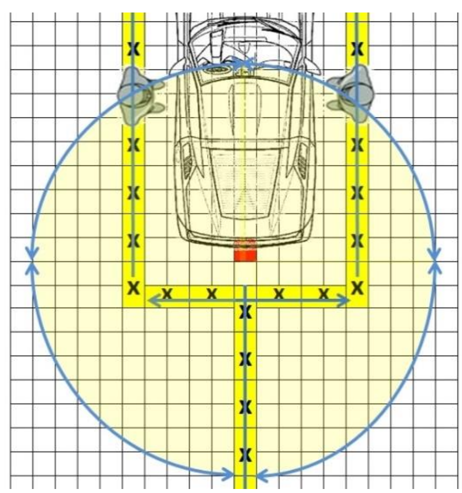
C7 Corvette Exhaust Sounds – A Definitive Paper

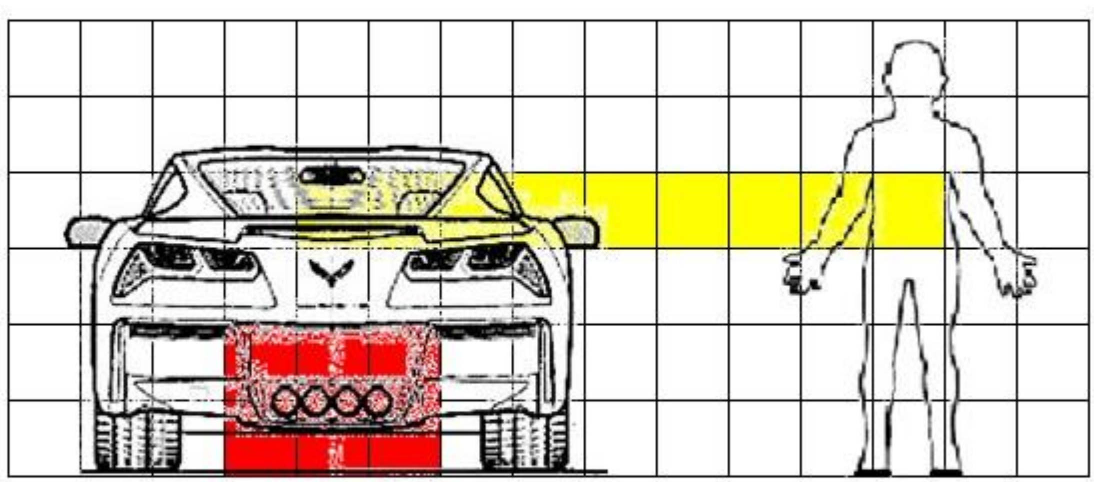
One of the most talked about aspects of the C7 Corvette is the SOUND of them. If you do a YouTube search on the key words having to do with Corvette sounds you will find hundreds of them; above you can see the first frame of 20 of them. The Videos almost always have the camera and microphone positioned behind the car and within about 9 feet of the exhaust at varying levels. Some are directly in line with the exhaust pipes and others are chest high and at an assortment of angles.



This paper, presentation and accompanying YouTube video will approach the subject of the SOUND of C7 Corvettes with a little bit (OK A LOT) more accuracy. All of this additional description will be in the context of the hundreds of videos already available. As mentioned above the positioning of the camera and microphones is key. In the appendix you will find an Excel Spread Sheet titled “Sound Field worksheet”. This work sheet lays out the details of the measurements made. The first measurement is the “Sound Field” itself shown here with the Yellow circle/blue border. Measurements were taken at a distance of approximately 9 feet from the outlet of the exhaust system (shown in the red square) and at a height of chest high.

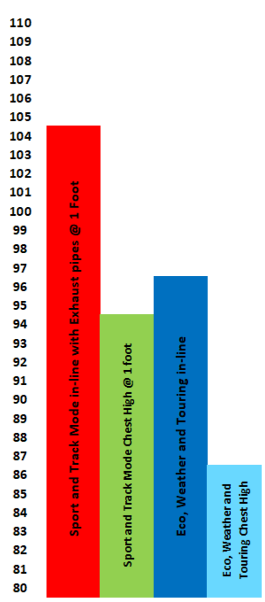
Two “modes” are measured, the opening and closing of the Exhaust Valve system. The Exhaust Valve system is OPEN for the SPORT and TRACK modes, and CLOSED for ECO, WEATHER and TOUR Modes, selected by the Mode Select switch on the center console of the C7 Corvette.

