

# Verstärkertechniken im Vergleich: class a/b < = > class d

Dipl. Ing. Hubert Reith - HiFiAkademie

**World-challenging**

**SINCLAIR X-10**

INTEGRATED 10 WATT AMPLIFIER AND PRE-AMP

SIZE 6" x 3"

AVAILABLE FOR BUILDING OR READY 8" x 1"

THE ONLY DESIGN IN THE WORLD TO GIVE YOU ALL THESE EXCITING FEATURES

THE ONLY CONSTRUCTIONAL AMPLIFIER IN THE WORLD USING PULSE WIDTH MODULATION

*Hi-fi quality for very low cost*

- ★ Pulse width modulated amplification.
- ★ Eleven transistor circuitry.
- ★ Unique four transistor output stage.
- ★ Input sensitivity of 1mV into 1K ohms.
- ★ 10 watts peak output into 15 ohms.
- ★ Total harmonic distortion less than 0.1%.
- ★ Choice of tone control system for mono or stereo to match pick-up, micro and radio inputs.
- ★ Power requirements—12 to 15 volts, D.C.
- ★ Very easy assembly.

By using pulse width modulation, the Sinclair X-10 integrated amplifier and pre-amp offers the constructor entirely new concepts of amplifier design and performance. Everything, except the tone and volume controls, is contained on the printed circuit board which measures only 6 x 3in. and since no heat sink is necessary, the saving in space is enormous. This gives the constructor the opportunity to build a modern sleek hi-fi installation. In performance, the X-10 is a revelation in quality and power. There is no falling off at higher frequencies up to 20Kc/s, transient response is superb and current consumption for the power output obtained is appreciably less than in comparably rated conventional amplifiers. In fact the X-10 will operate perfectly well from two 6-volt lantern batteries. The Sinclair X-10 Manual included with every X-10 Amplifier explains how it functions and gives tone control and stereo matching circuits none of which costs more than a few shillings.

**BLOCK DIAGRAM**

shows in simplified form the stages of function of this remarkable amplifier. Such design with its very much better standards of performance is made possible by use of the very latest transistors and high quality components.

INPUT → TWO STAGE PRE-AMP → SQUARE WAVE GENERATOR → PULSE WAVE INTEGRATOR → CURRENT ADDER → SIGNAL TRIGGER → 2NPN/2NPN complementary pair → 2PNP/2PNP complementary pair

All parts for building, including 11 transistors, with X-10 Manual and instructions come to **£5.19.6**

Ready built and tested with X-10 Manual **£6.19.6**

X-10 Power Supply Unit (ready built) for A.C. Mains. **£2.14.0**

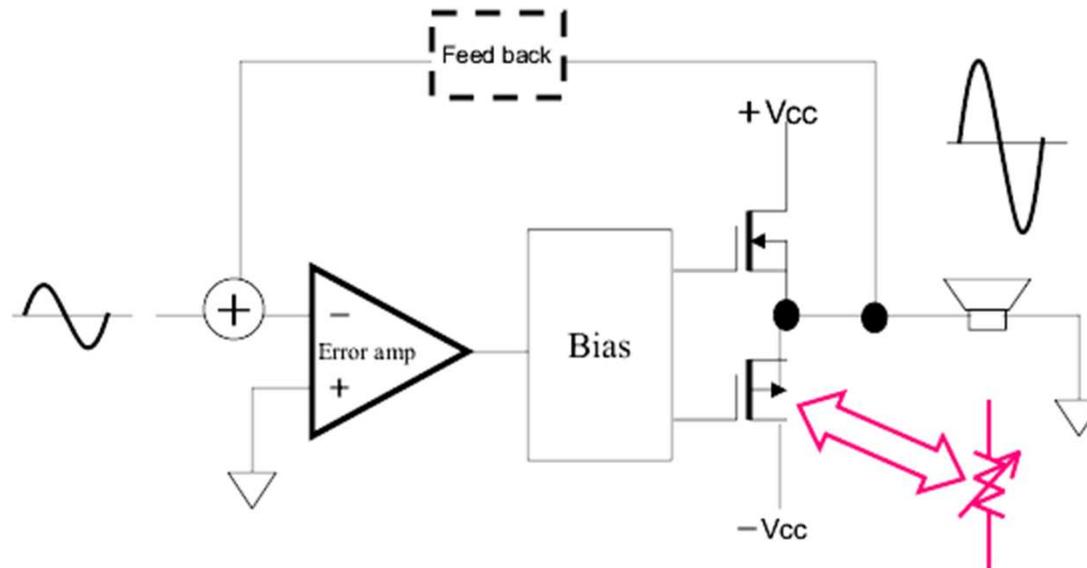
★ FULL SERVICE FACILITIES ALWAYS AVAILABLE TO SINCLAIR CUSTOMERS

**sinclair** **SINCLAIR RADIONICS LTD.**  
COMBERTON Cambridge Telephone COMBERTON 682

Class d:

Erste Patente aus 1946  
Erster Bausatz aus 1964

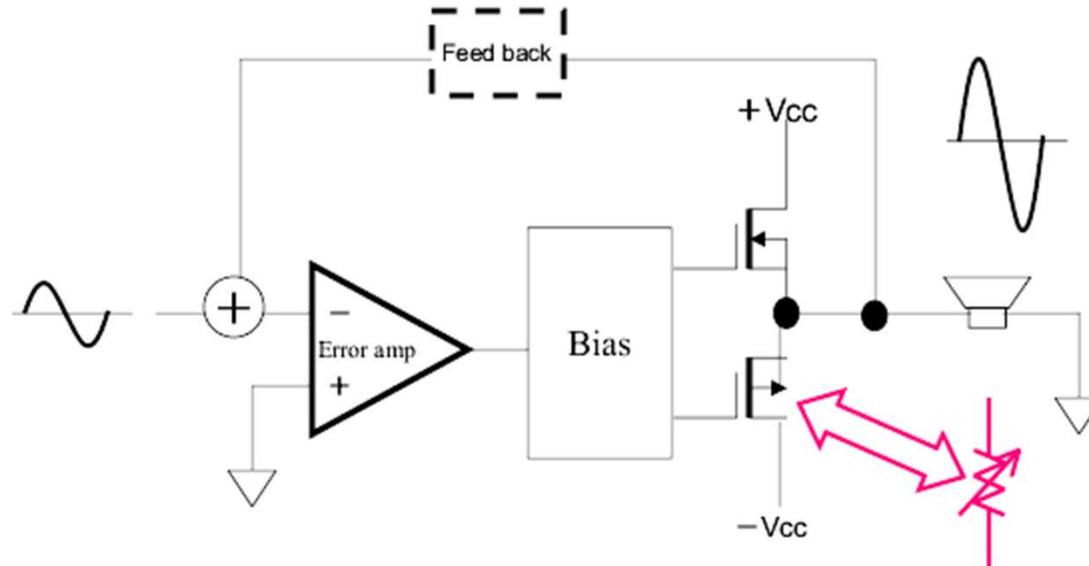
Mark Levinson spricht von  
ersten PWM-Verstärkern aus  
1932



