CALCULATING DRIVER SAG AND SUITABILITY FOR VERTICAL MOUNTING

Often times, you'd like to mount a driver facing down, such as in a Sonotube™ enclosure. However, you may not be sure whether the driver you have is suitable for such an arrangement. Will the driver hold up to horizontal mounting? Will the relentless pull of gravity be too much, and cause intolerable amounts of sag?

Well, there's actually a way to calculate the sag a driver will exhibit when mounted in a downfiring (or upfiring) position! And you don't need anything more than the Fs, Vas, effective surface area (Sd), and the Xmax of the driver.

To calculate the sag, we first need to calculate the acoustic compliance of the driver. That is, how soft is the suspension? This parameter is called Cms, and is related to Vas. Cms is the acoustic compliance of the driver, and has the units of meters per Newton. It is calculated as:

Cms = Vas / (1180 * c^2 * (Sd/10000)^2)

where

Vas is the equivalent compliance of the driver, in liters
c is the speed of sound, in m/s (use 343 m/s as a good approximation)
Sd is the effective surface area of the driver, in square cm

Note that you can use the following rough Sd estimates for drivers: 8” = 230, 10” = 340, 12” = 480, 15” = 800, 18” = 1150.

Now that we have the Cms of the driver, we'll need to calculate the effective mass of the driver, Mmd. For this, we'll need Cms and Fs.

Mms = 1 / ((2*pi*Fs)^2 * Cms)

where

pi = 3.1415927...
Fs is the resonant frequency, in Hz
Cms is as calculated above

So, with the Mms and Cms, we're almost there. To calculate the actual sag, you'll need to multiply the stiffness of the suspension times the mass of the diphragm times the pull of gravity:

Sag = Cms * Mms * g

where

Cms is as calculated above
Mms is as calculated above
g is the acceleration of gravity (9.81 m/s2)

This will give us the sag in meters. So, multiply by 1000 to get to millimeters. Here's an example, using our Shiva subwoofer:

Vas = 136.6 liters
Fs = 21.6 Hz
Sd = 481 cm^2

So, we calculate the Cms as:

Cms = Vas / (1180 * c^2 * (Sd/10000)^2)
Cms = 136.6 / (1180 * 343^2 * (481/10000)^2)
Cms = 0.0004253

So, now we calculate the Mms:

Mms = 1 / ((2*pi*Fs)^2 * Cms)
Mms = 1 / (2 * 3.1415927 * 21.6)^2 * 0.0004253)
Mms = 0.12766 kilograms

or 127.66 grams. Lastly, we need to calculate the sag of the driver:

Sag = Cms * Mms * g
Sag = 0.0004253 * 0.12766 * 9.81
Sag = 0.0005326 meters
Sag = 0.5326mm.

So, that's all fine and dandy. We can calculate sag. But what does it mean, and how can it tell us if the driver is OK for horizontal mounting? Well, as a general rule-of-thumb, we use the following:
If the sag is more than 5% If the sag is more than 5% of the Xmax of the driver, then it's not meant for horizontal mounting.

Simply put, if you lose more than 1/20th of your Xmax from sag, then it shouldn't be mounted that way.
To finish off the example, let's look at Shiva:

Xmax = 15.9mm one way
Sag = 0.5326mm
Percent Sag = (Sag / Xmax) * 100
Percent Sag = (0.5326 / 15.9) * 100
Percent Sag = 3.35%

So, Shiva would be OK for horizontal mounting. And now you can calculate the suitability of your favorite driver, too! Just run the numbers, and if you're less than 5% of Xmax, you're sitting pretty!