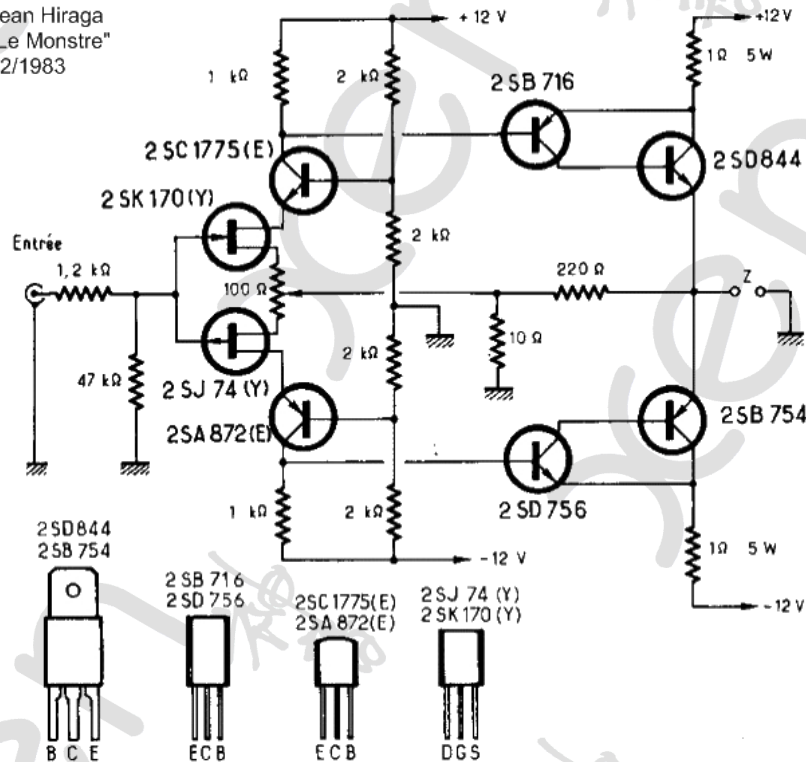


Hiraga Le Monstre Revisited 2024

XEN Audio

May 2024

Jean Hiraga
"Le Monstre"
02/1983



The Hiraga Le Monstre has been on the to-do list for decades. The goal was to replicate the 1983 design as much as possible, without any attempt to change or improve things, unless out of necessity.

The JFET Problem

Part of the reason for not taking it up earlier has been the lack of alternative devices to the originals. Especially the Y-Grade Toshiba JFETs are impossible to find. A recent discussion at the diyaudio forum about active devices for the Le Classe A revitalised the interest. After some searching, it appears a practical solution can be found.

The Y-grade JFETs have an I_{dss} of 1~3mA. Y-grade 2SK246 / 2SJ103 can still be found, but the transconductance is too low resulting in a big loss in open loop gain and hence high distortion. What about GR-grade? These are mostly between 3~6mA, mostly centred around 4mA. Simulations show that they can still be used without any major changes in the original circuit. The bias of the output stage will go up from 500mA to 1A, compared to Y-grade. Even with I_{dss} 6mA, one can readjust the output bias current by reducing the front end drain resistors, or increasing the 1R emitter resistors. Change in distortion is about 6dB increase in 2nd harmonics.

But GR-grade JFETs are also a rare commodity. Can we not figure a way to use the BL grade still widely available?

Someone did mention using a constant current source in parallel to the 1k drain resistors. But the voltage headroom is hardly more than 1.2V, and even worse, modulates with signal. A 2-pin CCS with

1.2V headroom is almost impossible to make, and one would have to go to current mirrors at both rails for a workable solution. Not impossible, but not so simple and elegant.

Luckily, the frontend JFETs are already cascoded at about half-rail voltage. So we can connect the CCS between the supply rail and the drain of the corresponding JFET, giving the CCS decent headroom of 6.6V, which more or less remains constant even in the presence of signal. Now, one can pretty much use JFETs of any I_{dss} larger than Y-grade, although it is still wise to keep it low.

