

# SIT Nemesis

By Nelson Pass

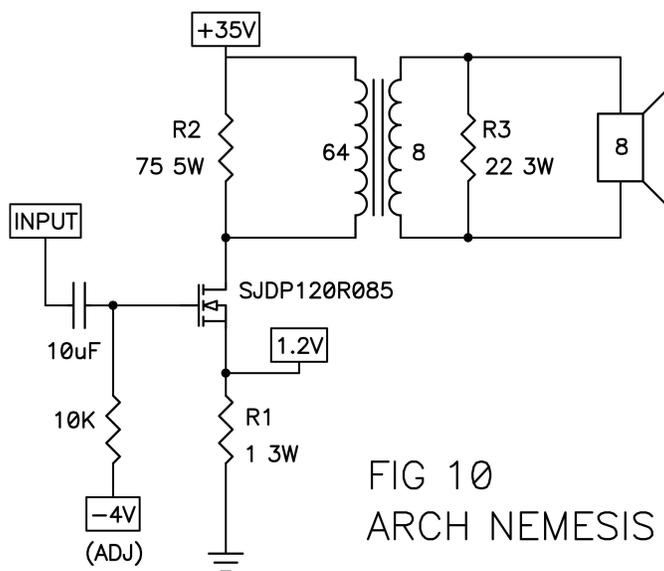
## Introduction

In the Volume 0 of Linear Audio I presented a redux of the 1985 Hiraga design, the Nemesis. The article explored some of the issues and variations that accompany the use of a simple single-ended Class A design coupled to the loudspeaker through an output transformer. This is an addendum to that piece.

## The Arch Nemesis

The “Arch Nemesis” had a central theme – the performance of a Common-Source mode power FET operating without feedback into an output coupling transformer. The transformer was originally commissioned by Jan Didden (our publisher) from Electra-Print in Las Vegas. Everything else was up for grabs, and so I played with a number of different Mosfet and Jfet devices, varying the supply voltage, bias current and resistive loading in an effort to locate the “sweet spot” for each device, and then compared the measured result.

You can see it all there, but to summarize, the best general result came from a new depletion mode Jfet, the SemiSouth SJDP120R085. Here is figure 10 from that article showing the specific circuit:



R1 was used to degenerate the gain of the Fet for lower distortion and increased bias stability with vertical Fets. The values of R2 and R3 here were used to give

a damping factor of 1 for the load. Without R3 and R2 the output impedance of the amplifier was about 28 ohms, which is considered quite high. There is another reason for R2 – a transformer works best when the source impedance is a small fraction of the primary impedance. This primary is 64 ohms, and the Drain resistance driving it is about 80 ohms.

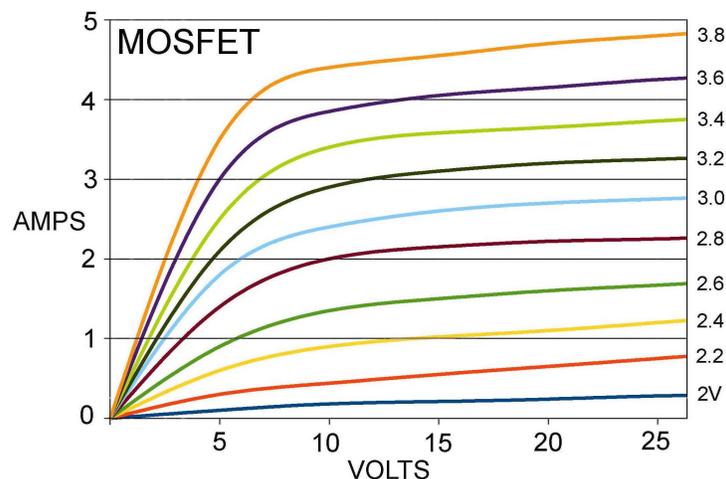
Driven by 80 ohms, the distortion and bandwidth figures for this transformer are not very good. Setting R2 at 75 ohms lowers the source impedance seen by the transformer and improves the lower frequency performance. Still lower values cause increased distortion in the power transistor.

If this were a SET amplifier with a 300B operated without feedback we could be looking at a damping factor of 2 or 3 at the speaker terminals, the result of a relatively low 700 ohm plate resistance working with maybe a 2500 ohm transformer primary. Non-feedback amplifiers of this type with very high quality transformers do better on the bottom end but suffer more tube distortion.

