Comments On The New 13600 And 3280 OTA Devices:

−by Serge Tcherepnin

Excerpt from Electronotes #113

EDITOR'S NOTES: This material is based on a letter from Serge, and since it was both informative and readable in its original form, no attempt was made to make it into something more like an article. −−−Bernie

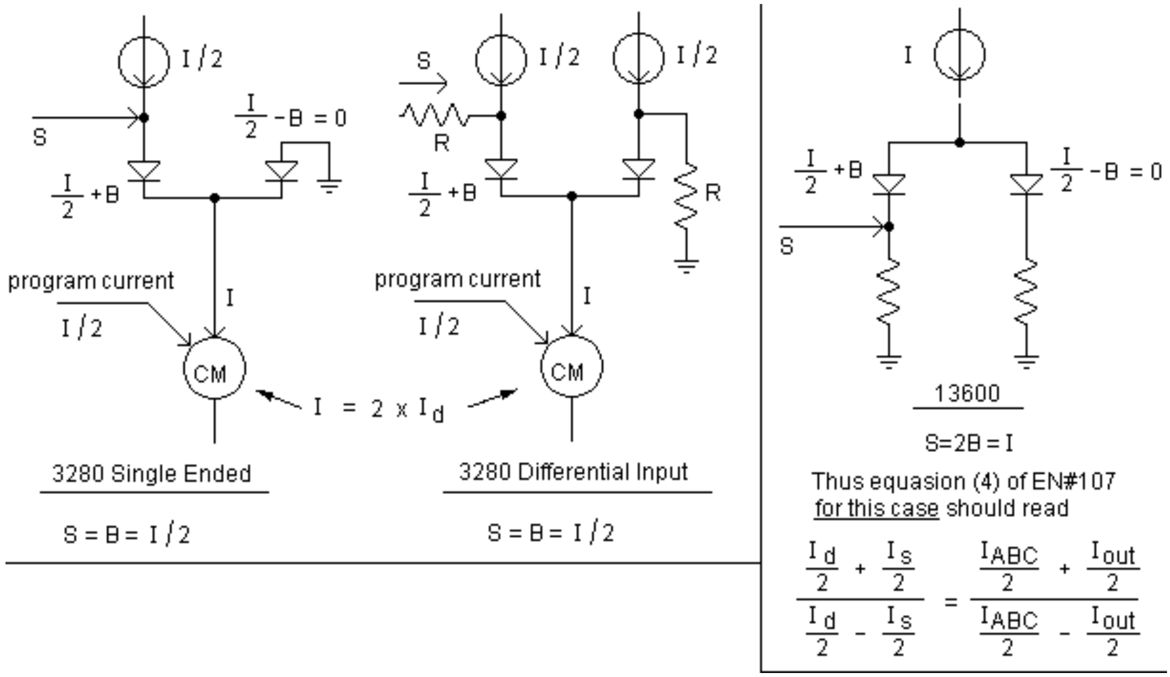
I read EN#107 ("The New OTA's; The CA3280 and the LM13600") with interest since so little is written about that particularly slippery device, the 3280. Also, your discussion of the 13600 was especially interesting to me, since I didn't even have a data sheet concerning this device.

When I came to the part in the notes in which you reveal the discrepancy between the experimental vs. theoretical results, I thought to myself, aha, here's another victim of the 3280's poor data sheet (as I was one myself, and had exactly the same discrepancy in my tests). I thought I'd write you a short note to explain the matter. However, I decided to take a look at the bad results regarding the 13600 also. Amazingly, the causes of the discrepancy are entirely different for each of the devices, though the net result was the same.

In the case of the 3280, the cause is the fact that twice the I_d is reflected, and thus each of the diodes sees 1/2 of 2 times Id. Where is this found in the data sheet? The RCA engineers should be strangled (I guess what will save them from my wrath is the fact that they invented and marketed such a marvelous device as the 3080!) By the way, the current mirrors built into the 3280 are not the garden variety found in the 3080; rather they have been optimized to work at much higher currents than the old 3080. Thus there is some fancy (unspecified in the data sheet) processing and circuitry which makes the current mirrors provide about 90% ratioing as concerns the diode programming, and 80% for I_{ABC} vs. output current. More on this later.

Your simplified equations are perfectly accurate for the current sourced diode network; they are not so for the 13600 diode network as hooked up in your experimental circuit. This can be quickly verified by asking the following question with reference to the various circuits shown (top of next page): what values S and B are needed for the I−B current through one of the arms of the diode network to approach zero? (See figures for explanation).

An interesting perception results when the complete equations governing the RCA vs. the National biasing schemes are developed (which includes the logging terms).



It is this: that the distortion rises quicker with increasing inputs for the National scheme versus the 3280. With 9/10ths of the maximum input signal current (equaling approximately I programming), distortion for the 3280 current mode biasing scheme is about 0.3%. For 500 ohm terminated grounded scheme such as the 13600, distortion at that level signal is more than 8%. A little further analysis showed that as the terminating resistances were increased, distortion decreased proportionally. This fact makes sense, of course, seeing the direction of the change toward pure current sourcing. The least distortion would be had with a 3280 current biased network fed from a pure current source signal: the 0.3% distortion is mainly due to the fact that a resistor was assumed sourcing the input current. Thus it is with the National part that using large resistors to a negative voltage would lead to better distortion figures.

