DHT Pre-amplifiers

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An unorthodox approach…

Purpose of today

Sharing my experience on DHT preamps throughout my long journey in combining quite a lot of sand in hollow circuits

About Myself

- Background
- Hobbies
- Audio

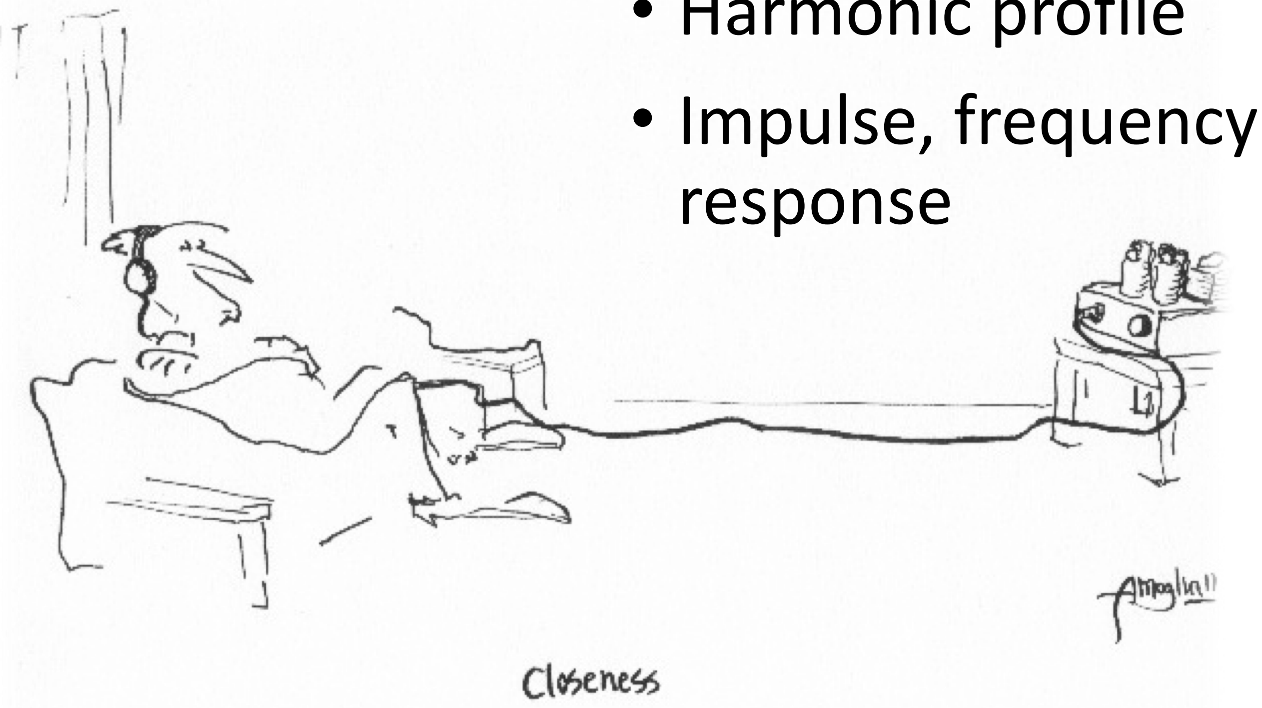
Why DHT in Pre-amps?