Klassischer Verstärker:

Ausgangsstufe mit bipolaren Transistoren, FET, Röhre.

Transistoren/Röhren wirken als steuerbarer Widerstand nach +-Versorgung.



Beispiel:

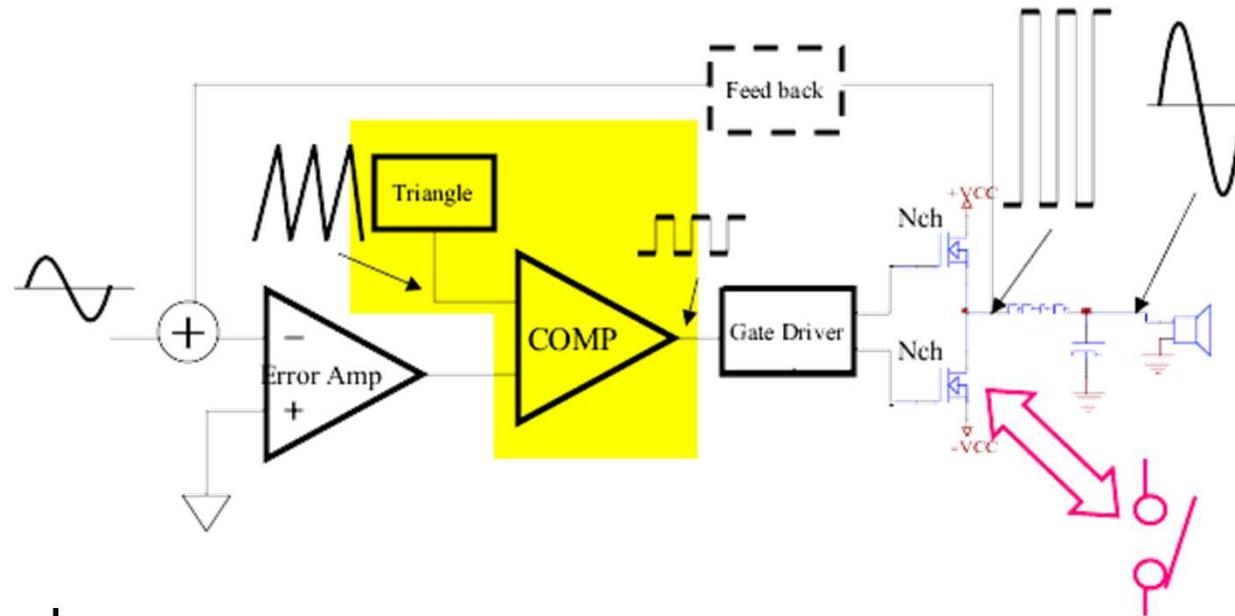
$$V_{cc} = \pm 55V ; R_l = 50\Omega$$

$$U_l = 5V ; I = 1A$$

$$P_l = 5V * 1A = 5W$$

$$P_v = 50V * 1A = 50W$$

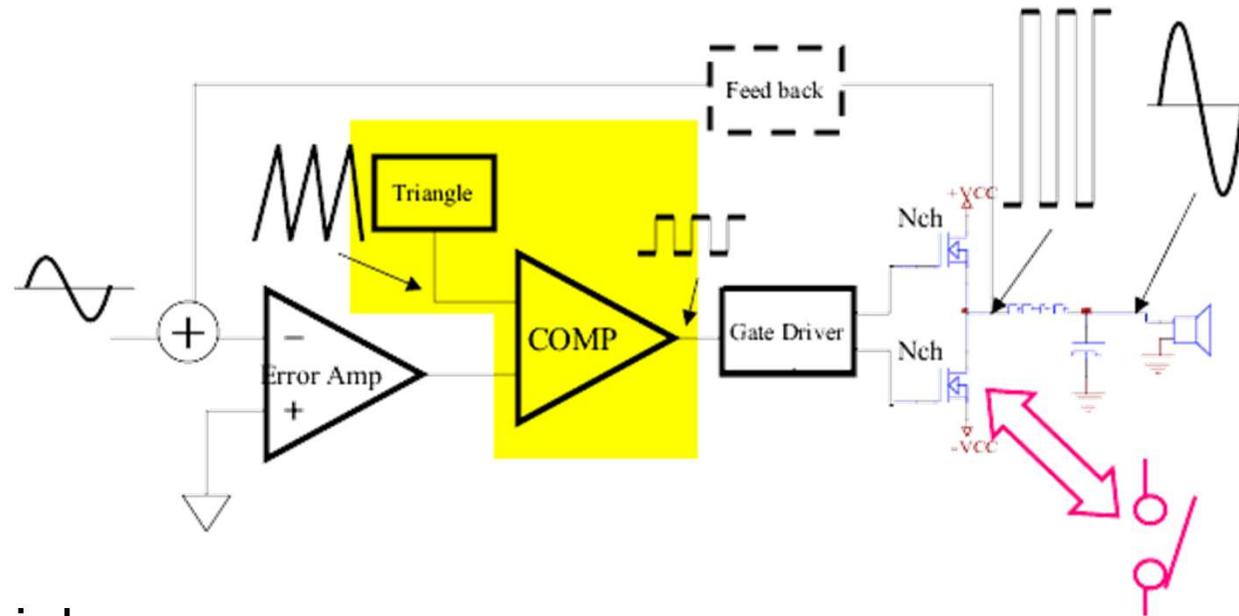
$$P_z = 55W$$



Class d:

Ausgangsstufe mit FET.

