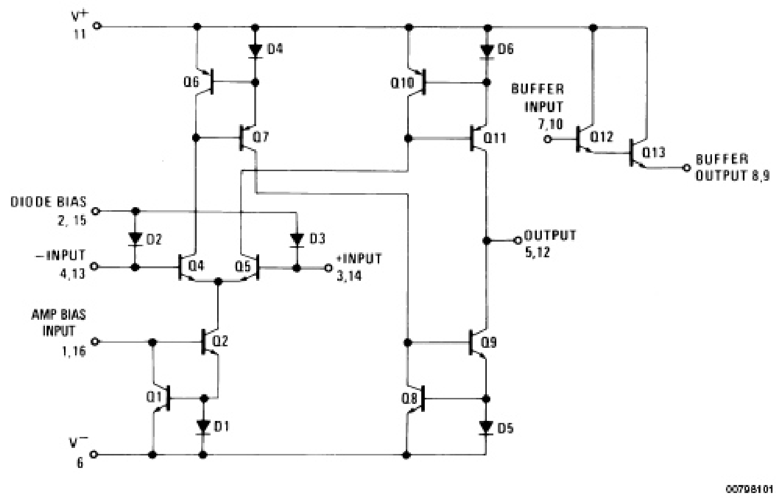
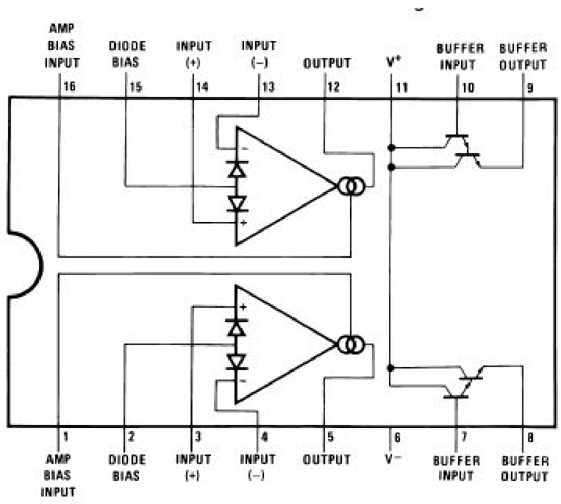
# SUPPLEMENTAL LM13700 APPLICATION EXAMPLES

## Schematic Diagram

One Operational Transconductance Amplifier




At the time when the LM13600/LM13700 datasheet was done, management was beginning to feel that the number of applications was getting out of hand. The LM13600/LM13700 data sheet was attempting to follow the LM3900 data sheet in that it now allowed customers to do things which up until then were not convenient. This application supplement attempts to add a few more examples
as to how this Operational Transconductive Amplifier can be used.




This IC was some what done at the request of an Analog Organ manufacturer. Actually it was done as training lay out for a new mask designer. Some how it managed to get turned into an actual IC, which was very unusual. Marketing was
not keen on supporting the creation of a new IC for a yet to be created market at
that time.

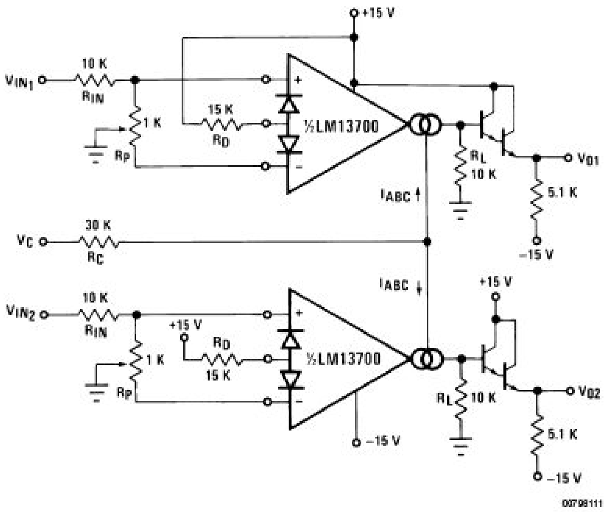
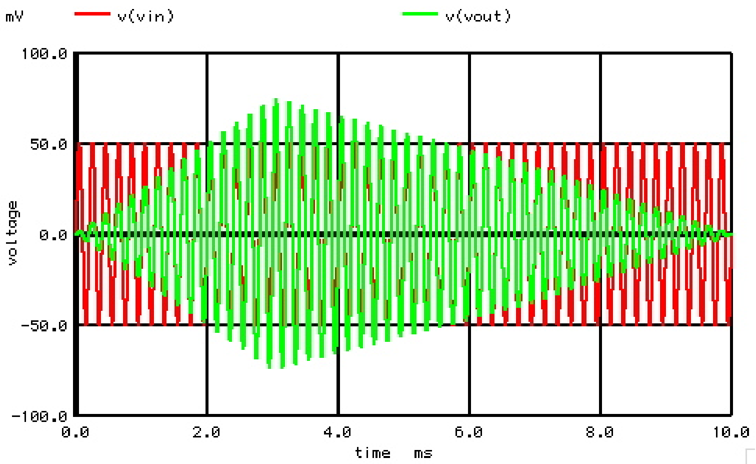