What we can hear

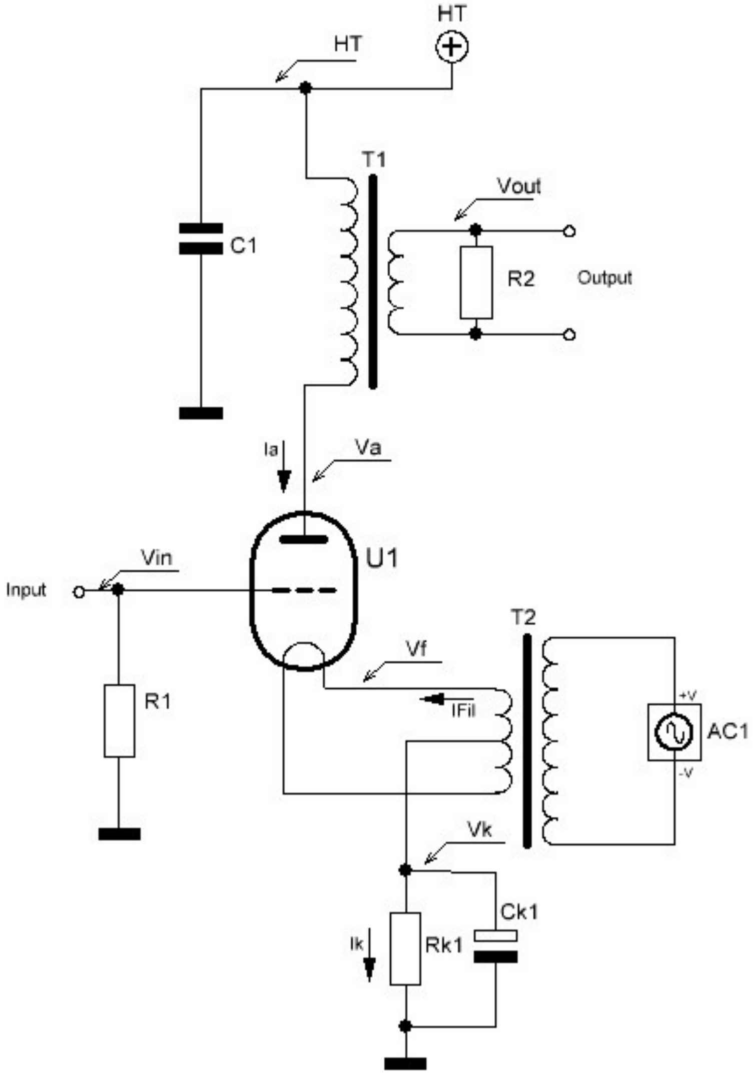
- Timbre
- Detail
- Distortion
- 3D image

What we can measure

- THD and IMD
- Harmonic profile
- Impulse, frequency & phase response



The Traditional Approach



- Advantages
  - Lower gain and output impedance
  - Simplicity
  - Galvanic isolation
- Disadvantages
  - Quality of OPT
  - PS isolation
  - Heater IM distortion
  - Cathode cap

