Measuring Acoustic Decibel Levels in Worship Services

With Economical SPL Meters

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Background

Economical SPL (Sound Pressure Level) meters of good quality are readily available, and can be useful for churches that want to establish loudness guidelines in their worship services.

The CM-130 SPL meter by Galaxy Audio is an example. With meters such as this, we have an economical means for measuring acoustic decibel levels during worship services. The CM-130 offers good accuracy & resolution, as well as wide dynamic range (e.g. one of the ranges is 80 to 110 dB, which works very well for our purposes, avoiding the need to constantly change the scale setting). The next step-up offered by Galaxy Audio is the CM-140 SPL meter, which provides better accuracy, wider frequency response, ANSI Type II performance, and other improved characteristics.[(1)] Although it has a higher price, the CM-140 cost is still reasonable for many church budgets. (At the time of this writing, the CM-130 has a street price of approximately $50 to $70, and the CM-140 typical price is $100, with a $10 optional case available for either, and shipping may be extra if ordered on-line). Either meter gives us a good tool for measuring sound levels.

The Radio Shack SPL meter is also widely used, and typically serves well, although I prefer the Galaxy Audio meters because of their wider dynamic range. (The digital-display model from Radio Shack sells for approximately $50 at the time of this writing.) Other manufacturers also offer economical models, but the Galaxy Audio & Radio Shack models are widely available. Another possibility that has come to my attention recently is an economical unit by American Recorder, model SPL-8810.

Whichever meter is selected, user questions typically arise: what settings are best when using this meter, and what guidelines for sound levels are reasonable?

The settings listed below are specific in some respects to the Galaxy Audio CM-130 meter, but the same general concepts can be extended to a variety of other SPL meters, including more expensive models and other brands.

Settings

For the Galaxy Audio CM-130 SPL Meter - (settings for other meters may vary slightly)
- Scale: 80 – 110 dB
- Weighting: C
- Time Response: Slow

Positioning the Meter – Quick Start

Position the meter so that you can quickly see the readout, hands-free, from time to time as needed during the service or event. Point the meter's microphone slightly upward and toward the sound source. It is best to mount the meter on a microphone stand or desk-top tripod, to keep it positioned away from surfaces and people.

More on Meter Positioning – Details, Details

Skip this section if you don't need, or don't want, this level of detail.

On the subject of meter (SLM) positioning, one author, Tom Young, writes the following: [(2)]
"Keep the SLM at arm's length, aimed in the direction of the sound source(s) and positioned away from room boundaries. (BTW- The mixing surface on a large (40-plus channel) mixing console will effect SPL measurement when the SLM is laid down on the mixing surface or angled against the meter bridge.)"

Yes, the boundary surface of the mixing console, or other surfaces on which the meter might be placed, will affect the measurements. However, if the meter is propped so that its microphone points away from the surface, and slightly upward toward the sound source, then the results are usually workable for purposes of comparative measurements when trying to set consistent levels. Many live sound engineers set their meter on the mixing console, propped up on the meter bridge, and I think most will tell you that they find the readings are affected only slightly by this practice. Even so, it should be remembered that these measurements are best treated as relative only, are not necessarily highly accurate, and are mainly useful only for comparing against measurements made with the meter positioned in exactly the same manner, and under the same circumstances. For the best accuracy, an appropriate meter stand should be used, as described.

Some technical literature advises that, for best accuracy, the meter might need to be positioned other than pointed directly at the source, because of angle-of-incidence response characteristics with some meter microphones, or other similar issues. [(2) (3)] Another consideration that applies to handheld meters is that possibly better accuracy is obtained by standing off to one side of the meter rather than in back of the meter (i.e. don't stand with your body directly behind the meter), to minimize the impact of your body on the measurement. [(4)] However, these fine points are often not carefully observed by live sound engineers, and the impact on the results is usually small for purposes of comparative measurements. Even so, when best accuracy is desired, it is advisable to consider such factors. As a minimum, always hold the meter away from your body, at arms length, when making handheld measurements, and consider the meter manufacturer's instructions concerning orientation of the measurement microphone toward the sound source. [(5)] For the Galaxy Audio CM meters, at the time of this writing, the manufacturer instructs the user to point the microphone at the sound source. [(6)] This indicates that it utilizes a "Free Field" microphone type. [(2)]