Transistoren wirken als Schalter nach +-Versorgung.



Beispiel:

$$V_{cc} = \pm 55V ; R_l = 50\Omega$$

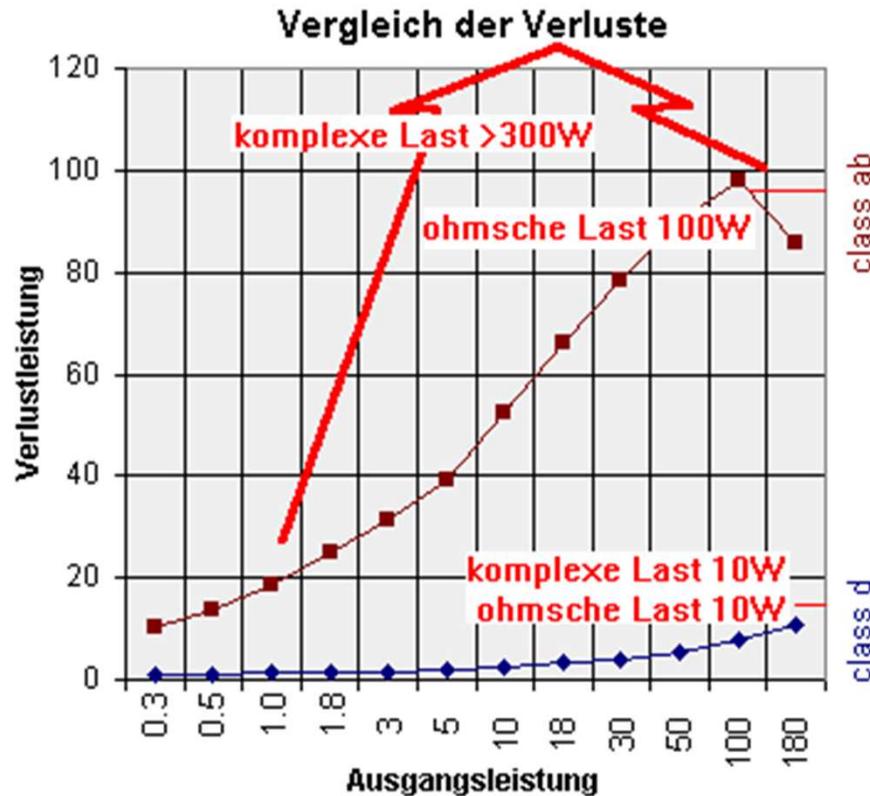
$$P_l = 5V * 1A = 5 W$$

$$U_l = 5V ; I = 1A$$

$$P_v = 1A^2 * 20m\Omega = 0,02W$$

$$R_{on} = 20m\Omega$$

$$P_z = 5,02W$$



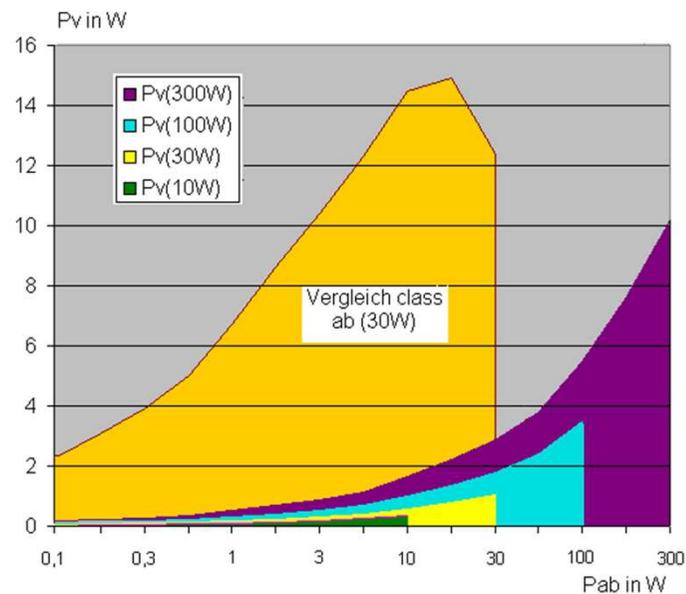
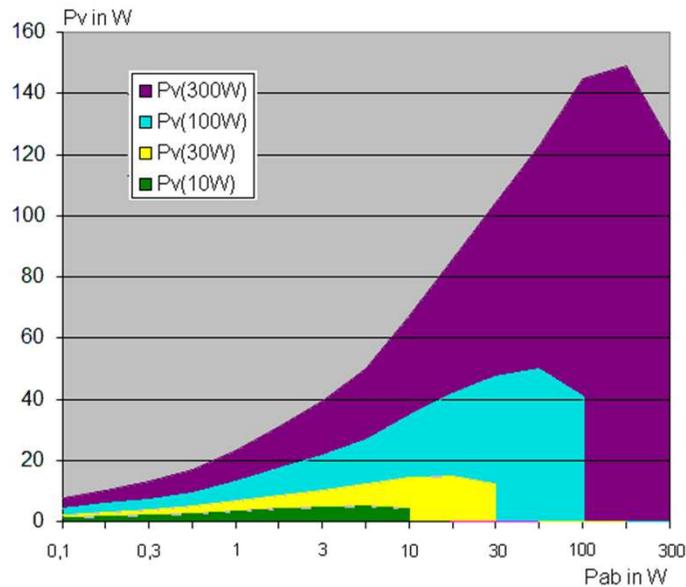
klassischer Amp =>  
hohe Verluste an ohmscher Last,  
extreme Verluste bei komplexer  
Last

class d =>  
niedrige Verluste, unabhängig  
vom Phasenwinkel der Last.

