

Preface: Dear reader,

in our 4th installment in the line of the "Effect-ive"-articles, Bernd Meiser investigates The Rat. For me personally, translating this article was a great way to catch up with history because somehow this pedal completely weaseled (or maybe "ratted"?) its way around me. Of course, I knew that this pedal existed, but at the time I was somehow so involved (and happy) with tube preamp & power amp distortion in my modded Fender amps that (to this day) I never even tried out The Rat. Maybe that's a mistake that needs to be corrected ... Anyway, don't let yourself get bitten (... too much ...)! T.Z.

From the "Effect-ive!" series of articles:

Big bites of distortion: The RAT

By **Bernd C. Meiser**, translation by **Tilman Zwicker**

In the business of music equipment, the ProCo company was no newcomer. We can trace precursors of the enterprise way back into the 1960's, in fact right back to repair department of the Rock & Drum Shack in Kalamazoo, Michigan. From these origins, and via a few intermediate stages, the Sound Factory developed in the early 1970's - this was the immediate predecessor of ProCo. Around that time, Scott Richard Burman joined the ranks of the troupe – he will go on to design the "RAT". Among the guitar-freaks of the time, the Sound Factory was a hot insider tip: they replaced, for example, the wimpish transistors in the then-hip Dallas-Arbiter Fuzz Faces by high-gain types from the most recent US-production.

Sidenote: the Brit Ivor Arbiter was the first GB-based importer of decent guitars produced in Holland and Germany, filling (at least to some extent) the void created by the fact that US-made guitars were almost impossible to come by in Britain until the end of the 1950's due to an import ban. This trade restriction was imposed by British government to supposedly help alleviate the debt that Great Britain amassed in WW2 with the associated lend-lease program. Even after the ban had been lifted, the situation changed only gradually in the early 1960's – and Arbiter was one of those who worked hardest and with best effect for the availability of American-made instruments. This was one reason why – in contrast to his local pedal competitor Colorsound – the man was successful stateside due to his good contacts, and due to the presence of his products there ... the Fuzz Face being one example.

In any case, the boys from Sound Factory had their finger on the pulse of the time and knew exactly what guitarists wanted – and they were gonna give it to them!

So, Burham designed a new circuit. MXR had already demonstrated in 1973 with their bestselling "Distortion+" how to get a decent distortion effect, and that device would be the starting point for ProCo's future mega-seller. Around 1975 the first prototypes were completed – as a custom order for local guitar players – and there was some fiddling about with the circuit during those early days. Commercial series-production commenced in 1979 employing a large black casing (**Fig. 1**) that was replaced in 1984 by a more compact version. In 1987, the "RAT 2" (**Fig. 2**) was released with the an LED status-indicator (a first for ProCo) – presumably for those people who were so hard of listening that still could not hear when the "hot" pedal was switched on. Two years later, the even hotter "Turbo RAT" (**Fig. 3**) appeared on the market. By now a well-established manufacturer, ProCo (of course) launched a reissue of the old original circuit designated "Vintage RAT" in 1990, and three years later they came out with another interesting circuit under the name of "BRAT".



Fig.1: RAT (1979)



Fig.: RAT 2 (1987)



Fig. 3: Turbo Rat (1989)

picture sources:<http://www.guitartoneoverload.com/2010/02/17/the-proco-rat-2-or-hot-to-make-your-strat-or-tele-sound-fat/>
<http://www.effectsdatabase.com/model/proco/rat/vintage>; <https://youtubemusicsucks.com/pro-co-turbo-rat-distortion-pedal-review/>

ProCo's „The RAT“

Let us now analyze the circuit (Fig. 4). The OP-amp is directly driven by the guitar signal – there is no impedance converter as it had been found only in early pre-production specimens. Just like in the MXR Distortion+, a 1-nF-capacitor C2 shunts the input and audibly reduces the resonance frequency of the connected guitar – pretty conducive for your wall-of-gain sound pickup but less of a good thing when the volume control of the guitar is turned down: now the sound easily becomes too blunted and dull. That is due to the output impedance of the volume pot that increases as the pot is turned down, and – in conjunction with the cable capacitance – a (first-order) low-pass consequently results. The resistor R1 substantially determines the input impedance of the circuit; this R1 changes in the course of the years. In the original pedal, it was as high as 1 MOhm.

