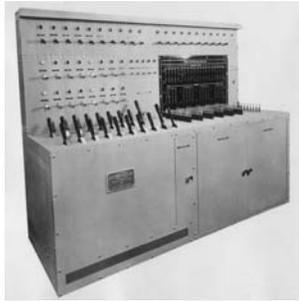




Strand Lighting will introduce their new Solid State Transformer (SST) series Sinewave dimmer modules at the LDI this year.

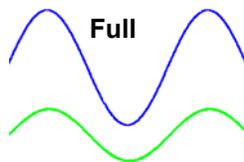
When electric lighting was first used in theatre over a century ago, controlling the intensity of lamps was a challenge. In the early days, various sorts of devices were used, from barrels filled with salt water to large variable DC resistors placed in series with the lamps. These techniques dimmed the lamps by reducing the amount of voltage delivered to them. This worked, but at the cost of waste heat and a large, bulky control.



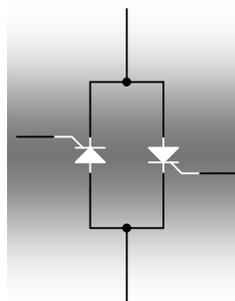
When alternating current became standard, autotransformers replaced the resistance plate dimmers. An autotransformer is a special type of transformer with a sliding tap that allows the output voltage to be adjusted from zero to full. The autotransformer was still large and bulky. It did not, however, produce nearly as much heat as the series resistance dimmer.

While these types of dimmers had the drawbacks of large size and excessive waste heat, they did have one big advantage: no lamp noise. The autotransformer produces an output that is a Sinewave with variable amplitude.

A dimmer set to half, for example, produced a Sinewave with half the amplitude of the input voltage.



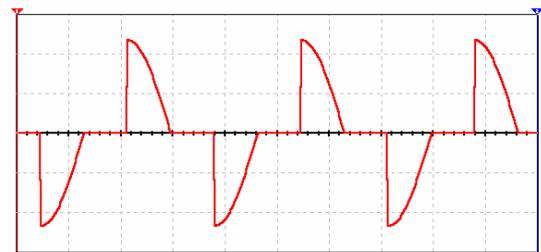
By the 1960's the marketplace wanted smaller, cooler dimmers that could be remote controlled by low voltage signals. The emerging semiconductor industry had produced the thyristor, the solid-state equivalent to a latching relay. A type of thyristor which conducts current in one direction only, called a silicon-controlled rectifier, or SCR, was used to build a new type of dimmer. A pair of SCRs, connected "back to back" to control current flow in both directions, produced a different type of output.



The SCR dimmer works by controlling when the SCR is turned on in the power line half-cycle. If it is turned on half way into the half cycle, it will remain on until the current falls to zero when the polarity of the power line reverses in

the next half cycle. The process repeats in this half cycle, producing a "chopped" waveform. If the timing of the turn-on is varied from zero to 100% of the half-cycle, the output power to the load varies from zero to full. This type of dimmer is called a "Forward phase controlled" dimmer. The phase control dimmer has been the dominant dimming technology since the 1960's. Strand Lighting has shipped over 2 million phase control dimmers in the successful LD90, EC90, CD80 and SLD families and their predecessors.

Phase controlled dimmers are compact, produce little wasted heat, and are inexpensive. They are remotely controlled from DMX or Ethernet and offer many advanced features. Unfortunately, the phase control waveform that makes them so efficient is their



A typical forward phase control waveform with a dimmer set to half exhibits severely chopped output.

Achilles heel. The chopped waveform produces audible noise in lamps due to the sharp turn-on. Large chokes are used to smooth out the sharp changes. These chokes add bulk, weight and heat to the system. They can reduce, but not eliminate the lamp noise.

The phase control waveform also has another undesirable effect. The chopped waveform produces discontinuous current flow in the power distribution system. In a standard 3-phase power system, these harmonics can result in currents in the neutral conductor up to 1.4 times the rated current. Harmonics can cause audible noise and overheating in the distributing wiring and feeder transformers, and possible penalties from the utility company. In the EU, pending legislation may require dimming systems to produce lower levels of harmonics than are possible for phase control systems.

