TAKING ON MIX-MINUS DESIGN:

4 BEST PRACTICES FOR SPEECH REINFORCEMENT

BIAMP SYSTEMS

mainline

OVERVIEW Running into a project that requires mix-minus or sound reinforcement can give you heartburn. Not only can a challenging mix-minus design add time to your job—and reduce profits—it can impact acoustic echo cancellation and system performance as well.

Mix-minus system design is as much art as it is science. In this paper, we'll show you four best practices that will help you master the science of mix-minus. You'll learn the right formula for determining gain settings and the physics behind it. The art is up to you.

WHITE PAPER

POP QUIZ

Your customer has a large boardroom that requires a mix-minus speech reinforcement system to ensure the 12 participants seated around the table, as well as in the extra seating around the walls, can all receive local participant's speech audio, at the same volume level with excellent intelligibility. The boardroom also has teleconferencing and videoconferencing capabilities. What do you do?

A) Grab your trusty scientific calculator and cancel the rest of your appointments.
B) Talk your customer into using headsets.
C) Head to the nearest bar for some liquid courage.
D) Design your mix-minus system with confidence and speed.

INTRODUCTION TO MIX-MINUS DESIGN

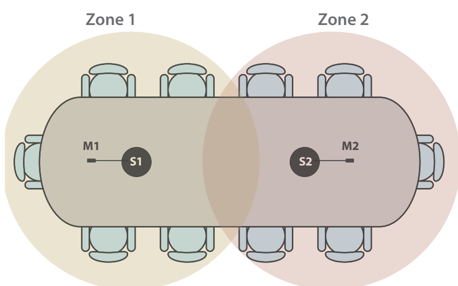
Mix-minus configuration is used to create unique audio feeds to any loudspeaker in the same acoustical space. According to the **Handbook for Sound Engineers**, "A mix minus output signal contains all input channels except for one or more, i.e. the complete mix of all inputs 'minus' one (or more) undesired inputs."[i]

The primary reason to design a mix-minus system is to prevent feedback in conferencing or sound reinforcement applications. For example, when a news anchor interviews a guest through a video or teleconference connection, the mix of audio returned to the guest would not include his own commentary and thereby prevent feedback. Though mix-minus is not used solely for the purpose of echo reduction, it can help reduce echo in broadcast applications—call it a fringe benefit.

In a sound reinforcement scenario, the mix of audio playing from the loudspeaker closest to the presenter should not include his own speech. Effective mix-minus configuration increases the mic to loudspeaker distance, which minimizes the possibility of feedback. Loudspeakers are always on but do not carry signal from every source in the system – only the ones that would be difficult to hear otherwise (like distant microphones at the other end of the room or recorded materials).[ii]

A basic application of mix-minus that has two zones with one microphone and ceiling loudspeaker in each zone is pretty straightforward. The mics are placed at each end of the table. To reinforce the sound, the signal from the Zone 1 mic is sent only to the Zone 2 loudspeaker. The signal from the Zone 2 mic is sent only to the Zone 1 loudspeaker.

FIGURE 1. A BASIC TWO ZONE CONFIGURATION.



However, today's DSPs support hundreds of audio inputs and outputs, creating much more complex mixing scenarios in a variety of venues. Most commonly, mix-minus systems are used in sound reinforcement and conferencing applications including:

- Boardrooms and conference rooms
- Training rooms
- University classrooms
- Auditoriums
- Presentation facilities

A CLOSER LOOK AT MIX-MINUS APPLICATIONS

Let's consider how one of these applications can be improved through mix-minus design: a boardroom. A long boardroom table is depicted in Figure 2.

The boardroom has eight zones, each containing a microphone and a loudspeaker. The loudspeaker in Zone 1 is 3' away from the mic in Zone 1. As you move further down the table, the distance between the Zone 1 mic and the loudspeakers in the adjacent zones increases.

If all zone loudspeakers receive the same mix of all mic signals in the room, it is very likely that you'll create feedback with the microphone and loudspeaker in Zone 1 because they are in close proximity.

THE MIC IN ZONE 1 SHOULD FEED THE LOUDSPEAKERS IN EVERY OTHER ZONE EXCEPT ZONE 1.