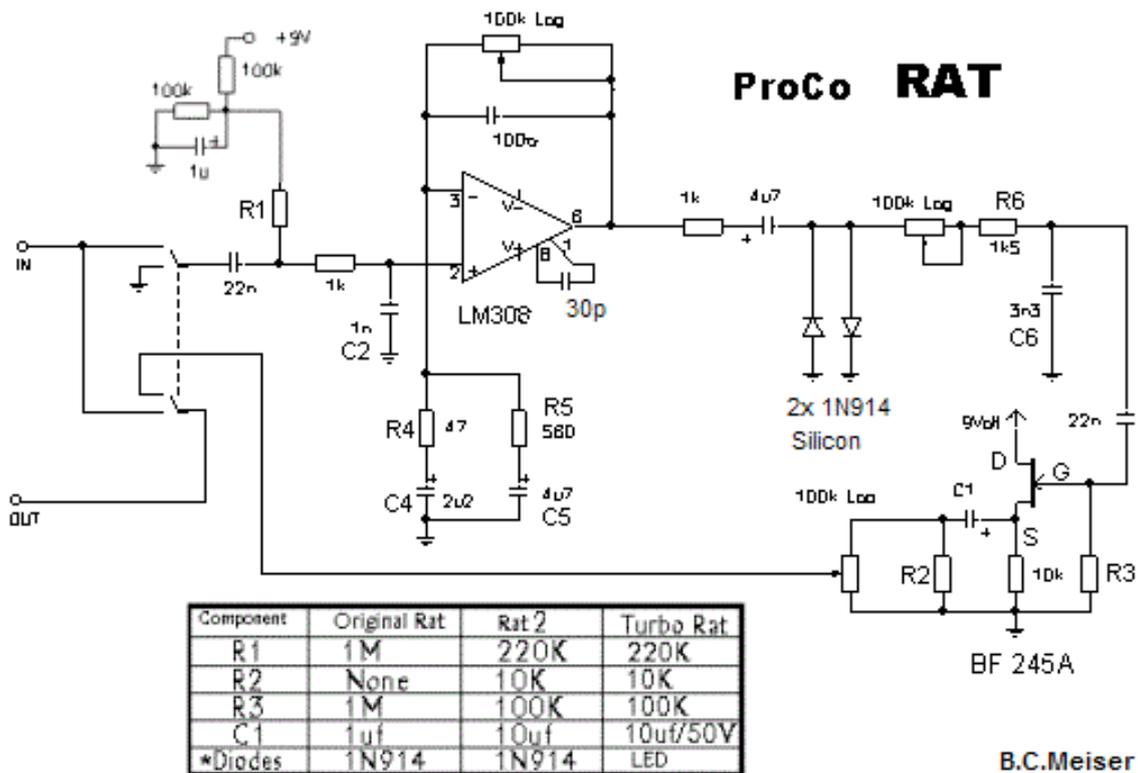


Fig. 4: Schematic of the RAT for several different variants.

The gain is taken care of by an LM308N (Motorola) – a US-made standard OP-amp of the early 1970's – sporting 2 additional inputs for compensation of the frequency-response. Using a 30-PF capacitor here makes the OP-amp quite slow, with the slew-rate dropping to below 1 V/μs. Moreover, at the maximum gain of 67 dB (see also below) we get a gain-bandwidth product of about 700 Hz. All this has effects on the large-signal processing at mid and high frequencies, and on the frequency response – because this is complex matter, we shall not investigate it further here. However, overall it needs to be noted here that the LM308N, with its additional compensation-capacitance, does coin the sound!

