Analog to Digital Converter, IsSpice already has an ADC based on a 1 bit pipelined model. While that can be used, a simplified approach uses the built-in Floor function. The floor function discards the fractional part, returning the integer that is just below the input value. To make this work as A/D quantizing noise, we define three parameter, "bits" , "fbits"and "one". The bits parameter is the number of A/D bits, excluding the sign bit. "fbits" are the bits to the right of the binary point. The parameter "one", which is the real value that represent a unit input. For a fractionally scaled system, one =1.0-2^-bits, fbits = bits, for integer scaling one = 2^bits, fbits=0. For mixed scaling one=2^fbits, the bits to the right of the binary point. Then the output is:

V=floor(v(in)*2^fbits+.5)/2^fbits.

In its current implementation the IsSpice floor and ceil functions return 0 for their derivatives. While that's true for infinitesimally small signals, it gives the wrong answer on a macro scale. That results in moving the wrong answer from the matrix RHS into the modified nodal admittance matrix, MNA. This problem has been corrected for the DSP designer release.

Notice that we only need the fbits parameter for this to work. That gives the proper transient behavior. But for AC analysis, we need to find the RMS noise. For broadband systems, the noise is found by assuming the measurement of an input variable is equally likely to be made anywhere in between A/D bits. Then drawing a straight line between –1/2LSB to +1/2LSB, the error is

$$E_{RMS}{}^{2} = \frac{1}{\Delta}\int_{-\Delta/2}^{\Delta/2} \Delta^2 ds = \frac{\Delta^2}{12}$$

Where $\Delta = LSB$
Then

$$E_{RMS} = \frac{\Delta}{\sqrt{12}} = \frac{LSB}{\sqrt{12}}$$

Now, the LSB is 2^-fbits so a series noise generator is added with AC = 2^-fbits/sqrt(12).

This calculation assumes the measured input is uniformly spread across the measurement space. Unfortunately, in control systems, the noise tends to synchronize and move to the frequency where gain peaks. For most controllers that's near the controller bandwidth. So it's better to use the peak-peak noise, LSB, to get the peak-peak noise at some node in the system. Usually the 2 most important nodes for switch-mode power supplies are D, the duty ratio and the output voltage. The new model can be found by searching for ADCNOISE.

An SMPS responds to quantizing noise by going into a hysteretic converter type of switching mode. With integral feedback, the average output voltage equals the controllers set point and the duty ratio switches back and forth to achieve the average. This sub harmonic switching pattern tends to be at the frequency of maximum controller gain, near the bandwidth of the controller as shown in Figure 1.

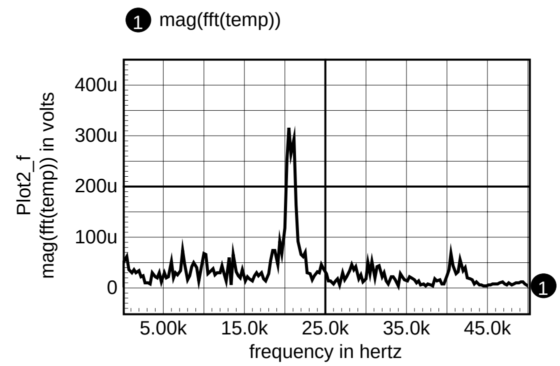

Figure 1, Simulated output noise spectrum using 10 bit ADC model in a Virtual Current Controller