FIGURE 4. Stereo Volume Control

Of course the first application was as a Voltage Controlled Amplifier. The Organ
people needed to be be able to adjust the attack and decay of a tone, and in spice today that can be simulated mathematically.




The whole Operational Transconductance Amplifier can be defined in one line..

B_OTA1 OUT 0 I = -1*v(VIABC)*tanh((v(INP)-v(INN))/.052)

```
                     0->1mA->0        RL = 100
                VIABC   ^           _/\   /\   /\__
                       /_\         |    \/   \/    _|_
          ____      |\  _| _       |               ///
VIN  ____  |INP|__|+\/ \/ \     _|_   ___   |\    ___
    _|_    |___|  | /  /\  \_|OUT|__|INB|_| \_|BUF|
   /_  \    ____  | \  \/  / |___|  |___| | / |___|
  // \  \  |INN|__|-/\_/\_/               |/
  \   \//  |___|  |/                        B_BUF1
   \___/    _|_       B_OTA1
    _|_     ///
    ///
```

Where a PWL source (VIABC) is set to track IABC over time...

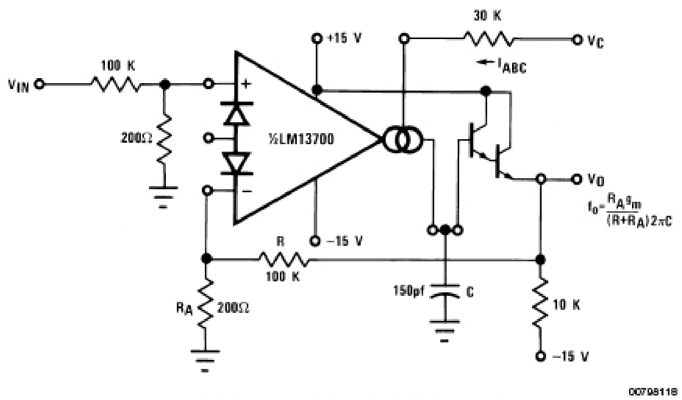
V_Iabc VIABC 0 PWL ( 0m 0m 3m 1m 10m 0m )

There is an extra feature in that the definition of the buffer need not include offset.

B_BUF1 BUF 0 V = v(OUT) or ...
B_BUF1 BUF 0 V = v(OUT) -1.2V

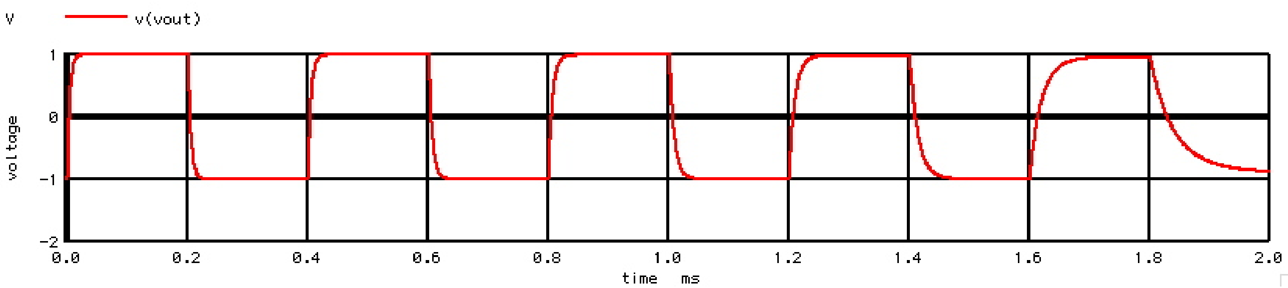
This can make the spice netlist of attack and decay simulations extremely simple.