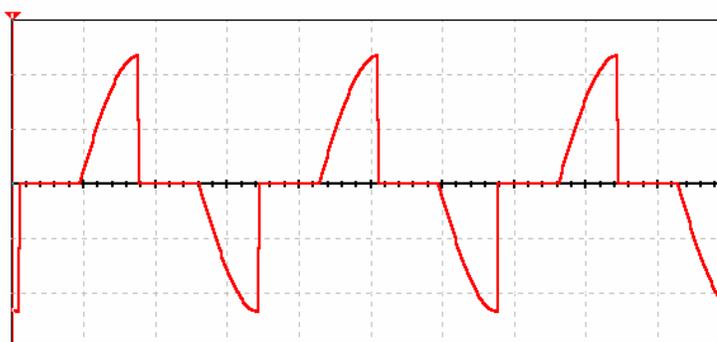
The drawbacks of phase control dimmers are becoming more important in the marketplace. More and more loads are not simple incandescent lamps. They include compact fluorescents, electronic dimming ballasts, LED's, electronic and magnetic low-voltage

and a host of other non-traditional sources. All of these have one thing in common: the phase control waveform is far from ideal for dimming them. In many cases the load will perform poorly; in extreme cases the load (and possibly the dimmer) will be damaged.

In the last decade, more advanced types of phase control dimmers have been produced using a type of power semiconductor called an IGBT.

The IGBT (Insulated Gate Bipolar Transistor) has been widely used in motor controllers due to its ruggedness and ease of control. IGBTs are also used in switch-mode power supplies, UPS systems, inverters, power-factor controllers--any place where a power device that combines the ruggedness of a bipolar transistor with the ease of control of a MOSFET is required.

Some of these new dimmers operate in reverse phase control where the dimmer is turned on at the line zero-crossing point, then turned off at the desired output voltage. The bulky choke is eliminated in favor of a controlled turn-off by the IGBT. These systems still suffer from many of the same



A typical Reverse Phase control waveform exhibits "chopping" similar to forward phase control dimmers

problems as any phase control dimmer. Reverse phase control dimming applies the voltage to the load at zero volts, and turns it off once the desired target voltage has been reached. This mode of operation is fine for a tungsten (resistive) or electronic low-voltage transformer (capacitive), but is unusable with inductive loads. Neon, ballasted loads, fans and small motors will generate destructive inductive kickback energy when dimmed by a reverse-phase control dimmer. RPC dimmers must not be used with these loads, or must switch to forward-phase control to dim these loads. In all cases, FPC or RPC, the dimmers are producing triplen harmonics.

While a typical 800uS reverse phase IGBT dimmer is more efficient than 790uS high-rise SCR dimmer (no choke loss), its efficiency is very similar to Sinewave. A large amount of heat is produced in these dimmers during the transitions (rise or fall time) since the IGBTs are operated in their linear region. When the dimmer is full on, the losses

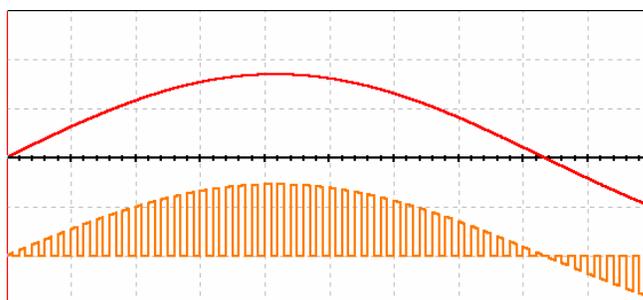
are what are called conducted losses across the fully-on IGBT. Sinewave only has conducted losses, since the IGBTs are not operated in their linear region. Sinewave has some losses through the input and output filters, but it is much less than the linear region losses in an IGBT dimmer.

How Does the Strand SST series Sinewave Dimmer Operate?