Suggested Levels

Based on my own experience, I list the following guidelines for those who prefer louder levels of worship music, but want a quantitative basis with which to set some reasonable boundaries and consistent levels:

Loud, energetic worship peaks	**	95 - 100 dBC
Sustained* energetic worship		90 - 95 dBC
Normal music level, for a few minutes		80 - 90 dBC

(* Sustained = several seconds to tens of seconds at a time)
(** I currently use a peak limit of 95 dBC during services at my home church, with occasional peaks to 96 or 97 dBC. This is a large metropolitan church with seating for 3,000, and with a broad mix of various age groups, including youth, young families, and middle-aged through elderly. The music tends to be mainly contemporary in style.)

Note: if your church prefers lower volume and more traditional or liturgical music styles, then you may need to scale down from the loudness levels listed above, even as an initial reference point.

Use these suggested levels (or your own scaled-down version) as a starting point for your own investigation, and then determine what levels are satisfactory to the greatest share of your regular audience. An acceptable level usually is established at a point where some would prefer it a little quieter, while some would like it a little louder, but preferably no one finds the level uncomfortable or annoying. With this said, you and your church leadership need to recognize that some churches are going to be "loud", or more energetic and contemporary, and others are going to be more moderate and traditional (by church standards). Both categories, and variations in between, are going to have their followings. You need to understand where you fit in this spectrum, and how it affects the sound levels you choose to target. After choosing the target, it falls to the sound technician to run consistently at the targeted sound levels.

It must be considered that system equalization settings (EQ) have a significant impact on what loudness levels sound pleasing. For example, bright EQ settings in the upper frequencies, or more prominent upper mid-range, may provide advantages in the judgment of some practitioners at moderate volume levels, but may produce harshness or other problems at the levels suggested above. In addition, overly-emphasized bass is often not desirable at louder volume levels in a large room. (Energetic bass levels perhaps, but don't overdo it.) It is advisable to have the system EQ set professionally for your specific situation, before establishing loudness guidelines. If your system EQ controls are user-accessible, make sure the professional settings are written down, or saved to electronic memory if the EQ/processor is digital, so that these settings can be recovered in cases where a guest operator makes changes. In addition, you need to make sure input channel EQ controls are reasonably set, by a proven specialist, when you establish loudness guidelines.

Interpreting the Meter Readings

With music or speech, the meter readings will vary continually. So how do you interpret these readings?

The sound technician must develop the ability to dissect what he/she is reading on the meter, based on how long the sound level is occurring. Dissecting readings into the 3 categories of sound levels that I listed above (loud energetic peak, sustained level for seconds, normal level for minutes) is one such approach. With practice and experience, the technician must be able to quickly understand what they are seeing on the meter, and mentally break it down into terms such as these. This is an acquired, but necessary skill in order to properly use an SPL meter for the purpose of consistently setting sound levels for worship services.

Weighting Considerations – A vs. C

For Noise Exposure Limits, OSHA specifies A-weighting for SPL measurements. However, for trying to achieve consistency in setting music levels that vary significantly in tonal content, I recommend using C-weighting. This weighting determines the frequency response of the meter. A-weighting provides a narrower response (although slightly more pronounced on the high end), while C-weighting provides a much wider response, especially on the low frequency end. The curves are complex, but basically A-weighting has a +/-3 dB response of 500 Hz to 12 kHz, and drops off very steeply below 500 Hz. On the other hand, C-weighting has a +/-3 dB response of 32 Hz to 8 kHz, but is still within -9 dB at 16 kHz. See the associated diagram below for these response curves. (Note: The CM-130 has a maximum frequency bandwidth, for +/-3 dB, of 125Hz to 8 kHz, no matter what weighting you select. See the slightly more expensive model, CM-140, for frequency response down to 32 Hz, as well as improved resolution and accuracy, and extended dynamic range.)