The DHT Pre-amp Challenges

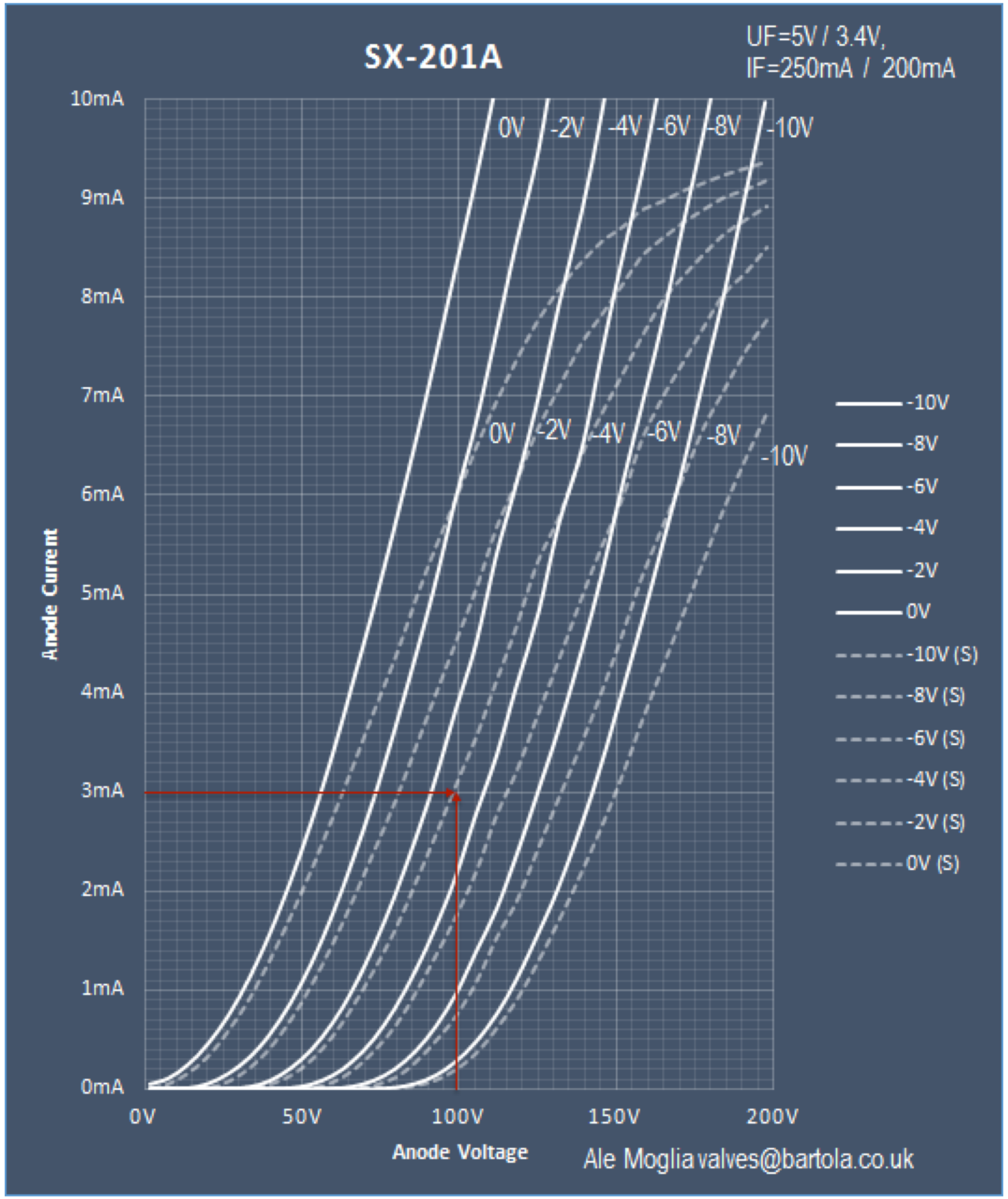
- Microphonic noise
- Hum
- Power supply complexity
- Load demands
- Bias arrangement
- Weight, heat and space!
- Gain (too much or too little)
- The DHT itself – cost, age, etc.

What I've Learnt Over The Years

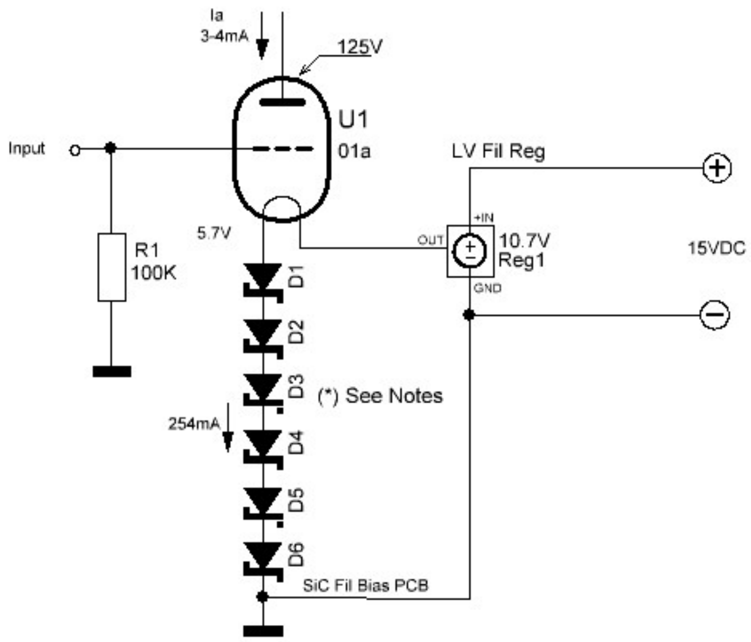
- What goes in the cathode is as important (or more than) as the anode load
  - Filament bias
  - SiC Diodes
- Filament supply
  - DC regulators
  - Choke input raw PSU
  - Filament starvation
- Keeping the noise down
  - Ground scheme and layout
  - Multi-chassis
  - Microphonic noise
- My preferred topologies and anode loads
  - Hybrid µ-follower (aka Gyrator)
  - Choke
  - CCS (with µ-output)
  - Transformer