The Strand SST Dimmer utilizes a micro controller to produce high frequency pulse width modulated control waveforms to the dimmer's IGBT power switches. The dimmer's high switching frequency reduces the size of the passive filter components and insures that any acoustic noise produced within the dimmer is well above the audible range. The 47Khz carrier frequency is divided into 255 steps, providing a voltage resolution on the output of less than 0.5%, resulting in a flawless Sinewave output.

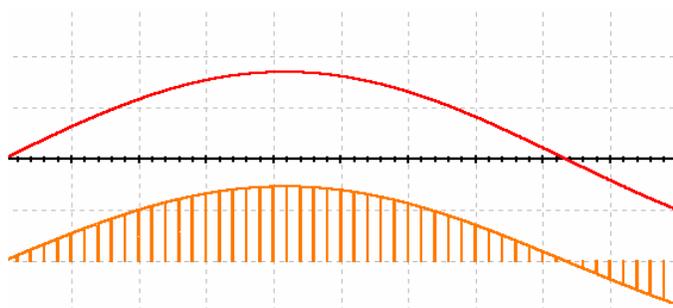
This superior reconstruction of the output waveform results in SST producing less than 1% total harmonic distortion back to the mains. A novel power stage design provides excellent performance with non-linear loads. There is no minimum load specification, and SST will produce a solid sinusoidal waveform output with no connected load.

The dimmer module reads the firing pulse produced by the SLD control processor and sets the PWM to produce the requested output voltage. Imagine a lamp connected to the AC mains through a switch. Now turn this switch on and off tens of thousands of times per second. The power line waveform will be "sliced" vertically into sections as shown in the diagram below.

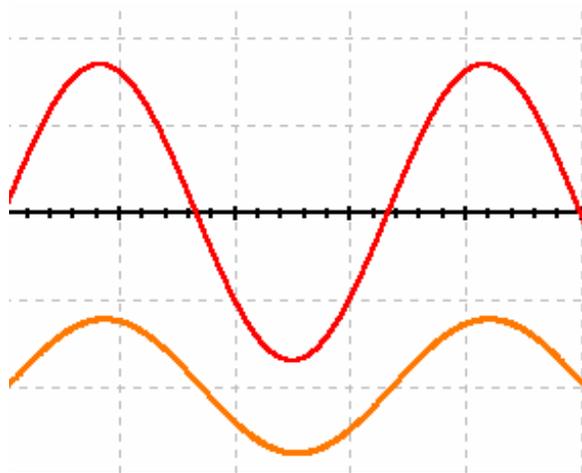


If the duty cycle of the switch is varied, the amount of

energy delivered to the load will vary. The waveform illustrated below shows a 95% duty cycle, which is almost full power.



The PWM waveforms cannot be directly used to control the load. They must be filtered to produce a Sinewave.



The above diagram shows the incoming line voltage in red, and the filtered 50% PWM output in orange. The result is a Sinewave with an amplitude that is 50% of the incoming line. Vary the PWM duty cycle, and you vary the output voltage.

The concept is simple. Building a practical Sinewave dimmer is not. The ideal switch is replaced by IGBT switching transistors, and the passive filter sections add size and weight. The size of the filters required, however, decreases as the switching frequency is increased.

Besides the variable amplitude Sinewave output, what other advantages does this technology provide? Recall that the phase-control dimmer produces power line harmonics by its very nature. The PWM Sinewave dimmer produces almost no harmonic distortion, typically less than 1%. With

an incandescent load, current is drawn during the entire power line cycle. For a non-linear load, such as a ballast or electronic low-voltage fixture, the load characteristics are passed through to the power line. The Sinewave dimmer is "transparent" to the load, neither adding nor subtracting from the load's current and voltage characteristics.

This is important. An ideal dimmer will deliver voltage and current to the load in the same way as a direct connection to the power line. No phase-control dimmer can do this. Many loads that were not controllable by phase-control dimmers may now be used. Magnetic low-voltage fixtures, electronic low-voltage fixtures, neon, cold-cathode, LEDs, fans or other small motors will now operate without problems.