**Typical Application**




Voltage Controlled Low-Pass Filter

The data sheet lists a voltage control lowpass filter as a typical application because of
a home Hi Fi project. The idea was to adjust the bandwidth of the audio channel
to always match the bandwidth of the music. A noticeable reduction in noise for
cassette tapes was the result. The Home project work so well that Delco decided
to use it instead of Dolby. More information on this can be found at Wikipedia.




Another application for this circuit could be as a Voltage Follower which has a Voltage Controllable Time Constant. Perhaps one might want an envelope with
a slow or fast attack and a fast or slow decay.

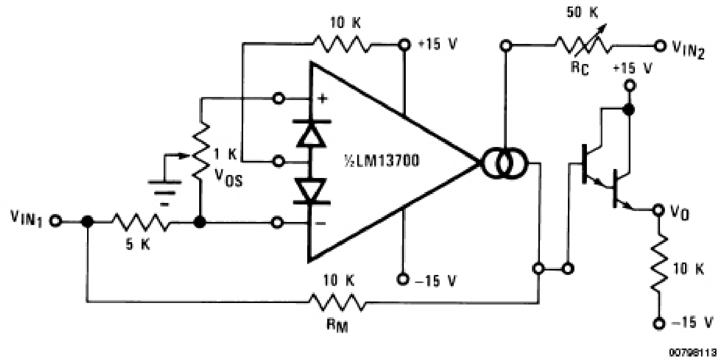



FIGURE 6. Four-Quadrant Multiplier

In some cases the Four-Quadrant spice simulation might make the data sheet schematic
a little easier to understand.

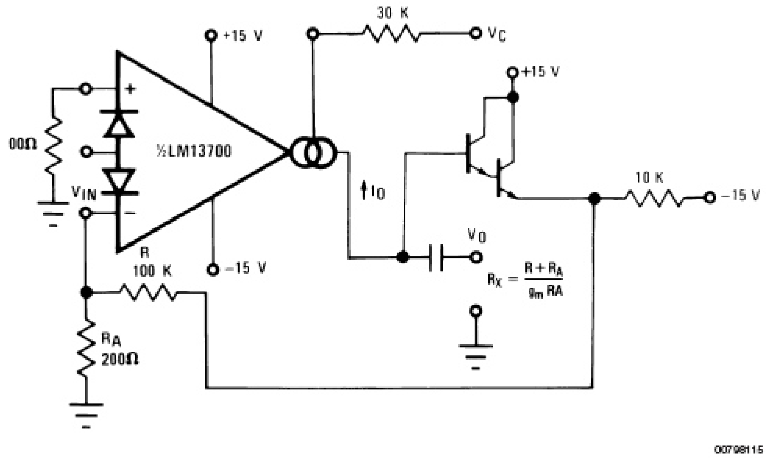



FIGURE 8. Voltage Controlled Resistor, Single-Ended

For the Voltage Controlled Resistor application, being able to simulate using perfect
buffers instead of darlingtons has its advantages. This is especially true when it comes
to building Voltage Controlled Capacitors and Voltage Controlled Inductors.

