

THE GYRATOR

Substituting A Choke ...

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There were so many inquiries about this little circuit that I decided to update this article.

The main theme was how to calculate the virtual inductance of the gyrator as well as the several parts if other apps require other figures.

So, I attached a math appendix at the back of the article, please see there.

I again wanted to thank Mr. van Hall for his splendid idea to feed the pre-stages (B1+) from the center point of the two serial caps of the B+ supply!

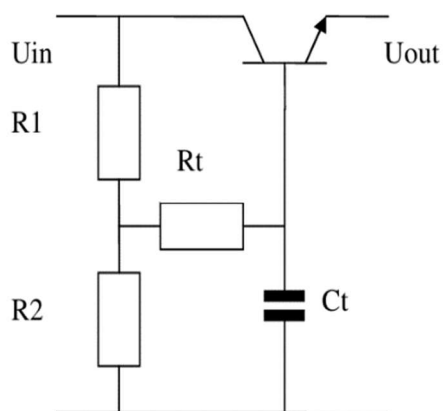
INTRO

... but there was a little problem with increased hum at the output! Because my efficient horn speakers reflected this problem in a very audible way, I turned back to the connection from before, taking B1+ from the B+ supply via a heavy resistor chain.

Knowing that this special idea could be brought to a better result, I started to research, which design could give a better hum and noise figure. The found solution is again a gyrator, which might be usable also for other applications, so I started to write a new article about.

This "B1+ gyrator" circuit is intended to replace the choke 10H/25mA/EI55 from the circuit shown at my website.

THE WAY IT WORKS



The basic function of any gyrator is that an inverting, amplifying part (enhancement MOSFET, transistor → NMOS) with a capacitance (C_t) at the gate (base), acts like an inductance across drain/source (collector/emitter).

The value of inductance, which is achievable by this configuration, is bigger than an "iron"-choke could become for the same price and/or space/weight. And, its hum and noise reduction are really good.

The critical values to calculate such a gyrator are R_t and C_t . These values define the final virtual inductance L_{virt} . The ratio of R_1 to R_2 defines the voltage drop of the circuit. Please read the math appendix in behind of this article.

FUNCTION:

Because the above schematic consists of two identical circuits, I shall explain the circuitry only by the one for the left channel. Substituting the choke, the terminals JP1 and JP2 are connected instead of the choke while JP3 is connected to GND.

THE SCHEMATIC

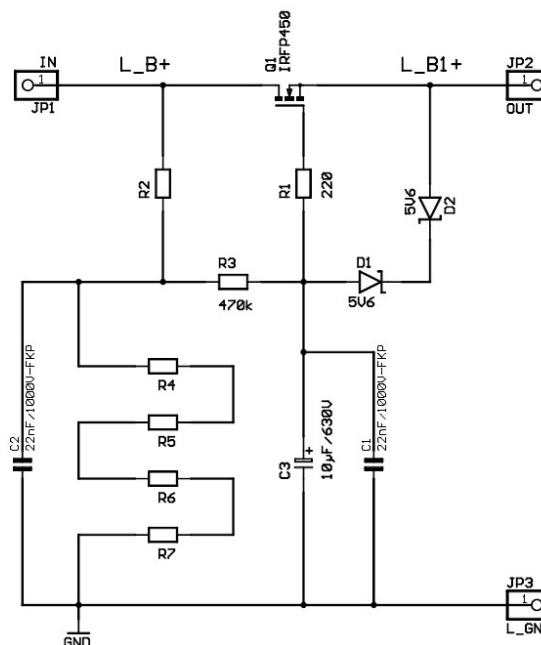
The supply comes from the center point of the two caps in series and it measures half of the B+, in this case is half of the +930VDC -> +465VDC. The current across the resistor chain R2, R4, R5, R6, R7 (1W, ±1%, metal film) should be set to app. 1mA, so the total dissipation within will stay to less than ½W. Values can be found from an EXCEL spreadsheet you can download from my website, and it is ready too to calculate the needed values for your "any other" special application.

