CONCEPTS and APPLICATIONS

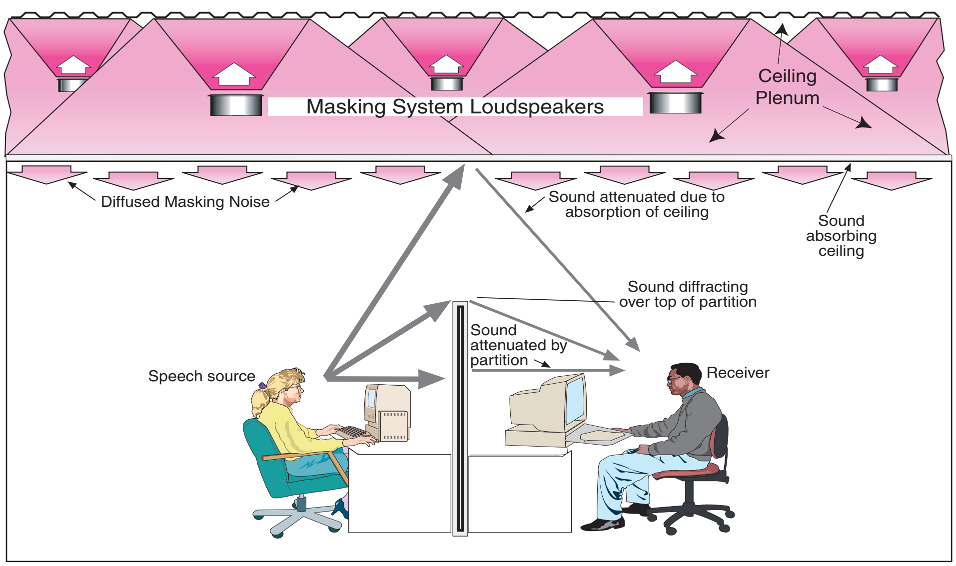
Noise that provides interference with the sounds that we wish to hear is common in our everyday activities. We hop in our automobile, turn on the radio, set the volume control at a comfortable level to receive the news report, and start down the street. Upon entering the interstate highway and increasing our speed, we find that we must increase the radio sound pressure level to produce the same speech intelligibility of the news broadcaster that we experienced at lower speeds. The increased speed has raised the noise level produced by the auto and *masking* of the newscaster's voice has occurred. Now, we decide some fresh air would be nice and we lower the driver's window. The auto interior noise level increases again and we must further increase the radio level to understand the news report... more masking is produced by the auto background (ambient) noise level.

While we may find the masking affect of automobile noise somewhat annoying, the addition of properly adjusted masking noise can create a more desirable environment.

In offices, courtrooms, libraries and other spaces one listener or group of listeners may be disturbed by sound created by another person or group of persons located in the same overall acoustical space. This disturbing sound is often intelligible speech. In such situations the presence of masking noise can be very helpful. Using electroacoustic techniques, it is often necessary to add masking noise to a particular space in order to decrease speech intelligibility between adjacent workstations, offices, etc. This is often the case in open plan offices where the noise reduction that might be provided by traditional walls between offices is not present.

In courtrooms the judge may wish to speak with attorneys without the jury being able to understand the conversation. The background noise level in the jury area may be raised so conversations being held at the judge's bench cannot be understood. This must be a temporary situation, since during most of the courtroom activities, the jury must be able to easily understand speech by the judge, counsel and witnesses.

TYPICAL OPEN PLAN OFFICE WITH MASKING NOISE SYSTEM



In situations where architectural construction provides insufficient noise reduction between adjacent spaces, such as in counseling offices, the introduction of masking noise may be helpful as a substitute for proper architectural noise reduction.

Although it may seem that the introduction of masking noise in any particular space is an easy task, the masking noise system must have certain attributes if it is to provide successful masking and if it is to be accepted by the occupants of the space.

This is particularly true where masking noise is continuous (required at all times).

Depending upon masking noise system design, the masking noise system may also provide background music distribution and/or paging.

Separate sound distributions systems for these audio programs are not necessarily required.

This discussion relates primarily to masking noise for open plan offices.

It should be noted, in typical open plan office situations, the introduction of proper masking noise will not normally be the entire solution to speech privacy and annoying sound problems from adjacent work stations. The electroacoustic masking noise system should be one part of a three-part solution to these acoustic problems.

The other two parts of the solution involve the use of effective sound absorbing surfaces, particularly for the ceiling, and the use of partial height partitions (acoustic barriers — higher is better) between workstations.

