Interactive Design Tools
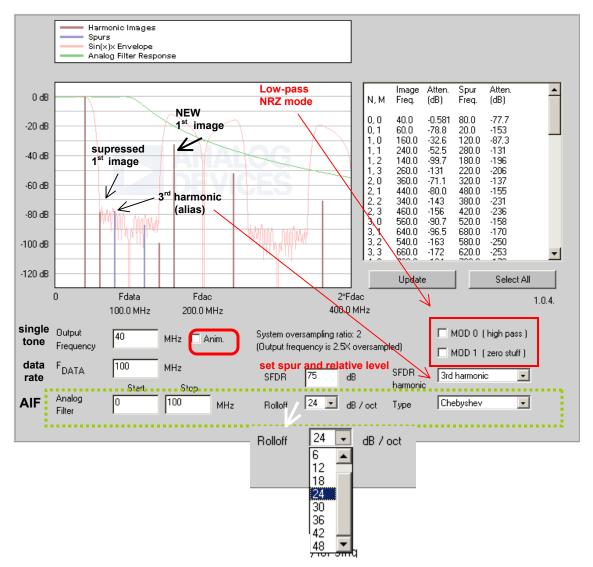
Digital-to-Analog Converters :

Harmonic Images [and spurs] in the AD9772A [interpolated] D/A Converter

Harmonic Images
Spurs
Sin(x)x Envelope
Analog Filter Response

Low-pass
NRZ mode

NEW
1st image

supressed
1st image

3rd harmonic
(alias)

0 dB
-20 dB
-40 dB
-60 dB
-80 dB
-100 dB
-120 dB

0   Fdata   Fdac   2*Fdac
    100.0 MHz   200.0 MHz   400.0 MHz

N, M	Image Freq.	Atten. (dB)	Spur Freq.	Atten. (dB)
0, 0	40.0	-0.581	80.0	-77.7
0, 1	60.0	-78.8	20.0	-153
1, 0	160.0	-32.6	120.0	-87.3
1, 1	240.0	-52.5	280.0	-131
1, 2	140.0	-99.7	180.0	-196
1, 3	260.0	-131	220.0	-206
2, 0	360.0	-71.1	320.0	-137
2, 1	440.0	-80.0	480.0	-155
2, 2	340.0	-143	380.0	-231
2, 3	460.0	-156	420.0	-236
3, 0	560.0	-90.7	520.0	-158
3, 1	640.0	-96.5	680.0	-170
3, 2	540.0	-163	580.0	-250
3, 3	660.0	-172	620.0	-253

Update   Select All

1.0.4.

single tone Output Frequency 40 MHz ☐ Anim.

System oversampling ratio: 2
(Output frequency is 2.5X oversampled)

☐ MOD 0 (high pass)
☐ MOD 1 (zero stuff)

data rate F_DATA 100 MHz

set spur and relative level
SFDR 75 dB

SFDR harmonic   3rd harmonic ▼

AIF   Analog Filter   Start 0   Stop 100   MHz   Rolloff 24 ▼ dB / oct   Type Chebyshev ▼

Rolloff 24 ▼ dB / oct

Rolloff 24 ▼ dB / oct
6
12
18
24
30
36
42
48

The model of the AD9772A is simplified and idealized - only SFDR is modeled and it is assumed frequency-independent. The AD9772A contains an integral **interpolator** which *doubles* the input data rate. The interpolation filter suppresses the upper image in low-pass mode (**MOD0 = 0**), or suppresses the fundamental when in high-pass mode (**MOD0 = 1**). The response characteristics of the internal digital filter have been approximated.

The AD9772 also has a "zero-stuffing" (RZ) mode: **MOD1 = 1** [vs. NRZ mode: **MOD1 = 0**]

To show external selection/suppression of desired/undesired images and spurs, the applet can apply a simulated post-DAC analog filter.

The **table** data is selectable and can be *copied and pasted* into a spreadsheet.
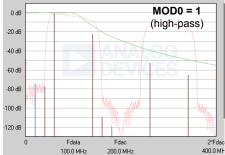
The images and spurs can be **animated** by clicking the "Anim." checkbox
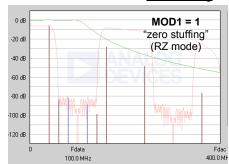
Instructions

The applet above shows the harmonic images (red) and spurs (blue) for single frequency output from an AD9772. The model of the AD9772 is simplified and idealized - only SFDR is modeled and it is assumed frequency-independent. The response characteristics of the internal digital filter have been approximated. See datasheet for actual performance data.

For an ordinary DAC (see our interactive DAC Harmonic Images calculator), images are located at $N*F_{DAC}$ +/- F_{OUT}.

The AD9772 contains an integral interpolator which doubles the input data rate creating an image of the output frequency mirrored about $F_{DATA}/2$. An interpolation filter suppresses the upper image in low-pass mode (**MOD0 = 0**), or suppresses the fundamental when in high-pass mode (**MOD0 = 1** →). Both the filtered and unfiltered images then create further images and spurs at the DAC data rate, according to the $N*F_{DAC}$ +/- F_{OUT} rule.

The AD9772 also has a "zero-stuffing" mode (↓ **MOD1 =1**) which allows the data stream to be doubled a second time by inserting zeroes between each sample. Zero-stuffing doubles again the number of images per F_{DAC} harmonic, but F_{DAC} is twice what it would be without zero-stuffing and the mathematics work so that the location of the images is the same as without zero-stuffing - only the amplitudes change. These new images are not filtered internally so that the upper image can be used for direct IF synthesis. MOD0 and MOD1 are often used together for this purpose.

Spurious 2nd or 3rd harmonics of each image are assumed to result from D/A nonlinearities and so are folded within the first Nyquist Zone (NZ) of F_{DAC}. These spurs then have their own harmonic images that roll off as sin(x)/x (where x = pi*F_{SPUR} / F_{DAC}). The magnitude response of the AD9772 combining its internal interpolation with the sin(x)/x envelope is shown in light red.

To show external selection/suppression of desired/undesired images and spurs, the applet can apply a simulated post-DAC **analog** filter.

How to use this applet:

Enter **F$_{DATA}$** and the **Output Frequency** in the provided text fields.
Hit "Enter" or click "Update" to recompute the display.

Select the **Start** and **Stop Frequencies** of the **Analog Filter**. A zero turns off that portion of the filter, i.e. entering a zero for the start frequency makes the filter low-pass only.

Select filter rolloff and type. The analog filter magnitude is shown in green.

Image frequencies and amplitudes are shown in a table at top right. The first column gives the DAC multiple, N, and then a sequence number for the image around that multiple. For non-zero-stuffing images, the order of these images for N>0 is $N*F_{DAC}$ + 1) -F_{OUT} 2) +F_{OUT} 3) -(F_{DATA}-F_{OUT}) and 4) +(F_{DATA}-F_{OUT}). The table data is selectable and can be copied and pasted into a spreadsheet. Use "Select all" to conveniently select the entire contents before copying.

SFDR is used to set the relative level of spurs, which are assumed here to be the result of D/A nonlinearity. **SFDR Harmonic** selects whether these distortion spurs are most prominent at 2X or 3X (default) an interpolation / zero-stuffing image.
In reality, SFDR depends on both the sample rate and output frequency, among other variables. However, a single compromise number is used here.

The images and spurs can be **animated** by clicking the "Anim." checkbox.
Note: this feature requires significant additional memory and may not function correctly on all browsers. A symptom of insufficient memory is that the display will flicker during animation.