The voltage across R2 should be kept to at least 6 - 7V_{DC}, so also the voltage across the power NMOS Q1 will be app. 10V_{DC}. The resistor R3 (0,5W, ±1%, metal film) charges the cap C3. Combined with a high value R1 (~1MΩ) it can be of small value (~ 1μF) since the gate of the NMOS is extremely high resistant. It resembles only a gate-charge of some nF. Resistor R1 (0,5W, ±1%, metal film) acts as a grid stopper and shall only prevent oscillation.

Cap C2 is used to filter noise from the incoming supply voltage. It somewhat improves the noise figure. C1 in parallel to C3 serves the same reason. Both should be foil-type (best are MKP-X2 or FKP).

Power-up delay of this circuitry will be app. 4 seconds. This will also prevent pops, coming from the charging of coupling caps.

The used NMOS (IRFP450, datasheet at my website) will stand 500V_{DC} across drain/source. If you wanted to use this circuit for a bigger voltage, you should consider a type showing bigger U_{ds}. Furthermore, the NMOS has to be mounted (properly insulated!) to a suitable heat sink (i.e. the amp-chassis itself). In the case of MA845, the power dissipation will be app. 0,2W during idling operation, but there will be some more during switch-on and if the circuit had to regulate, i.e. due to mains variations, it will be even more. If you increase the value of R2, the NMOS will drop more voltage, so you could also adjust a personal B1+ within your amp. This again will lead to bigger dissipation and will increase heat. So be aware to apply a proper heat sink!



THE MATH APPENDIX

For to achieve a good filtering effect, the X_L of the choke @ $2 * f_{\text{mains}}$ (in Europe $f_{\text{mains}} = 50\text{Hz}$ while in the US $f_{\text{mains}} = 60\text{Hz}$) should be app. >3 times the value of the load circuit. Considering our MA845 B1+ supply, we have a supply voltage of 430V_{DC} and a load current of app. 18mA, therefore R_{load} is 23,9kΩ. So, we target an X_L of app. 75kΩ or more.

$$X_L = 3 * \frac{B1 +}{I_{\text{load}}}$$

$$X_L = 2 * \pi * (2 * f_{mains}) * L$$

$$L = \frac{X_L}{[2 * \pi * (2 * f_{mains})]}$$

We insert $X_L = 75k\Omega$ and $f_{mains} = 50Hz \rightarrow L = 75000 / 628 = \text{app. } 120H$

If we now chose R3 and C3 like from the evaluation of above the virtual value L of $[L_{virt}]$ is given by

$$L_{virt} = \frac{R3 * C3}{gm}$$

Whereas gm is the value of forward transconductance of the chosen NMOS. In our case (IRFP450) its gm is ~20 Siemens ($I_d=11A$, $U_{ds}=25V$) like from its datasheet. So, our result is $(1M\Omega * 1\mu F) / 20S = 20mH$. That's too small, but if we check the graph of the NMOS at its datasheet, we cannot see how small gm really is, because all the graphs start at zero. NMOS show really low gm at low I_d current. Therefore, I would give it a try and if the effect must be increased, we could always increase the value of either R3 or C3.

OK – experiments show, that the real gm of the IRFP450 at low I_d is app. 10 - 100mS in some setups even less. And – due to a big el.cap in behind of the gyrator we get what we wanted at even less L_{virt} , because the virtual R_{load} is less too for AC than we calculated for DC. So, it works like we prospected.

Like an iron choke, the gyrator shows a drop in DC-voltage too. With the iron choke, this DC-drop comes due the R_{dc} of the copper winding. In our case this drop is app. 10V_{DC} (pls. see EXCEL spreadsheet). So, we calculate $10V / 18mA = 555\Omega$. This value can be adjusted by simply changing the value of R2, which makes it possible to customize the output voltage to the needed value. Since a gyrator does not store energy like an iron choke, it is essentially necessary to choose a DC voltage-drop bigger than the peak-to-peak ripple of the input voltage! Pls. check your actual amount of peak-to-peak ripple by scope.

THE CHOICE OF COMPONENTS

Caps are MKP-X2 by TENTA and/or WIMA

El.Caps - in the supply I used standard NICHICON, type VY

Resistors are standard metal film 1%, type SMA-0207 or -0414

NMOS are by IR

Diodes and **Z-diodes** are from several brands. Pls. refer to the schematic!

As you know - all information about the printable, full-size schematic and the PCB is again situated in a binder enclosed to this website.

If you have any further question, you can contact me via eMail.