I use C weighting because it incorporates a wider frequency response, which includes the lower frequencies that are normally reproduced aggressively in modern sound reinforcement systems. C-weighted measurements will typically read higher than A-weighted for wideband music sources. It's not uncommon

for 85 dBA to measure as 90 to 95 dBC with high energy music sources (depending on the frequency content of the source). Using A-weighting disregards, to a large extent, the low frequency content. Therefore, the sound pressure level of the low end may be dramatically different from one instance to another, but the difference is not reflected in the A-weighted meter reading. This makes it difficult to achieve consistency in setting sound levels for music in worship spaces when using the A-weighted setting. (For a different perspective on this matter, see the article by Tom Young, who writes that an A-weighted curve with slow response is "most frequently used for measurement of pop music SPL's." [(2)] If you do use the A-weighted setting, you will need to scale down accordingly from my suggested guidelines listed above.)

If you are measuring SPL for purposes of checking against exposure limits with regards to hearing-safety purposes, then clearly you should use A-weighting. This allows you to compare your measured results against standard tables, such as the Permissible Noise Exposure values specified by OSHA (See below for the OSHA table, and for further discussion on hearing safety.) However, if you are trying to achieve consistent sound levels for music during worship services, then I recommend using C-weighting because of the low-frequency response, as I've described.

Hearing-Safety vs. Loudness Preference

Concerning hearing conservation & safety, I submit that my suggested guidelines above (even without taking into account the difference in weighting, which provides further margin of safety) clearly comply with the OSHA standard (see associated table further below), and also with the more conservative NISOH recommended exposure limits, in particular:

From NIOSH (only a subset of the specified values is listed here) - [(7)]
85 dBA for 8 hours
90 dBA for 2.5 hours
95 dBA for 47 minutes
100 dBA for 15 minutes

It is commonly encountered that people don't clearly understand that hearing-safety is related to both the sound level (i.e. dBA level) and duration (i.e. time) of hearing exposure. The 85 dBA limit, taken from NIOSH & OSHA, and cited by many when discussing or writing about hearing safety, is an 8-hour, continuous duration condition. It does ***not*** follow that 85 dBA is the maximum impulsive or short-duration exposure limit! People who wish to discuss the matter of music sound level vs. hearing safety on a well-informed basis need to make sure they correctly handle this aspect.

Some people may express concerns about hearing safety when experiencing sound levels within the guidelines that I've suggested. Of course, hearing sensitivity varies widely, and it is almost certain that a few people will have hearing discomfort even at levels that comply with the most conservative accepted standards. (In such cases, it might be advisable for them to wear hearing protection regularly, because there are many situations in routine daily life that expose us to sound levels that reach or surpass these guidelines.) However, when operating within my suggested guidelines listed above, this should not present a hearing-safety question for the large majority of people. When the issue of hearing-safety is brought into question, it is best to record your readings with A-weighting, so they can be referenced to the OSHA standard. (Remember, use A-weighting for exposure measurements, C-weighting for music-level consistency measurements.)

Typically when someone complains about the suggested levels that I've listed, their reaction is stirred from a strong preference of music style, not an actual hearing-safety problem, even though they may express it as a hearing-safety issue. This doesn't dismiss their reaction, because it may well be important to your church leadership when considering the breadth of style for worship that you are trying to achieve, and the audience

satisfaction that you seek in trying to minister to people. Even so, I think it's important to recognize that the suggested levels I've listed are not irresponsible with regards to hearing-safety.