For the CCS, a long-tail, low-noise JFET is a good candidate, and some degeneration helps to improve current stability. For this purpose, the widely available 2SK208GR is considered a very good candidate. A degeneration resistor at the source allows the CCS current to be adjusted, and a large-value gate stopper helps to reduce noise. The target CCS current should be such that the DC bias voltage across the frontend drain resistors should be 1.2~1.6V, depending on the target output bias current.

Alternative BJT's

So the Y-grade JFET problem is solved. How about the other devices ?

The cascode devices are not so critical, as long as they have a high h_{fe} and is reasonable low noise and low capacitance.

Let's have a look at the major specifications of the others :

Device	Vce	Ic	hfe	ft	Cob
2SB716	120V	50mA	250~800	150MHz	1.8p
2SD756	120V	50mA	250~800	350MHz	1.6p
2SB754	50V	7A	70~240	10MHz	300p
2SD844	50V	7A	70~240	15MHz	250p

These can still be found in small quantities and are not that expensive, should you want to stick to the original 100%. But for the longer term, wouldn't it be nice if we can find "modern-day" alternatives with identical or similar performance ?

Restricting to our search for alternatively to only active devices, we came up with the following :

KSA992	120V	50mA	300~600	100MHz	2p
KSC1845	120V	50mA	300~600	100MHz	1.6p
2SA1943	230V	15A	80~160	30MHz	360p
2SC5200	230V	15A	80~160	30MHz	200p

They are actually quite good replacements, especially in terms of h_{fe} and h_{fe} linearity. The Onsemi BJTs are a bit lower in dissipation, but the actual dissipation is only ~100mW, so still well within specification. Spice simulations suggest there is a slight advantage in distortion by using 2x in parallel, despite doubling the capacitance. This option will be accounted for in board design.

Toshiba Fans will want to use Toshiba devices throughout, not ? If you can find 2SC2240 / 2SA970 in BL grade, then they are just as good as 2x Onsemi in parallel :

2SA970BL	120V	100mA	350~700	100MHz	4p
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Note that we have deliberately chosen the N-version of the power devices, instead of the O-version with higher hfe. This is to follow Hiraga in his original article, in which he stated that the optimum hfe should be 60~80.

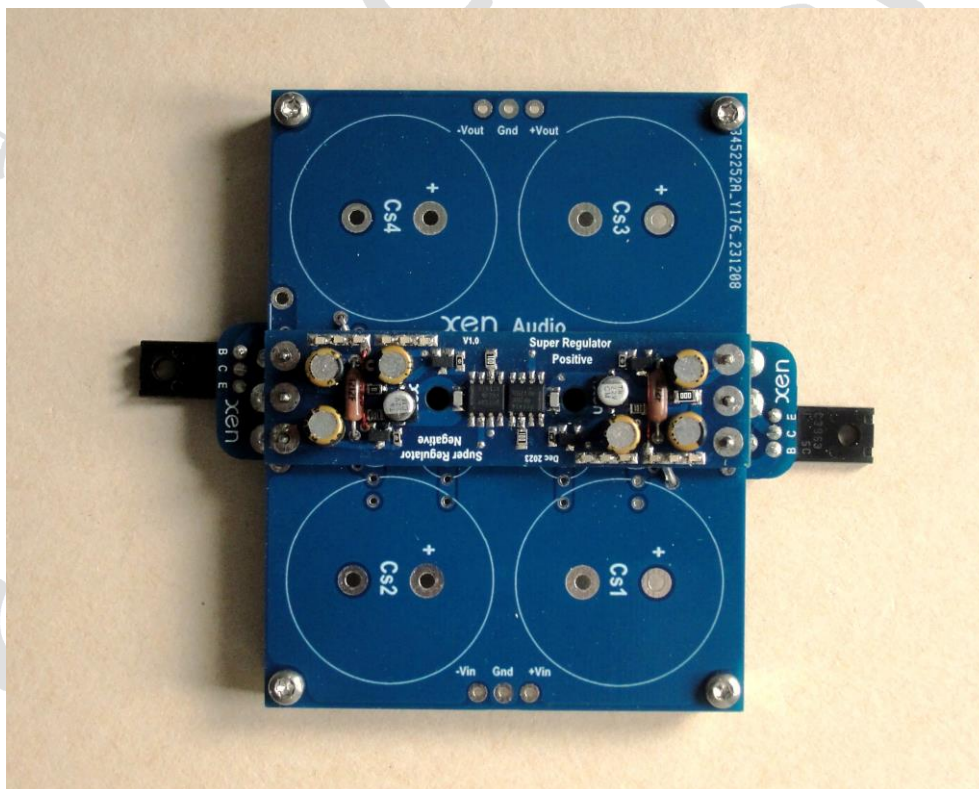
After some searching, we managed to acquire a few sets of the original BJTs. This will allow a 1:1 comparison with the modern-day alternatives. A prototype was built and worked perfectly first time -- perfect square waves and no signs of ringing or oscillations.

