ELECTRONOTES

WEBNOTE 08/15/2009

CHOICE OF OP-AMPS

When you look at old (say 1970's) circuits in Electronotes, you may well come across unfamiliar parts. In particular we need to know about the choices of op-amps, and it helps to consider the history of what was available. It is also useful to keep in mind that at times, a part was chosen on the basis of whatever was available, sometimes even what was within reach without getting up from the bench!

THE TYPE 741 AS A BENCHMARK

The first IC op-amp I ever encountered was the type 709. I think they initially cost about $70 each, and were very easy to burn out by accident. I certainly never bought one at that price: I did have some later, and might have even used a couple. (I still have five of them in 14-pin gold-plated DIP.) The first op-amp I ever bought was the type 741 – they were $3.50 in the early 70's. I recklessly bought a couple. I also used them in a filter design lab I took at Cornell – a course which I later taught for years in an evolving form. The 741 became practical when they got down to 35 cents, and they seemed very good. I still think in terms of the 741. Typically, a 741 is just fine; or I might need a faster one (faster slew rate) or a wider gain-bandwidth product, or I might need one with a smaller input bias current.

LESS BIAS CURRENT: THE 307 (and BB3500)

Soon after getting used to the 741 another one, type 307 became available for about the same price. It had a lower bias current, but the same speed/bandwidth characteristics. We used a lot of 307's. At times, you may see us specify the BB3500 (Burr-Brown) which was an excellent op-amp which we used like the 307, even though the 3500's were better. This is not a common op-amp, but we acquired about 5000 of them for pennies and resold them, when we were in the parts business.

FASTER: THE 556 and Bi-FETS LIKE THE LF351

Generally, for synthesizer circuits, speed/bandwidth issues are mainly speed issues. Encouraged by Dave Rossum of E-mu Systems, we often thought of "full-sized" signals as ±10 volts instead of just ±5 volts. This meant that our 741/307 choices were a bit slow, and Dave used the type 556 (I believe its full name was a MC1556). You will see a lot of 556 op-amps is our circuits. What we are asking for here is a slew rate greater than a 741. Two points about the 556: (1) there are a number of non-op-amp parts with this general number to confuse the issue, and (2) if you are generally using "modern" Bi-FET op amps such as the LF351 or the TL series, you have made a good substitution for the 556.

LOWER BIAS CURRENT: THE LF13741 (SL32005)

Modern Bi-FET type op-amps are orders of magnitude better than the 741 when it comes to input bias current. Since the "ideal" op-amp has zero input bias current, lower is better, but in many cases, not at all necessary. For applications like sample-and-hold buffers, it is very important. This brings us to another favorite, the LF13741. Note that last three digits: 741. This is a Bi-FET input (low input bias current) with 741 speed/bandwidth characteristics. We had this under the "house number" SL32005, and we sold thousands of them – again bought for pennies.

UNCOMPENSATED: THE 748 AND THE 301

The 741 and the 307 also came in uncompensated versions: the 748 and the 301 respectively. Here we will not go into the details of compensation – most op-amps you use today (the modern Bi-FET types) are, like the 741, internally compensated. Uncompensated (to be custom compensated with external components) op-amps were used mainly in audio circuits. Compensation slows down an op-amp. One place where you don't want to be slowed down is in a comparator, which should jump suddenly, and which, being open-loop (no negative feedback) needs no compensation. It seemed then logical to use uncompensated type for comparators, although not absolutely necessary. If you are using modern Bi-FET types (internally compensated), the speed is probably as fast as the uncompensated types we used.

WHY NOT JUST BI-FET TYPES EVERYWHERE

Indeed – why not? Well, in a few cases, the extra speed/bandwidth offers the opportunity to misbehave. (If your clunker car maxes out at 55, you are not going to get a speeding ticket on the interstate, and it will get you through a 10 mile limits school zone just fine.) For example, if you have a capacitive load, the output resistance of the op-amp and the capacitor form a simple R-C lowpass , inside the feedback loop (Fig. 1), which has phase shift, and is capable of turning negative feedback into positive feedback, and the op-amp will oscillate at high frequency and low amplitude automatically. This we have seen in the lab where a scope cable (a capacitor!) was attached directly to a LF351 op-amp output (logical enough). Often you would see a "fuzz" added to whatever else you may have wanted (most often with an associated "dc" shift if you were also monitoring with a DVM). If you took the cable off, the fuzz disappeared from the scope (of course!) but also the dc shift disappeared from the DVM. So it was only there when you watched (which led to some obvious jokes)! If you then substituted an LF13741 for the LF351, there was no problem. The slower op-amp just could not go fast enough to get in trouble. I got in the habit of using mostly LF351's and Lf13741's. If I did not need speed (it could only cause possible trouble) I used an LF13741. Of course, the 13741's had only cost me a few pennies, while the 351's cost perhaps 30 cents, and that was probably the real consideration.

If you are, in your final constructions, using the convention of supplying signal to jacks with a 1000 ohm resistor in series (Fig. 2), you should have no problems with cable loading. In this case, the R-C filter is still formed, but (largely) after the feedback loop.

Fig. 1

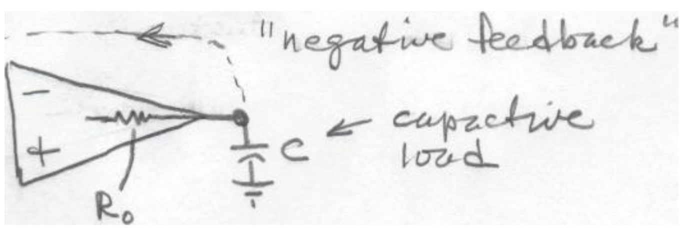

Fig. 2