This pamphlet contains basic information on lighting theory and the equipment necessary to fulfill this theory for the design of theatrical style lighting in multipurpose facilities including: theaters, churches, and other performance spaces. This updated brochure includes the article “Lighting Noise in Your Sanctuary”. 
DESIGN CONSIDERATIONS

Lighting a space indoors for the presentation of plays, musical reviews, church services or even a speaker at a podium requires some knowledge of the basic theories for stage lighting. The selection of lighting equipment can only occur after the following theories are applied to the specific performance space.

GENERAL LIGHTING THEORY

Indoor theatrical lighting is designed in a manner to emulate the natural highlights and shadows created by the sun and, similarly, the sun’s reflection off of the moon. Without these highlights and shadows the human mind will sense an incongruity in the lighting of an object and attempt to correct the view by refocusing the eye. Eventually, both will tire and lose interest. Once this occurs, the eye will seek other stimulation, resulting in not only the loss of visual contact, but also the audio contact. Proper highlights and shadows, at sufficient light levels, will maintain longer eye and audio contact which keeps the audiences’ attention focused on the event.

THE BASIS FOR THEATRICAL LIGHTING THEORY

The sun strikes the northern hemisphere at a relative 45 degree angle producing specific highlights and shadows that the human eye is conditioned to consider normal. We expect to see this angle of light which must then be reproduced indoors when a normal lighting look is desired.

The extreme intensity of the sun creates a strong highlight on one side of a three-dimensional object. When lighting indoors, a primary set of lights are used to emulate this function of the sun and are often called Key Lights. The sun is so intense it generates a great deal of reflected (or fill) light off of the surfaces surrounding the three-dimensional object. This reflected light fills in the shadows created by the key light at a reduced intensity. The lights used to emulate this reflection are often called Fill Lights.

The perceived color of light from the sun is white and is considered warm and dominant. As sunlight reflects off of a surface adjacent to an object, it picks up the color of that surface and fills the shadows on the object with the colored light which tend to be less bright and cooler in relation to the direct sunlight. This natural occurrence is the basic justification of colored lighting for theatrical productions. It would be easy to simulate the sun and corresponding shadows indoors if there was a lighting fixture that could produce the same intensity as the sun. Unfortunately, such a fixture is not
available so we must use multiple lighting fixtures to simulate the sun’s brilliance and reflected coloring in an indoor setting.

The moon provides a similar source and angle of light but there are some significant differences between sunlight and moonlight worth noting. Moonlight is less bright by nature since it is reflected sunlight, thus it lacks the intensity to create the same level of bounce or fill light. An increase in contrast between the primary light from the moon and the corresponding shadows is seen because of this reduced intensity of fill light. Any reflected colors are significantly muted or non-existent.

THEATRICAL LIGHTING THEORY

Straight on Viewing
To duplicate the sun’s highlights and associated bounce light indoors, we must provide a minimum of three lighting instruments to produce the same 360 degree coverage produced by the sun: one fixture must be used to create the highlight (the key light) and two fixtures must be positioned to create the associated fill light. Though positions can vary, a basic design would include one fixture placed at a 45 degree angle above and 45 degrees to one side of the object; this would be used as the key light. (See Figure 1). The second fixture at the same 45 degree angle above and to the other side would be the first fill light. A third light needs to be placed directly above

![Diagram](image)
(downlight) or up to 45 degrees from the rear (backlight) of the object as a second fill light. Positioning the fixtures in this manner can adequately illuminate a three-dimensional object on all sides, providing the highlights and shadows the mind’s eye expects to see.

The 45 degree angle is not non-negotiable, but keep in mind that extreme angles cause extreme effects (See Figure 2). A flat angle will create a generally shadow-less light, making the person’s or object’s features appear too even and without definition due to the lack of shadows. In order to escape the undefined visual, the mind will work in conjunction with the eye to insert shadows in order to correct the lack of definition, and as described earlier, both will eventually tire and move on to something more interesting. Conversely, an extremely sharp low angle of light from above or below will create exaggerated shadows on the face, which the eye is not accustomed to seeing. For example, a monster effect can be created by lighting a face from below causing reversed shadows and an unnatural look. Although completely different than natural lighting, the mind and eye seem to maintain interest in this lighting longer since it is abnormal and does not require an internal correction of the shadows.

The lighting for a night scene should use the same basic 45 degree angle arrangement since the moon is at the same relative angle as the sun. For economic reasons the same fixtures are normally used, but set at a lower intensity with a different dominant color.