[illegible]

Le Monstre supposedly got its name not from the amplifier itself, but from the massive supply. The reasoning was already detailed in Hiraga's article. Again, one can of course follow the original 1:1, and use 45Ah lead acid batteries. There are probably Lithium alternatives which are less bulky, but maybe not everyone likes to deal with the complexity of the charging and balancing circuits.

Various favours of power supplies have been published in association with the Le Monstre. For an amplifier with such high bandwidth and not particularly high PSRR, it is perhaps wise to avoid SMPS. We have therefore chosen to use the proven transformer / rectifier / C_Reg_C configuration instead. Here the Reg does not have to be a voltage regulator with negative feedback, in the traditional sense. Hiraga stated the importance of fast current-delivery capability. And most regulators are known to become inductive at high frequencies. So perhaps a capacitor multiplier, a la John Lindsley Hood Class A, is a better choice.

It has been mentioned elsewhere that a Walt-Jung / Jan-Didden type super regulator capable of 2A current delivery produces great results with the Le Monstre. We do have a stack-on daughter board which will convert our Cap Multiplier PCB into a Didden regulator. For lowest noise, however, it is better to use bipolar Darlingtons as pass devices, instead of UHC-MOSFETs. If we are to design the power supply for a maximum current delivery of 5A, the Darlington should have a hfe of at least 5000, in order not to load the regulator opamp excessively. Using the 2SC5200-O / 2SA1943-O as power devices, the base current at 5A output is still ~50mA. The driver transistor would have to be TO-126 types to be able to deliver the current and dissipate the heat. And to keep the input capacitances low, high-voltage devices such as KSC3503 / KSA1381 should be considered. The combined hfe should be in excess of 10,000. Even at 1A DC bias, base current is less than 0.1mA, so that even 5k resistors can be used in the RC filter of the cap multiplier.



Which option to chose, in the end, has to be an individual decision.

Even more Power for 4 Ohm Load ?