Or, in other words, Zone 1 receives a mix of all microphones minus the Zone 1 mic. This enables all participants to hear each other clearly without feedback.

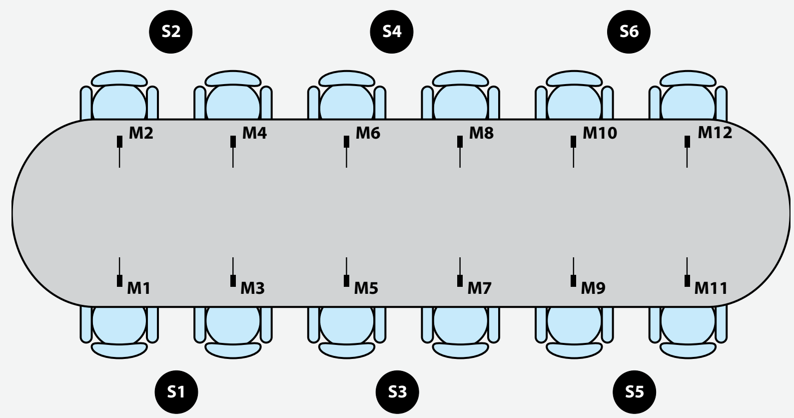


FIGURE 2. A SIX ZONE CONFIGURATION.

As conferences become larger and participants are more physically distant, the need for mix-minus increases. Understanding mix-minus design will help you take on these challenges:

- Systems are larger, spaces are bigger but participant speech still needs to be intelligible.
- Current DSP products combine auto-mixing, attenuation, and routing in a single “box.” Mastering mix-minus will allow you to take advantage of the efficiencies and convenience of these DSP solutions.
- Large spaces create special issues—both architectural and acoustical.

By understanding the physics or the “why” behind the problem mix-minus design solves, you’ll be on your way to mastering it.

A SHORT PHYSICS REFRESHER

QUICK TIP:
The inverse square law is a great place to start. However, don’t forget that conference room tables are reflective surfaces and could add about 3dB to your levels.

The inverse square law is defined as “any physical law stating that a specified physical quantity or strength is inversely proportional to the square of the distance from the source of that physical quantity.” Wait, wait don’t stop reading. In non-physics-major terms, it means the farther away you get from sound, the lower in volume it seems to be. This happens because distance affects the sound pressure level (SPL). In fact, the SPL decreases by half for every doubling of distance.

For example, if you move from a distance of 4' away from the person speaking to 8' away, the voice level will decrease by 6dB. The reverse is also true. If you move from 8' to 4', the voice level will increase by 6dB.

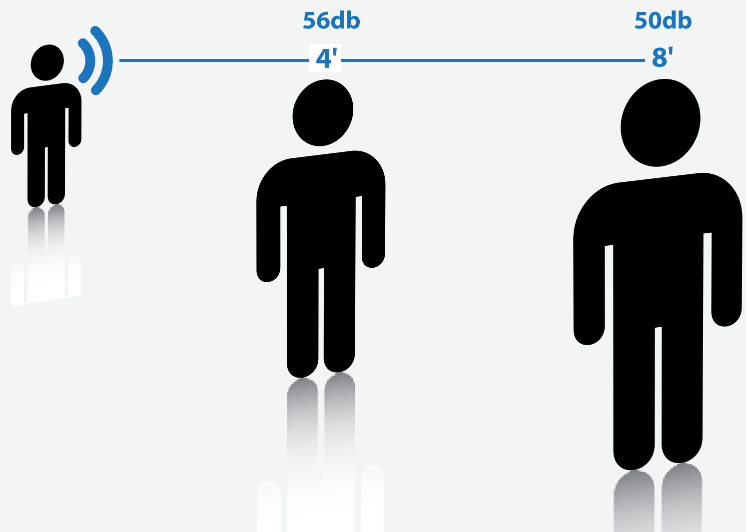


FIGURE 3: THE INVERSE SQUARE LAW MEANS THAT THE FARTHER YOU ARE FROM THE NOISE SOURCE, THE LOWER IN VOLUME IT SEEMS TO BE.