Providing more options and colors to your lighting setup will require additional fixtures to be installed using the same principle. First, try adding back or down lights to increase the number of fill colors from the rear. Next, add fixtures from the front for more key and front fill possibilities.
Multiple View Angles
The theory detailed above is the basic design for one direction of viewing. If there is seating on three sides of a platform the theory remains the same, however the minimum layout of fixtures must increase. Using only two fixtures from the front leaves viewers sitting on the extreme sides seeing either all key light or all fill light, defeating the modeling effect you are trying to create. It is necessary to maintain the key and fill relationship for all viewing angles in order to create the shadows and highlights for modeling the object. A four-light front lighting scheme, with two keys and two fills, provides this necessary relationship for ¾ round seating. (See Figure 3). The number of fill lights from the back remain the same.

One cost-effective option to the four-light system is the three-light system (See Figure 4). Similar in theory to using four lights, three lights are positioned so that each viewing angle sees a key and a fill light. Two key lights from the sides and a fill light from the front will allow the fill light to perform double duty (acts as a fill from the left for the right hand fixture and
a fill from the right for the left hand fixture) and will provide each viewing angle with a key light. This method provides correct modeling but does not allow directional control of the colors. For example, actors could reference the moon coming from house left, yet the highlight is aimed from both directions.

**Expanded View Angles**
Additional viewing angles will require more fixtures using the same methods.

Other positions can be used to enhance lighting effects while still maintaining the theory-dictated parameters. Since bounce light radiates 360 degrees from the source, fixtures that act as fill lights can be hung in any position in relation to the key light. For example, lighting from a low side position can act as appropriate fill light and provides excellent modeling of the body. This position is often used in lighting for ballet to enhance the dance movements.
COLOR THEORY

Incandescent Lighting
Once the angles are chosen for illumination the next design element is color selection. Humans, either from natural or artificial lighting, have been conditioned to associate certain colors of light with specific times of the day. The sun is considered yellow or light amber, although it is really white light, since the sun itself appears yellow in the sky. Most people think of a middle-blue to dark-blue color as night, which the eye has the most difficulty discerning since it is higher in the color spectrum. Because moonlight is less intense and harder to see in than sunlight, dark blue colors are easily associated with moonlight (even though moonlight is actually white). Red is connected with fire, although fire can include the full spectrum of light. These ingrained color responses allow the theatrical designer to light indoors while simulating outdoor lighting moods.

Traditional theatre lighting fixtures are manufactured with a holder that accepts thin sheets of plastic color called gels (originally these colored sheets were made of gelatin). Although gels are available in hundreds of shades, the selection and application of color is very difficult to learn from a book or technical manual. Given that sheets of gel are relatively inexpensive, trial and error can be the best method for finding the colors that will suit your purposes.

Ideally, the selection of the basic key and fill colors emulate the sun or moon. The key color should be warm like sunlight and the fill should symbolize a reflection of sun from the surface behind the object which typically is cooler than the sun, like gray concrete, brown wood or green leaves. A good rule of thumb for basic lighting set ups is to choose a warm and cool color with similar color intensities. A brilliant yellow light would seldom produce a dark blue reflection; however, a deep lavender key could produce this reflection. When using multiple key and fill angles, it is possible to select gel colors which act as both a warm and cool light. For example, when using three angles of front light, a rose tint could be used from the right, light lavender in the center and a medium blue from the left. The lavender would look cool when compared with the rose, yet warm when compared to the blue. Potentially, the medium blue raised to full intensity could become the warm against a very low-intensity lavender. During a production with many parts, the entire color look of the light could be altered from scene to scene while still maintaining the basic lighting theory.
Gel colors must also be selected with scenery and costumes in mind. White light is a combination of the primary (red, blue and green) and secondary (magenta, cyan and yellow) colors of light. These colors, also referred to as wavelengths, are necessary for viewing pigment colors. Pigment is the substance that provides color in objects. A blue fabric has blue pigment and will only appear blue if part of the light that strikes it contains a blue wavelength. Since white light has all the colors of the spectrum, all pigments are excited and look natural under the sun or an un-gelled lighting fixture. When light that contains only a red wavelength hits blue fabric, the fabric will appear as an off color shade of red (depending on the fabric's makeup of primary and secondary pigments). True red, being a primary color, contains none of the blue wavelength. Similarly, the fabric would appear green if only the primary green light was shone on it, warm blue if magenta was the only light and cool blue if cyan was used (magenta and cyan being secondary colors that contain blue). The shades of blue will appear different given that we base our “natural” blue color on observance under white light; remove one part of the light spectrum and any pigment will look different. For beginners, the wrong selection of color can become a great calamity. The scenery, costumes and makeup can appear completely foreign to the designers and directors because they have most likely been viewing these items under relatively white incandescent light or slightly green fluorescent light. Having the correct colors in the fixtures will keep the directors and designers' vision intact avoiding potential problems during tech rehearsals.