Fig. 5 shows the actual frequency response of the RAT with the LM308. We notice a "voicing" at about 700 Hz for the gain adjusted towards high settings - due to the s low gain-bandwidth product. For lower gain settings, the voicing travels to higher frequencies, and the frequency response increasingly becomes flatter. Thus, the low values the slew-rate and gain-bandwidth product the old LM308N indeed are of essential importance. Any modern OP-amp would be ashamed to display such data ... but it should noted that exchanging the dinosaur-OP-amp in the RAT for a newer, seemingly "better", type would, due to the then higher gain-bandwidth product, remove the voicing described above, and the RAT would loose its typical high-gain sound!

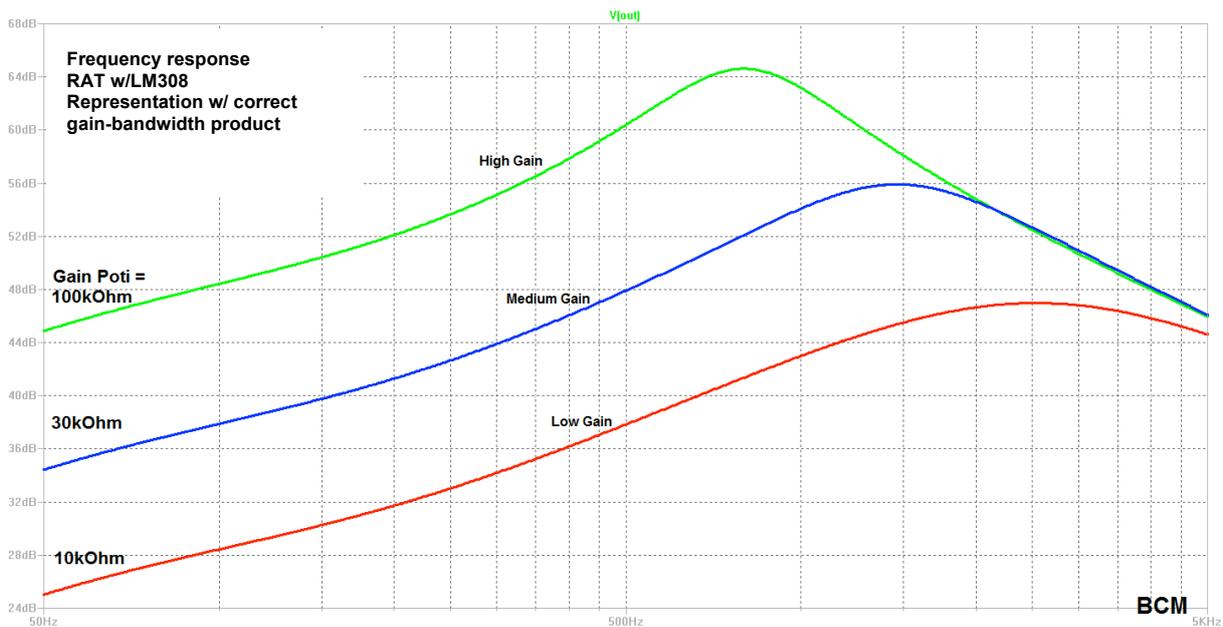


Fig 5: Frequency response for different gain settings

Frequency response

In his frequency design, Burnham opted for a fixed cutoff frequency of the high-pass – in contrast to what MXR went for.

Let's recap: the cutoff frequency of the high-pass is determined via a RC-circuit in the branch of the negative feedback connected between the "-"-input of the OP-amp and (signal-) ground. If we introduce the gain-pot into the series branch of the negative

feedback (i.e. between the "-"-input and the output of the OP-amp), the cutoff-frequency remains constant, because the resistance in the branch to ground is not subject to any change anymore. Burnham also positioned the whole range of the fundamental frequencies of the guitar (everything below 1.3 kHz) within the flank of the high-pass (having a cutoff frequency of 1.5 kHz: 47 Ohm in conjunction with 2.2 μ F). He (and the majority of his customers) was a sucker for gain - thus the diminutive R4.

