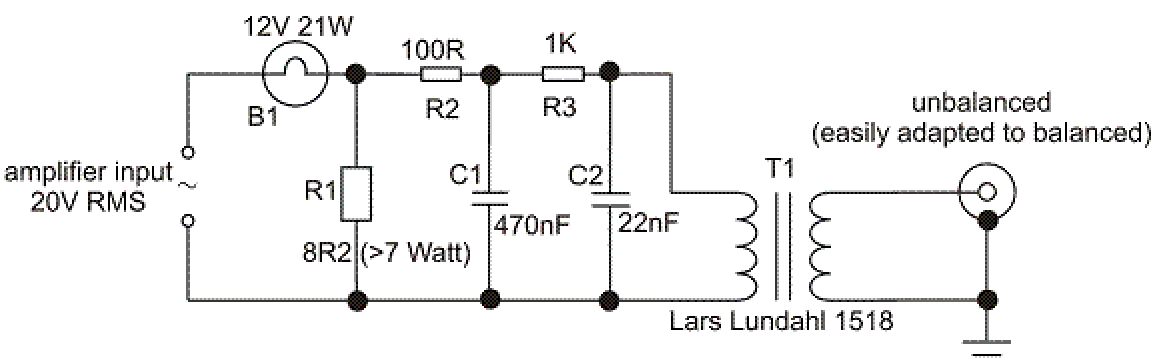
# The “Hot-Lamp" speaker-simulator which models HT supply depression and voice-coil heating effects

Although there exist excellent, digital amplifier, speaker and cabinet simulation products for home recording, I suspect many guitarists - like myself - want to try to capture the sound that we realise playing live. I have long noted that guitar amplifiers driven hard in a late-night "gig" environment take on a particular sound which I might describe as "smooth and coherent" - a sound which appears difficult to “pull-off” in the home studio. What causes this "smooth" sound (other than alcohol-based altered-perceptions)? It is almost certainly due to various compression effects; the most likely being depression of the amplifier HT rails under extreme load, and power-compression due to the heating of the loudspeaker voice-coil. Naturally, the possibility always exists of miking the guitar cabinet directly in the studio and driving the amplifier really hard. But this technique, quite apart from the fact that it causes some family disruption, proves problematic in a confined space, in that it provokes unwanted room-modes and howl-round.

In an attempt to capture this "live" sound in a small home studio, I have experimented with various "dummy" loads (8 or 15 ohm resistors) substituted in place of the usual loudspeaker; the recorded signal being derived across the resistor. Whilst effective in loading the amplifier so that HT rail depression is accurately provoked, simple dummy loads fail in one very straightforward respect: they do not model the effect of the loudspeaker and cabinet; the most important limitation being a predominantly band-pass response with a gently falling low-frequency characteristic and a rapidly-falling, high-frequency response. This frequency-shaping may easily be modelled, either using analogue filter technology (as in various commercial "speaker simulators") or by means of convolving the "clean" input signal with an impulse-response derived from measuring a real guitar loudspeaker and cabinet (as is done in "state-of-the-art" guitar "amp-modelling" products.) The approach described below differs from either of the above in that, in addition to modelling the band-pass effect, the effect of voice-coil heating is modelled.




The circuit for the "Hot Lamp" speaker-simulator is given in figure 1. It is a "cinch" to build: it is so simple that a PCB is not required. (The photo' below illustrates the working prototype).

To the traditional dummy-load (the power-resistor R1) is appended the filter circuit of R2, R3, C1, C2 and T1, and - importantly - B1, a 12V, 21W car indicator or stop light. The filament of a traditional, tungsten light-bulb has a high, positive temperature coefficient. The resistance of a tungsten filament is approximately related to its temperature by the following relation:


$$R = R_{20} \{1 + 0.0045(T-20)\}$$

where $R_{20}$ is the resistance at 20 °C (the "cold" resistance) and T is expressed in °C.

Working through this expression, we can calculate that the resistance of a tungsten light filament when cold is only about 1/10 of its resistance when hot. This is far more resistance change than we would ever expect from a typical loudspeaker voice coil which we would expect to perhaps double its value[1]. But this is no problem provided the value of R1 and B1 are chosen correctly.

In my case I wanted to model the output of a 50Watt amplifier and eight-ohm loudspeaker (maximum amplifier output 20V RMS). R1 provides the bulk of the "cold" static load of 8 ohms, the cold-resistance of the lamp being no more than 1/2 ohm. When the amplifier is driven hard, so that the bulb twinkles brightly along with peaks in the music signal, its filament resistance rises to about 7 ohms, this provides about 4.5dB of signal compression.

The upper skirt of the band-pass response is modelled in the RC, ladder-filter R1&2, C1&2. The high-pass characteristic, which models the 6dB/octave, circulation effect of an open-back cabinet, is accomplished by driving the isolating transformer with an impedance dominated by R2. The primary inductance of T1 is insufficient to provide a flat LF response much below 100Hz (which is typical of a real cabinet). The transformer itself is a "must" to ensure safety and to prevent hum-loops when recording. An incidental benefit of driving the transformer with a high impedance is to derive a certain amount of low-frequency distortion (as there is insufficient current to magnetise and demagnetise the core), which models the effect of suspension related distortion in a real loudspeaker and adds a subjectively pleasant "grunt" to lower string tones.

The performance of this circuit is very good (at least to my ears). I have put a couple of samples here for you to judge for yourself.

Rock n' roll sample
Jazz sample

In use, the amplifier power is adjusted so that the bulb just burns brightly on absolute signal peaks. Do not overdrive the circuit because it is possible to over-run and destroy the bulb. This is fail-safe, in the sense that the signal path is broken, thereby protecting any downstream electronics. However, care should be exercised, especially with valve amplifiers which do not like operating into an open circuit.

1. MONITORS versus HI-FI SPEAKERS (For Project Studio Monitoring) Phil Ward, SOS July 2002

*Richard Brice - January 2006*

---

## Links

Back to home page

Address all mail to richard@richardbrice.net

Perfect Pitch Music

---