Setting up for this sound field measurement meant making a decision of and for consistency. It was decided that the “microphone” would be held approximately chest high for an average human being. Note below that the area in-line with the exhaust outlet is shown in red and the “chest high” level is shown in yellow.



You will also note that the word “microphone” was and is in quotes. This is because a microphone has no ability to be certified for a specific level of sound energy. So the instrumentation used in this paper is done with two Sound Pressure Level sensors. One of the SPL sensors is a “free-field” sensor that has a limited directional capability; it is considered an “Overall” sensor for the sound field being measured. The other SPL sensor used is highly directional and is able to provide much more precise measurements for sound sources coming from a specific location, within an open area (sound field).

The two different exhaust modes were checked with the Free-Field SPL sensor at a distance of 1 foot from the exhaust outlets, both in-line with the exhaust system outlets and at the chest-high positions.



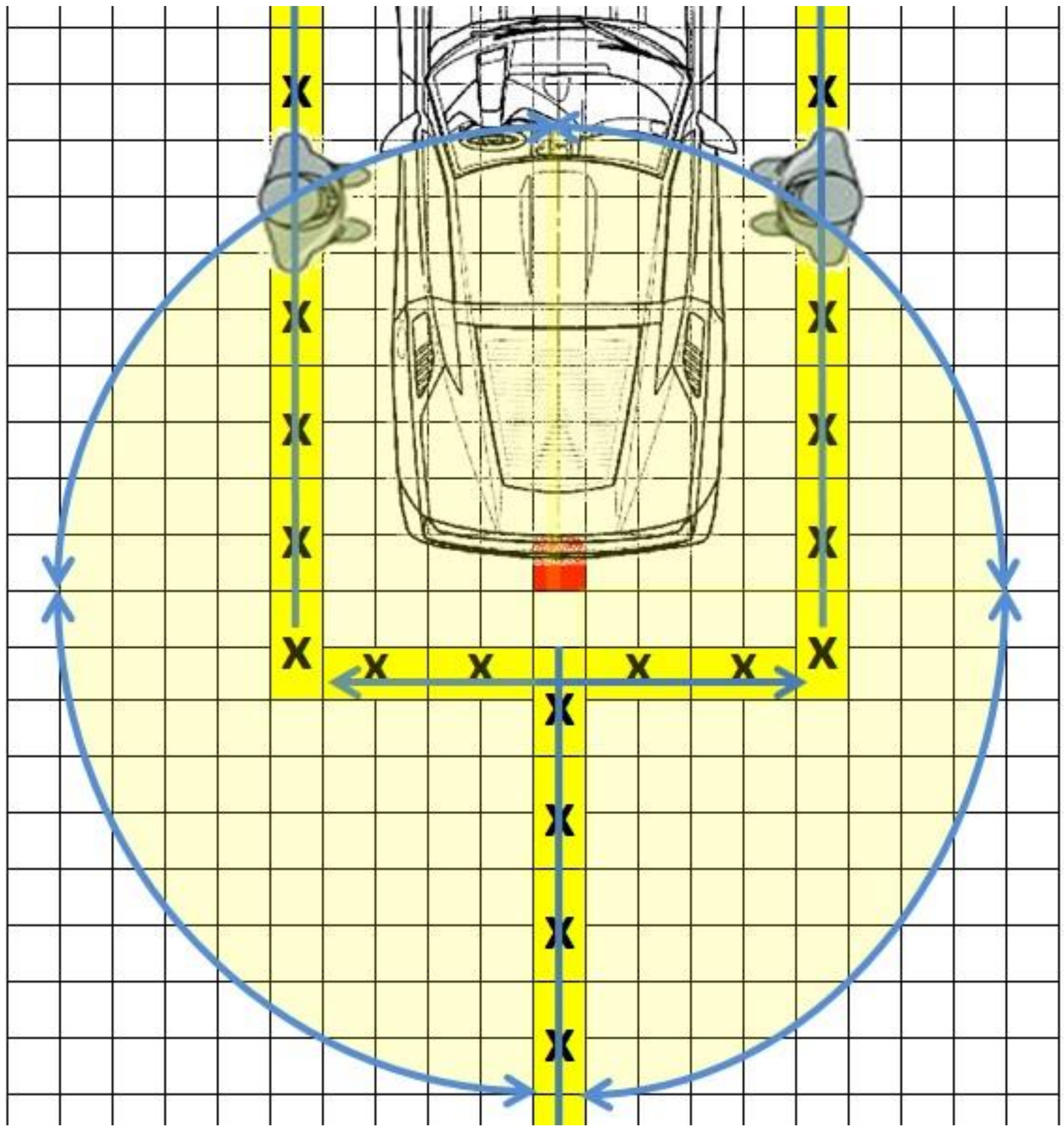
In the “Sport and Track” mode the sound level was found to be averaging **104dB**. when the sensor was in-line.