SUCCESSFUL MASKING NOISE SYSTEM CHARACTERISTICS

An electroacoustic masking noise system for open plan offices should possess the following major characteristics:

- ❑ Masking noise sound pressure level should be sufficient to submerse the sounds that are to be masked, but not so high as to disturb the occupants of the space.
- ❑ The masking noise must contain no information. Thus, music is normally not an effective masking sound. This is also true for mechanical system noise where its presence is often translated by the listener as thermal comfort information.
- ❑ The masking noise must not provide directional cues as to the location of the loudspeakers producing the noise.
- ❑ The spectrum (frequency response) of the masking noise must be established to provide suitable masking while, at the same time, allowing the masking noise levels to be higher than might otherwise be tolerated by occupants without proper spectrum adjustment.

  The spectrum must be *continuous*. That is, there must not be wide level variations between adjacent frequency bands.
- ❑ Masking noise levels must be suitably uniform throughout the architectural space where masking noise is to be introduced. A location-to-location variation not exceeding 3 dB at mid-frequencies is very desirable.
- ❑ In an existing space where masking noise is to be added, occupants of the space must not be forced to accept the addition of masking noise *all at once*. Masking noise levels should be slowly raised over a fairly long period of time (days not hours) until the previously determined maximum levels are established. And, if a masking noise system should fail, the masking noise levels should be reestablished slowly.
- ❑ Where office ambient noise levels (noise levels before adding masking noise) vary with the time-of-day, it is best to employ a masking noise controller which will automatically and slowly lower masking noise levels for periods of time when office ambient noise is low such as is normally the case during evening and night time hours.
- ❑ Sufficient audio power must be provided to establish the desired masking noise levels.

  Several factors must be considered.

  1. The crest factor of the noise program.
  2. The attenuation of the ceiling panels between the loudspeakers and the occupants.
  3. The needs of paging or background music if these programs are to be served by the masking sound system.

See **How much power is needed?** on page 3.

ARCHITECTURAL and MECHANICAL SYSTEM CONSIDERATIONS

Since open plan offices provide the most common use for masking noise systems, the system designer must be aware of the architectural design of the open plan office space.

The illustration on page 1 shows paths for transmission of sound from one workstation to an adjacent station and the introduction of masking noise by loudspeakers located above a suspended sound absorbing ceiling.

Techniques have been established to quantify the noise reduction between workstations as provided by architectural materials and elements. However, the masking system designer and/or installer seldom have much influence on the architectural elements of the space. Proper architectural design will include the following:

- Suspended sound absorbing ceiling using a ceiling tile or board with high coefficients of absorption in the 500, 1000, 2000 and 4000Hz octave frequency bands... Absorption should be 0.85 or greater with NRC (**N**oise **R**eduction **C**oefficient) of 0.90 or higher.

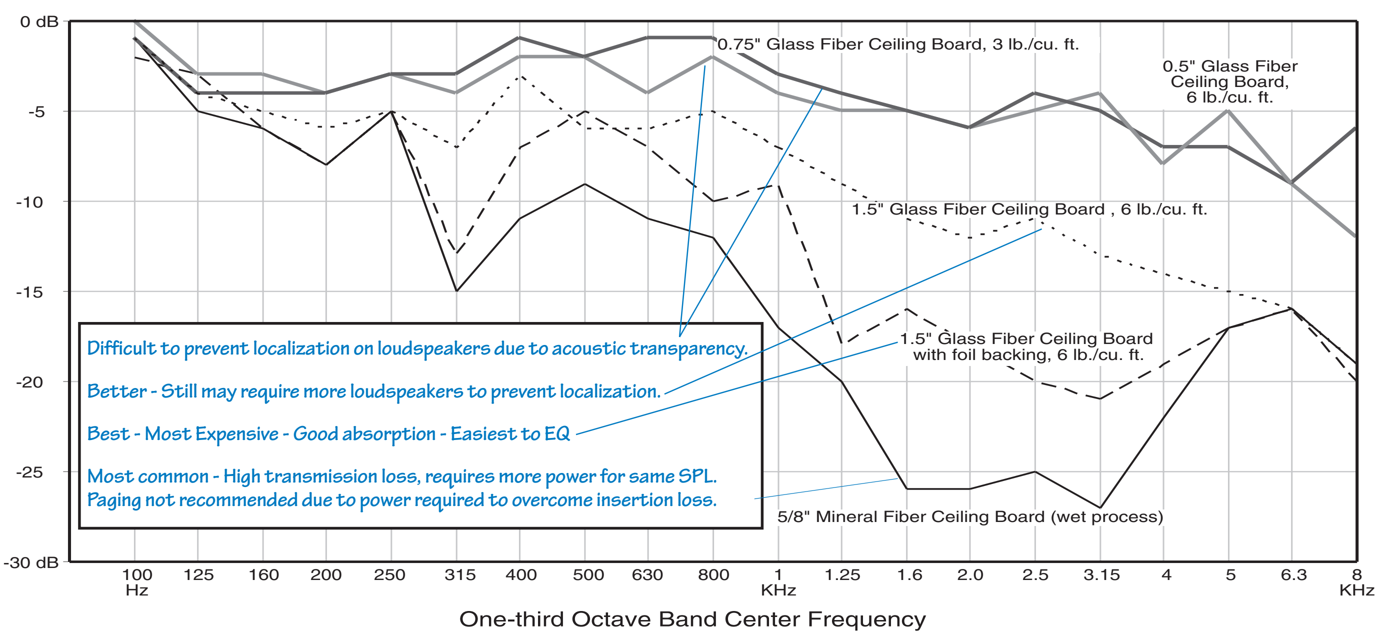
This normally requires the use of glass fiber ceiling board. The most common, wet process mineral fiber ceiling board or tile, typically does not provide the absorption required to adequately control ceiling sound reflections.

