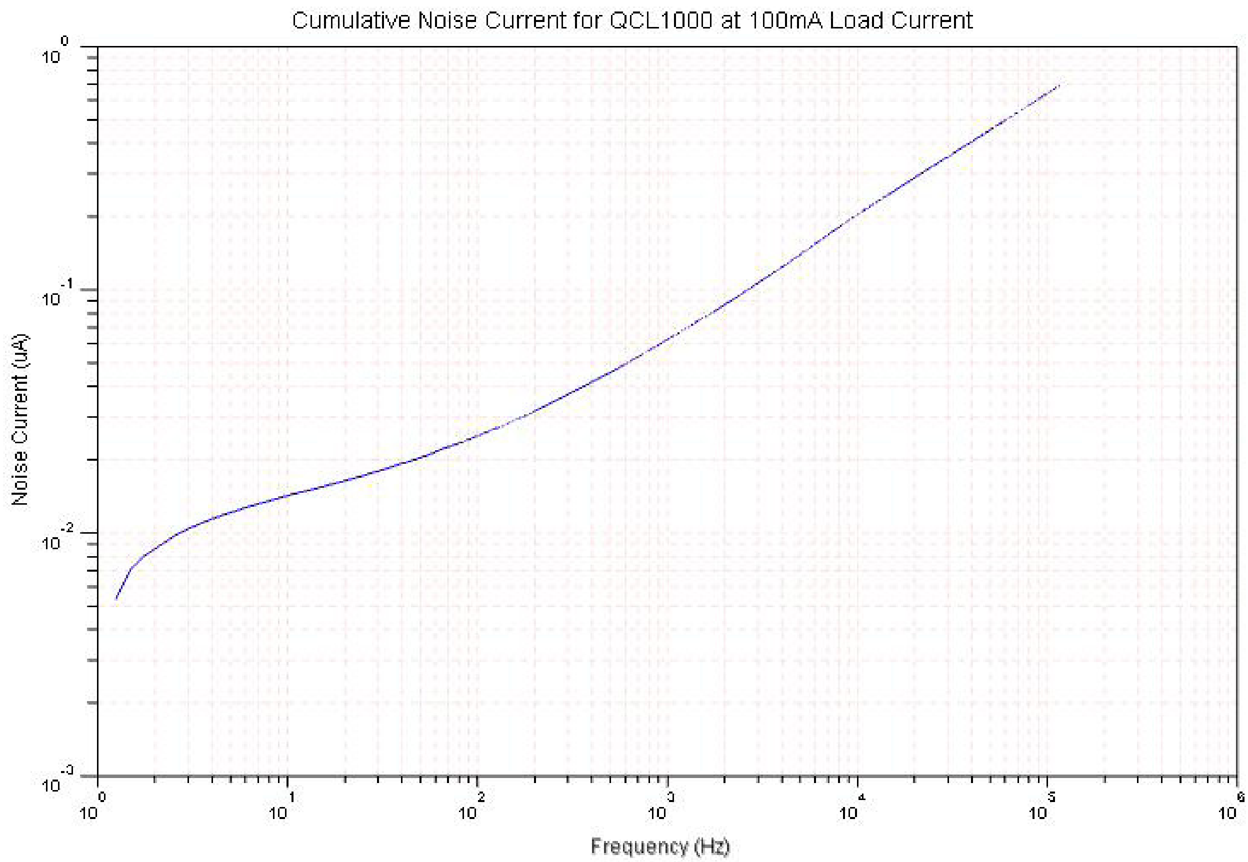
The second half of the noise current specification is the RMS noise current graph. This graph is an integration of the spectral noise density graph and provides a method to easily determine the accumulated noise current at any arbitrary bandwidth. An example is shown in Figure 2. Simply find the noise current data point that corresponds to the bandwidth of interest and this is the total noise current.

If, for example, the required noise bandwidth is 1 Hz to 50 kHz, then simply pick off the data point at 50 kHz on the graph. In this case, the RMS noise current is 0.45 μA. This corresponds to a 50 kHz bandwidth. Obviously, the RMS noise current climbs as the bandwidth increases because more and more bins of noise density are integrated into the RMS measurement. The graph is provided to allow easy determination of driver noise current in different applications.

CONCLUSION

An RMS noise current specification consolidates data across frequency. In order to truly understand electrical noise as it is evidenced in a Quantum Cascade Laser sensor system, WEI (with assistance from PNNL) introduces a more detailed standard of measurement.

Figure 2. RMS Noise - Integration of data from Figure 1b



REVISION HISTORY

REV	DATE	NOTES
A	29-Nov-10	Release
B	5-May-15	Updated test equipment names

KEYWORDS

Quantum Cascade Laser Driver, Low Noise, current source, spectral noise density