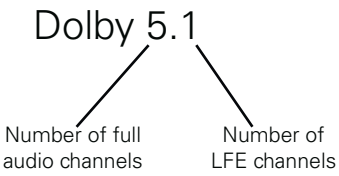
Surround Sound
in Home Cinemas



Home cinema installations commonly include a Dolby or DTS surround sound system. For example a Dolby 5.1 system describes the configuration with 5 full audio channels (left, center, right, left surround, right surround) and one LFE (Low Frequency Effects) channel. The LFE channel originates from the cinema world with its rumbling bomb explosions and dinosaur stomps. These special sound effects are generated by a sub woofer covering the frequency range 20 Hz - 120 Hz.

Follow these guidelines to optimize the surround sound performance of a home cinema installation.

Exel Line: Digirator DR2 with XL2 Audio and Acoustic Analyzer

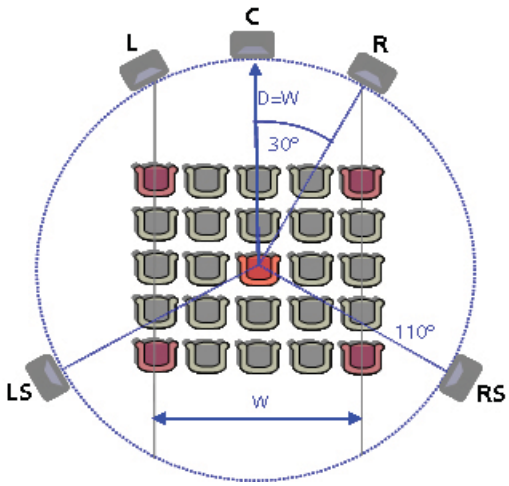
1. Tips on Room Design for a Home Cinema

Listeners enjoy best sound performance from the direct speaker sound. Any additional reflections from walls, floor or ceilings can deteriorate the surround sound image and even influence the perception of direction of the sound source. The basic guideline for the architectural room design is to follow the common cinema approach:

- The side walls should not be parallel, they should widen from the front to the rear. This design leads any sound reflections from the side wall directly to the rear wall.
- Sound absorbing treatment on the rear wall
- The ceiling should not be parallel to the floor
- Carpets on the floor, curtains on the walls
- Prevent any hard, solid reflecting materials, such as glass
- Seating areas should be made with cushioned seats instead of hard wooden chairs
- Reverberative response of the room. An average-sized home cinema should typically have an RT60 time between 0.3 and 0.6 seconds.
- Background noise level. Recommended Noise Curve level NC 30-35

2. Tips on Speaker Positioning for a Home Cinema

Align the speakers along the perimeter of a circle centered on the main seating position (the golden seat). In case of space restrictions, for best sound performance the speaker arrangement should be as close as possible to the circle alignment.



Dolby 5.1 Layout

The Center channel speaker (C) is the most important speaker as it produces 80% of what we hear, which is dialog, and should therefore be anchored above or below the screen.

Left (L) and Right (R) produce musical swells or things moving off and onto the screen.

The optimal speaker height is slightly above the listener's ears, i.e. 130-140 cm.

The LFE sub woofer positioning need not be within line-of-sight of the audience as bass sound is non-directional. However the LFE positioning is important with respect to the Room Modes (see later in this document). Commonly the LFE is situated on the floor near the center speaker.

3. The Tools and Measurement Positions

Exel Surround Sound Set

Requirements:

- Digirator DR2 with extended file set (from the DVD)
- XL2 Audio and Acoustic Analyzer
- M2211 or M2230 Measurement Microphone
- Microphone stand
- XLR audio cable

Some surround systems complete a basic commissioning process automatically. The resulting sound performance is based on default settings. This guideline allows you to customized settings to suit your personal perception of sound quality.

Home Cinema Test Configuration

Measurements may be taken at the golden seat and repeated at the four corner seating positions.

The NTi Audio Digirator DR2 generates digital surround sound test sequences for verification and adjustment of professional Dolby and DTS installations.

The XL2 Audio and Acoustic Analyzer in combination with the M2211 or M2230 measurement microphone measures the acoustic output.

All data captured by the XL2 may be documented on your PC for backup and later verification.