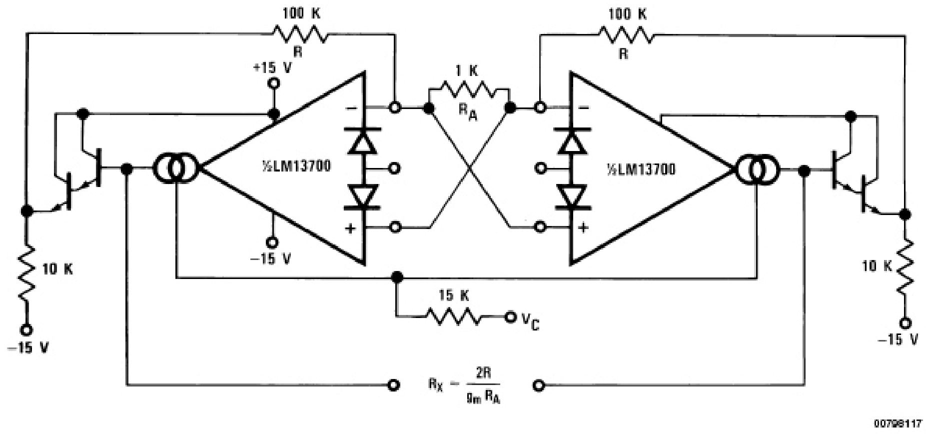
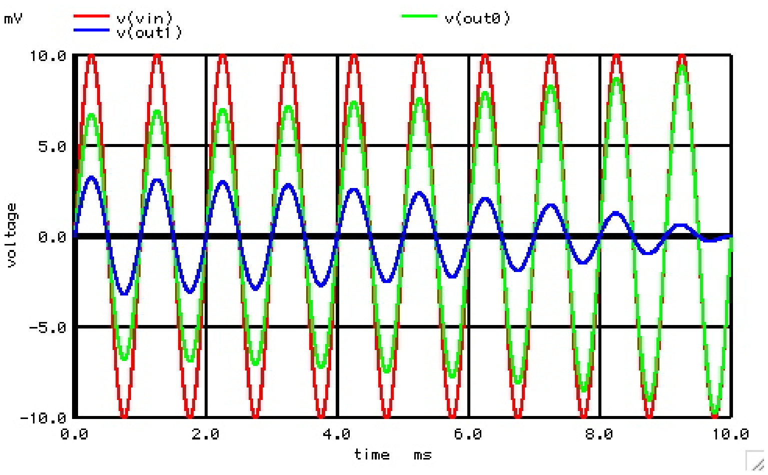



FIGURE 10. Floating Voltage Controlled Resistor

The Floating Voltage Controlled Resistor functions just fine with the darlington 1.2V offsets. The simulation of this circuit shows why. To see the floating resistor in action, the example needs to be put into a resistor network.

```
  VIN      R1                                            R2
    _/\   /\   /\_ OUT0                          OUT1 __/\   /\   /\__
   |   \/   \/    |         IABC= 1mA->0             |    \/   \/    _|_
  _|_             |                                  |               \\\
 /_  \            |        INP0=INN1     INP1=INN0   |
// \  \      /|   |      /|________     _____|\     |   |\  VOUT1
\   \//   __/ |__|_/\/\/ |        |  |      | \/\/\_|__| \__
 \___/   |   \ |   \/\/\ |_______/|\_|    __| /\/\/    | /   |
  _|_    |    \|       \| |       |_____|  |/         |/    |
  ///    |B_BUF0  B_OTA0  |            | B_OTA1             |
         |           R3   |    R4      |       R5           |
         |_____/\   /\   /\__|_/\  /\  /\_|____/\  /\  /\____|
      VOUT0    \/   \/  1NN0  \/  \/  INN1   \/  \/
```

With IABC going from 1mA to zero, the floating resistor appears to be going from 10K Ohms to Open. The wave forms below shows that.




But any type of Voltage Controlled Impedance can be made using OTAs. A Voltage Controlled Negative Resistor can cancel out the current loading of a Load Resistor. And a Voltage Controlled Negative Capacitor can cancel out stray capacitance to greatly improve speed.

