BLACKSTONE~NEY ULTRASONICS

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Introduces

Advances in Megasonic Generator Technology

Liquid-borne acoustic energy in the frequency range between 350kHz and up to about 5MHz is finding growing usefulness in a number of cleaning applications which require processing of extremely delicate parts and assemblies to remove particles ranging from a few microns down to a fraction of a micron in size. This "megasonic" energy varies from the traditional "ultrasonic" energy in that the frequency of operation is more than an order of magnitude higher than that of a conventional ultrasonic system. Just as in an ultrasonic system, a megasonic system requires a source of electrical energy at the operating frequency of the driver or "transducer" to power the sound producing device. This source is the "generator." New developments in generator technology by Blackstone-NEY Ultrasonics promise to improve the efficiency and reliability of megasonic generators while reducing their size. The new generator technology will also make it possible to operate transducers efficiently at more than one frequency thereby extending their process effectiveness.

Transmission of High Frequency Electrical Power

In ultrasonic systems operating at frequencies up to about 350kHz, delivery of the electrical energy from the source or "generator" to the ultrasonic transducer is easily accomplished using shielded cables. As frequency increases and the wavelength of the driving electrical signal becomes shorter and shorter, however, efficient delivery of electrical power to the megasonic transducer becomes increasingly problematic. Impedance matching of the source, the load and power reflection in the transmission line from the transducer to the generator become issues of significant concern.

Direct current, known as DC, has a frequency of "zero" and has no wavelength as the voltage, by definition, does not vary other than as a result of the resistance of the wire over its length. Alternating current, known as AC, however, varies in voltage over time and, if not frequency modulated, varies at a specific rate or frequency. A consistent AC signal of any waveform exhibits a wavelength which is defined as the speed of travel of electricity through the conductor divided by the frequency of the signal. At low frequency, the wavelength is very long. As a result, the variation in voltage over even a relatively long transmission wire is very slight as the signal passes down the conductor. As frequency is increased and the wave length becomes shorter, however, a condition occurs where the voltage along the length of the wire is not constant and a "standing wave" will develop. When this condition is reached, reflections occur in the transmission line which result in power being reflected from the transducer back to the generator. Furthermore, the impedance of the transducer may no longer be matched to the generator or the transmission line resulting in additional losses.

The condition described above can be avoided by keeping transmission lines very short or by careful "matching" of the complex impedance of the signal source and the load to that of the transmission line at the operating frequency. This solution is effective as long as the impedance of the load or transducer remains constant. Any variation in the impedance of the transducer will upset what is often a delicate balance. Unfortunately, even if one manages to stabilize and match the transmission cable, variations in the impedance characteristics of the transducer are inevitable in almost every application as the transducer temperature, liquid depth and cleaning load vary in normal use.

Megasonic Generator Morphology

Early megasonic technology generators were no more than linear amplifiers driven by a signal generator. Because of the increased frequency, however, certain modifications and compromises were made to accommodate operating conditions present at the higher frequencies. In many cases, devices and components that operated satisfactorily at ultrasonic frequencies had to be de-rated to allow for impedance mis-match and power reflection issues at megasonic frequencies. One inevitable outcome has been a physical growth of the megasonic technology generator package to the point that many installations require a large number of electrically inefficient generators to power even modestly-sized process tanks.

New Megasonic Generator Technology

An alternative solution is to design the megasonic generator in such a way that it can quickly and effectively adjust its output to optimize complex impedance matching under variable impedance conditions. Blackstone-NEY Ultrasonics has addressed these issues in their new-generation megasonic generator which has the following features –

- Automatic complex impedance compensation in less than 3 microseconds for up to a 300% transducer mis-match. Power reflected from the load is not dissipated in the generator but is, instead, reflected back to the load.
- Automatic complex impedance compensation in less than 3 microseconds for cable lengths from .1 to 50 meters.
- Automatic complex impedance compensation for tank operating temperatures from 20 to 90°C.
- Automatic frequency compensation of up to ±10kHz (normal transducer frequency variations are approximately 7kHz) using a Phase Lock Loop with a bandwidth greater than 20kHz at an operating frequency centered on 430kHz. Capture bandwidth increases progressively as frequency is increased up to 3MHz.
- True output amplitude power control from 0 to 100% of the full generator capability into any transducer load using a 0 to 5 volt DC input control signal.