Filament Starvation

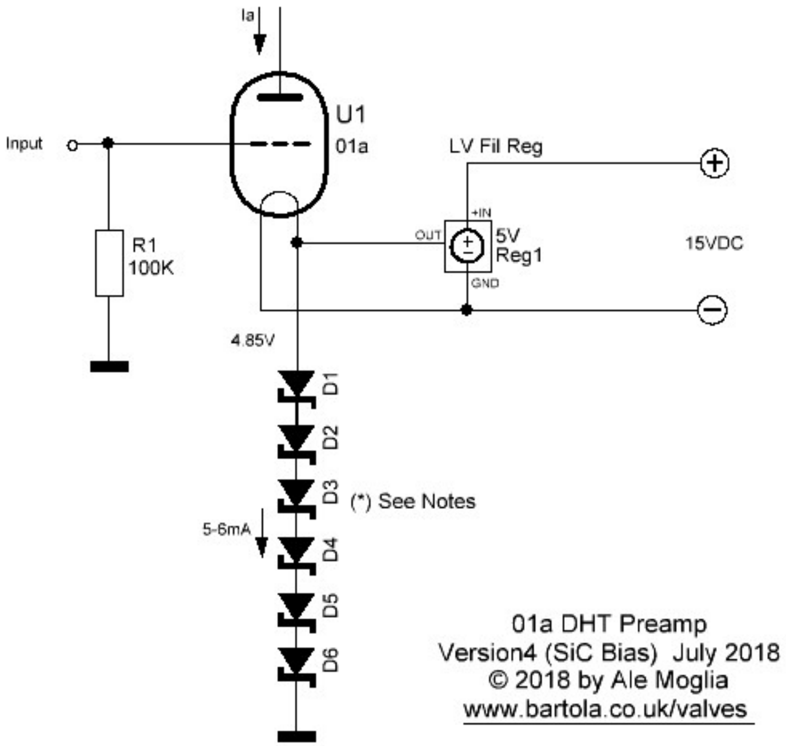
- Reduced microphonic noise
- Reduced emission
- Increased ra, reduced gm and (nearly) constant μ
- Reduced distortion
  - Increased region where gm, ra and μ are constant [5]
- Reduced valve life
  - Surface-level barium depletion (Oxide Fil)
  - “Cathode stripping” (TT filaments)