4. Overview of the Recommended Tests

The recommended tests for a home cinema installation

System

- Presence
  a quick check to establish that sound is present at each speaker at a reasonable sound pressure level.
- Polarity
  ensure that all speakers have the correct polarity.
- Gain Structure
  optimize the signal level throughout the entire signal chain.

Room

- RT60
  determine if the room may need more absorption treatment or reflection redirection.
- Noise Curves
  determine if external sound sources (e.g. room's ventilation system) can be reduced or removed, or if the room may need to be more insulated (e.g. from street traffic).
- Room Modes
  discover resonances (particularly at low frequencies).

Quality

- Delays
  sound should arrive at the golden seat from all directions at the same time.
- Frequency

  Measure

  the Average Frequency Response for the room. Mea sure the frequency response at several points and get an average picture of the room.

  or

  at the Golden Seat. Mmeasure the frequency response at the golden seat position.

  Adjust

  the equalization to smooth the frequency response according to the X-Curve. Measure again.

  Verify

  that the shape of the spectrum at each audience member's listening position contains no significant deviations from the X-Curve.
- Levels
  all speakers should provide appropriate sound pressure level.

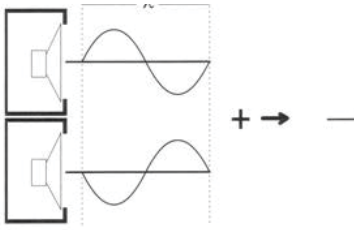
5. How to Use the Tools

Presence

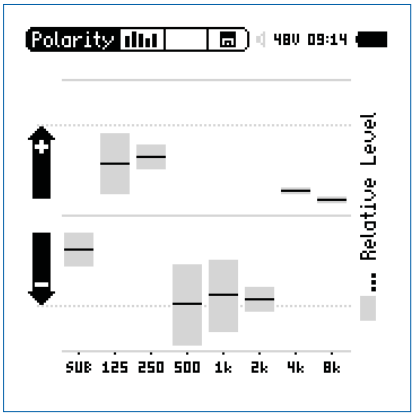
Check that all channels are connected and set at the typical listening level.

- Connect the Digirator to a system input and select
  DLBY -> D_51 ->
  Ch_i_l (identification for left channel),
  Ch_i_ c (center),
  Ch_i_ r (right),
  Ch_i_ rs (right surround),
  Ch_i_ ls (left surround),
  Ch_i_ lfe (lfe),
  consecutively.
- Sit in the golden seat and listen.
- Adjust the gain for each speaker as necessary.

Polarity



Opposite polarity results in cancellations



XL2 Polarity Details Screen with polarity frequency pattern

The polarity test verifies the correct cable and speaker polarity. Incorrect polarity may result in a completely wrong stereo image and cancel out some frequency ranges.

- Digirator: Select DLBY -> D_51 -> Pola_all
- XL2: Select Polarity -> Signal Source -> XLR Input
- With the measurement microphone connected directly to the XL2 Audio and Acoustic Analyzer, position the microphone 10 to 20 cm in front of the left speaker, pointing at the center of the speaker cone.
- Measure the polarity of each speaker, saving a screenshot of the XL2 Polarity Details screen for each.

It is a fallacy to assume that all speakers should have positive polarity as some loudspeaker manufacturers intentionally design speakers with negative polarity for better sound performance. Rather, speakers of the same model should have the same polarity frequency pattern.

If the polarity measurements are not correct, verify that the measurement microphone is consistently positioned relative to each speaker during the test, then invert the speaker cabling and measure gain.

Gain Structure

Review the entire signal chain and ensure that the gain structure is optimally configured so as not to unnecessarily decrease the signal-to-noise ratio or introduce clipping. Try to run all components at unity gain*. If you need to interrupt the signal chain to measure, use the XL2 RMS/THD function.

- Digirator: Select DLBY -> D_51 -> Sine_1k
- XL2: Select RMS/THD+N
- Connect the audio line at the desired measurement point directly to the XL2 Audio and Acoustic Analyzer.

* Unity gain (also known as “0 dB”) is where both input and output are at the same voltage level.

RT60 (Reverberation Time)

To measure RT60 you need to inject Pink Noise at 35 dB above the noise floor in all of 8 frequency bands. It is best to utilize an omni-source such as a dodec. We will measure at each of the five seating positions to obtain an average RT60 result for the room and measure at least three times at each position.