Using this color knowledge, lighting can be designed to greatly affect the emotion of the presentation. A play's dramatic turn from depressing to happy could be made even more dramatic if the lighting transforms the entire set from cool to warm. If the scenery was predominantly blue, the mood change can be accomplished by changing the lighting from a cool blue-green light that suppresses the blue fabric color to a blue or violet light that allows (or enhances) the warm natural color of the fabric.

A limited selection of fixtures and colors does not necessarily mean a limited color palette. If your lighting instruments are attached to dimmers, you can change the colors of a single gel simply by increasing or decreasing the intensity of the lamp (light bulb). The light from a lavender gel will become increasingly red as its lamp intensity is reduced. This is due to both the change of intensity and the shift in color temperature of the lamp.

With practice and experimentation, you will learn how colors react to different intensities and how they respond when used together.

**LED Lighting**

With the introduction of LED lighting fixtures for theatrical lighting it is
important to remember that all the same theories apply. The correct lighting angles are still used and the key and fill lighting concepts are necessary to emulate normal lighting. Most LED fixtures are color changing so additional lighting fixtures may not be required to increase your color palette; however, with the availability of both key and fill colors within each fixture it is easy to lose those concepts. Always remember to maintain these relationships so that the fill color is in response to the key color.

The colors available from LED fixtures are dependent on the type and color of the light emitting diodes that are used in the manufacture of the fixture. Although most utilize the primary colors of red, green and blue, man-made pigments and dyes are seldom true to the color spectrum. This defect makes it difficult to achieve secondary colors or even all the colors available in color media form. If possible, select fixtures that include additional amber, cyan and magenta LED’s, these will reproduce the majority of colors.

**LIGHTING APPLICATION**

The basic lighting theory is applied using standard theatrical equipment. This equipment also dictates the physical layout of the three-fixture theory. What follows is a description of lighting fixtures, their layout and an overview of the equipment that is used to power and control the fixtures.

**Determining Lighting Areas**

To accommodate interior lighting we must rely on multiple fixtures since we do not have a fixture that can replicate the output of the sun. The fixtures designed for theatrical use create appropriate light levels when they project a 12 to 14 foot circular beam of light. To illuminate a typical stage many fixtures are needed and the overall area to be lit must be broken down into smaller units called focus areas. It is easiest to create 8-foot to 10 foot squares to allow the 12 to 14 foot beams to overlap for complete coverage and even illumination from square to square. If the stage or platform to be lit is 16 feet wide by 16 feet deep there would be a minimum of 4 focus areas using the basic design discussed above. For straight on viewing, utilize 8 fixtures from the front and 4 fixtures from above or back (one key and fill from the front and one fill from the back per area). If the platform is to be viewed from three sides, the amount of fixtures should be modified by adding one or two front lights per area for a minimum of 12 fixtures, but still using 4 fixtures from behind.

The same lighting method is used to spotlight special areas, such as a single person or piano. In this case, the focus area may be smaller in order to cover only the specified object, which will affect the fixture selection. These fixtures are normally referred to as “specials.”
Determining Fixture Needs
Several types of fixtures are available, so different capabilities and uses must be considered. To achieve proper illumination, the fixtures must produce a minimum of 100 foot-candles (an old light measurement based on the illumination of one wax candle) of light on the object in the roughly 12 to 14 feet diameter. This level may seem bright, but the foot-candles will be reduced when color is added to the lighting fixture; how much reduction will depend on the transmission value of the gel, so this minimum output is essential (the darker the gel, the less transmission of light).

There are several fixtures that have specific uses and most can utilize various wattage lamps. Once the fixture is selected for the proper distance, the lamp must be chosen for the proper foot-candles. Below is a brief list of the most common fixtures and their uses.