Not all loads are designed to operate at voltage lower than their rating. Many types of lamp ballasts, neon lamps, fans, and motors will not run at reduced voltages. A simple rule of thumb for determining if a load may be controlled is to see if it will operate correctly on an autotransformer.

Input Power

In any installation the nature of the power line can have an effect on system noise. Engineers characterize power service as being either "hard" or "soft". A "hard" service is one that is able to deliver large amounts of load current with very little voltage drop. Buildings with a "soft" service, experience the reverse often encountering a substantial voltage drop as the load on the system increases. We often see this as a drop in light levels. Both types of power can create noise within a system. A hard service can cause increased noise when a conventional SCR switches on due to its ability to supply the high current pulses that cause lamp noise. Similarly a soft service can have increased noise due to the line's inability to effectively deal with power line harmonics generated by a dimming system.

The new SST dimmer from Strand generates a Sinewave output that has no triplen harmonics and no sharp switching components as are generated by both forward phase (SSR/Thyristor dimmers) or reverse phase (IGBT dimmers) and as a result will provide quiet loads regardless of the nature of the power present.

SLD Control Electronics

The SLD processor provides the excellent voltage regulation characteristics of the standard SLD thyris-

tor module to the SST. The micro controller monitors output current and module temperature to insure that the power stage is within its limits, and will shut the module down if exceeded. This information is passed back to the SLD processor, just as in the standard thyristor modules.



All of the powerful features of the SLD system are available with Sinewave modules including line compensation, full dimmer status reporting and superior waveform analysis and control. Whether you are dimming a single LED, a low voltage incandescent load or even a motor the Strand SST dimmer will provide smooth stable operation.

The market for silent dimming has always existed, however achieving this goal has been difficult. The new SLD SST Sinewave dimmer is a modern Solid State Transformer and may be used in any application where an early autotransformer dimmer might be used. Any load that can be dimmed by a transformer can be dimmed by the SLD SST module.

The dimmer is not load sensitive and the output will remain stable at all times making the dimmer ideal for dimming any electronic ballast track light, most LED loads and a wide range of neon and cold cathode loads.

Any application where silence is important and system designers want to eliminate all lamp sing should consider using a Sinewave dimmer as there will be no audible lamp filament noise from any luminaire connected to these dimmers. Since the Sinewave module can be mixed with regular dimmers system designers can choose SST Sinewave modules for House lights and Concert lighting and use conventional dimmers backstage and in all less noise sensitive spaces.

Fast Facts:

- NO lamp noise - not just quiet lamps, but SILENT lamps
- Total harmonic distortion of less than 1%.
- No triplen harmonics - no need for K rated transformers or oversized neutrals.
- Ability to dim any load that can be dimmed by an autotransformer, with no need to switch operating modes, e.g. neon, magnetic ballasts, electronic low-voltage transformers, fans, small motors, and so on
- Efficiency comparable to high-risetime SCR or forward/reverse phase control IGBT dimmer
- Unity Power Factor



Power Line Harmonics

Power line harmonics can generate a host of problems for users of large scale dimming systems. They manifest themselves in the form of neutral overheating, voltage drops and transformers that overheat and generate noise.

Phase control dimming systems are seen as non linear loads by the transformers used to supply power to the system. Both forward and reverse phase dimmers operate by switching on (or off) for only part of each line cycle as a result the load current is not continuous. This can result in significant amounts of harmonic distortion within a dimming system.

Harmonics occur at multiples of the fundamental frequency for power line voltages. In North America this frequency is 60Hz. The second harmonic would be 120Hz, the third 180 Hz, and it is these harmonics that can cause heating in the cores of a transformer. Odd number harmonics (the 3rd harmonic specifically) are additive in the neutral of all 3 phase systems and do not cancel at certain phase angles even if loads are carefully balanced. We often see this manifested in dimmers set at 30% where the neutral current can exceed the load on the phase conductors.

In an ideal power system with no harmonic currents, the single phase line-to-neutral load currents would flow in each phase conductor and return in the common neutral conductor. A true Sinewave dimming system has none of the switching problems caused by forward or reverse phase dimmer operation as the output is a symmetrical sine wave at all times.