The megasonic generator newly offered by Blackstone-NEY Ultrasonics is rated at a total capacity of 1,800 Watts output and is built into a package conveniently designed for mounting in a 19” 2U rack. The generator is comprised of two internal modules each producing up to 900 watts of continuous wave output. Each module provides independent impedance and frequency compensation to optimize performance of its segment of the overall attached transducer array. An input control voltage from 0 to 5 volts DC sets the output of both internal modules. True power output is computed within the generator using the formula

$$\text{Output Power in Watts} = 1/\text{T} \int_0^T v(t) * i(t) dt$$

with a monitoring output of 1 volt DC per every 200 watts of power delivered to the transducer.

Because of its highly efficient use of power through automatic impedance matching and compensation for other variables, the generator package is able to operate at an efficiency in excess of 80% from a 200 to 240 volt AC, 50 or 60 Hz mains power supply. It boasts the highest output power per unit volume of any megasonic generator available. In addition, this new generator includes integral FCC filtration effective from 9kHz to 30MHz which may or may not be available as a standard feature on competitive units.

Programmed and Multiple Frequency Megasonic Operation

Starting in the mid 1980's, it was demonstrated that a number of ultrasonic process variables not previously explored could be controlled in an ultrasonic system to significantly enhance its cleaning performance. In 1991, NEY Ultrasonics, a division of the J. M. Ney Company, now incorporated with Blackstone Ultrasonics as Blackstone-NEY Ultrasonics, first introduced ultrasonic equipment with programmable modes of operation with up to 20 process "schemes" stored in an external controller memory. Variables included the following:

- Center (operating) Frequency (the ultrasonic frequency)
- Frequency Sweep Bandwidth (excursion of frequency sweep from the center frequency)
- Sweep Time Up (time for frequency to sweep from lowest to highest)
- Sweep Time Down (time for frequency to sweep from highest to lowest)
- "Train" Time (time duration of the amplitude modulation scheme or "train")
- Degas Time (time off for bubble release between "trains")
- Burst Time (ultrasonic on time as a portion of the train time)
- Quiet Time (ultrasonic off time as a portion of the train time)

This equipment was first manufactured and sold in 1991 under the name compuSONIK. The compuSONIK system was an upgade to the NEY proSONIK™ line which had an internal, resistive (potentiometer) settable memory for parameters including sweep bandwidth and sweep rate, and which has been sold under the NEY Ultrasonics and Blackstone-NEY Ultrasonics names starting in 1988.

Later development work identified the benefit of using more than one ultrasonic frequency in succession in an ultrasonic cleaning process to enhance the removal of various sized particles from a surface. This need was initially addressed by using a series of process tanks each operating at a different frequency. Over a decade later, today's mature multiSONIK™ technology offered by Blackstone-NEY Ultrasonics provides the same capability in a single process tank using a single ultrasonic generator. Multiple-frequency capable transducers are powered by an ultrasonic generator under the control of an internal memory or external PLC which invokes process variables including ultrasonic frequency (or discreet frequencies in a predetermined sequence of frequency and process time), ultrasonic power, bandwidth of frequency sweep and rate of frequency sweep as well as amplitude modulation, with programmable magnitude and waveform pattern. The ability to operate at more than one process point has proven valuable in conventional ultrasonic systems and shows promise at megasonic frequencies as well. To this end, Blackstone-NEY Ultrasonics' new megasonic generator/transducer system also provides frequency and power selection as desirable attributes in a megasonic generator. Frequencies currently available are 430kHz and 1.3MHz with further enhancements planned.

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