Stabilität:

klassischer Amp =>  
Schwingneigung bei komplexen  
Lasten, komplexe  
Schutzschaltung notwendig.

class d =>  
meist extrem unabhängig von der  
Last, nur Strommessung  
notwendig

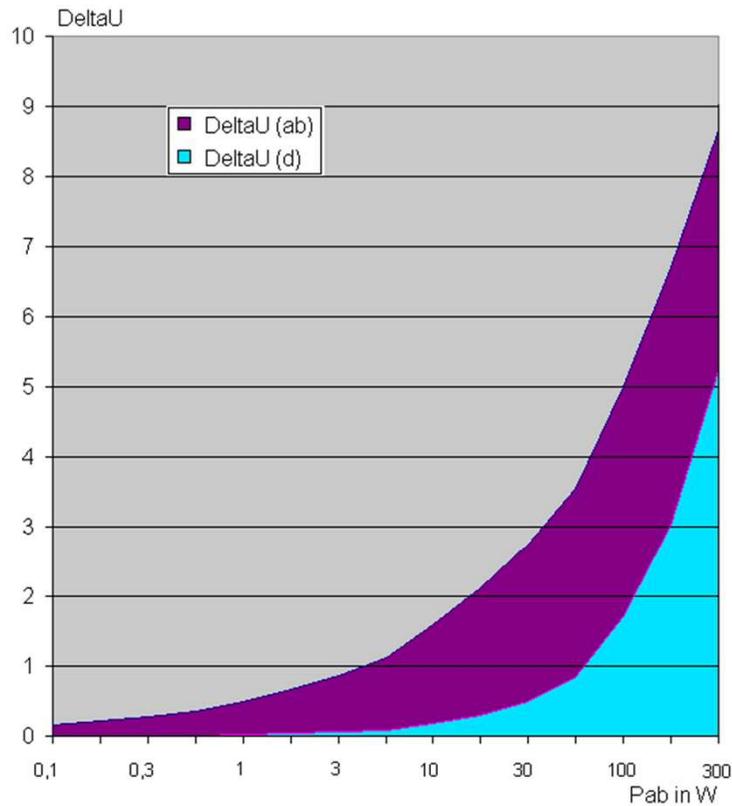


klassischer Amp =>  
je höher die Maximalleistung  
desto schlechter die Effizienz

auch bei kleinen  
Ausgangsleistungen hohe  
Verluste

class d =>  
auch bei hohen  
Maximalleistungen sehr gute  
Effizienz

in der Praxis Begrenzung durch  
endliche Schaltzeiten und  
Restwiderstände



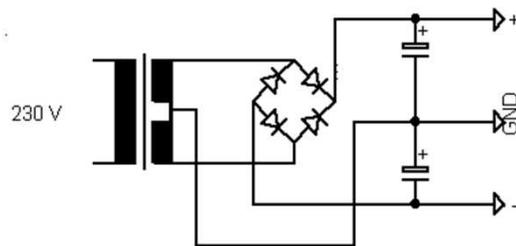
klassischer Amp =>  
starke Schwankung der  
Versorgung

auch bei kleinen und mittleren  
Abgabeleistungen

class d =>  
wesentlich geringere  
Schwankung der Versorgung

bei kleinen und mittleren  
Leistungen nur 1/100..1/10

kleineren Elkos, stabilere  
Versorgung



## Transistor-Kennlinie:

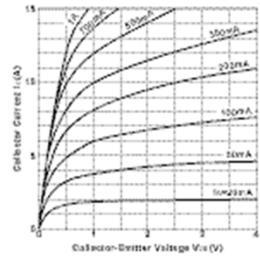
Quadrat- oder E-Funktion als Übertragungskennlinie.

Alle Parameter vom Arbeitspunkt, Temperatur.... abhängig.

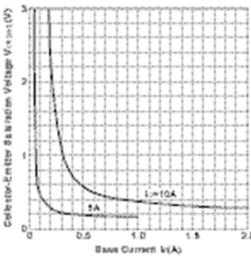
Starke Streuung.

N/P-Typen nur begrenzt vergleichbar

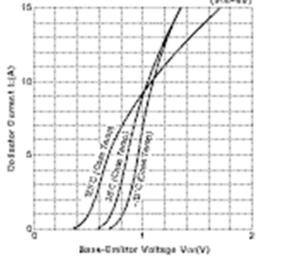
Ic-Vce Characteristics (Typical)



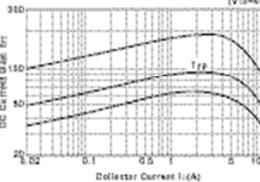
Vce(sat)-Ib Characteristics (Typical)



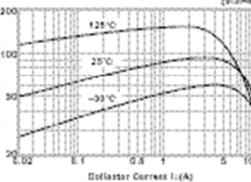
Ic-Vce Temperature Characteristics (Typical)



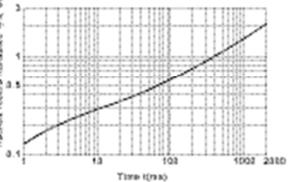
hFE-Ic Characteristics (Typical)



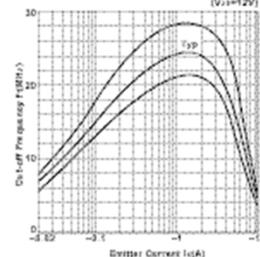
hFE-Ic Temperature Characteristics (Typical)



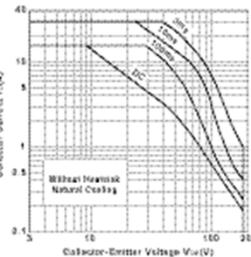
βj-x-t Characteristics



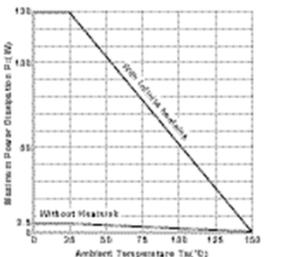
fT-Ic Characteristics (Typical)