On the XL2 select RT60. With a quiet room, press the SET function to measure the room noise floor.

Digirator: Select DLBY -> D_51 -> Pnoise

Now use ear protection.

Play the Pink Noise and turn up the system volume until the black bars cover the grey bars. (You may want to boost the LFE).

Press the PLAY button on the XL2.

Allow the Pink Noise to play for 5 seconds and then mute the Digirator. The black bars decrease and the AVRG number increases by 1. Play the Pink Noise again for 5 seconds.

Repeat to measure at least 3 cycles, then press the STOP button on the XL2.

To see the results, press the Page button.

Measure again with the mic at the next seating position.

For tips on measuring RT60, see Appendix A

Noise Curves

Noise Criterion (US) and Noise Rating Curves (Europe) define the limits of octave band spectra for background noise that meet the design requirements of your home cinema installation.

Background noise can be caused, for example, by the room's ventilation system or automobile traffic in a nearby street.

For a home cinema, the recommended level is NC 30-35 or NR 35-40.

We will measure at each of the five seating positions. To measure, connect the measurement microphone to the XL2 Audio and Acoustic Analyzer.

Ensure that the room is quiet.

On the XL2, select "Noise Curves" from the Main Menu.

Choose your required Noise Curve Type and Standard.

Press the Play button to measure.

After 30 seconds, stop and save the measurement result.

Save also a screenshot of each result.

Measure again with the mic at the next seating position.

Drop _Report.txt file into MS Excel and insert screenshot too.

Room Modes

Resonance is the tendency of the air or items in the cinema room to oscillate with greater amplitude at some frequencies than at others.

Room modes are the collection of resonances that exist in a room.

The input of acoustic energy to the room at the modal frequencies causes standing waves. These standing waves result in the loudness of the particular resonant frequency being different at different locations of the room.

An acoustic resonance usually occurs at more than one resonance frequency; especially at harmonics of the strongest resonance.

Excessive resonance can have a negative effect on the quality of the system, so it's a good idea to get a feel for the resonances in the room before you tune your system.

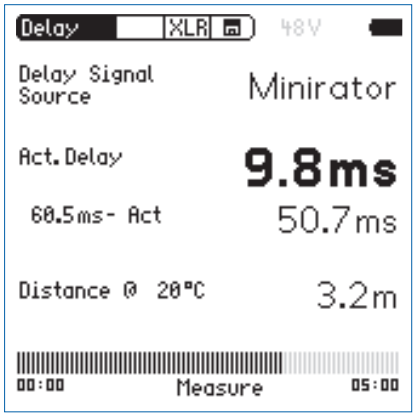
To test for excessive resonance, the room should be injected with energy at each frequency. It is usually sufficient to examine within the frequency range 20 Hz to 300 Hz. Play a 5-second chirp between these frequencies. Walk around the room and you will hear

the resonant frequencies. Also during this test you determine that there are no audible rattles or buzzes caused by mechanical installations in the room.

TIP: The frequency bands with the longest RT60 times may indicate where to find resonant frequencies.

A cure may be as simple as re-positioning the LFE speaker, or you may need to add absorbent material to the room to damp such resonances.

Equalization of the sound system to compensate for the uneven frequency response caused by room resonances is of very limited use as the equalization only works for one specific listening position and will actually cause the response to be worse in other listening positions.



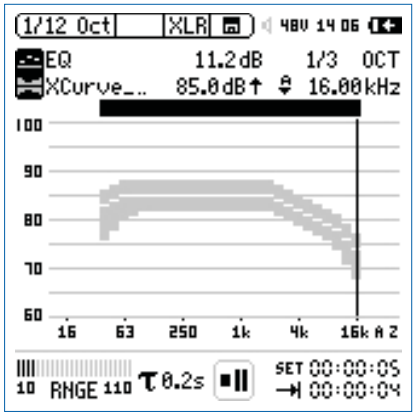
XL2 Screenshot Delay

Delays

The sound from all surround sound speakers should arrive at the same time at the golden seat. To achieve this, signals will have to be delayed for those speakers that are physically located closer to the golden seat.

- MR-PRO: Select DELAY (delay test signal)
- XL2: Select Delay measurement function
- Connect the MR-PRO to the XL2 with an XLR cable to synchronize the clocks of the two devices.
- Now connect the MR-PRO to an analog input of the system, and play the delay signal consecutively through each speaker.
- Measure with the XL2 at the golden seat position and adjust the delay time for each speaker appropriately.