In the “Sport and Track” modes the sound level was found to be averaging **94dB**. when the sensor was chest-high.

In the “Eco, Weather, and Tour” modes the sound level was found to be **96dB**. when the sensor was in-line.

In the “Eco, Weather, and Tour” modes the sound level was found to be **86dB**. when the sensor was chest-high.

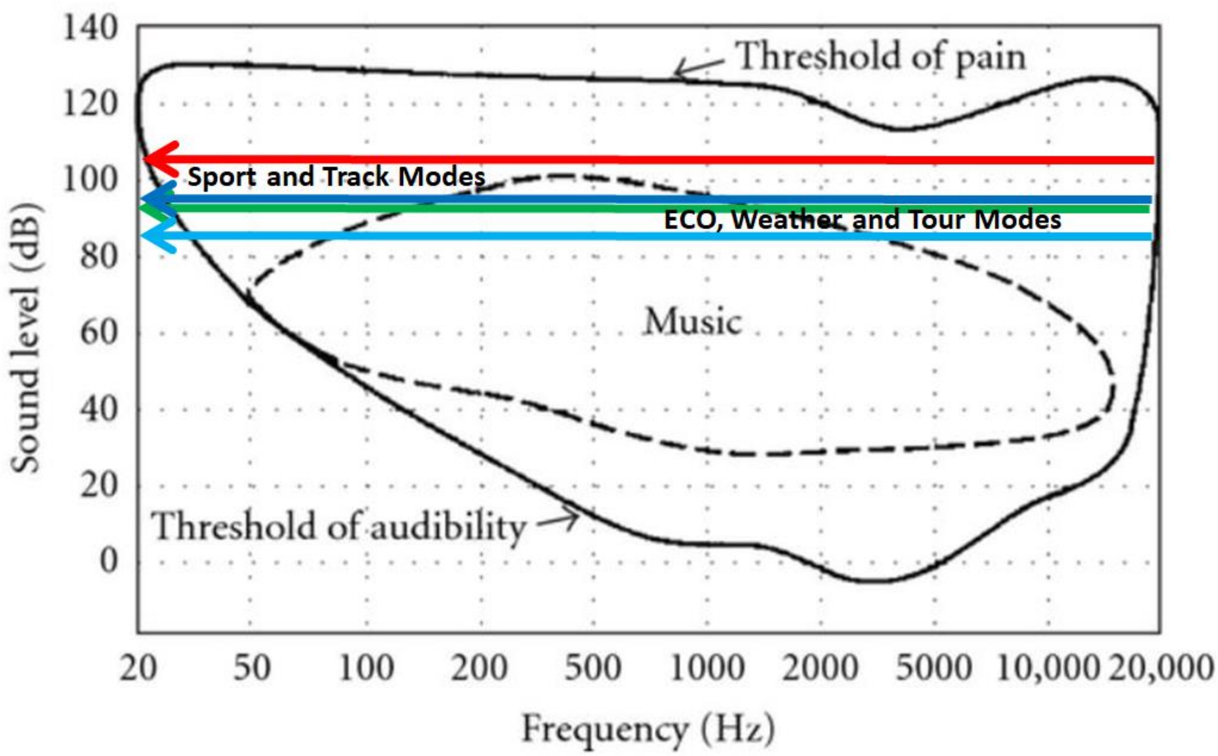
It was interesting to note during this preliminary measurement, needed to validate the sound field, that there was a 10dB difference due to the position of the SPL sensor in both the Open and Closed positions of the exhaust valve and an 8dB difference in the valve closure. This allows for a 2dB difference between the two ranges of the valve position. Knowing that sound energy power is halved every 3dB of change; the difference in the Open and Closed positions of the valve and the SPL position for sound measurement is significant.