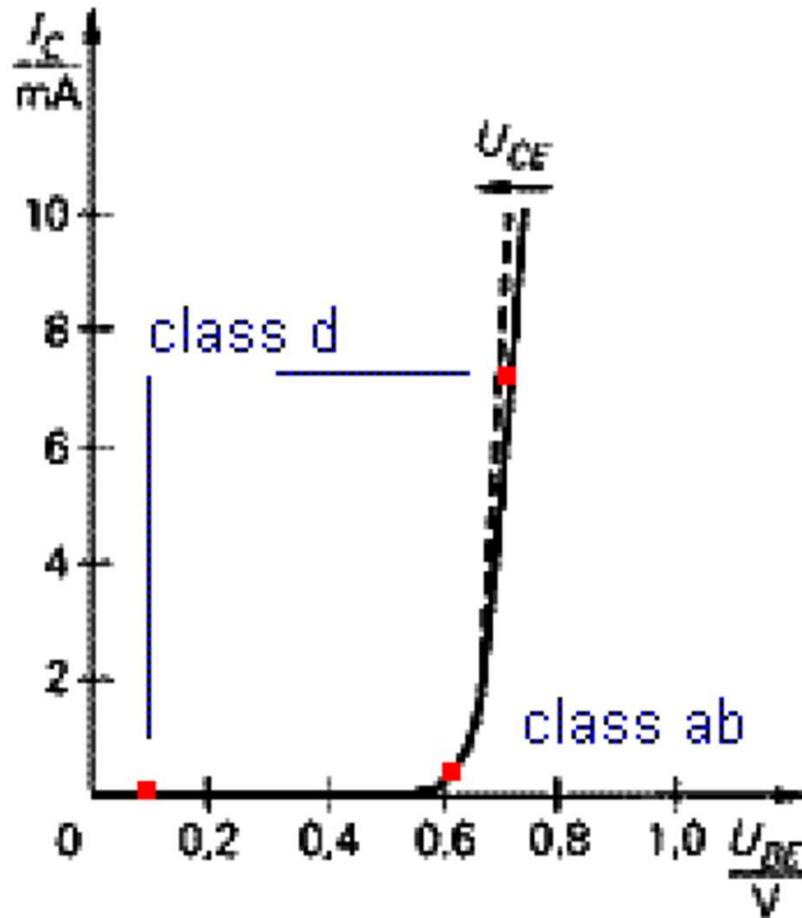


Safe Operating Area (Single Pulse)



Pc-Ta Derating





Arbeitspunkt:

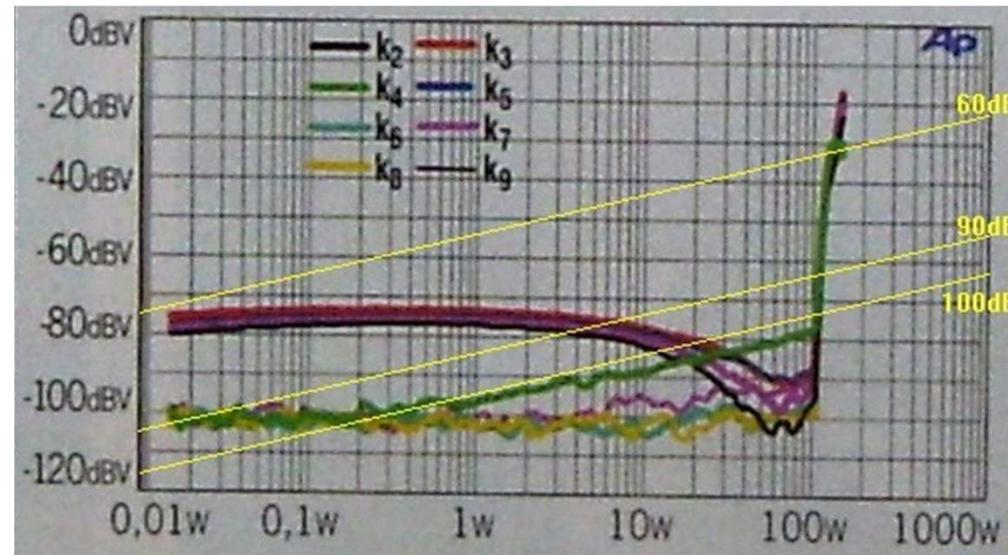
klassischer Amp =>

im Knick, relativ hoher  $R_i$ , sehr unlinear

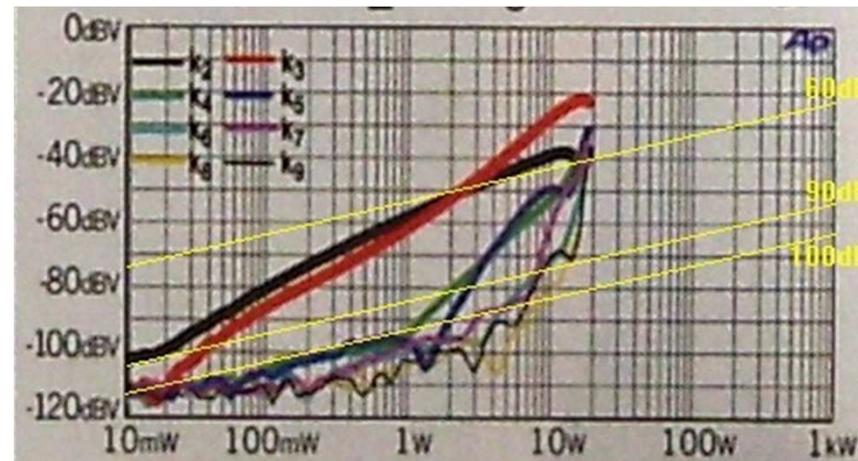
class d =>

an den Enden, relativ niederohmig, sehr linear

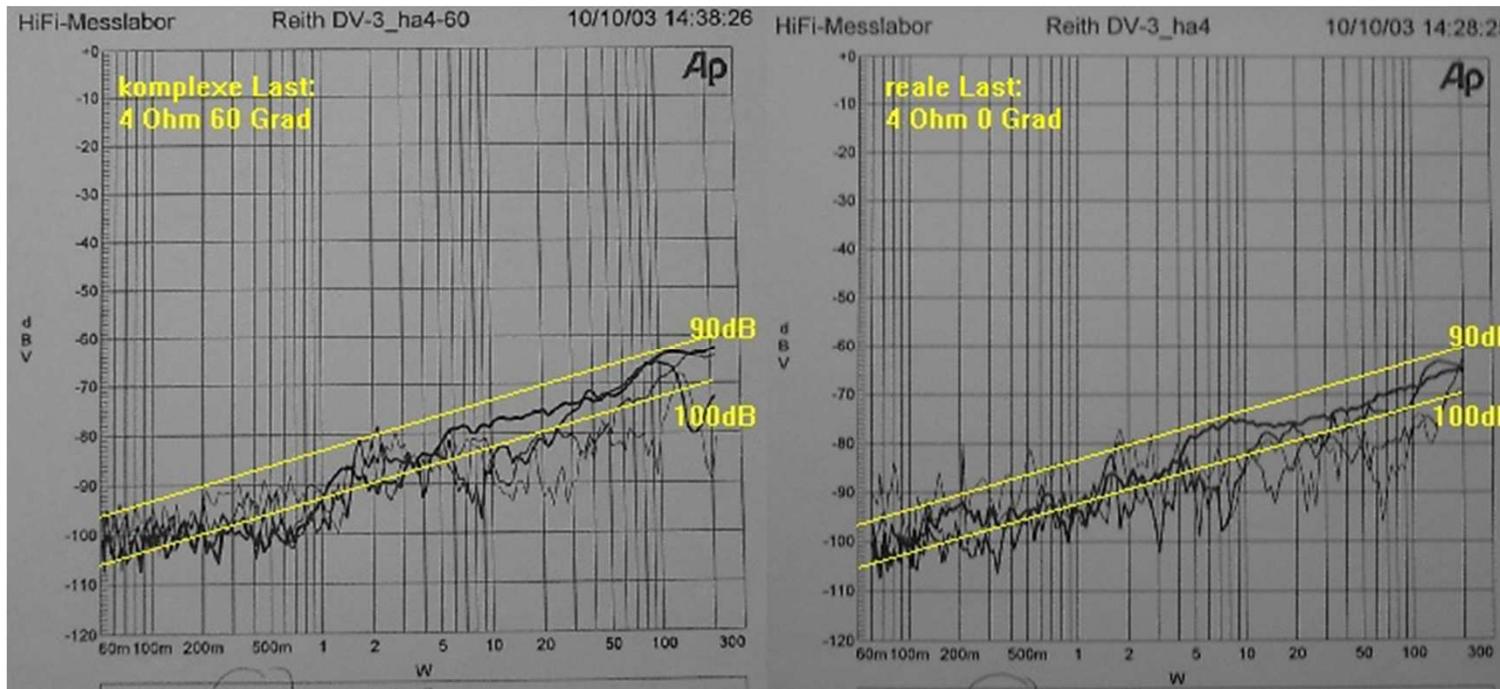
Klassischer Amp => meist zu höheren Leistungen fallend