If only there were a good linear Fet with a low Drain resistance...

### The Pentode Character of a Mosfet

The characteristics of an amplifying device's curves are quite important to the performance. Your ordinary Jfet or Mosfet has a set of curves which resemble those of a Pentode tube:

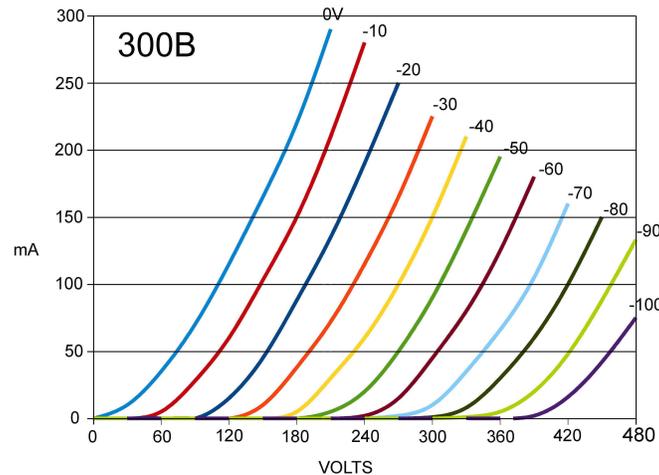


The current passing from Drain to Source ( $I_{ds}$ ) in a Mosfet is reflected in the vertical scale in Amperes, and the voltage from Drain to Source ( $V_{ds}$ ) is the horizontal scale. Ten different curves are shown, each for a different value of the Gate to Source control voltage ( $V_{gs}$ ). We see that for a given value of  $V_{gs}$

the current rises proportionally with  $V_{ds}$  from 0 to roughly 5 volts and then levels off. This region from 0 to 5 volts is known as the “linear” or “ohmic” region, where the Fet acts as like a variable resistor. The region above about 5 volts is known as the “saturation” region where the current through the device is much less dependent on  $V_{ds}$  and acts like a variable current source.

We could also say that in the linear region the device acts mostly like a voltage controlled resistor, and in the saturation region it acts mostly like a voltage controlled current source. Because the current  $I_{ds}$  is very dependent on the  $V_{ds}$  at low voltage values, in the linear/ohmic region the output resistance at the Drain is quite low - in this case as low as 1 ohm or so. In the saturation region the Drain resistance increases dramatically to 100 ohms or more.

By contrast, here are the curves of a 300B power Triode tube:



The voltages are much higher and the current much lower than that of the Mosfet example. In a Triode the Plate current is dependent on the Grid to Cathode voltage but also on the Plate to Cathode voltage, much as with the linear region of the Mosfet. However the curves do not flatten out at higher voltages, and the Plate resistance of the Triode remains relatively low (in this case about 700 ohms – low for a tube!)

## Enter the SIT

SIT stands for *Static Induction Transistor*. It is a form of power Jfet invented in Japan by Professor Junichi Nishizawa which found its way into audio in the form of the Vfet power amplifiers produced by Yamaha and Sony in the mid-1970's. They were called Vfets at the time because they have a vertical structure, but the subsequent invention and dominance of vertical Mosfets has made use of the term confusing. SITs are very fast devices and have found use in radar and



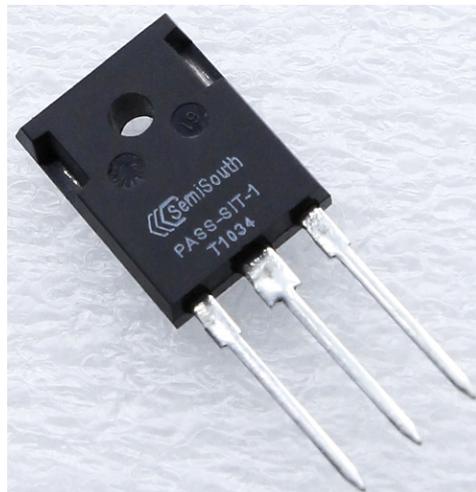
As you can see from the slopes of the curves, these devices have a linear/ohmic character throughout their operating region much like a power triode.