The sound absorbing material applied to the deck *above* the drop ceiling also affects the masking noise system. The masking loudspeakers typically face upward, using the ceiling plenum as a noise mixing chamber to diffuse and delocalize the noise sources. The noise is transmitted into the occupied space *through* the drop ceiling material... sort of a leaky box.

Glass fiber ceiling board 1.5 inches thick with cloth facing and with foil backing is the best overall ceiling material to use. Mineral fiber ceiling board provides greater transmission attenuation of the mid and higher frequencies (more of a high pass filter) when compared with glass fiber ceiling board. However, glass fiber ceiling board without foil backing is too transparent acoustically. Thus, localization of the masking noise sources (loudspeakers) is greater.

- Partial height partitions between workspaces with height of *at least* 63 inches... Partition surfaces should be sound absorbing wherever possible; and where such sound absorbing surfaces are used, the partition must include a solid septum to prevent sound from *going directly through* the partition.
- Ceiling plenum with height of 30 inches or more to provide space for masking noise loudspeakers (as well as air handling ducts, sprinkler piping, etc.)
- Carpeted floor... Typical commercial carpet is desirable but not essential.
- The minimum number of lighting fixtures (assuming the use of flush mounted fluorescent luminaires) necessary to provide the illumination required... The horizontal fluorescent light diffusers provide sound reflecting surfaces which allow significant ceiling sound reflection between adjacent work stations, particularly when large size luminaires are used.
- Sound absorbing treatment for fixed wall surfaces when such surfaces provide significant sound reflections between office spaces.

TYPICAL INSERTION LOSS OF CEILING PANELS



HVAC MECHANICAL SYSTEM REQUIREMENTS

Mechanical systems serving spaces in which masking noise is to be introduced can affect masking system performance.

HVAC (**H**eating, **V**entilating and **A**ir **C**onditioning) systems should be designed so that they produce less noise than the electroacoustic masking noise system.

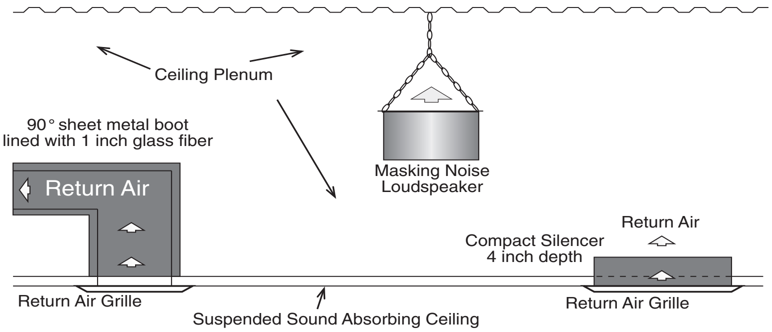
For general office spaces, the mechanical system designer should strive to design a system that produces ambient noise levels described by NC-30 (**N**oise **C**riteria **30**) or lower.

Actual results of NC-35 or RC-35(N) (**R**oom **C**riteria **35** **N**eutral) may prove acceptable, but the designer must have a “safety factor” of about 5 NC points since much of the data used for mechanical system noise control is approximate. However, it is not unusual for the mechanical system to produce low frequency noise in excess of the desirable masking noise levels at lower frequencies. This will affect the field adjustment of the masking system levels and spectrum as discussed on page 4.

Larger air handling ducts located in the ceiling plenum sometimes cause physical problems in locating masking noise loudspeakers in the plenum space. And, openings in the suspended ceiling for return air often disturb the uniformity of masking noise at the listening level and/or provide a noticeable direction to the masking noise. Conflicts in this regard are normally unavoidable. However, using the following procedures should resolve at least some of the problems.