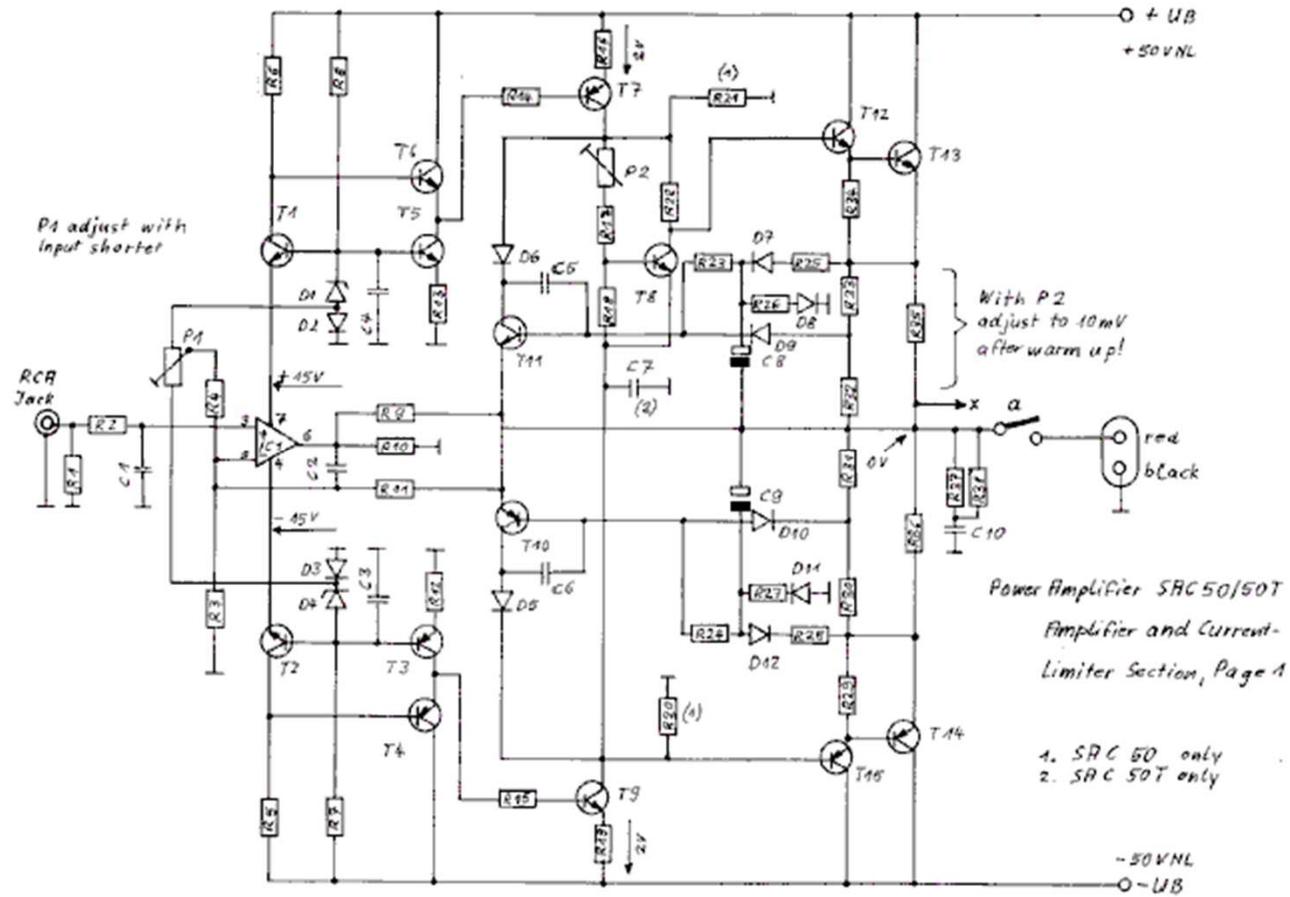


Röhre => deutlich steigend

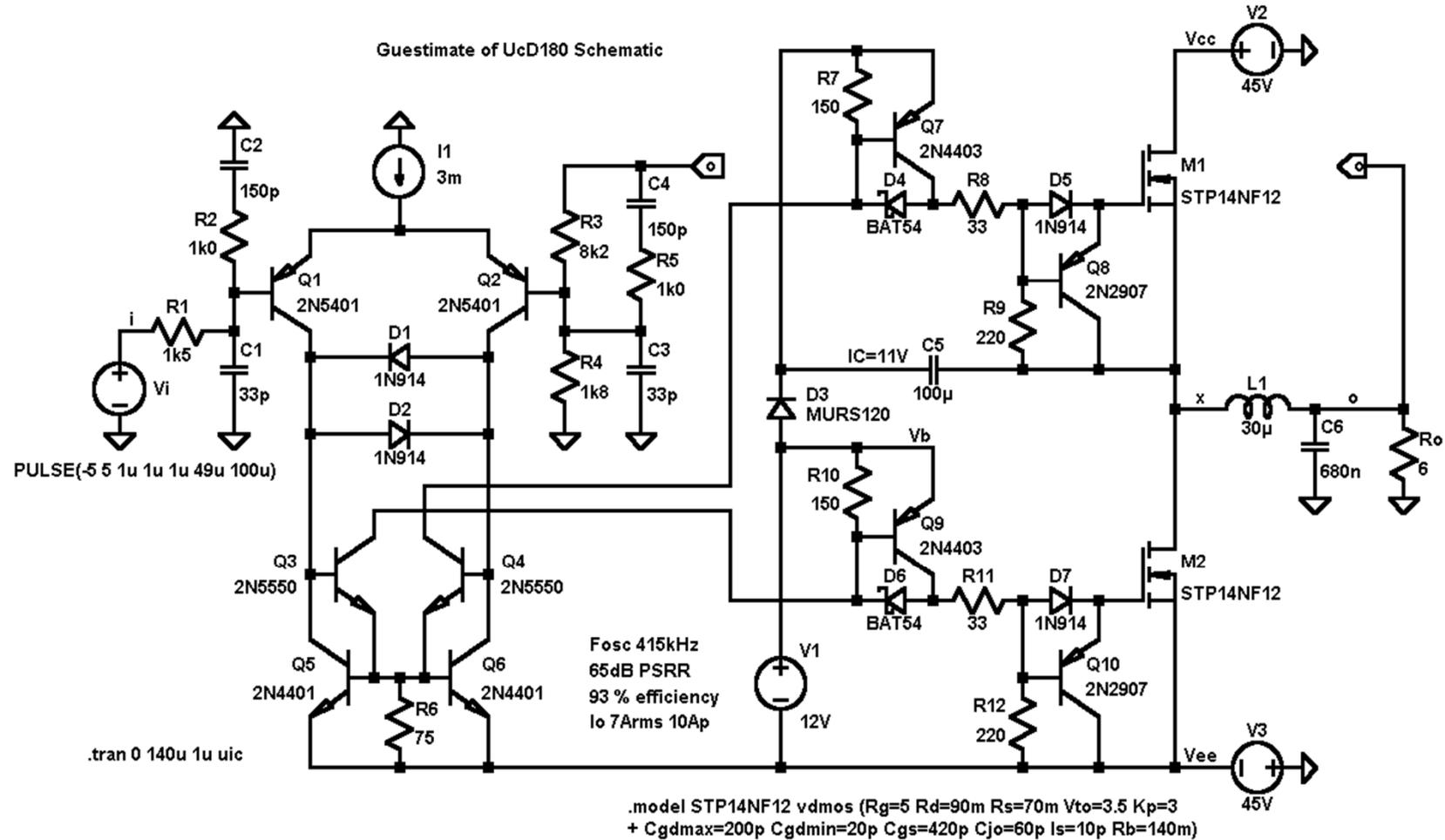


Class d => relativ unabhängig von der Aussteuerung



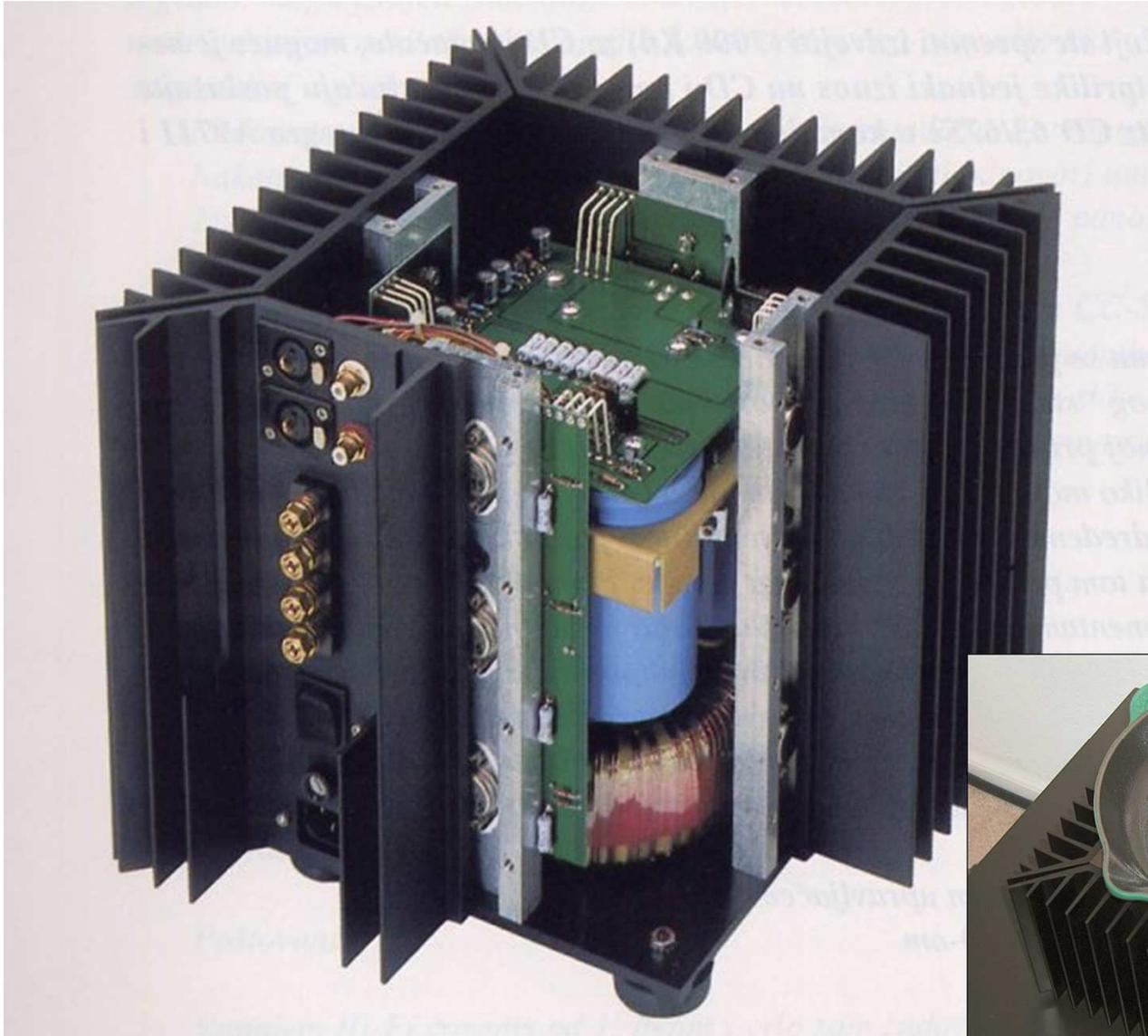


Aufbau klassischer Amp



Aufbau class d

# Beispiel class a 16/20



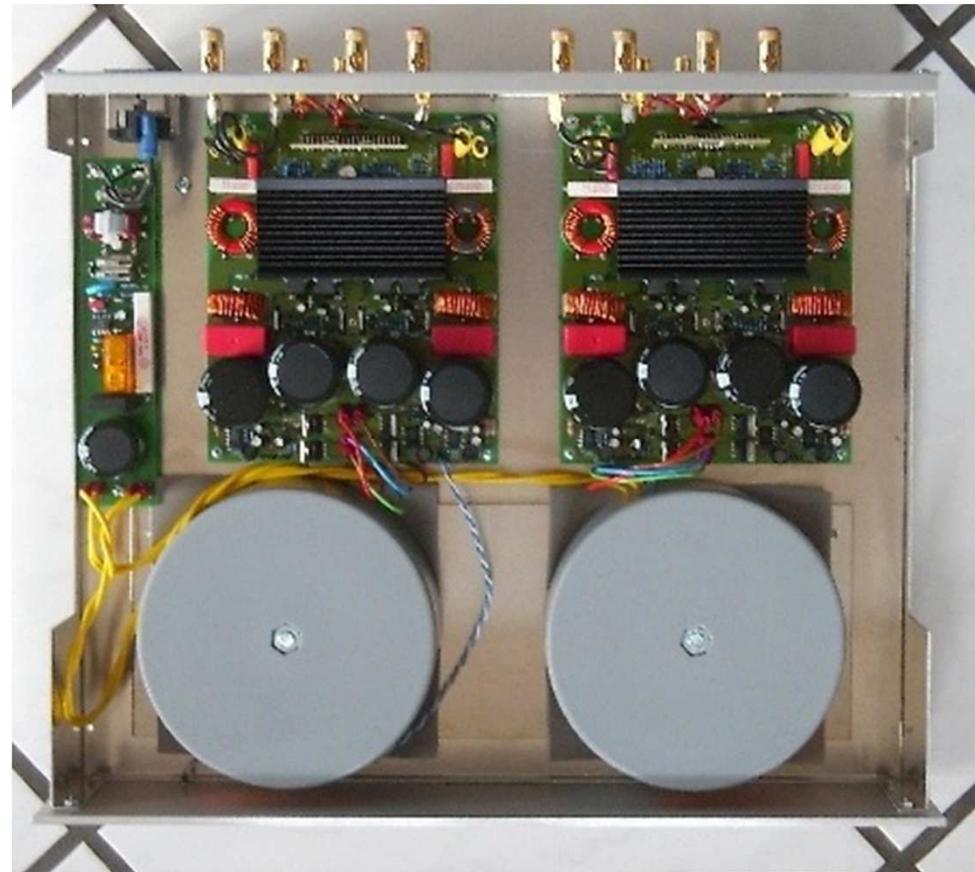
$$P_{ab} = 2 \times 60W$$

$$P_z = 250W$$



$P_{ab} = 2 \times 250W; 4 \times 250W$