Note: Do not connect the measurement microphone to the XL2 as the internal Voice Note microphone is used during this test.



XL2 Test "TemplateHomeCinema"

Frequency

The next quality test is to shape the frequencies of the sound.

The frequency response differs at every seating position. In order to enhance the quality of sound for all seating positions you should optimize the shape of the frequency spectrum while ensuring that each audience member's listening experience contains no significant frequency peaks or troughs. You then average these measurements to get an overall picture of the room.

- XL2: Select 1/12 Oct function -> Load Test "TemplateHomeCinema" (1/3 OCT resolution, EQ value, single mode, SET 00:00:20, XCurve_SMPTE202M tolerance)

- Digirator: Select DLBY -> D_51 -> Pnoise_l (pink noise signal at left channel)
- Connect the microphone to the XL2 Audio and Acoustic Analyzer using an XLR cable.
- Consecutively position the measurement microphone at each of the seating positions; the golden seat, front-left, front-right, back-left and back-right, using a microphone stand to set the microphone to the typical height of the listener's head. i.e. 130-140 cm, and pointing the mic in the direction of the speaker from where the sound is being produced.

At each position,

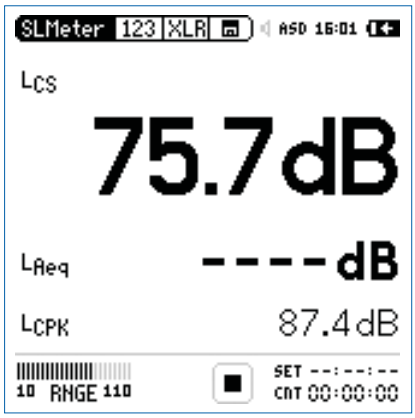
- Stand away from the microphone so as not to influence the results by you absorbing or reflecting sound.
- Press the play button on the XL2. The equivalent (EQ) frequency response will now be measured. The measurement will stop automatically after 20 seconds.
- If the limit light is red at the end of the measurement, adjust the equalization of the system to smooth the frequency response to within the tolerance band and remove peaks and troughs*. Start measuring again from the first position.

  OTHERWISE
- Capture EQ and store it with an appropriate name, such as Gold for the golden seat, FrLf for front-left, FrRt for front-right, BkLf for back-left and BkRt for back-right.

- Calculate the Mean value and display it.
- Save Test with an appropriate name, such as Speaker_Left_Tol, for later retrieval of the Mean value and the tolerance data to your PC.
- Exit tolerance mode and Save Test again with an appropriate name, such as Speaker_Left_Data, for later retrieval of the measurement data at each seat position to your PC.
- Repeat the entire process for each of the other 4 speakers.
- Connect your XL2 to your PC, open the plain text files that were saved (\Projects\MyProject) and paste the data into a report. e.g. "NTi Audio XL2 Frequency Report.xlt".

*** A note on equalization**: Equalization of the sound system to compensate for the uneven frequency response caused by room resonances is of very limited use as the equalization only works for one specific listening position and will actually cause the response to be worse in other listening positions.

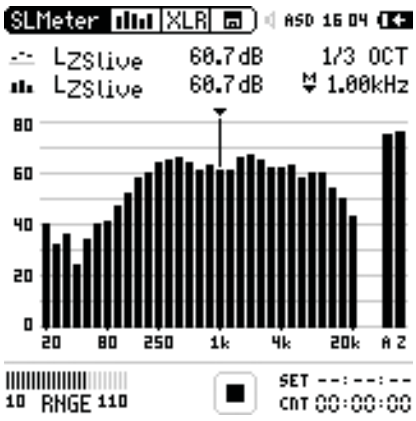
Levels



XL2 Screenshot Sound Level Meter

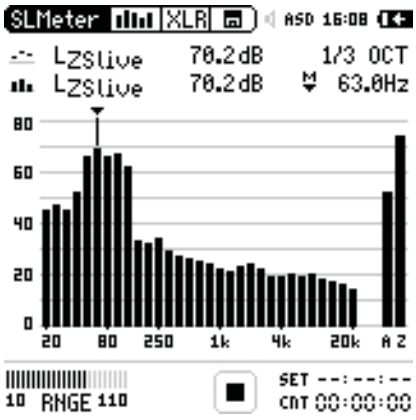
All speakers should provide the required sound pressure level measured at the golden seat.