Practically speaking, the inverse square law means that without sound reinforcement, the further your seat is from the person speaking, the harder it will be to hear. And there is another problem — the bass loss problem. Not only will the sound be perceived as less loud, it will also be deficient in the bass frequencies. Without compensating for bass loss, the unlucky participants in the back row will not hear audio that sounds natural.

To offset the effects of the inverse square law, we must determine the amount of sound reinforcement required. The mathematical equation for calculating this is:

$$Snew=Sref + (20 * \text{Log}_{10} (Dref/Dnew)$$

Where: Dref = Reference Distance

Dnew = New Distance

Sref = Reference Sound Level

Snew = New Sound Level

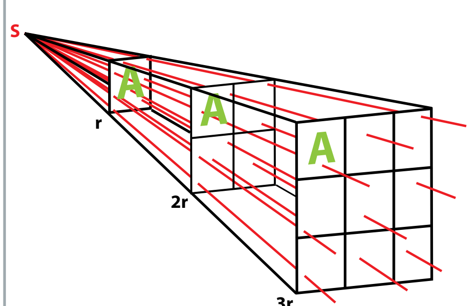


FIGURE 4. THE SOUND SIGNAL LOSES STRENGTH OVER DISTANCE – SHOWN AT 3 REFERENCE POINTS.

There are a number of mathematical formulas to help you uncover Potential Acoustic Gain, critical distance, how much gain is needed, and how much the system can produce. But if you're not a math guru—and few of us are—you can fortunately arrive at the same answers with a sound level meter. If you'd like to learn more about the formulas, check out the references at the end of this paper.

When reinforcing speech, it is important to ensure the sound from the loudspeaker arrives at the same time as the direct sound. This synchronization keeps the listener's attention on the person talking—where it should be. To learn more about delay, register for a lunch and learn training session.

FOUR BEST PRACTICES FOR MIX-MINUS SUCCESS

EXPERT ADVICE FROM MARIO J. MALTESE CTS-D, CTS-I

Designing mix-minus systems requires a strong grasp of the fundamentals such as how the system should perform, what levels talkers produce, and what listeners expect. Without understanding the fundamentals, it is hard to make the customer happy—or leave the job site.

A lot of mix-minus work can be done before arriving at the job site. Once you get the geometry of the room, you can use math to prepare the system programming. This approach is similar to how you equalize a loudspeaker. It saves you time. You'll always have to tweak the system a little because every acoustic environment is different, but using math can get you very close—within a few dB.

Mario J. Maltese is the CEO of Audio Visual Resources, Inc. He is well recognized as an AV instructor and mix-minus expert.

While there are many steps to configuring mix-minus, particularly the more complex the installation, mastering these four techniques will help you avoid the most common mix-minus issues.

1. SET PROPER GAIN STRUCTURE

Improperly configured gain structure is the number one killer of mix-minus and acoustic echo cancellation (AEC). Your goal in creating a gain structure is to get equal, balanced signals into the microphones and then out of the system. Easy, right? If we break it down, the steps to gain structure include:

- Establish ample signal strength at the first part of the signal chain (microphone). Creating consistency among all mics is the primary goal.
- Adjust input gain and check peak levels. Add just enough gain for enhanced intelligibility and comfortable conversation.
- Monitor the signal chain with meters.
- Maintain good signal strength through audio path.
- Keep the signal strong, attenuate at the end (frequently at the power amplifier).

Gain configuration requires diligence. You need to determine the level standards for your project and then adhere to them. This means every microphone will be at "X" level and every amplifier will be set to X amount. If any of them are off, it will throw your whole system off.

The starting point is to determine the level of a typical talker (person speaking) in the room and set up your mic for that level. The average level for a talker in a quiet room is 65dB when measured from the talker to the microphone, at a distance of 2.5 feet. Configure the input gain for every mic such that the input level of each while it is being spoken into at a typical volume and from a typical distance is as similar as possible. In many cases, this will require different input gain settings for different mics in the room.

For this reason, it is critical to test every mic in the system. When you design a mix-minus system, you assume that when you speak into a mic at 70 dB, it's going to come out the speaker at the desired level. If one of the settings along the chain is not the way you think it is, your assumption is wrong and so is your system.