Bias Using SiC Diodes

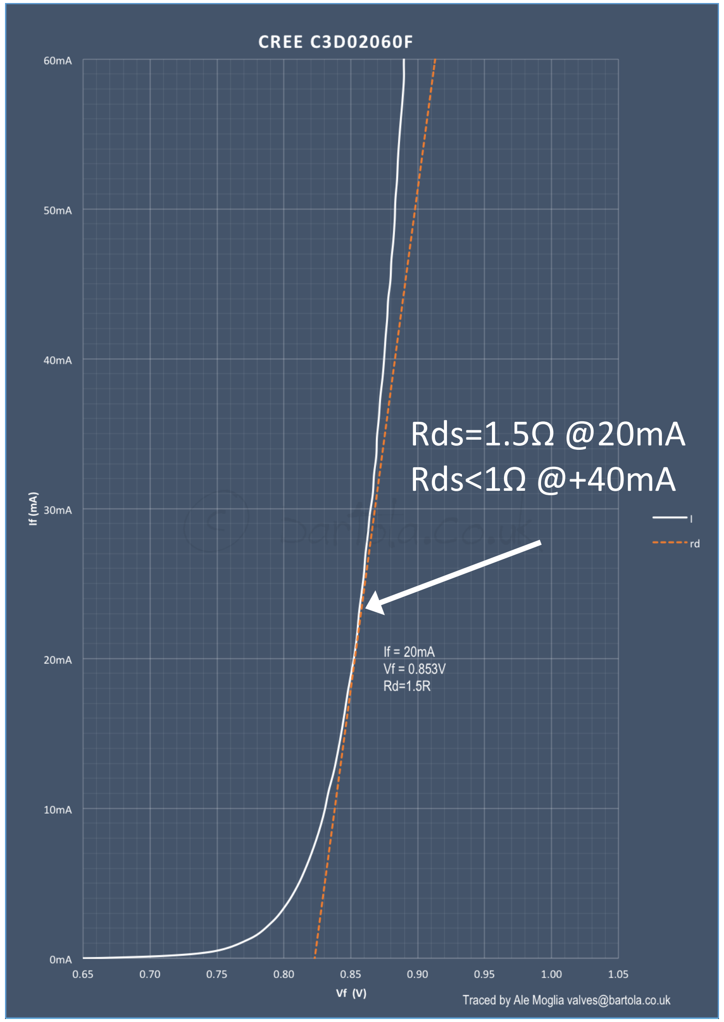


Filament SiC Bias

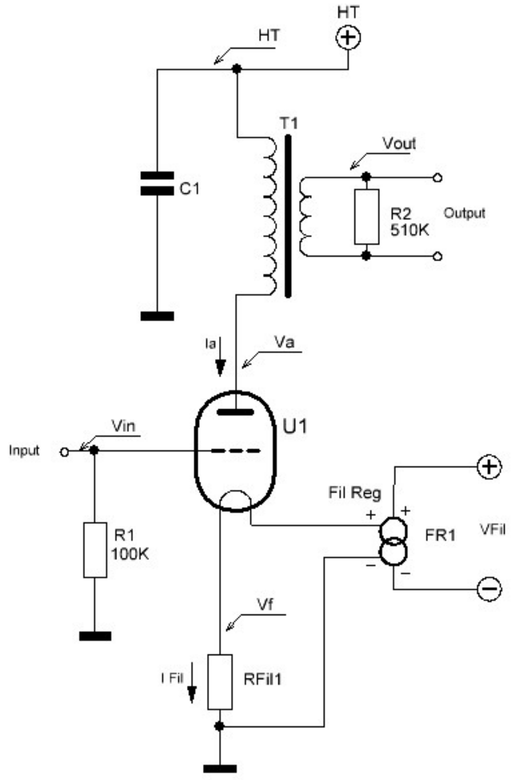


Cathode SiC Bias

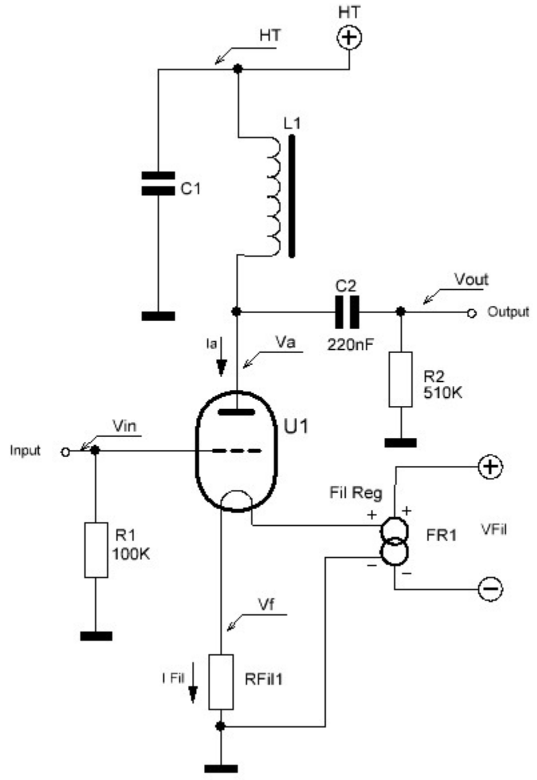
C3D02060F Example



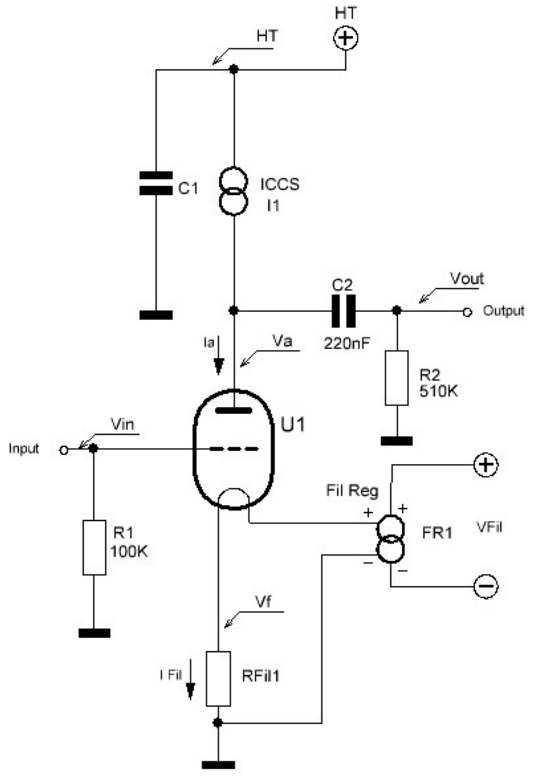
DHT Pre-amp Evolution