- Do not attach masking loudspeakers directly to ducts. If a masking loudspeaker must be suspended below a duct, use a trapeze arrangement to suspend the loudspeaker independent from the duct.
- Where a duct and a masking loudspeaker must occupy the same horizontal space, install the loudspeaker with a spacing of at least 24 inches from the side of the duct.
- Do not locate masking loudspeakers above return air grilles. It may be necessary to solve this problem by installing compact silencers or lined sheet metal boots for return air grilles as shown below. Compact silencers with a depth of 4 inches are fabricated by several manufacturers of mechanical system noise control equipment.

PREVENTION OF MASKING NOISE LEAKAGE FROM RETURN AIR GRILLES



DESIGN and FIELD ADJUSTMENT OF MASKING NOISE SYSTEMS

MASKING NOISE SYSTEM DESIGN

The design of a masking noise system is not difficult when compared with the design of most sound reinforcement systems. Many times one design or one overall system will apply to several building areas that have similar acoustical characteristics. Following are some design suggestions that have proven to produce successful masking noise systems in actual applications.

Sound Distribution

- Just as for all sound systems, the sound distribution (loudspeaker) system is of paramount importance. The other portions of the system, noise generators, controller, equalizers, power amplifiers, are certainly important. But, without proper sound distribution the system will not be successful and well received by the occupants of the space.
- Install 8 inch cone type loudspeakers mounted in enclosures and directed up into the ceiling space. In most cases, directing the loudspeakers up will provide the most uniform sound distribution in the occupied space with reasonable loudspeaker spacing.
- Except where plenum space is very limited, where a loudspeaker must be installed beneath an air handling duct, etc., install the masking loudspeakers with a space of at least 12 inches between the bottom of the enclosure and the upper surface of the suspended ceiling.
- Install the masking loudspeakers on about 12 foot centers using a staggered pattern where practical.
- Extend masking noise distribution into conventional offices that open directly into open plan office areas and also extend masking into lobbies and similar spaces that are adjacent to the open plan office areas. For these adjacent offices and lobbies it is a good idea to use masking loudspeaker assemblies that have a switch for 70 volt transformer tap selection. In this way, the masking levels can be reduced by 3 or 6 dB if this produces a more pleasant atmosphere in these areas or if demanded by a particular office occupant.
- As noted under suggestions for masking noise controllers, use two or three pink noise generators to form two or three incoherent noise programs.

How much power is needed?

Assuming the worst case in regard to ceiling sound insertion loss, a ceiling using mineral fiber lay-in board, allow 0.5 watts of audio power per loudspeaker if masking noise only is being distributed.

Actual measurements indicate that a masking noise level of NC-42 can be produced by average power of 25 mW per loudspeaker. However, the crest factor of the noise, typically 12 dB, must be handled without power amplifier output clipping. 12 dB headroom requires that the average power be multiplied by 15.8. The power per loudspeaker is therefore 0.4 watts. Thus, the connection to use on most 70 volt loudspeaker transformers is 0.5 watts. Even if the ceiling board is foil backed glass fiber with lower insertion loss (refer to Figure 2), it is suggested that power of 0.5 watts per loudspeaker be maintained.

If paging is to be distributed along with masking noise, the audio power requirements are significantly increased.

To produce mid-frequency paging sound pressure levels of 60 to 65 dB, an increase of approximately 20 dB or 100 times power over average masking noise power is required. Therefore, average paging power required is about 2.5 watts per loudspeaker. But, headroom of at least 10 dB is required for the paging audio. 25 watts of audio power should therefore be allowed if the ceiling is mineral fiber lay-in board. This amount of audio power per loudspeaker does seem to be impractical.

Of course, the solution to this situation is to use glass fiber ceiling board with foil back which has a mid-to-high frequency insertion loss approximately 10 dB less than exhibited by typical mineral fiber ceiling board.

Therefore, with a foil backed glass fiber board ceiling, power per loudspeaker of 2.5 watts should be just adequate. Good practice is to allow 5 watts per loudspeaker when both masking noise and paging are to be distributed. For paging programs it is assumed that adjustable compression or limiting is provided.

Power Amplifiers

- Please see the comments above about audio power requirements.
- Power amplifiers with detented gain controls in 1 or 2 dB steps are recommended. *Accurate* level changes can then be easily made and previous levels can be accurately restored.
- Of course, most masking systems will use 70.7 volt distribution.

