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Bruce Trump *Feb 26, 2013*

It may not always be obvious how the gain-bandwidth product (GBW) of an op amp may affect your circuits. Macro-models have a fixed GBW. Though you can look inside these models, it's best not to tinker with them. What to do?

You can use a generic op amp model in SPICE to check your circuits for sensitivity to GBW. Most SPICE-based circuit simulators have a simple op amp model that you can easily modify. TINA's is shown in figure 1.

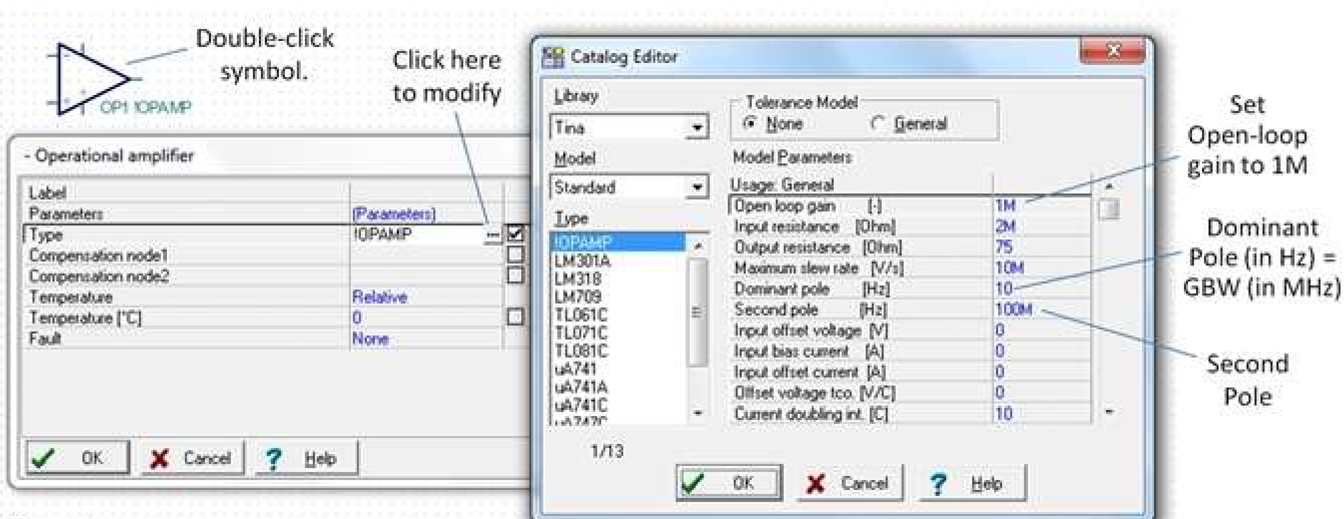

Figure 1.

First, set its DC open-loop gain to 1M (120dB). Then, a dominate pole frequency (entered in Hz) will create a GBW of the amplifier *in MHz*. In this example, a 10Hz dominate pole creates a GBW of 10MHz. Figure 2 shows the open-loop response for three different gain-bandwidths, 5MHz, 10MHz and 100MHz.

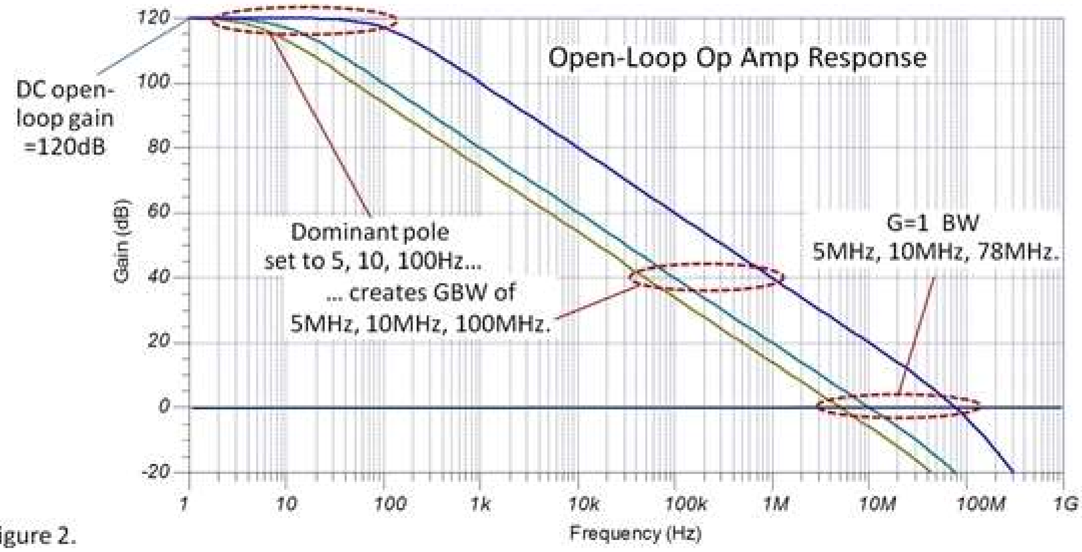

Figure 2.