Ellipsoidal Reflector Spotlights (Lekos, Ellipsoids, Source Fours, ERS, 6x9, 6x12, etc.)
Ellipsoidal Reflector Spotlights are fixtures that produce a beam of light that is well defined with a hard edged circular beam. They are normally used for front lighting since there is little spill light coming from the fixture. Spill light is undesirable, as it could light up the audience or walls of the space. Also, these fixtures are equipped with shutters used to shape the beam of light. Squares, rectangles and other geometric shapes are formed with shutters, and the beam can be cut off of the edge of the stage, or wall, eliminating the spill light. Typically, these fixtures are also equipped with a template slot so the beam of light can also be shaped through the use of patterns (templates, gobos, cookies, etc.). Patterns come in many designs ranging from simple breakups, which add texture to the light, to city scapes or custom designs.

All of these fixtures create a cone-shaped beam of light. When a fixed focal-length fixture is placed at different distances from an object, the diameter of the beam of light directed at the object changes (the further away the larger the beam). The focal-length is a measurement of the lenses in a fixture which determines the size of beam produced. More expensive versions are available that vary the relationship between the lenses, effectively altering their focal-length. With the expensive versions, the same beam size can be achieved at different distances. Once the location and distance from a focus area are determined, a fixture with the proper focal-length must then be selected.
**Scoops** (Ellipsoidal Reflector Floodlights)
A fixture that produces a fixed open beam of light and is intended to light large areas such as backdrop or cyclorama curtains. Although Scoops have the same shape reflectors as ellipsoidals they have no lenses to redefine the beam, which creates a soft diffused output. Scoops have fallen out of use lately in favor of more efficient Cyc fixtures that are now utilized to light backdrop curtains and cycloramas. Scoops are now relegated mostly to work light functions.

**Fresnel Fixtures**
Fresnel fixtures are spotlights that produce a very soft-edged beam of light. These fixtures are often used for down or back lighting, although they can be used as front lights if the spill will not be a concern. They are less controllable than ellipsoidals in their focus because they have no shutters or template slots. Barndoors can be added in front of the lens of these fixtures and will eliminate some of the spill light, but the Fresnel lens will always create spill and can never be completely shaped by the barndoors. These units are variable-focus fixtures; moving the lamp in relation to the lens changes the diameter of the beam, making them very flexible. Fresnels are the recommended choice for small systems and some touring situations because they cost less than ellipsoidals and can be placed at different distances and still achieve the correct beam size.

**PAR Cans**
These fixtures are an addition to theatrical lighting from the Rock & Roll business. Basically, they are housings that hold lamps similar to an old car headlight. The lamps produce an intense oval-shaped beam that has a fixed beam spread. Because PAR lamps include the reflector, filament and lens in one unit, the lamps determine the width of the beam, not the fixtures. They are used for intense back lighting, but they can also be used for front lighting when spill light and the shape of the beam is not an issue. The only way to create a wider beam from a fixed position is to replace the lamp. Lamps cost between $30 and $55, so this can be an expensive stock item. The modern addition to the PAR fixture line are energy efficient lensed units. ETC first introduced a theatrical version called the Source
Four PAR. This unit uses the popular HPL lamp and has a fixed reflector with interchangeable lenses. To create different size beams the reusable lens is changed at a cost of approximately $4. These lenses are available in the same beam spreads as the PAR lamps.

**Borderlights** (Striplights)

These units are continuous rows of lamps intended to light a large linear area, usually from overhead. They have also been used to light cyclorama curtains and are typically installed in theaters where they can be concealed behind curtains. This fixture has three or four alternating colors and can easily provide separate color washes from above. However, each color is controlled as one big area that cannot be isolated into smaller areas. Because of cost, electrical efficiency and reduced availability of lamps, these fixtures are rapidly being discontinued and replaced by Fresnels for down or backlight and Broad Cycs to light cyclorama curtains.

**Broad Cycs**

This style of wash lights produce a fixed open beam of light and are intended to light large areas such as backdrop curtains and cycloramas. They are somewhat similar to scoops but they have a specifically designed reflector to produce a square shaped beam that collects more, and projects a greater, level of light than scoops onto a curtain with significantly better energy efficiency.