Those comfortable with tubes should feel reasonably at home. Like a Triode, the SIT is a depletion mode device – the Gate voltage operates at a negative voltage with respect to the Source. The notion of “Mu”, the amplification factor, is also familiar – it is the product of the transconductance times the output (Drain) resistance. As with a Triode, the Mu of the SIT is relatively constant because there is a reciprocal relationship between the transconductance and the output resistance. This makes for convenient adjustment for different loads by simply altering the voltage and current ratios in equal proportions while remaining near the optimal operating point.

In addition to delivering a low output Drain impedance, the SIT allows you to “work the load line” like a Triode. The gain increases with current, but also increases with voltage across the device. Variation in gain creates distortion, but the operating point of the device can be chosen to have these variations cancel. You can read more about that in “The Sweet Spot” to be found at [www.passdiy.com](http://www.passdiy.com).

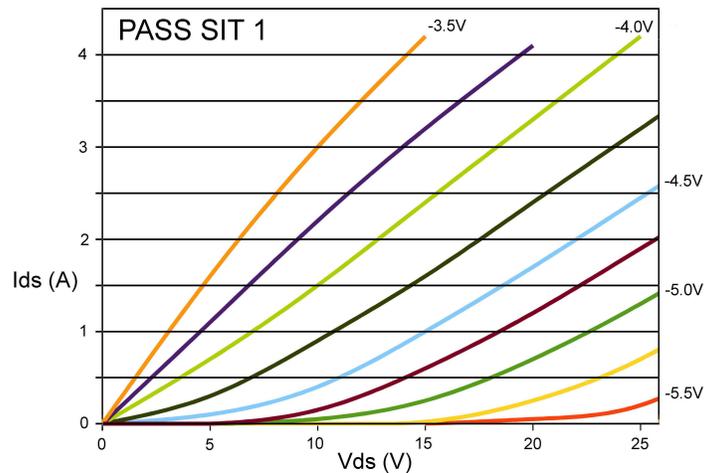
## SIT Nemesis

Already having a pair of Arch Nemesis laying around, I have tried the Sony 2SK82's, but I was a little disappointed as the transconductance was low and they did not develop much voltage gain. So instead I used this:

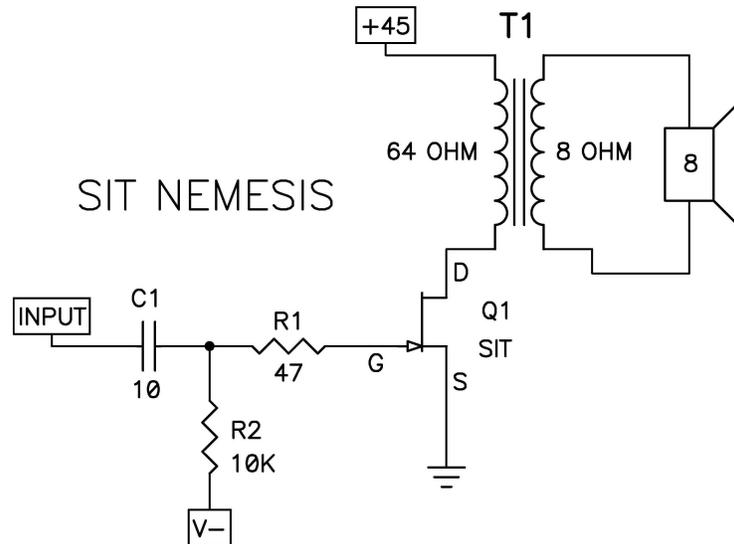


I had a small batch of these made last year with an eye toward putting them into a First Watt product. I've spent a year getting acquainted with them and exploring the potential for power amplifiers, including of course, the Nemesis.

It has a transconductance of about 2 and a Drain resistance of about 7 ohms:



It's a nice looking part, so in it goes. After a little playing around, the circuit looks like this:



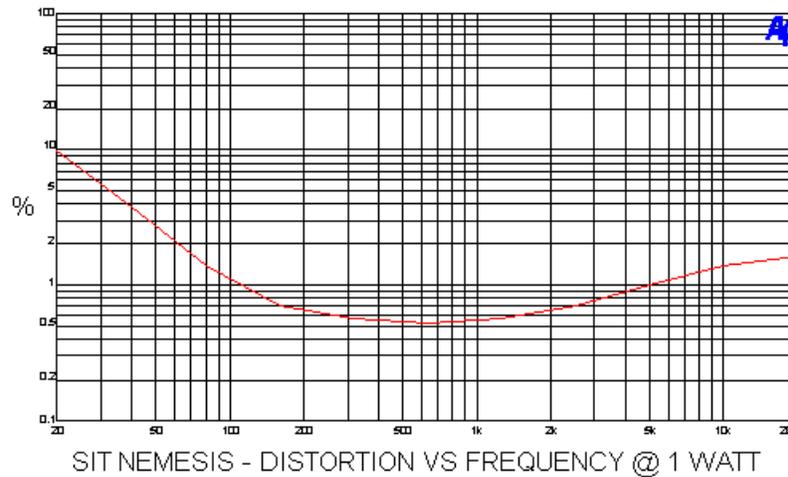
It's a somewhat simpler circuit than the Arch Nemesis. Gone are the 1 ohm resistor degenerating the Source connection to ground, as well as the primary and secondary load resistors. The amplifier biases up at about 0.9 Amps with a Gate voltage of about -7 volts. The gain is about 17 dB into 8 ohms and the damping factor is about 2.

The gain is 3 dB higher, the output impedance has been halved from 8 ohms to 4 ohms and the low frequency distortion of the transformer has been about halved. As seen in the curves, we also have much better performance into 4 ohms. The frequency response of the transformer has not improved, nor has the midband distortion, where the transistor appears to be responsible for about one third of the harmonic content.

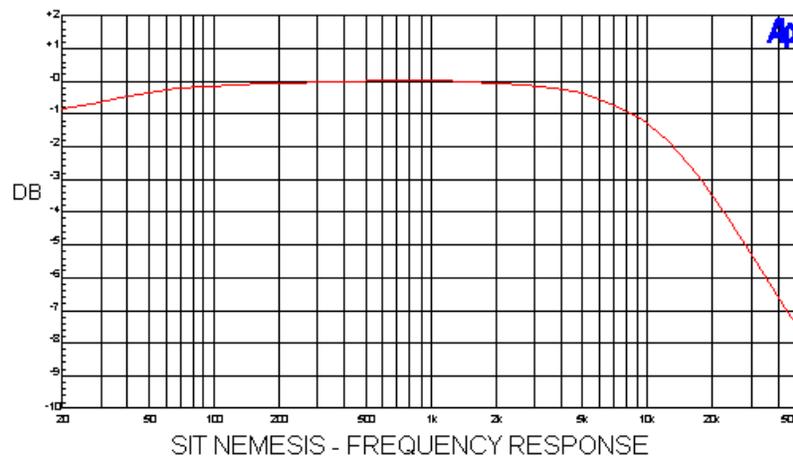
Here is the distortion into 4 and 8 ohms:



And the distortion vs frequency at 1 watt:



Here is the frequency response curve:



The real question of course is how is it different sonically? Having only two transformers, there was not an opportunity to compare versions side-by-side, but I didn't have any problem preferring the SIT version. The R085, the best of the previous batch, was somewhat dry by comparison and the SIT was more lively and had better depth. It shared something interesting with some other SIT prototypes, which when properly adjusted has the ability to present instruments in ensemble with a very individual character. You can easily focus on one instrument individually from the others.

This quality seems to be dependent on the specifics of the load-line. The amplitude distribution of the 2<sup>nd</sup> and 3<sup>rd</sup> harmonic and phase of the 2<sup>nd</sup> harmonic distortion vary as you adjust the supply voltage and the bias current. You can simply adjust for lowest distortion, or you can tweak these parameters to vary the sonic signature. It seems that Hiraga favored a ratio of 2<sup>nd</sup> to 3<sup>rd</sup> harmonic with the 2<sup>nd</sup> harmonic being dominant, but I am not aware that he specified the phase.

Clearly one potential improvement is to seek out *and pay a lot more for* a better transformer, one with more and perhaps better magnetic material and a wider high frequency bandwidth. As I understand it, Jan's copies of the Nemesis had an enormous transformer with much better high frequency bandwidth. From the measurements he has shared, though, it did not look to have lower distortion in the bass, likely because of the high Drain impedance of the Mosfet used.

Possibly Jan will follow up on this in the future with his better transformers.

Another possibility is to eliminate the transformer altogether and bias SITs to directly drive the load impedance. I am working on this, and I expect to present some interesting results in the near future.

Also I have reason to believe that we will see some new SIT parts from a couple of sources in the coming year – parts that you should be able to actually buy.

You should probably start saving for them now...

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