Note that that this simple model also includes a second pole (some folks call it a nuisance pole). In some cases, you may want to make this second pole a very high frequency such as 10GHz. This will create an ideal 90° phase margin for any reasonable GBW. In this example, I set the second pole at 100MHz, equal to the highest GBW that I'm simulating. You can see the effect of this second pole in the 100MHz GBW response, causing the open-loop response to bend downward at 100MHz. It causes the unity-gain bandwidth to pull in to approximately 78MHz, similar to what you might see with a real op amp of this GBW. Unity-gain bandwidth and GBW of a real op amp are not necessarily the same number. (Does this need another blog?)

Active filter designs can be tricky to judge GBW requirements and are a good case for use of this technique. FilterPro, used to design the Chebyshev[1] filter in figure 3, provides GBW recommendations but its guidelines may be more stringent than needed in some circumstances. For this design, it recommends a 100MHz or greater GBW to achieve nearly ideal filter design characteristics. I simulated the design using the three gain-bandwidths shown in figure 2, 5MHz, 10MHz and 100MHz. With these results you might decide that a GBW less than 100MHz could be satisfactory. For final simulations, you should use the macro-model for the op amp you select.

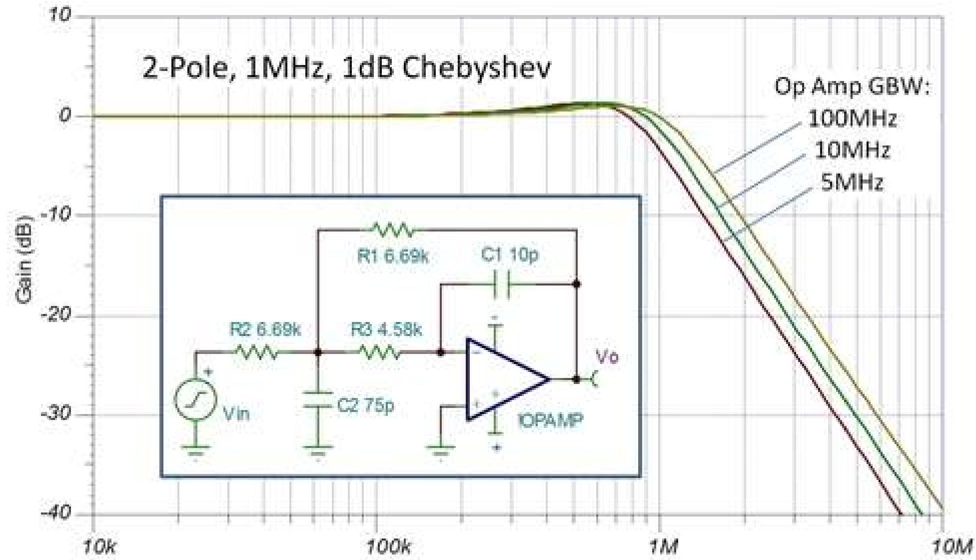

Figure 3.

I used the parameter stepping function in TINA, varying the dominate pole to change the GBW. Other simulators have similar capability. Of course, parameters could be changed manually, too. Either way, varying the GBW of a generic op amp model will give you insight on its effect in your circuits.

Have you used a generic op amp model to vary other parameters? Comments welcome.

Bruce email: thesignal@list.ti.com (Email for direct communications. Comments for all, below.)

Table of Contents for all *The Signal* blogs.

Simulations use fee TINA-TI. Filter designs use free FilterPro.

Note 1: Geek fact—Chebyshev (Чебышёв) was a Russian mathematician who died in 1894. Use of his polynomials to create equal-ripple filters came later.

5 comments 0 members are here

Tim Sobering *over 12 years ago*

Bruce,

I've been told that IC manufacturers control the DC open loop gain quite well, which means the frequency of the dominant pole and the unity gain crossover frequency can (and must) vary (as you show in figure 2). Is that correct, or is more attention paid to f_t? What about the second pole...does it move in relation?

Tim

Bruce Trump *over 12 years ago*

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Tim-- The GBW of a given op amp type is typically well-controlled with variation in the range of +/-15% or so. The DC open-loop gain is not so well-controlled and can vary over quite a wide range. This means that the first pole frequency actually varies a lot. Don't panic--this rarely affects circuits. What matters is the GBW. Simulating with a fixed DC open-loop gain and variable first pole is just an easy way to fiddle with the GBW. Sorry I can't draw a picture in this comment. Does this need a blog to explain? -- Bruce

Tim Sobering *over 12 years ago*

Thanks Bruce. I got it backwards. Not enough coffee yet this morning apparently. I'm recalling Bob Pease's discussion of DC gain now. As you note, active filters can really exacerbate these problems. While you are changing the f_t frequency in your simulation, the effect on the active filter is due to the reduction in the "headroom" between the filter gain and the open loop gain curve at the filter cutoff frequency, i.e. the remaining loop gain in the system. Clearly headroom and GBW and f_t are all interrelated, but if your filter cutoff was at 50kHz instead of 1MHz, you wouldn't see much change in the filter performance over the 20x change in GBW, just as variations in DC gain have little impact on low-frequency performance. I guess maybe I'm nit-picking, but I'm kind of obsessed with looking at loop gain (and phase!).

HaveEE_WillTravel *over 12 years ago*

The link to TINA is wrong. It should be <www.ti.com/.../tina-ti>

Bruce Trump *over 12 years ago*

Thanks, LLC. I fixed the link and it now works. -- Bruce