With the different positions for the SPL sensor measuring the two different modes, it was determined that a level of 80dB would best fit what could be considered the Sound Field, regardless of SPL position. The car was then set-up in Sport Mode and a level of 80dB was watched for on the SPL Free-Field sensor. A number of positions were checked for this level working around the C7 from the Driver's side to the Passenger side. Nearly a perfect circle was found from the driver's seated position around to the passenger's seated position; a distance of 9 feet from just behind the exhaust outlets.

With the sound field now defined, it was time to establish the test scheme for the "loudness" curve and the identification of the frequency range of that loudness.

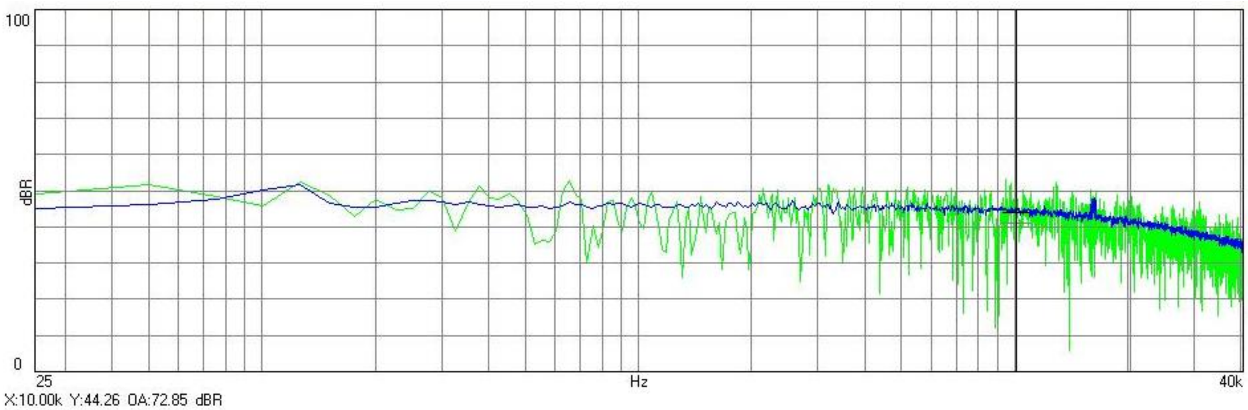
Up until this point the SPL has been measured in OVERALL level. It is important to understand that the human hearing range has differing sensitivities depending on the frequencies. Shown here is a graph showing the hearing range sensitivity and frequency range. Without this understanding of Frequency you can see that all four of the OA SPL levels of the C7 Corvette Exhaust are about half-way between the range of "Music" and the "Threshold of pain". And we all know that, that can't be true; we all LOVE the sound of the C7 exhaust system, why else would all those people post hundreds of YouTube Videos.