The maximum gain (there it is!) amounts no less than a factor of about 2300 (from 100kOhm & 47Ohm || 560Ohm), corresponding to a whopping 67 dB. This clearly leaves the MXR Distortion+ (achieving 20 dB less) way behind in the dust. Positioned in parallel to the gain control, the 100-pF-capacitance contributes to stabilizing the OP-amp, and reduces higher-frequency noise at high gain settings (together, the resistance of the pot and the cap form a low-pass). In **Fig. 6**, neither the effect of this capacitor nor the weak gain-bandwidth characteristics of the LM308 are considered because we want to look at some other details which would be difficult to highlight if we included the cap and the data of the OP-amp, as well.

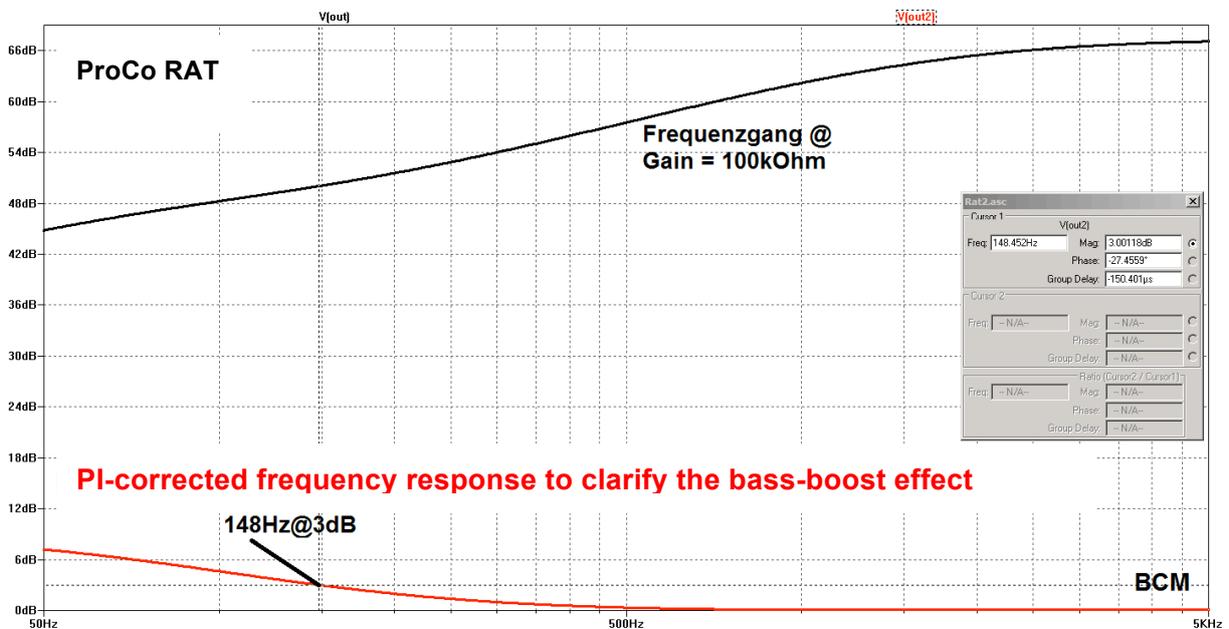


Fig. 6: Bass-boost effect

Relative bass-boost

S.R. Burnham felt that the bass was not sufficiently massive. He (and even more so his clients) sought that "fat bottom end". The treble-boost effect (i.e. the high-pass cutoff frequency cast way up to the last octave of the range of the fundamental frequencies) allowed for a detailed and transparent distortion with no danger of any mushy-ness at high gain, and also made for a good dose of penetration within the overall soundscape. The bass, on the other hand, seemed more on the lean side, especially for the E6-string.