Equalizers

- One-third octave band equalization is recommended for curve adjustment ease.
- For systems where cost is a major issue, full octave band equalization may be satisfactory.
- Parametric equalization may also be used, but it is more difficult to adjust and make subtle changes.
- A separate equalizer channel is required for each noise program channel.
- Separate equalization is required for the paging and/or background music channel.
- Each major office area that has significantly different acoustical characteristics due to different ceiling material, major differences in ceiling plenum space, or major differences in open plan furniture and furniture arrangements will need a separate set of equalizers.

Masking Noise Controller

Noise Generators

- As previously mentioned, employ at least two noise generators to form two or more incoherent noise programs.
- Use a controller that provides *time-of-day level control* so that masking levels can be

unobtrusively changed with major changes in office occupancy and the resulting changes in office ambient noise (not including masking noise). Time-of-day level control is normally used to slowly reduce masking noise by about 9 dB over a 30 minute or 1 hour period beginning at the end of the normal workday. The daytime level is then restored over the same time period so that daytime levels are present at or near the beginning of the normal workday.

- Employ a controller that provides slow restoration of masking noise levels over a several minute period after an electrical power failure.
- Use a controller that provides very slow *start-up* of a masking noise system that has been added to an existing office space. The final acoustic levels should be reached over a period of several days. This technique will avoid some comments by office occupants that the noise is too loud or disturbing.

FINAL ADJUSTMENT OF MASKING NOISE SYSTEMS

Four basic tasks must be accomplished during masking system test and adjustment.

1. All audio equipment including each loudspeaker must be checked for proper operation. This includes making sure that loudspeaker transformers are properly connected (an impedance meter or impedance bridge will help with this task) and that, with "flat" equalization, the spectrum of the noise appearing at the output of each power amplifier is "flat" unmodified pink noise (a real time spectrum analyzer used as a voltmeter will assist with this task).

2. The masking system controller must be adjusted in regard to time-of-day attenuation, slow start-up and other features that may be provided by the particular controller being used.

3. The acoustic response of the system must be adjusted by using the one-third octave band equalizers. System response is most easily measured in one-third octave bands by a real time spectrum analyzer.

Either a dedicated hardware spectrum analyzer or an FFT based software analyzer and computer may be used.

If a computer is employed it is essential that the sound card have a flat frequency response over the frequency range of about 63 Hz to 8000 Hz

The microphone used should be omnidirectional and flat over the same frequency range.

The measured response should be *averaged* over at least three typical locations in the office space.

The target curve below illustrates a spectrum that will provide good results in most applications. This spectrum should be considered as a starting place. It may be necessary to modify it somewhat to achieve the desired masking for the particular application. Please note that the target spectrum is defined by measurements in one-third octave bands.

The masking system spectrum is typically adjusted by observing one-third octave frequency band sound pressure levels. This may be most easily accomplished by initially setting the levels somewhat higher than indicated by the target curve chart, perhaps 6 dB higher in each one-third octave band.

If your test equipment does not provide for making *calibrated* SPL measurements in third octave bands, select levels that are *above* ambient noise by at least 8 to 10 dB in each band.

4. After the curve *shape* is achieved by adjusting the system equalizers, the proper system *levels* can be set by using the detented power amplifier gain controls.

If your equipment only measures SPL's in octave bands or is only calibrated for A scale, the levels will be different from the third octave levels. The shape of the desired curve, of course, will be the same. Adjust the sound pressure level in the 500 Hz octave band within the range of 49 dBA for the upper limit or 43 dBA for the lower limit.

It may be possible to raise system levels by 2 or 3 dB above the upper target levels indicated, but some complaints from office occupants can be anticipated.

If this occurs, *slowly* lower the overall levels by about 6 dB for several hours and then increase the levels by 4 dB over a period of at least one hour, thus making a 2 dB net reduction. Then wait for reaction to this somewhat lower masking level.

If the air handling system is producing noise greater than the desired masking noise at lower frequencies, it may be necessary to increase the masking levels until they are about 4 or 5 dB below the mechanical system octave band noise levels.

If the air handling system is of the variable volume type, it may also be of the *variable noise* type. Thus, it is important to observe sound pressure levels at both extremes of the mechanical system noise. With lower HVAC air flow the masking system levels may be predominant. Increasing the masking noise levels at lower frequencies somewhat above the desired levels will provide less of a contrast for office occupants. Levels should be adjusted to make a smooth transition to masking system levels at 250 Hz or 500 Hz.

After the masking system has been adjusted and is placed in service, subjective observations should be made relating to speech privacy between work stations, acceptability of system levels in relation to annoyance and general acceptance of the office acoustical conditions.

Masking Level Envelope Target Curve
measured in one third octave bands