The horizontal axis of the graph above is Frequency measured in Hertz (Hz), low frequency on the left and higher frequencies on the right. The typical human hearing range is from approximately 20Hz to about 20Kilo-Hertz (kHz).The vertical axis is in decibels (dB), the same units as the calibrated measurements of the SPL sensors. Decibels are the preferred unit to express sound energy and expresses the amount of sound energy this can be heard. Note that between 2kHz and 5kHz not very much energy is required at all. That suits those of us who wish to hear people whispering to us – not much energy is needed at all. With the onset of age the upper frequency starts to drop as does the overall sensitivity. At the low end you will note that the "hearing" range drops off in sensitivity from needing 10dB @ 500Hz to nearly 120dB @ 20Hz. Now then at that low end of the spectrum there is really no "downside" to the C7's exhaust "sound" because below 500Hz the sense of "***feel***ing" (touch) takes over. At the lower frequencies below 500Hz you ***FEEL*** the sound more than hearing the sound. Some might ask well what about the upper end? Corvette engineers don't concern themselves with sounds above 5kHz; that region is set aside for Porsche's and BMW's whose owners identify with high frequency whine, rather than the guttural sound of power.

With the sound field, overall levels, and "hearing" explained; it is now time to map out the frequency content of the C7 exhaust sounds in terms of hearing and "feel".

Before we start presenting the data from the C7 Corvette, please understand that the remaining data presented in this paper is going to be presented using very high grade instrumentation. It will be using an ACO Pacific Sound Pressure Level sensor (SPL) and a Dynamic Signal Analyzer (DSA) for the presentation of that data. The two devices when coupled together and used to measure the "sounds" have a spectacular dynamic range and almost flat "noise floor" across the frequency span already shown in this paper. To illustrate that the following graph is provided:

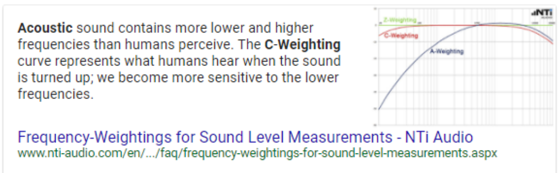


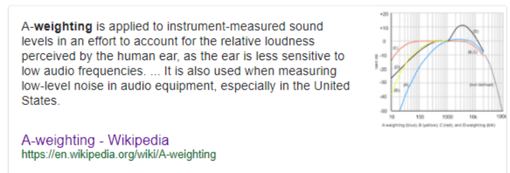
Note that in this graph the highest frequency displayed is 40kHz, well beyond the 20kHz shown in the previous graph. This frequency span (Spectrum) was selected to show you the "flatness" of the measurement system that includes the SPL sensor and the Analyzer (DSA). The **Green** data trace shows an instant in time, whereas over time the data will average out to a relatively flat line (**Blue** data trace). Also important to note is the flatness of the spectrum at not only the included 20kHz to 40kHz span, but the area below (and to the left) of 10kHz. If you will recall from the previous plots this right most span drops off in sensitivity, and yet it is shown flat here. This means that the SPL and DSA are showing the Sound Pressure Level as it actually is; it is NOT showing what the human ears would hear.

One minor detail that is shown on this graph and all subsequent graphs is the "Cursor Readout". There is a very faintly shown cross-hair cursor placed on the data. In the graph above this cursor happens to be placed at the 10kHz point (X:) on the **Blue** data trace. This 10kHz spot aligns nicely with the point at which in the "Human Hearing" graph starts to roll off to the low point @ 20kHz. Note that the SPL and DSA are also showing the start of a roll-off that ends at 40kHz. The numbers shown below the lower left corner of the graph is the "Cursor Readout". In this case it tells us that the cursor is placed at 10kHz (X:) and that the amplitude of the spectrum at the point is 44.26dB and that the Overall (OA:) is 72.85dBR (the "R" indicates "relative").

72.85dB is significantly less than the 80dB sound level used to map the sound field. This was expected in a noise free environment with the C7 NOT running. The overall level is the summation of all the energy in the spectrum which includes that momentary single point at 10kHz where at that instant the level was 44.26dB.