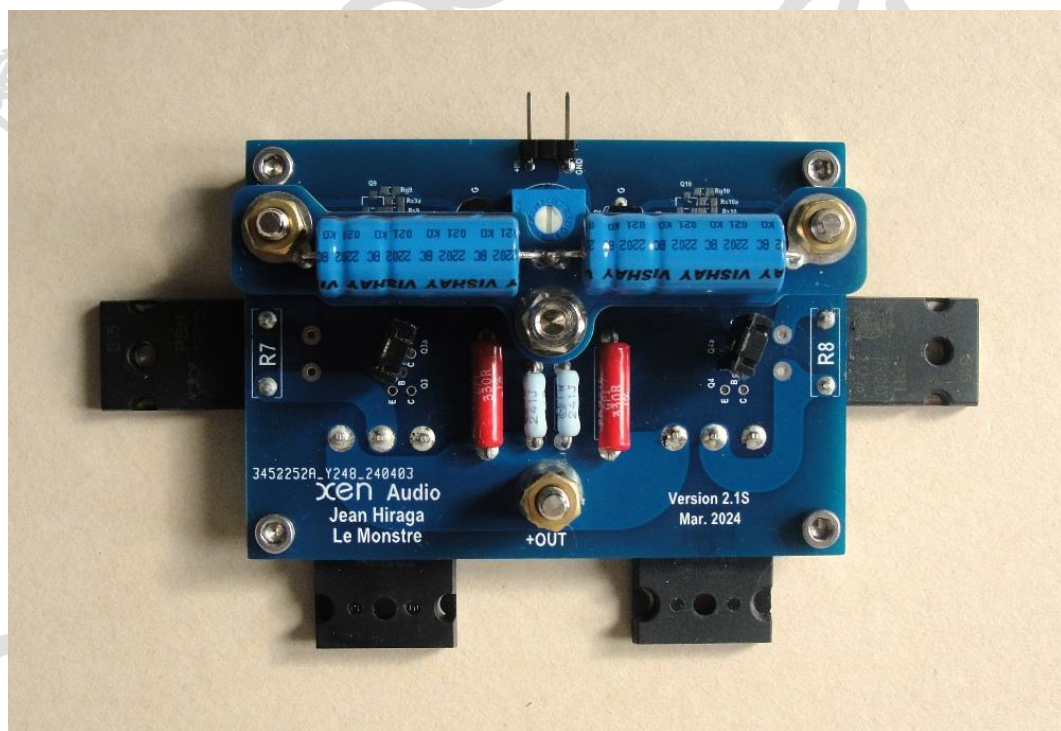
A friend has a 4-ohm speaker with a SPL of 88dB at 1m, 2.8Vrms, and wants to use the Le Monstre for that. For room-filling bass, the system should be capable of 98dB at 1m, meaning 8.4Vrms, or +/- 12V. The Le Monstre with 12V rails will certainly come short.

Then just build the Hiraga Le Classe A, one would say. But can't we just use the Le Monstre with increased the rail voltages and output bias current ?

Knut Harald Nygaard^[1] did post a 24V version of the Le Monstre on his website, using GR grade JFETs, Toshiba BJT cascodes, Sanyo 2SA1209 / 2SC2911 drivers, and 2SA1943 / 2SC5200 for the output. But for +/-12V into 4 ohm, 19V rails and 1.7A bias would be more optimal, with the output device dissipation limited to 33W, pretty much standard in numerous Class-A projects. The

temperature above heat sink for the output devices is a healthy 30°C, but now the drivers will have to take 300mW each. 3x Onsemi TO92s in parallel would be required if we do not want to sacrifice the high hfe. Alternatively, KSC3503 / KSA1381 could be used, keeping the low capacitance and providing much more reserve for current delivery, at the expense of 3x lower hfe. It is worth mentioning the addition of a 220R resistor by Nygaard between the bases of the two output devices, “introduced to limit the current variation in the driver transistors”. It adds 6mA to their DC bias current. At least in simulations this does not seem to improve things.

The open loop gain, just like the Pass F5, is load dependent. With 4R load, this is halved compared to 8R. To compensate for this, one could reduce the gain by increasing the 10R feedback resistor to 20R. The output impedance is still something in the order of 0.7R. So the speaker should have relatively flat impedance over the audio band.



How about Passives ?

The sonic signature depends largely on the behaviour of its components, in particular active components, under operating conditions. For such a simple circuit, once those components and their operating points have been chosen, there is not much one can do to improve things further.

The PSRR of the front end cascode can be improved by changing the outer two 2k resistors by current regulating diodes such as Semitec E352, and the inner two by shunt references such as LM329, or 4x red LED (HLMP6000) in series. The improvement is minimal, especially with a well-regulated, low-noise power supply.

Some people swear on tantalum nitride resistors^[2]. And you can still get them at a premium price, although some review stated that they were sonically not neutral. Even better, one can get 0.1% 25ppm/K SMD resistors in tantalum nitride from the Vishay PTN or PAT series. 0805 sizes can be used at the input divider, and 1206 sizes for the drain resistors and in the feedback network. The PCB

has enough space such that R10a,b on our PCB can each be replaced with 9x 1206 resistors in series-parallel on a small adaptor PCB. Using these in the cascode would be a total waste.

We have chosen to use Futaba MPC74, or their equivalent from KOA, for the power resistors at the output in the other prototypes. These are non-inductive, and do not require heat-sinking. But if the very best must be used, then Riedon PF2203 is thin film in addition to low tempco (50ppm/K). They do need mounting onto the main heat sink.