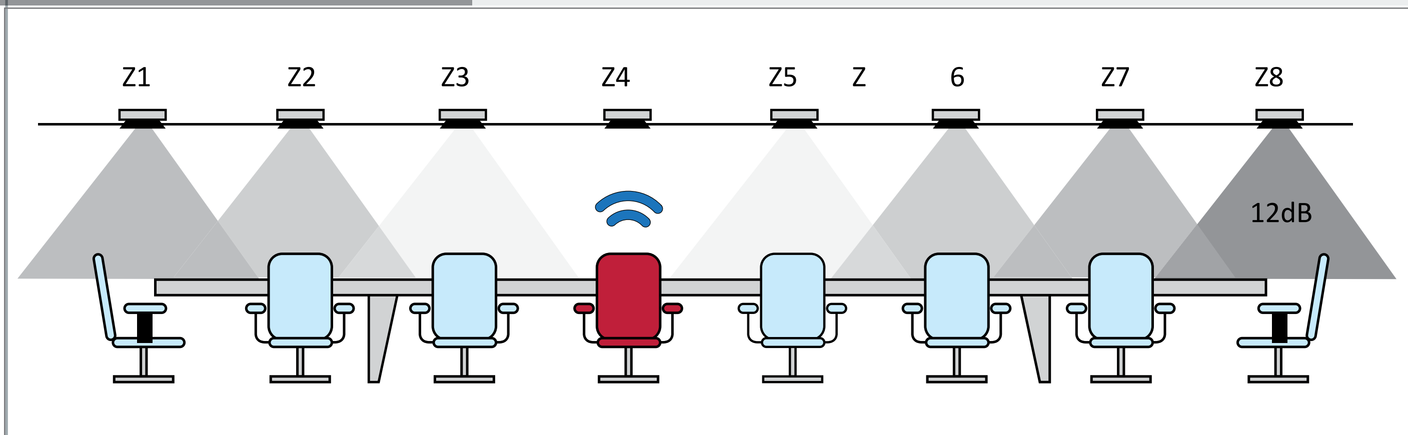


FIGURE 5: THE AMOUNT OF SOUND REINFORCEMENT REQUIRED DEPENDS ON THE DISTANCE OF THE LISTENER FROM THE TALKER. IN THIS EXAMPLE, IF THE TALKER IS IN ZONE 4, ZONE 8 WILL REQUIRE THE MOST REINFORCEMENT.

2. DETERMINE ATTENUATION FROM ZONE TO ZONE

Some systems integrators and contractors like to set up their design file prior to coming on the job site. If you know the distances between the mics, loudspeakers, and participants, you can run your mathematical equations ahead of time. This approach will get in the ballpark with your attenuation setting. However, you will still need to adjust the settings to compensate for room acoustics. Whether you decide to set up a design file beforehand or simply test from scratch is up to you. Both approaches will work.

This is where the inverse square law factors in. The normal level for someone in a quiet room is 65dB. Every doubling of distance away from that person will reduce or attenuate the sound level by 6dB. If you move from 2 feet from the talker to 16 feet away, the SPL will drop by 18dB and you'll hear the person at about 47dB.

You'll find a great reference sheet on adding decibel values at http://www.casellausa.com/en/docs/apps/cel/decibel_add_and_subtract.pdf

There are two ways to calculate this. The first way is to count how many times the distance has doubled. From 2 ft. to 4 ft. is one doubling, 4 to 8 is the second, and 8 to 16 is the third. Each doubling reduces by 6dB, so 6*3 = 18dB. The second way is to use the equation introduced above:

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Snew=Sref + (20 * Log10 (Dref/Dnew)
Snew = 65 + (20* Log10 (2/16)). Snew = 46.94dB.
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To provide the same experience the person enjoyed when standing close to the talker, you will need to compensate for the attenuation. To do this, ensure that the direct level + the amplified level = the desired level. In this case, the direct level is 47dB and the desired level is 65dB. Since the direct level is so low, it only contributes negligibly to the desired level. So, you would need the speaker to produce a full 65dB level at this listening position.