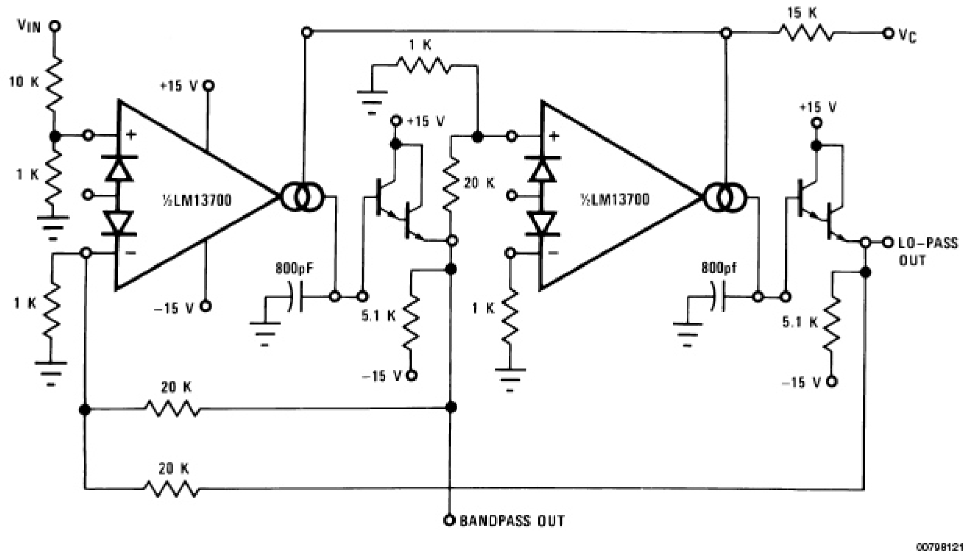
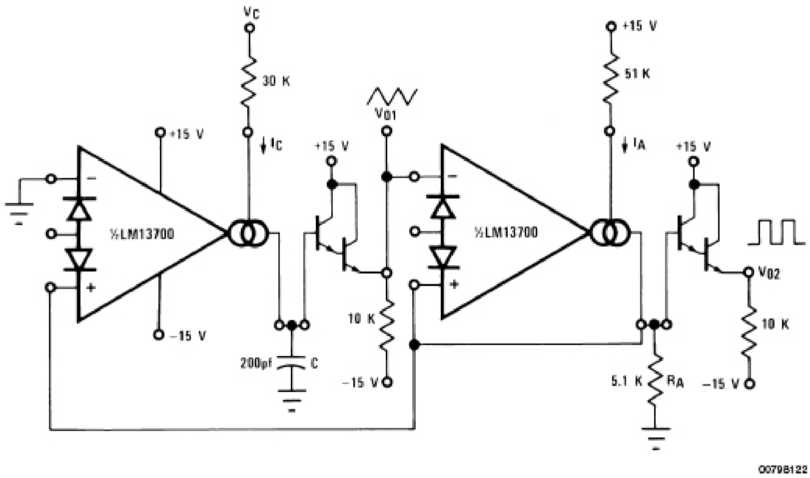



FIGURE 14. Voltage Controlled State Variable Filter

The State Variable Filters are by far the most beautiful of all the filters. Different filters can be made simply by changing voltage feedback. For instance a Bessel filter has a set of feedbacks such that a low pass filter signal is not shaped distorted. If maximally flat gain is required, then the feedback can be adjusted to form a Butterworth filter.

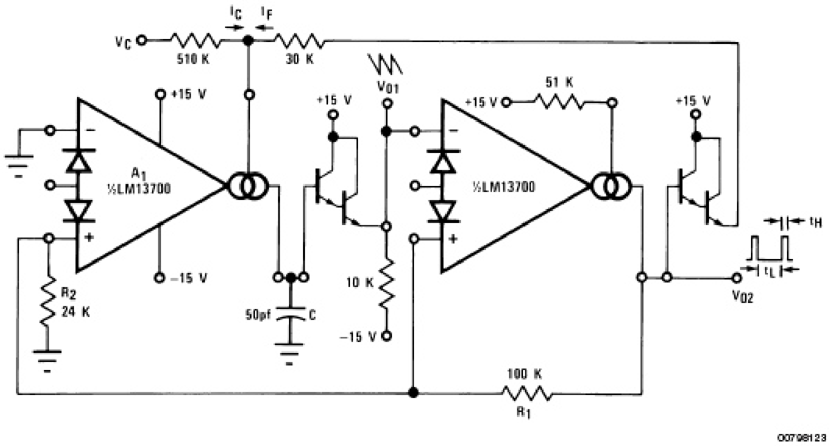
Regardless of type of filter, the frequency response is independently controllable
over up to maybe 5 orders of magnitude for the LM13600 (not LM13700) and may get as high a 10-12 orders of magnitude in frequency if it were built in BiCMOS
today.




$$f_{OSC} = \frac{I_C}{4CI_AR_A}$$

FIGURE 15. Triangular/Square-Wave VCO

The circuit above can come in very handy in a lab which tends to have a shortage of equipment. The LM13600 output stage allows this circuit to have almost a 1Hz to 1Mhz frequency range. This circuit can fill in for a lab function generator in most applications. Of course to have a true function generator, there should also be a sine wave output.




$$V_{PK} = \frac{(V^{+} \pm 0.8V)\,R_2}{R_1 + R_2}$$

$$t_H \approx \frac{2V_{PK}C}{I_F}$$

$$t_L = \frac{2V_{PK}C}{I_C}$$

$$f_0 \approx \frac{I_C}{2V_{PK}C} \text{ for } I_C << I_F$$

FIGURE 16. Ramp/Pulse VCO

The wide dynamic range of bipolar transistor maybe very under appreciated. For a LM13600, almost 6 orders of magnitude in current range mean having almost 6 orders of magnitude in control over timing. Given that transistors in BiCMOS are much faster and perhaps have 10 to 12 orders of magnitude, could there be some timing applications which could use this performance?