I could write a volume concerning the 3280 which I consider one of the slipperiest devices (full of non−obvious quirks...) that I have seen. In the balance, I consider it a better work of the IC designer's art than the 13600, mainly because of the interdigital input transistor structure which ensures very low noise (about as good as the 381) and excellent offset voltage matching over changes of IABC. How often have we had to de−select a 3080 for extremely bad offset degradation?

Typically, a 76db S/N ratio can be achieved (ref 0 db) with the 3280. 3dbs can be gained if the two amps are used in parallel for a single VCA; and another 3 dbs for a smashing 83dbs/N can be had by paralleling two entire packages! (RMS logic). The CV rejection is also similarly improved. However, to achieve the S/N, a careful trim of the I_d max should be made to obtain the necessary I_{ABC} minimum.

For maximum CV rejection, differential resistors *and* DC coupling must be used, since the change of input bias current with changing I_{ABC} will otherwise wreak havoc. And of course, the larger Id, the better these biasing currents are swamped. We've realized better than 60 dbs of CV rejection; on the other hand, when CV rejection is not primordial, a single ended input resistor, with the second amplifier input tied to ground, is very convenient because it allows capacitive coupling.

Due to parallel biasing of the internal PNP mirrors directly by I_{ABC} it is not possible to inject a current into the available emitter pins, (unless an I_{ABC} of similar magnitude is also input. This is one of the lousy features of the 3280 which makes direct drive by an external exponential source impossible, alas....

My tests revealed that the inputs to the mirrors have very tight matching; thus the terminals can be tied together quite simply (as for use with VCF's).

As you may be aware, the equation for the 3280 is 16 times I_{ABC} : G_m . It turns out however, that the old equation for the 3080 applies in a modified form: 19.2 times I_{out} max : G_m . The consequences of this fact are beneficial to whomever wishes to design VCA's and to know what peak output voltage one might expect for a given G_m . No doubt this is why you discovered in EN#107 that lout was 20% low, i.e., 16:19.2 low.

The 3280 is not as well speced with regard to input and output isolation and leakage as the 3080; thus is not advisable for sample−and−hold circuits.

My tests also reveal that the reflected I_d is 1.8 the programming current. Another good feature is that the PNP currents in each of the two branches match extremely closely (within 2%). On the other hand, the sum of the PNP currents is not precisely equal to the NPN source, and thus a common mode difference exists. The worst of this is that it can be positive or negative.

Other facts:

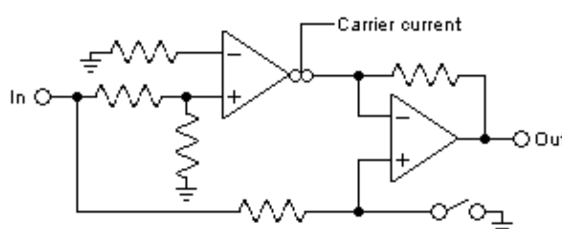
- V_{ni} is 3.4db better with the 3280 than the 13600 at I_{ABC} = 150 na
- V_{ni} is 4.6db better with the 3280 than the 13600 at I_{ABC} = 500 na
- V_{ni} is 4 db better with the 3280 than the 13600 at I_{ABC} = I ma

For the 3280, V_{ni} is

- −117.4 db/0 ref at 150 na (BW 16 − 16kHz)
- −120.4 db/0 ref at 500 na
- −122 db/0 ref at 1.5 ma
- −127 db/0 ref at 5 ma

. Flicker noise however increases in the milliamp region

One last word: I appreciate reading about your simple ring modulator. In fact, I designed a related circuit many moons ago (1973).



This had the advantage that I so configured the circuit to allow using the PC board for either a ring modulator (with VC changeover from ring through amplitude to no modulation) or as a VCA (switch above closed) with exponential and linear CV inputs. The trick for achieving both circuits was using a PNP long tail multiplier to supply the IABC. Somewhat sly was the fact that in my realization the trimming of signal cancellation was left to the user (in form of the knob which controlled whether the circuit behaved as a ring, amplitude, or non−modulator). Sly, because without diode predistortion as in the 3280, G_m shifts with temperature making signal cancellation a changing thing. The 3280's advent was the cause for my redesigning the module. In fact, I find that 3080−like transconductors are far superior to true ring modulators (possibly because there are fewer internal VBE cancellations needed). Superior because carrier suppression can be far superior. My new ring modulator, however, is another breed altogether. Carrier rejection is better than 78 dbs down / 0db ref. This uses two 3280's. Two of the amps are used for compression of the input signal, and expansion of the ring modulated signal. Very economical since the same precision rectifier controls both equally! (With a small averaging cap since distortion cancels)

The other two amps are used 1) for the modulator and 2) to provide the I_{ABC} driving multiplier as needed to smoothly change the circuit from full ring through amplitude and non−modulation modes (manually or via VC). In this circuit, nulling is not left to the user! It's really a pleasure to hear very distortion free ring modulation at all signal amplitude levels: very, very clean, and with no squelching glitch as in the Moog−Bode module. (Compression and expansion are other great uses for the 3280's good linearity).

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