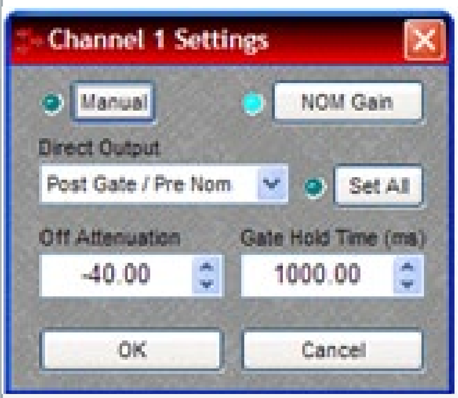
Mix-minus position 0 is the position that receives full level from the noise source without reinforcement. By using a meter or math, determine how much attenuation occurs from zone to zone. Figure 5 shows a typical attenuation pattern with our boardroom example. In this example, we lose 3dB from Zone 1 to Zone 2, 6dB from Zone 1 to Zone 3, and 12dB from Zone 1 to Zone 4.

3. COMPENSATE FOR NOM

The Number of Open Mics (NOM) is another potential pitfall for mix-minus systems. NOM is based on the fact that, for every doubling in open/live microphones (1-2-4-8), the potential for feedback increases by 3dB. NOM attenuation is a method of ensuring that the overall level (not gain) in the room is as consistent as possible.

It works by taking note of how many microphones are being used simultaneously, and reducing the overall output level such that an increase in the number of mics won't result in an increase in level. In other words, a person talking into one mic at 70dB yields a 70dB output. Two people talking into two mics at 70dB yields a 73dB output, so NOM attenuation would attenuate by 3dB to compensate. Four people talking into four mics at 70dB yields a 76dB output, so NOM attenuation would reduce the level by 6dB to compensate.

NOM attenuation is used in auto mixers in live sound applications to help control feedback by attenuating the output every time more microphones are added to the mix. However, in smaller, properly designed mix-minus systems, feedback is not an issue. In general, NOM usage needs to be limited as much as possible. Set NOM limit to about 20% of the available mics.



In mix-minus systems, the best practice is to use pre-NOM attenuation outputs on the direct out because you have already determined the attenuation for your system. By default the Audia software is set to pre-NOM attenuation on outputs.

4. PRACTICE GOOD SYSTEM DESIGN

The fundamentals of good room design are critical to a successful mix-minus system. There are two areas in particular that will have a significant impact. The first is microphones and loudspeaker placement. The second is acoustic treatments. The first rule in mic application is to get the mic as close as possible to the sound source. This means headsets are the ideal, however impractical.

General rules for mic design are:

- Avoid close coupling of microphones and loudspeakers
- Increase Echo Return Loss (ERL).
- Use microphones that minimize distance to conference participants such as a gooseneck-type.
- Avoid ceiling mics because they will typically be closer to the loudspeaker than the talker.