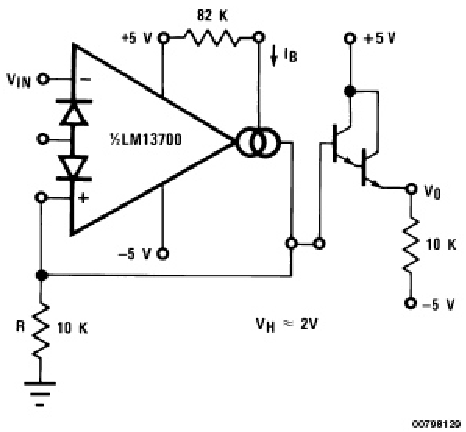
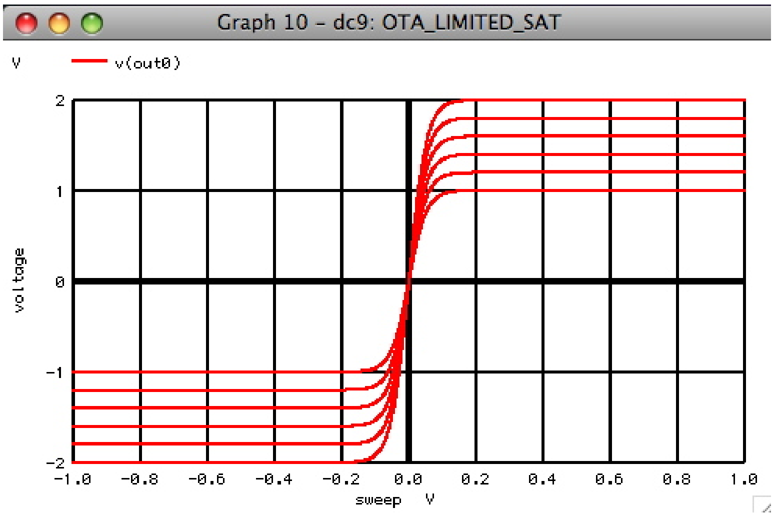


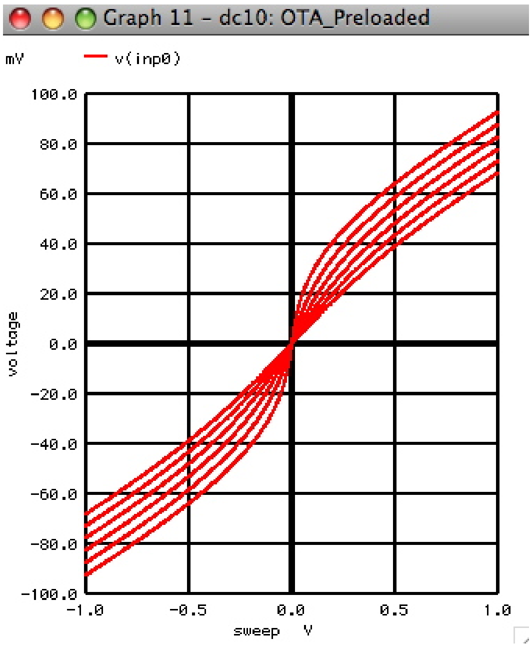

FIGURE 22. Schmitt Trigger

There are a whole class of nonlinear relationships that one encounters applying
electronics to the real world. The Schmitt Trigger application was an attempt to
investigate this area. The following are some of these nonlinear relationships