**Followspots**

Followspots are fixtures that are physically controlled by a person. They are mounted on a stand that allows the operator to follow a performer with a sharp-edged beam of light. The beam can vary in size and the fixture generally includes six or more colors. They are available in many sizes and intensities to match any throw distance. Although they are normally used from the front, alternate positions from above can produce interesting highlights on the performer. This is the only sure method to follow a performer, especially while he or she is dancing or moving rapidly. Some versions incorporate electronically controlled iris and color changing, which can be remotely controlled by any DMX control console. This allows preprogramming of the critical changes and allows the operator to focus on only aiming the fixture to match the actors’ movement.
**Moving Lights**

Moving lights include a wide range of fixtures that are controlled remotely. Each unit contains dichroic filters or color mixing modules so the colors can change on demand. The beam sizes are automatically variable and multiple patterns can be included in each unit. The fixtures can be used as front lighting, back lighting and special effects. New computer controls and belt packs may be utilized so fixtures will respond as automatic followspots for basic following functions.

**LED Fixtures**

Several styles of LED fixtures have entered the theatrical lighting world in the last few years; however, they have just begun to meet the output levels that make them viable alternatives to traditional fixtures. Ellipsoids, Fresnels, PARs, Cycs and moving light fixtures are all now available in LED versions. The cost for the initial purchase of LED based fixtures is significantly higher than traditional fixtures, but the reduced long-term electrical and lamp replacement expenses can outweigh this large initial investment.

Many LED fixtures on the market have been designed for bar and nightclub use. Although they have moved into the theatrical market, the purchaser should take precautions when buying these units to ensure a wise investment is made. The following are several key points for purchasing LED fixtures.

1. Reliable Manufacturer: Many imported fixtures may seem like a deal, but the quality of the unit will determine cost efficiency. The fixture is made up of a power supply, LED emitters and electronics. Although the LED emitters might be rated for 50,000 hours of use, the power supplies may not be. In addition, many manufacturers overdrive their LED emitters with a higher voltage to increase light output which shortens the life of the LED’s and they may not achieve the energy savings desired. Stick with known manufacturers when selecting these fixtures.

2. Quality Electronics: The electronics portion of the fixture is critical to producing a subtle dimming curve of the light. Many fixtures are designed for bar and nightclub venues where there is no need for a 50 count fade, an example being, a long smooth fade at the end of a romantic scene. Many units may fade well at the top end of intensity but the light could appear to be stepping down rather than fading at the lower end. High quality electronics and designs are necessary in an LED fixture to produce good fading curves.
for use in theater.

3. Proper LED Alignment: Most LED fixtures utilize multiple LED emitters set in a circular or square array. Some of these fixtures position the LEDs to combine to a point inside or in front of the fixture to mix the multiple beams of light before producing the final beam that will be used to light the object. This combination is important since each beam of the emitter has the potential of creating a shadow. If all the LEDs are white, the multiple shadows are not much of an issue since only one color of shadow is produced. If they are individual red, blue and green, then separate red, blue and green shadows will be created and the multiple shadows will be distracting to the audience. Some fixtures use 50 or 60 LEDs to achieve enough output, providing the potential for 50 or 60 shadows. Check the shadows created by the fixture before purchasing.

4. Adjustable Color Tuning: Many imported fixture manufacturers change models every year. They are also known to alter the supplier of their LED emitters without notice. Purchasing 10 fixtures today and 10 more a year from now will probably produce a mixture of hues even when sending the same control signal value to each fixture. This will result in an unbalanced stage look and much frustration for the designer and board operator. Quality manufacturers like Altman, ETC and Strand work hard to fabricate fixtures that produce the same colors at the same control values from batch to batch. Many of their fixtures can be tuned in the field by authorized service technicians. It is important to purchase equipment from manufacturers who have a known track record of reliability in this area.

5. Light Output: Buying the fixture with the correct light output is critical. Many suppliers claim that their fixtures work in theatrical environments, yet some of the less expensive units won’t. A good rule of thumb is to purchase an LED fixture of 100 watts, or preferably more, if it is intended to illuminate a single lighting area. Those fixtures designed to be used in groups for cyclorama lighting or large wash areas can be of lesser wattage since the beams will be overlapping. Purchase higher wattage fixtures that will create the appropriate output.

6. Know the Differences: Color changing LED fixtures produce light by combining the output of primary colored LEDs (better fixtures include the secondary colors as well) and using a white LED to alter the hues. More light output is produced when all the LEDs are turned on as opposed to when a single color is outputting. Traditional quartz lighting fixtures are always at their maximum brightness when turned on at full power without color, however their light output decreases the moment a gel is placed in front of the lens. The new ETC Source Four LED fixtures are not as bright projecting white light as the original 575 watt quartz Source Four without
color. However, if you add a dark blue gel to the original and set the LED to the same color, the LED fixture is brighter. Compare the outputs of LED fixtures to your traditional fixtures to make certain you will have the output you need for your performance space.