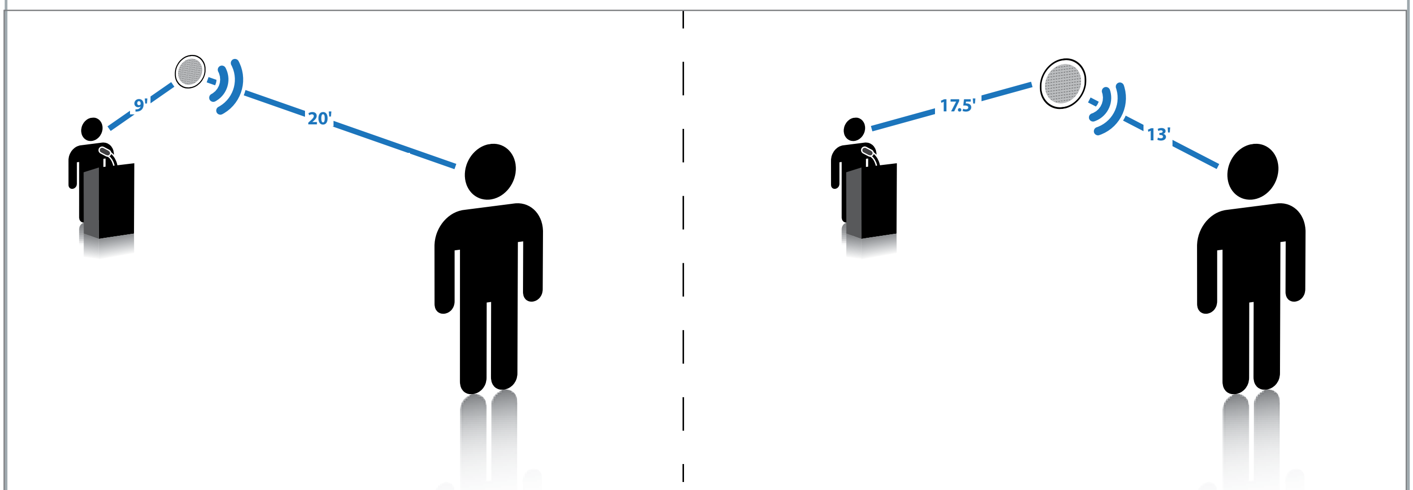


FIGURE 7A. CLOSE COUPLING OF MIC AND LOUDSPEAKER.

FIGURE 7B. IMPROVED MIC AND LOUDSPEAKER POSITIONING.

General rules for room acoustics include:

- Rooms that already yield poor intelligibility make for terrible conferencing rooms.
- Correcting an acoustical problem is best solved using acoustical treatments.
- Surfaces such as carpets, acoustic tiles, and bookshelves are good surfaces to absorb, dampen or at least attenuate acoustic echo and increase ERL. On the other hand, highly reflective surfaces (glass, bricks) will tend to reflect most of the acoustic signal and create reverberation.

A FINAL WORD ABOUT AEC

Whenever a mix-minus design includes conferencing capabilities and AEC references it adds a level of complexity. Most importantly, you will need to synchronize the level control for sound reinforcement signals with the level control to the AEC reference. Any level changes made to the sound reinforcement feed needs to be reflected to the AEC reference. Here are common issues to watch out for:

AEC MAY CAUSE ARTIFACTS IN AUDIO SIGNALS.	Choose a high quality DSP processor.
LOCAL REINFORCED AUDIO MAY CAUSE FALSE GATING OF MICROPHONES.	The safe solution is to just turn down the volume of the reinforced audio, or reduce the maximum NOM in the auto mixer. The risky solution is to add the signals from other mics to a microphone's AEC reference. You never want to send a microphone to its own references, but in some cases you can send other microphones a reference. If successful, this will result in the reinforced audio being cancelled from those inputs and no longer incorrectly gating the mics.
THE MIC IS HEARING DIFFERENT SET OF SIGNALS FROM THE SPEAKERS THAN ANOTHER MICROPHONE.	Multiple references may be required in larger spaces.
WIRELESS MICROPHONES MAY ROAM BETWEEN SPEAKER ZONES.	Mobile microphones generally cannot be integrated into mix-minus systems in a meaningful way. Avoid if possible.

REFERENCES

[i] Handbook for Sound Engineers, Glen Ballou. Focal Press, 2002.

[ii] Fxing it in the Mix - the Mix-Minus Design, Gordon Moore, CTS. INS Asia April/May 2004.

ABOUT BIAMP

Biamp Systems is a leading manufacturer of professional-quality AV systems and products. Through a worldwide network of systems integrators, distributors, and independent representative firms, Biamp delivers products that meet the audio requirements for a range of applications, including corporate boardrooms, conference centers, performing-arts venues, courtrooms, educational campuses, hospitals, stadiums and recreational facilities.

Biamp is headquartered in Beaverton, Oregon (USA), its base of operation for more than 30 years. The company's innovation is reflected in systems that provide the greatest efficiencies to customers, and unmatched performance and cost savings to end users.

NEXT STEPS

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Clinton Muntean
321-253-2030
cmuntean@mainlinemarketing.com

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To continue learning about mix-minus, join us at a lunch and learn. We'll dive deeper into mix-minus with examples, a discussion of how to make mix-minus work for you, and how to refine the system. Register now.

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