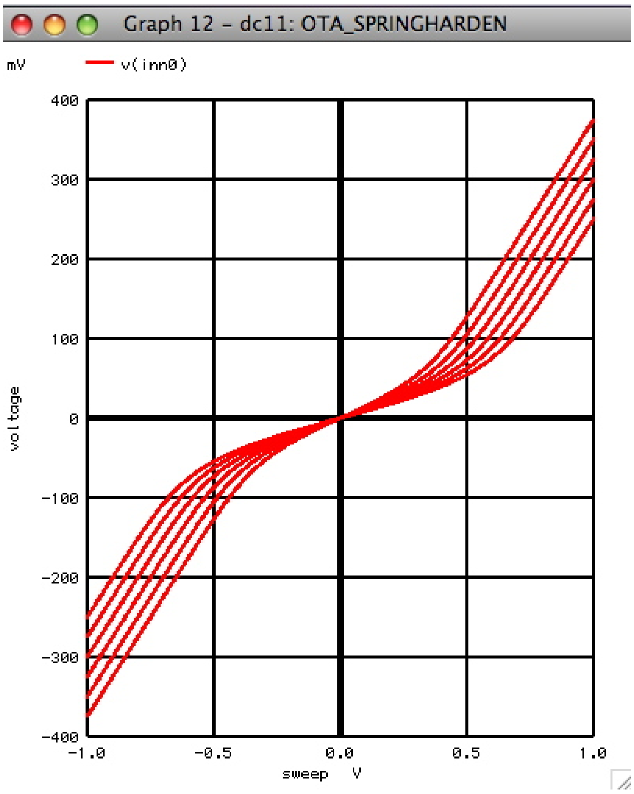
listed
under their common system names.



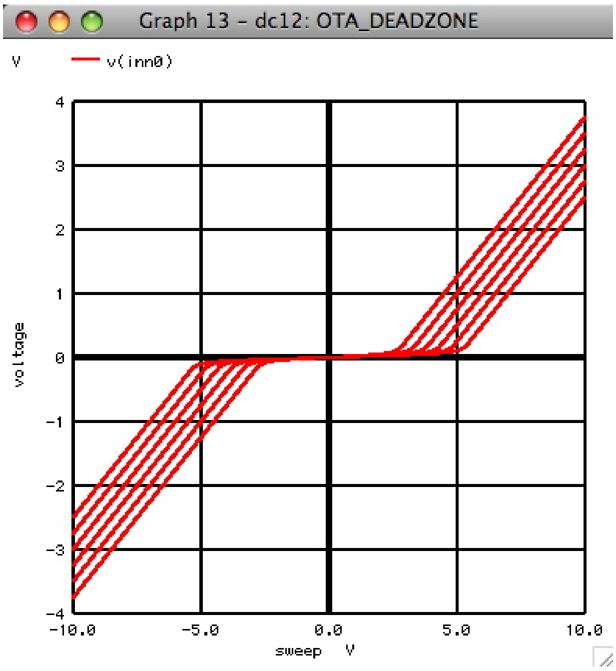

The limited Saturation is of course the natural nonlinearity of OTAs. This nonlinearity together with other types of nonlinearity may allow good modeling of a saturating magnetic core.



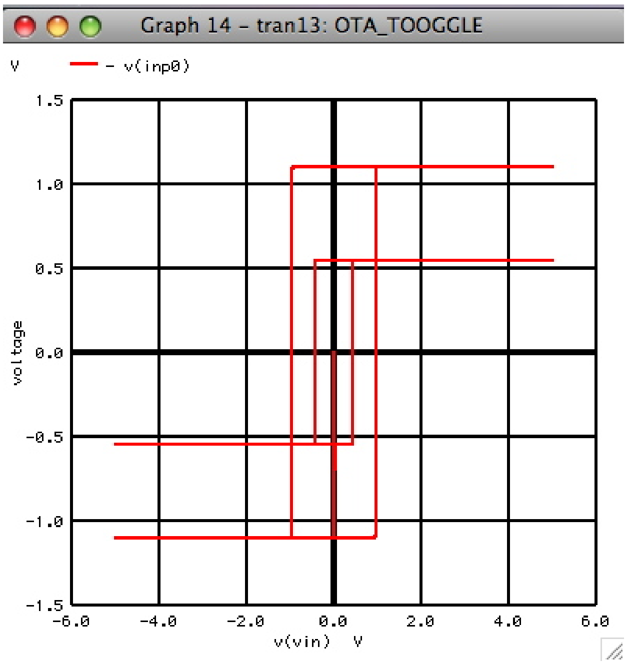

Preloaded means something is under stress without an external load.




This one is called Spring Hardening.




This is called Dead Zone.




The Toggle which is also the schmitt trigger application has memory of its past input signal built in. Combining this feature with some of the other nonlinearities may allow close modeling of magnetic components.