My purpose is not to defend poorly designed and poorly operated sound systems, or rooms with bad acoustics, all of which often sound bad at moderate volumes and worse at higher volumes, or rock-concert volumes that actually do pose a real threat to hearing safety. Nor is my intention to discount those who strongly prefer lower volumes or different styles of music. It's no easy task for the Church to accommodate the wide range of musical tastes and cultural perspectives that exist in our society today. I have one taste in music, you may have another, and neither may be right or wrong. In the midst of this, when trying to reach workable guidelines in a specific case, let's focus on the real goals, and avoid bringing inaccurate information about hearing safety to the discussion.

With that said, musicians within a worship team that leads contemporary music services may well be at risk for hearing loss problems, since they are much closer to amplified instruments and loud drum kits. In fact, even musicians in a more traditional church, such as an organist or a brass player, may be at risk. They should be aware of this risk and take suitable precautions. This subject is outside the main scope of this paper, but it is addressed well by Marshall Chasin in his book on the matter. **(8)** Various products to help musicians with this issue are available from Westone Laboratories, Inc., including those based on custom ear-mold technology. **(9)**

Conclusion

With appropriate knowledge & practice, economical SPL meters can be used to achieve better consistency in setting satisfactory sound levels for worship services. It is my hope that the thoughts written above will prove helpful toward this goal.

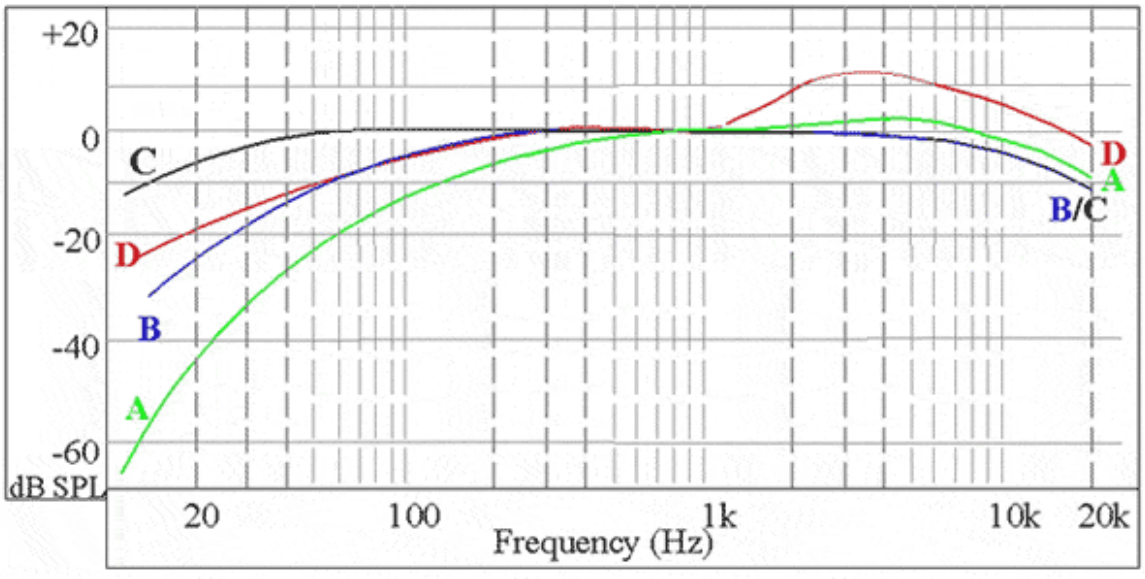

Figure 1: Standard Response Curves for SPL Weighting [10]

(Note: A specific meter model may be more limited on the high or low frequency ends; see meter specifications for more details.)

Table: OSHA Standard Values [11]

The following chart, OSHA Table G-16, is taken from OSHA Standard 1910.95, "Occupational Noise Exposure":

TABLE G-16 - PERMISSIBLE NOISE EXPOSURES (1)

Duration per day, hours	Sound level dBA slow response
8	90
6	92
4	95
3	97
2	100
1 1/2	102
1	105
1/2	110
1/4 or less	115

Footnote(1) When the daily noise exposure is composed of two or more periods of noise exposure of different levels, their combined effect should be considered, rather than the individual effect of each. If the sum of the following fractions: C(1)/T(1) + C(2)/T(2) C(n)/T(n) exceeds unity, then, the mixed exposure should be considered to exceed the limit value. Cn indicates the total time of exposure at a specified noise level, and Tn indicates the total time of exposure permitted at that level. Exposure to impulsive or impact noise should not exceed 140 dB peak sound pressure level.