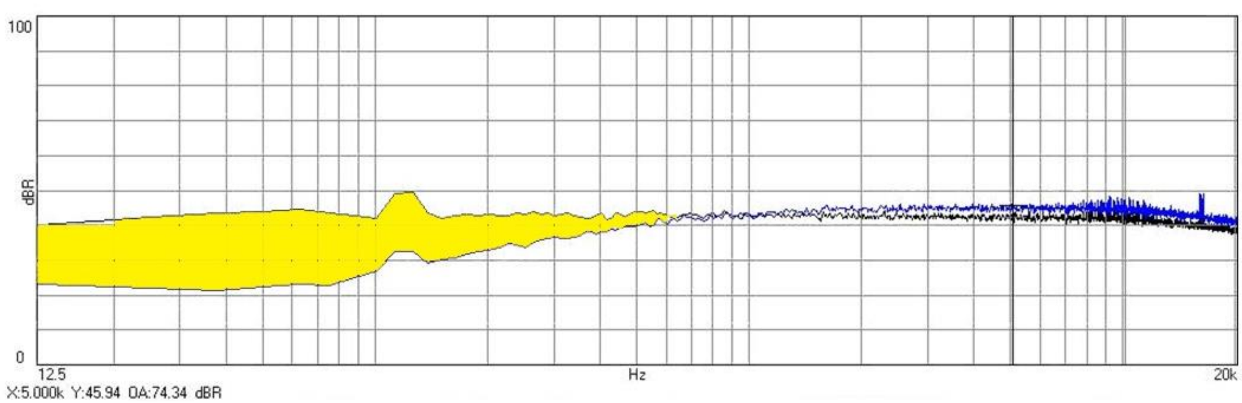
The International standard [IEC](#) 61672:2003; specifies two “treatments” of acoustic data, when comparing instrumentation systems capability and attempting to show what the human ear actually perceives. These two treatments are known as A and C weighting:





Wikipedia and other sources provide excellent descriptions beyond these two brief descriptions, and you can research those if you wish.

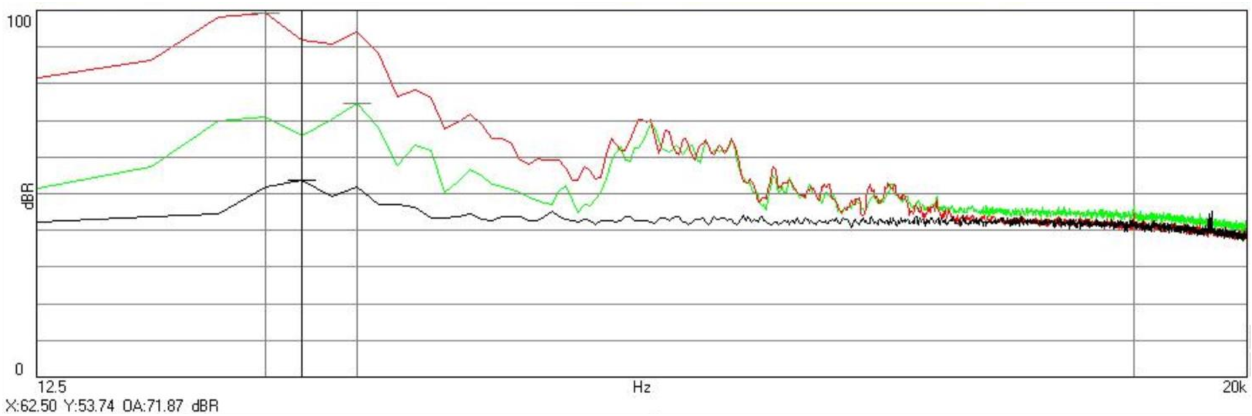
In this paper BOTH A and C weighted data is going to be presented. The reason for this is that Sound Pressure Level as detected by the SPL sensor and the DSA provide the intensity of not only the airborne waveforms you hear as sound, but also the pressure waves that one would actually FEEL.



For all intent and purpose the graph shown here compares the A weighted and C weighted data by the standard measured at two different times, in essentially the same environment. Note the nearly 10 and 20dB differences shown in yellow. This is the major difference between the two “weighting functions” whereas the differences between the Blue Data trace and the Black data trace in the upper frequencies are negligable, perhaps a 2 or 3 dB difference, and can be accounted for by the different measurement times. Note also that the cursor is reporting the amplitude at 5kHz of the Blue Data trace @ 45.94dB with the overall at 74.34dB.