**Dimming and Distribution**

Dimming varies the intensity of the traditional lighting fixtures. The distribution equipment is the set of electrical boxes that contain the individual receptacles the fixtures plug into. For a new facility or portable installation, the quantity and locations of the receptacles and dimming can be designed once the quantity and position of the lighting fixtures are laid out. In general, individual control of each fixture would be the most desirable. If this is not possible, group the control of the fixtures by angle and/or color i.e., all front cools that come from the house right direction could work together on the same dimmer. Similarly, all same angle/color warms and then all same angle/color backs could work together. This control method is less flexible but allows you to dim the fixtures by color to change from day to night. Traditional dimming includes a centralized dimmer rack, such as the ETC Sensor, that feeds the distribution equipment. Distributed dimming systems using small dimmer packages that mount adjacent to the fixtures can reduce wiring costs and are excellent for portable systems. These systems include portable packs and the higher quality Strand S21 Dimmer Strips.

**Control**

The control of the lighting can be just as critical as the selection of color and fixture angles. How the light changes from scene to scene is an important part of the lighting design and can maintain or alter the continuity of the show. An abrupt change of lighting at the end of a tender romantic scene can destroy the entire mood created by the actors. A good dimming system with a quality control console, preferably computerized for accurate playback, is important to any lighting design. The basic control console is termed a “Preset Console,” and has one or two rows of potentiometers that are manually manipulated to set the lighting levels. Some of these units are enhanced with memory that records a full scene for playback from each potentiometer. A “Memory Console” is a custom computer with both a
keypad and potentiometers for playback of prerecorded cues these typically include a monitor for display of recorded information. There are some memory consoles, such as the Jands Vista, that are created by adding software and an output module to a standard personal computer. Any console purchased should produce DMX512 signal outputs to allow full operation of dimmers, moving lights and effects (fog machines, color changers, etc). The size of console is highly dependent on the number of these devices that may eventually be used in the facility and should be purchased for the maximum number of control channels that will be required.

**DESIGN PROCESS – RECAP**

This concludes the basic description of the lighting theory and equipment necessary to fulfill the theory for a theatrical style lighting setup. Many factors are necessary to develop a complete setup of this equipment; however, this information will aid you in developing appropriate designs. Below is a short recap of the design process and equipment selection:

1. Design lighting layout for proper three-point illumination. Break platform into 8-foot to 10-foot focus areas. Include additional areas for specials.

2. From the layout of areas, select the proper positions for the lighting fixtures.

3. Select the lighting fixtures to produce 12 foot to 14 foot beams based on the mounting distance to areas. The wattage of the lamps should also be selected for the proper foot-candle level.

4. Connect lighting fixtures to the dimming system to allow for individual or angle/color groupings. Watch the wattage of your fixtures to be certain not to overload the dimmer.

5. Select the gel colors for appropriate mood of the production, taking into consideration the scenery and costume colors.

6. Create lighting cues that enhance or direct the mood of each scene, including the timing of lighting changes.
Lighting Noise in Your Sanctuary
Having a quiet space is essential for moments of silence during a performance or during prayer, yet many facets of a lighting system can increase noise to a point of disrupting these times.

There are several sources of lighting noise, the most basic being the filaments used in the lamps (light bulbs) of the lighting fixtures. Most filaments are quiet if given 100% of the voltage they require. If the fixtures are wired to a dimmer, the manipulated voltage from that dimmer can create an audible buzz in the lamp filaments. Dimmers switch AC current on and off to raise or lower the voltage supplied to a lamp - the lower the voltage, the lower the intensity of the light. In actuality the voltage turns off for an instant on each half of the AC sine wave. The lamp appears to stay on because of the momentum of the heat built up in the filament. You may have noticed this at home when you turn off the light switch and the light does not go out instantaneously, but takes a few seconds to go out completely (cool off). The switching of the AC has the effect of slamming the filaments 120 times a second, which creates vibrations in the filaments. These vibrations are audible and are the cause of the hum that can be heard when lights are dimmed.

