# An Research System for Chronic Exploration of Novel Stimulation Patterns

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This work presents a prototype neurostimulation system that seeks to meet a key need for translational neuroengineering: the investigation of how the nervous system responds to different methods and patterns of actuation. Many common patterns of neurostimulation were derived empirically, and there remains a need to better understand the transfer functions of the nervous system. By allowing a more flexible and complete investigation of potential stimulator patterns, we hope this research system may yield insight into more effective patterns of neurostimulation in the future. Please note that the system presented is an investigational prototype restricted to research, and is not approved for commercial use in the United States.

The components of this system include a User Interface executing on a Windows PC and a customized telemetry head for interfacing to an implantable research stimulator. The implantable research stimulator consists of a commercially available implantable device running temporary research firmware. For assurance of research compliance, there is an access code generator to restrict the use of the system to approved investigational studies. The system can be used with a range of implantable research devices (IRDs) which allows for exploration of several neural circuits in the brain, spinal cord, etc. The key functional feature of this research system is to expand their technological capabilities for stimulation patterns beyond what is commercially available.

These capabilities include:

- Expanded parameter ranges and resolutions for amplitude, frequency [Figure 1], and pulse width
- Biphasic and burst stimulation patterns
- Stochastic stimulation patterns (both random and constrained within set frequency boundaries)
- Sunset timer to self-remove capabilities upon completion of investigation

The architecture of the system segments the pattern generation in firmware from the stimulation actuation in hardware. The pattern generator can be driven by flexible neural codes that are achieved via a firmware upgrade through a wireless telemetry download. The download of these patterns and capabilities into the IRD can be used to drive complex sequences such as that illustrated in [Figure 2]. Patterns that can be generated include stochastic patterns, bounded spread spectrum, bursts, and look up tables. Once research is completed, the investigational firmware can be reverted back to market released firmware without undergoing another download.

This prototype technology work, developed exclusively for neural circuit investigation, allows researchers to investigate novel stimulation pulse patterns in a chronic protocol that greatly expands the potential use conditions. Collaboration was a key component to creating the prototype research system requirements. Understanding the intended use of stimulation in the researcher's work helps to tailor a system that best pairs existing IRD hardware to form the complete research system. Future work may include developing additional firmware downloads or development tool kits to allow even greater access to technological capabilities; these enhancements are based on the developing understanding of neural circuit transfer functions.

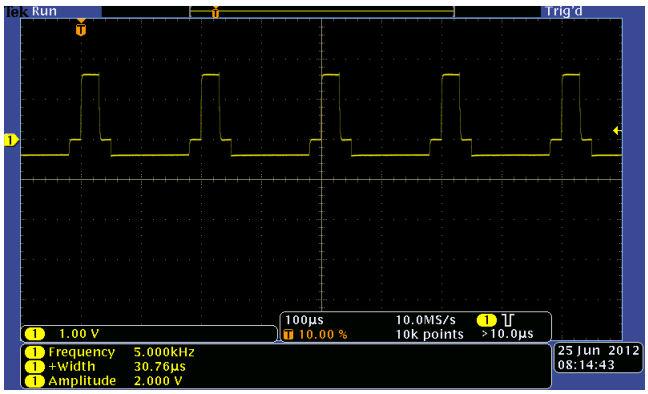


**Figure 1 - Conventional Stimulation at higher frequency**

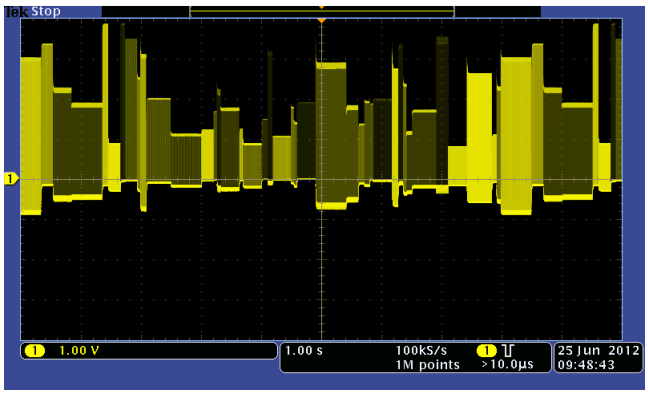


**Figure 2 - Stochastic Stimulation**

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