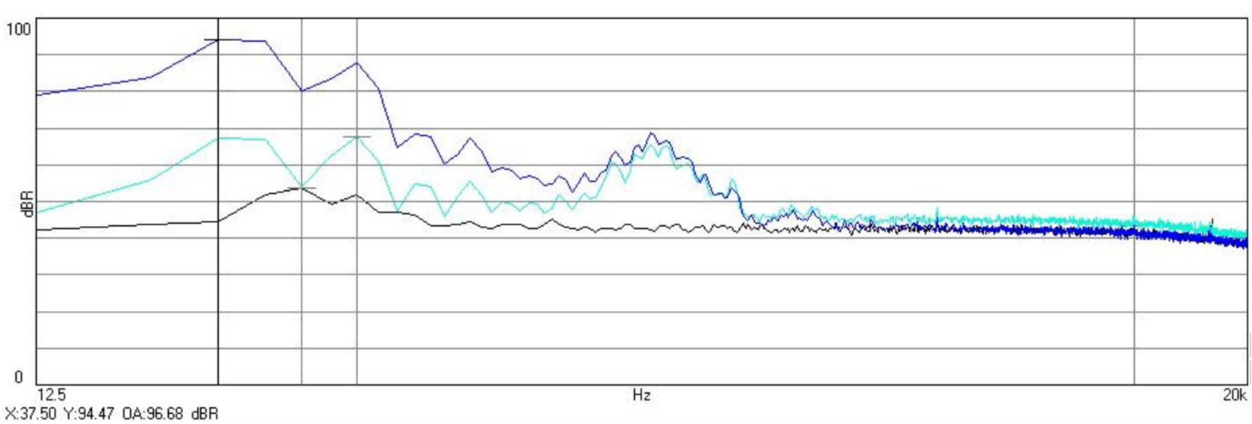
The following comparisons take into account the A and C weighting and the SPL sensor is positioned at a distance of 2 feet from the outlet of the C7’s Exhaust, centered between the four outlets.

The Corvette is running at idle speed and is at an operating temperature of 219^{o} F. For comparison under these operating conditions an additional SPL measurement is taken C weighted and aimed away from the car perpendicular to the driver's side door.

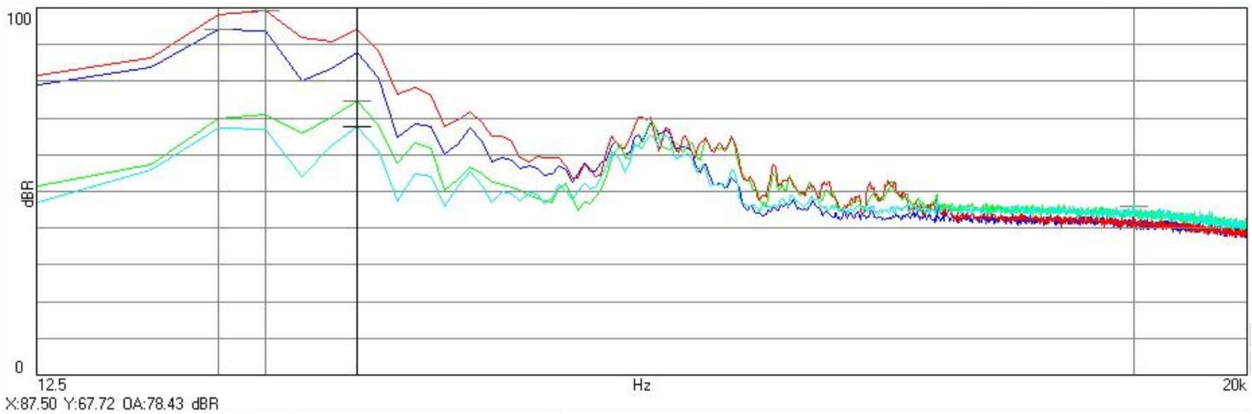


Shown here is the SPORT and TRACK modes of the C7, following the color coding of earlier in this paper. The **Red** data Trace is C weighted data, and the **Green** is A weighted data, remembering that the **Black** data trace is C weighted without the car running.