$P_z = 12W \quad ; \quad 24W$

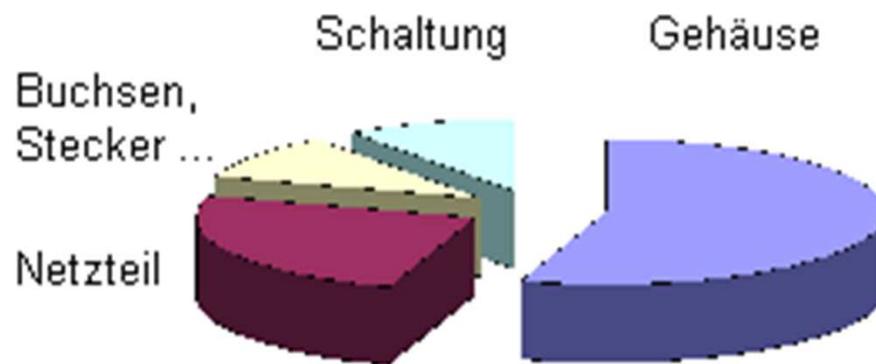


## Kosten:

wichtigster Kostenfaktor ist  
NICHT die Elektronik.

Verstärkerschaltungen lassen  
sich für wenige 10.-EUR  
aufbauen.

bei class-d kann Gehäuse und  
Netzteil preiswerter ausfallen



Keine Nachteile?

Ausgangsfiter notwendig

HF-Design notwendig

EMV

kein Gewichts-HiFi

DANKE

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