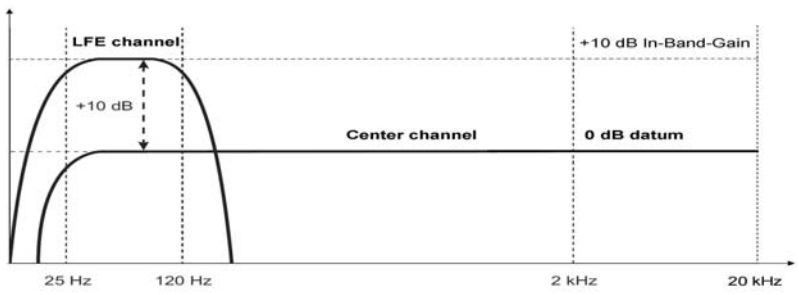
- Connect the measurement microphone to the XL2 Audio and Acoustic Analyzer using an XLR cable.
- Position the microphone at the golden seat, using a microphone stand to set the microphone to the typical height of the listener's head. i.e. 130-140 cm
- XL2: Select SLMeter, 123, L_{CS}.
- Connect the Digirator to a system input and select
  DLBY -> D_51 ->
  Pnoise_l (pink noise signal at left channel),
  Pnoise_c (center), Pnoise_r (right),
  Pnoise_rs (right surround), Pnoise_ls (left surround),
  consecutively.
- Measure. If you do not get a stable result, increase the overall sound pressure level. Adjust the sound pressure level of each speaker to the required relative level.
- Note the typical L_{ZS} sound pressure level at 1 kHz displayed in the RTA mode. This reading is required for the LFE level setting.



The LFE channel is tailored for the rumbling bomb explosions and dinosaur stomps. The LFE sound pressure level shall be about 10 dB higher than the surround level within the typical LFE frequency range 20 Hz - 120 Hz.

- Digirator: Select DLBY -> D_51 -> Pnoi_lfe (pink noise signal at LFE channel)
- XL2: Select the SLMeter, RTA Mode, 1/3 oct., L_{ZS}
- Measure the sound pressure level of the LFE sub woofer in the lower frequency bands 20Hz - 120Hz. The setting should be about 10 dB higher than the reading at 1 kHz of the full audio channels.





Level alignment of LFE and surround sound speakers

Appendix A

Tips on measuring RT60

Use ear protection during the RT60 measurements.

The pink noise used to generate the signal for the RT60 measurement must be at least 35 dB above the noise floor in each frequency band. To achieve this, it is often necessary to boost the lower band frequencies with equalization or by turning up the amplifiers to the LFE speakers.

Within each cyclic RT60 measurement it is necessary to saturate the room with as much sound energy as possible within each frequency band. This "saturation" occurs when a sound is played for a continuous period and that sound has "had enough time to reflect on all possible surfaces". The RT60 value for the room is a good indication of the time required for this saturation to occur. Thus for the pink noise we choose a cycle time of at least the RT60 value of the room.

What is the Correlation Percentage?

After the pink noise is turned off, the XL2 starts to measure the time taken for the energy in each frequency band to decay. It may be the case that sound in the environment does not decay in a linear manner. This is indicated by a low correlation percentage. For example, the room may consist of more than one area of different sizes, or a door may be open, or objects in the room may rattle at certain resonant frequencies and sound pressure levels, or the background noise may be sporadic. All these may interfere with the linearity of the decay during the RT60 reading giving you either an incorrect RT60 value or no value at all. Some such inconsistencies, such as the room consisting of more than one area of different sizes, may not be fixed. Others may be fixed. For example, if you can not completely remove the background noise (traffic noise from outside), then measure many RT60 cycles and delete the outlying cycles.

What is the Uncertainty Percentage?

Pink Noise is by nature a fluctuating signal. Over a longer period of time, Pink Noise contains all frequencies. Over a short period, certain (particularly low) frequencies are not always present. The possibility of the absence of such frequencies is indicated by the uncertainty percentage. Uncertainty is thus higher at lower frequencies and with shorter RT60 values. To reduce this uncertainty we measure at least 3 times at each measurement position.

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