Supplemental Information (to OSHA Table G-16): OSHA Standard Values

In addition to the "Permissible Noise Exposures" specified in OSHA Table G-16, it is important to understand that OSHA also specifies that an 8-hour time-weighted average sound level of 85 dBA or higher is cause for concern, and employers must take appropriate measures when conditions exist that expose workers to such levels. **(12)** Note that this 8-hours/85dBA OSHA "action level" coincides with the NIOSH recommendation, listed earlier in this paper, for an 8-hour exposure limit.

Technical References / Acknowledgements

(1) Galaxy Audio, Data Sheet: **Check Mate SPL Meters.** (2 pages)
http://www.galaxyaudio.com/products/PDF2/CMsCUTSHEET.pdf

(2) Young, Tom, "The Primer: Sound Level Meters (SLM's)"; On-line article (same article from which standard response curves are taken), at the following URL:
http://www.prosoundweb.com/studyhall/lastudyhall/slm/slm.shtml

(3) Peterson, Arnold P.G. and Gross, Ervin E. Jr., **Handbook of Noise Measurement - 7th Edition.** General Radio Company, 1972, Concord, MA. Pages 173 – 176, sections titled, "Direction of Arrival of Sound at the Microphone", and "Position of Microphone."

(4) Peterson, Arnold P.G. and Gross, Ervin E. Jr., **Handbook of Noise Measurement - 7th Edition.** General Radio Company, 1972, Concord, MA. Pages 177 – 178, section titled, "Effects of Room and Nearby Objects".

(5) U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention (CDC), National Institute for Occupational Safety and Health (NIOSH); "Criteria For A Recommended Standard, Occupational Noise Exposure, Revised Criteria 1998"; Chapter 4, section 4.1.3, titled "Microphones for Sound Level Meters."
http://www.cdc.gov/niosh/docs/98-126/pdfs/98-126b.pdf

(6) Galaxy Audio, **Instruction Manual. Check Mate SPL Meter CM-130.** (8 pages)
http://www.galaxyaudio.com/products/Pdf/CM130OperationManual.pdf

(7) U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention (CDC), National Institute for Occupational Safety and Health (NIOSH); "Criteria For A Recommended Standard, Occupational Noise Exposure, Revised Criteria 1998"; Chapter 1, titled "Recommendations for a Noise Standard."
http://www.cdc.gov/niosh/docs/98-126/pdfs/98-126a.pdf

(8) Marshall Chasin (Audiologist), **Hear The Music – Hearing Loss Prevention for Musicians**, (2001); 88 pages; Paperback; ISBN # 0-920445-74-8; see the following for more details:
http://www.amphl.org/articles/bookreview3.html

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http://www.westone.com/music/

(10) Young, Tom, "The Primer: Sound Level Meters (SLM's)"; On-line article; Standard Response Curves are taken from the following:
http://www.prosoundweb.com/studyhall/lastudyhall/slm/slm_3.shtml

(11) U.S. Department of Labor, OSHA, Occupational noise exposure. - 1910.95(b)(2), Table G-16
http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9735&p_text_version=FALSE

(12) U.S. Department of Labor, OSHA, Occupational noise exposure. - 1910.95(c)(1) & 1910.95(c)(2)
http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9735&p_text_version=FALSE

(13) "How Loud is your Church", on-line article by Leon Sievers:
http://www.experiencingworship.com/articles/sound/2001-9-How-Loud-is.html
(This author does not agree with a number of Sievers' perspectives on the subject, but others may be interested in his thoughts as they consider their own individual situation.)