Given Z_L as the impedance of the series-branch between output and "-"-input of the OP-amp, and Z_Q as the impedance between the "-"-input and ground, the following formula holds for the gain V_u :

$$V_u = 1 + Z_L / Z_Q \quad (1)$$

To increase the gain V_u in the bass-range in view of equation (1), we need to take care of further decreasing the impedance Z_Q in that range. Z_L is constant (it's the frequency independent value of the gain-control pot), and therefore V_u can only change via a variation of Z_Q – as the denominator becomes smaller, the result increases. This impedance-reduction in the frequency range that interests us right now is realized by a cleverly dimensioned RC-series-circuit that is connected in parallel to the already present R4+C4 high-pass. In order to achieve an easily recognizable boost, a purposeful value of the required C5 would seem to be double the value of C4 – this is in fact what Burham chooses: 4.7 μ F. Via R5+C5, a connection frequency of 148Hz (= E6-Saite/ 10ter Bund = d) is realized; below that, the desired "fat bottom end" emerges. That is the secret behind the "punch" of the RAT much loved by its users ... that subtle, understated fatness in the lowest guitar octave (E ... d).

Systemically, this small bass boost is difficult to see within your regular depiction of the frequency response (see the uppermost curve in **Fig. 6**). I have therefore resorted to a little mathematical trick (PI-correction term, from control theory) depicted in the red, lower curve in **Fig. 6**. It neutralizes the primary high-pass frequency response (upper black line) in **Fig. 6** such that only that special bass-boost effect remains in isolated fashion - and it is clearly visible now.

As if that weren't enough, Burham straight away also designed a beautiful tone filter into his new device, a so-called "roll-off filter".

Roll-off Filter

This filter is a simple 1st-order RC-low-pass with a variable series resistor that enables the user to adjust the cutoff frequency over a wide range. The slope of 6 dB/oct = 20 dB/decade is retained at all conceivable settings - a specialty of that passive filter type. However, this feature is only satisfactorily maintained if the output of the filter remains without any substantial (electrical) loading - implying that we need a subsequent amplifier with high input impedance. Such an amp can be realized via a field-effect transistor (FET) or bipolar junction transistor (BJT) with high current amplification and operated in a suitable configuration as impedance converter. Burbank opted for a J-FET (Junction-FET) that allowed for a simpler overall circuitry.

At the time, J-FETs were true "high-tech" in stomp boxes – plus they were rather "low maintenance" as a positive side effect. The input impedance of the given J-FET circuit in fact depends merely on the gate-resistance of the FET, amounting to about 1 MOhm in the present case. This high impedance now indeed renders the tone-filer discussed above "unloaded". The upper cutoff frequency of 32 kHz (tone pot at 0 Ohm + R6 & C6) can be pushed down to 470 Hz (tone pot at 100 kOhm + R6 & C6) which is quite an enormous range of 70 to 1.

Further details

During the first years of production, the periphery of the OP-amp included tantalum-capacitors - that was the modern approach then and admittedly also rather practical due to the small size of these capacitors. At some point, Burham was in a discussion with HiFi-purist who set him straight about the audiophile blunder that the tantalum caps represent – the latter then disappeared very quickly from the printed circuit boards. Old-school electrolytic capacitors made a comeback – to the benefit of the tone!

Moreover, during the pre-LED production years, the switching of the effect was accomplished using a DPDT-footswitch, i.e. "true-bypass". With the changeover to the LED-fitted generation, the input of the circuit out of necessity remained constantly connected to the signal (i.e. the guitar which was now always subjected to the input impedance and capacitance of the circuit), and only the output was switched. Presumably due to cost-reasons, ProCo did not go for a 3PDT-solution ... and the LED requiring its own switch-pole took its toll.