Many electronic dimmers utilize two Silicon Controlled Rectifiers (SCR’s) to manipulate the voltage of one dimming circuit. These are the devices that turn on and off, or chop, the AC sine wave. Without filtering (slowing down the voltage), the slamming of the filaments would be so intense that it would reduce lamp life and present unbearable noise. The greatest amount of noise is generated when the lamp is dimmed approximately 35% to 70% of its output. Most churches will dim the congregation area not only to draw focus to the platform, but also to set a calming mood. If the slide pots of your dimmer control are set to 5, you will have dimmed the light to its most noisy filament range. To reduce this filament noise, manufacturers add chokes to the dimming circuit. A choke is a doughnut shaped metal core with wires wound around it. This design creates a magnetic field, which slows the voltage as it passes through the wire wound around the core, lessening the slamming impact to the filaments. Filter chokes are measured in micro second rise time; the most basic choke is rated at 350 microseconds with 500 and 800 microsecond rise time chokes also available. Generally, the higher the rise time of the choke, the less filament noise it will produce. Unfortunately, to achieve higher rise time, the choke requires more wire to be wound around the core. This increases the production costs; hence
the dimmer will cost more. Inexpensive dimmer packs are less costly for a reason. They use lower quality components, including lower rise time chokes and ultimately may cost you more in repairs and noise problems. Purchasing a well-built dimmer is a worth while investment to reduce noise in the sanctuary.

Aside from the filament hum, dimming induced noise in sound systems is always a concern. Through the operation of dimmers, RFI (Radio Frequency Interference) can be produced. This interference is a radio signal that radiates from the dimmers and through the load wiring to the fixtures. Any sound related cable placed close to this wiring may pick up this RFI, which will disrupt the sound signals and thereby create a buzz in the sound system. This buzz will only be present when the dimmers are in operation and will increase and decrease in intensity, especially within the 35% to 70% dimming range which is the same range that causes the worst case filament noise. It is very easy to run sound extension cords to a new speaker or microphone location without taking into consideration the RFI created by the dimming system. Interference can also travel over the power systems in a building, particularly over the neutral wires. Sound equipment should have an isolated power feed to avoid the potential RFI produced by the dimmers.

Switchgear and distribution chatter is both a noise issue and a potential fire hazard. Switchgear can include disconnect switches, breakers panels, fuse boxes and transformers. Distribution is the wiring between the switchgear and the lighting fixtures. Modern dimming systems are larger in dimmer quantity, more heavily loaded with fixtures and more accurately fired than ever before. Electronic dimming can present many stresses on the electrical transformer that feeds the dimming system, which will make this switchgear chatter and potentially overheat the wiring and the transformer. In general terms, the SCR switching distorts the normally smooth AC waveform. This distortion is the worst in the dimming range of 35% to 70% and travels through all of the wiring involved in the system. A typical power feed to a dimmer rack would have three hot legs, one neutral and a ground wire (three-phase four wire + ground 120/208 volt service) all rated for 400 amps. A well-loaded dimmer rack could carry 300 amps of power per hot leg. If all of the dimmers are set for a 35% dimming range, it may be possible to measure 500+ amps being carried on the neutral wire. If your wiring is only sized for 400 amps, the neutral wire (which typically does not have a circuit breaker) could continuously carry the 500 amps, overheating the wire covering, wire connections and the transformer. At this point the main circuit breaker would not have tripped, because the draw on the hot legs is still below the 400-amp capacity. While conditions necessary to cause this are not typical, they are certainly possible under normal operations.
The chatter of the switchgear is an audible warning of a potentially critical problem.

There are several ways to minimize lighting related noise in sanctuaries. Using dimmers with higher micro second rise time filter chokes will reduce audible noise and RFI, but not necessarily the switchgear chatter. Dimming systems are available that produce fewer harmonic distortions on the power feed by altering the method of SCR firing and utilizing devices other than SCRs. These systems produce less noise from filament hum, as well as reducing RFI and switchgear noise. Specific (and much more expensive) transformers are available to partially deal with the overloading of the neutral produced by the dimming harmonics. The layout of wiring can also influence these noise problems.

The use of LED lighting fixtures will correct many of these issues. The lower wattage LEDs and the lack of harmonics kicked back on the power feed (the LEDs are electronically dimmed, not dimmed by changes in voltage) reduces the need for special transformers and high power feeds. More significant control wiring is required for LEDs, but these are low voltage control networks.

Consulting with a dimming professional for the design of your lighting system will help insure that the proper equipment and wiring layout have been selected to avoid noise issues in your theater or sanctuary.