It is interesting to note that the most extreme difference of the Sound Pressure Level measured is in the region between the A and C weighted data. This seems to imply that most of the "Sound" difference is actually being ***felt*** rather than ***heard***. The area where the **Red** and **Green** data traces converge is the part of the spectrum that is actually being **heard**. It is also interesting that the actual "Peak" frequencies are all well towards the lower end of the frequency range, with the A weighted highest peak (that which is close to the human hearing sensitivity) being the highest peak frequency; whereas the "**felt**" highest peak is lowest in frequency, both bracketing the highest peak with there being no engine noise.

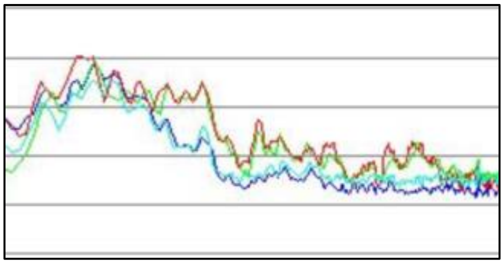


The ECO, WEATHER, and TOUR mode present a similar comparison, although there is a noticeable shift in overall levels when compared to the SPORT and TRACK mode. In the frequency span where the "heard" Sound Pressure Level converge there is a very similar and characteristic "hump" of energy, but it is lower and more round across the top of the "hump" when compared to the SPORT and TRACK profiles above. For a better comparison the final graph of this part of the paper, on the next page shows the four data traces that can be correlated with the SPL bar graph back on pages 2 and 4.

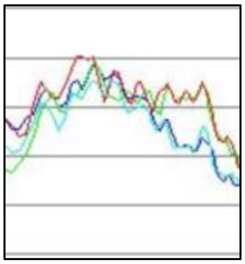


Again, using the color scheme established earlier in the paper:

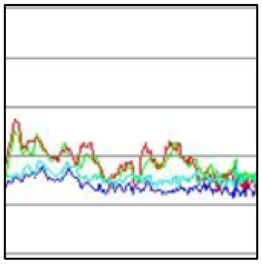
- RED = C Weighted SPORT and TRACK mode FELT
- GREEN = A Weighted SPORT and TRACK mode HEARD
- DARK BLUE = C Weighted ECO, WEATHER, and TOUR mode FELT
- LIGHT BLUE = A Weighted ECO, WEATHER, and TOUR mode HEARD



That which you "hear" while watching the various YouTube videos is in all likelyhood only this part of the spectrum. This region of the spectrum is between 350Hz and 3,500Hz. Is it by coincidence that this is approximately the same range as human speech? Think about the fact that the lower end of this particular range is the Male voice whereas the higher range is typically female. Further to this split of the "speech range" compare the two "modes".



Note that in comparison to the SPORT and TRACK modes that the TOUR mode has a "flip" taking place when the emphasis is on the "heard" part of the spectrum. Note that the A weighted upper range is higher in amplitude than the C weighted, which is opposite to the TRACK mode in the lower range.



This seems to imply that the engineers planned on the concept that perhaps conversation between the driver and passenger (regardless of gender) as being a more important aspect than the gutteral exhaust sound, when you are TOURING. This may also offer an explanation as to why the Mode Switch that changes between ECO, WEATHER, TOUR and SPORT, TRACK is located in the center console, between the two occupants.

BUT the paper has started to digress from the original objective. So on to the next stage of measurement; the mapping of the sound profile increasing / decreasing with distance.

The Sound Field Worksheet outlines the pattern that will be used for the sound distance measurements. The Yellow “Y” shape illustrates the pattern for the 21 measurements being taken with the SPL sensor (and camera) located at each “X” along the pattern. There will be four sets of data taken. Two sets consist of movement of the SPL sensor down the left and right side of the car in SPORT / TRACK mode (11 measurement points each). Both of these sets of measurements will have the 10 positions behind the C7 in common. Then a second set of measurements will be taken in a like manner with the C7 in ECO/WEATHER/TOUR mode.

Following the measurement session of the C7-Z51 optioned car, the four measurements will be repeated with a Z06 model of the C7.