Last but not least, one dare not forget the DC offset trimmer. We were able to source some of the original TOCOS RA12P wire-wound trimmers. One may also consider the Vishay Accutrim 1204 bulk foil trimmer, or Bourns 3250P multi-turn wire-wound, if cost is no issue.

Setting up the Bypass Current Source

As mentioned above, the higher drain current resulting from the use of GR (or even BL) grade of Toshiba JFETs can be compensated for by using a bypass current source from supply rails to the cascoded JFET drains, as this provides enough voltage headroom (~6.6V) which remains essentially constant due to cascoding.

To determine the bypass current required, one should first measure the drain current of each JFET together with a 50R resistor at the source, while applying 6V from drain to resistor free end. For GR grade JFETs, this should be around 2mA. Assume actual measured value to be 2.1mA, for example.

The next step is to determine what voltage is needed across the 1k drain resistor. This is equal to V_{be} of the driver BJTs, plus bias current $\times 1R$. Hiraga specifies bias to be between 0.6A to 0.8A. And allowing for 20% increase with temperature, the cold setting bias should be 0.6A. That means the desired current through the drain resistor is 1.2mA, which gives a bypass current of 0.9mA.

One can first check this by using a fixed resistor instead of a CCS for the bypass. For 0.9mA across 6.6V, the resistor should be ~ 7.5k. With only the frontend soldered on the PCB, the 100R trimmer set at mid-point, and with the 7.5k resistors in place, the voltage across the drain resistor can be measured and compared to the target value. Of course one can also use an additional 10k trimmer instead of a fixed resistor, if one wants to be exact.

One can then consider just using a fixed resistor for the bypass current instead of the CCS, as long as the resistor value is large enough (say $\gg 5k$). For JFETs with higher I_{dss} , the required bypass current will increase, and thus the resistor value will decrease. The current source has the advantage that its dynamic impedance is much higher and less sensitive to the required bypass current value. But it is more complicated.

In the prototype, 2SK208GRs were used for the bypass current source. Their I_{dss} vary within a range as specified in the datasheet, so the exact value of the degeneration resistor has to be determined individually. But from the examples already build, an empirical approximation formula can be used to calculate the starting value of the R_{degen} :

$R_{degen} \sim 4.48 - 4.24 \times I_{bypass}$ where R_{degen} is on kOhm, and I_{bypass} in mA.

Measurements

The first prototype built with original transistors (and "normal" passive components) has a flat frequency beyond 1MHz. In modern home environments, this is likely to pick up RF noise. We therefore decided to add a PPS cap of 330p in parallel to the 47k at the input, to reduce bandwidth

somewhat to ~400kHz. Still very high for a power amp. Also, to improve stability margin, we added 47p Ccom to the driver BJT's, same as Knut Harald Nygaard.

Distortions were measured for all variants at 1W, 1kHz, after 60 minutes thermal stabilisation, and trimming DC to < 5mV. For the 19V variants, the load is 4 ohm. All others have 8 ohm resistive load.

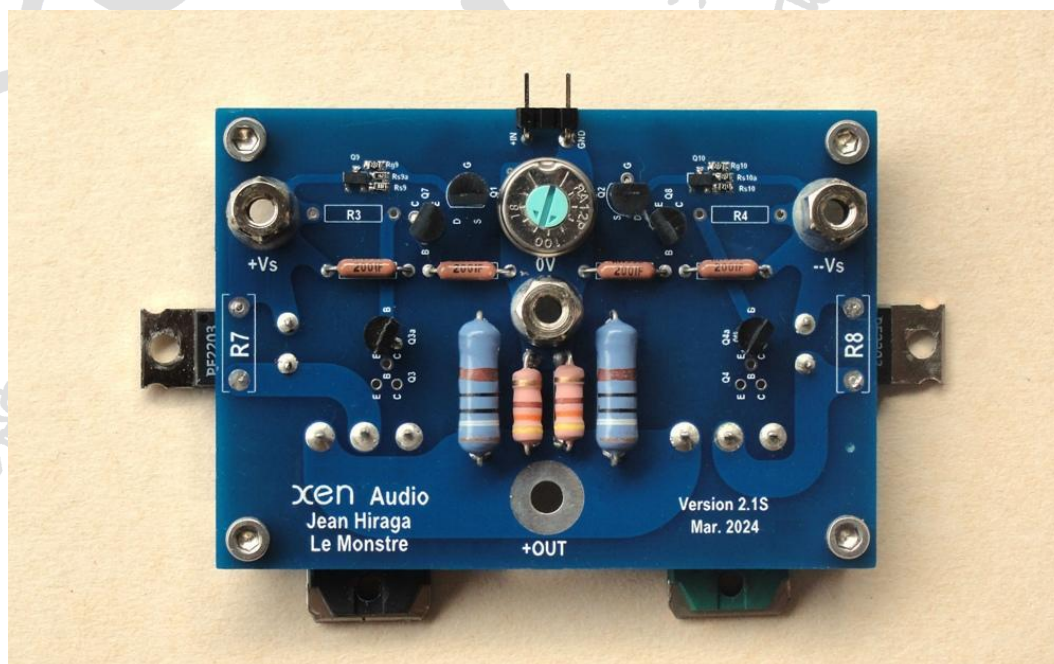
A comparison table is as follows :

	H2	H3	H4	H5	H6
	dB	dB	dB	dB	dB
LM Original BJT's	-55	-58	-64	-75	-89
LM Modern BJT's	-72	-72	-98	-112	-111
LM 19V 4R 1.4A	-70	-83	-111	-116	-116
LM 19V 4R 1.7A	-71	-85	-113	-116	-115

Somewhat surprising is the large difference in distortion between modern and legacy active devices. Although the original devices are genuine, it is impossible to tell whether they are exactly the same as they were 40 years ago. But with modern active devices, distortion is easily 5~10x lower. Also, the 19V 4-ohm version behaves equally well, and has even 10dB lower H3. Of course, it does not tell you which one sounds better to your ears.

DC offset is quite stable with temperature, but bias current increases from cold to steady state by 20~25%. This has to be accounted for in the initial setup.

The Deluxe Version



To convince ourselves of the importance of passive components (if any), we tried to build a “Deluxe” version as close to the Hiraga original as possible today.

Except for the potential divider for the cascode (Vishay RN55), all other resistors are Vishay PTN series TaN. The large feedback resistor is made up of 2x Shinkoh 1W 390R in parallel, and the 1R 5W is Riedon PF2203 mounted on heatsink. We also managed to source the original TOCOS RA12 wire-wound trimmer, but only in 10R, which we placed in series with 2x 42.2R PTN to make up 100R. This proves to be more beneficial actually, as it allows much easier trimming for DC offsets.

As mentioned earlier, we apply the bypass current source to allow for the use of GR grade JFETs while retaining the 1k drain resistors. The set of JFETs used in the prototype have an I_d of $\sim 1.8\text{mA}$ with 50R source degeneration (this was measured upfront). As we wish to set the initial bias to 600mA, the target current through the 1k drain resistors should be 1.2mA. Thus 0.6mA of bypass current was set with the appropriate source resistors to the 2SK208GR JFETs.

What's next ?

Sonic impressions can only be subjective. So we try to organise ABx tests with a panel of DIY enthusiasts. To enable simultaneous switching between two amplifiers, an ABx Switch Box based on MOSFET relays has been specially constructed.

Two separate amplifier cases with sufficiently large heat sinks need to be organised. For power supplies, 2x 45Ah car batteries will be connected to a pair of 150,000 μF capacitors via inrush current limiters, before connecting to the amplifier boards. The latter have additional 1000 μF 16V axial capacitors directly on board. For the regulated version, laboratory power supplies set at 15V 2A will be used to feed the Didden Super Power Regulators.

And then it is down to auditioning by the panel. Which will of course take time to organise.

References

1. andiha.no/audio/projects/AlaHiraga.html
2. <https://www.diyaudio.com/community/threads/hiraga-le-monstre.5462/post-7565433>