Transformer Loaded

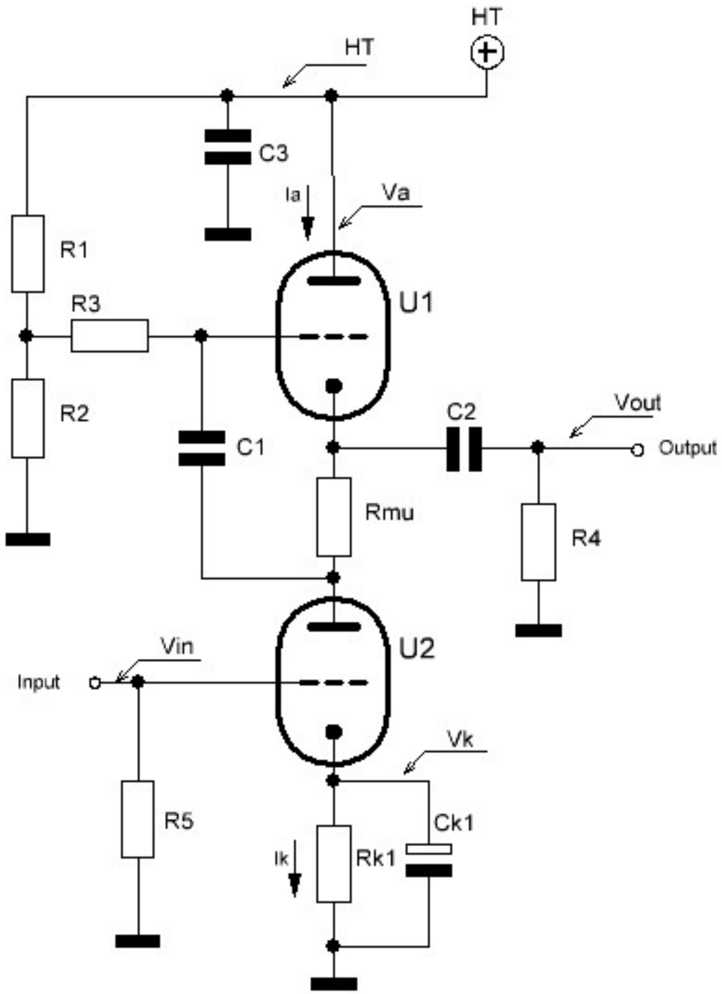


Choke Loaded



CCS Loaded

The μ-follower



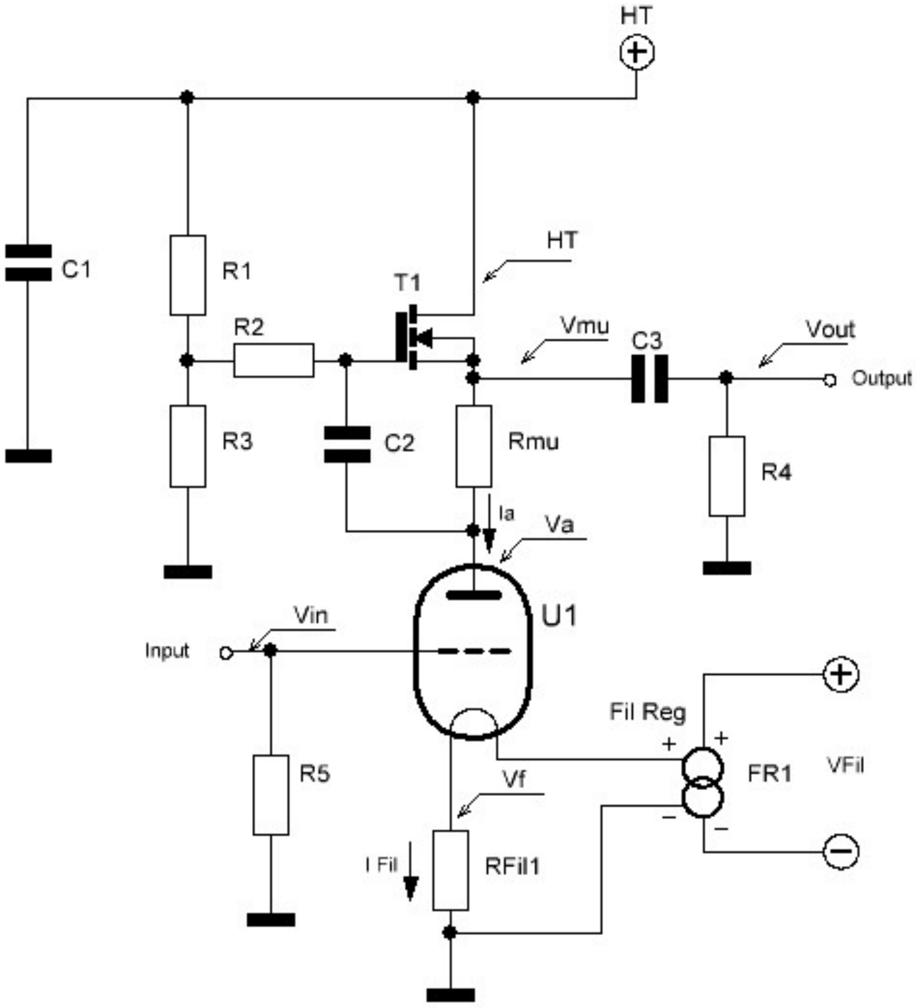
Advantages

- Push-pull
- Low output impedance
- Lowest distortion when optimized for specific load
- Higher bandwidth
- U1 Pentode: constant gm, lower distortion and better PSR

Disadvantages

- HT to accommodate full output swing
- Optimisation only for a specific load
- Heater supply (and elevation)
- The higher Rμ, the lower the current drive

The Hybrid µ-follower



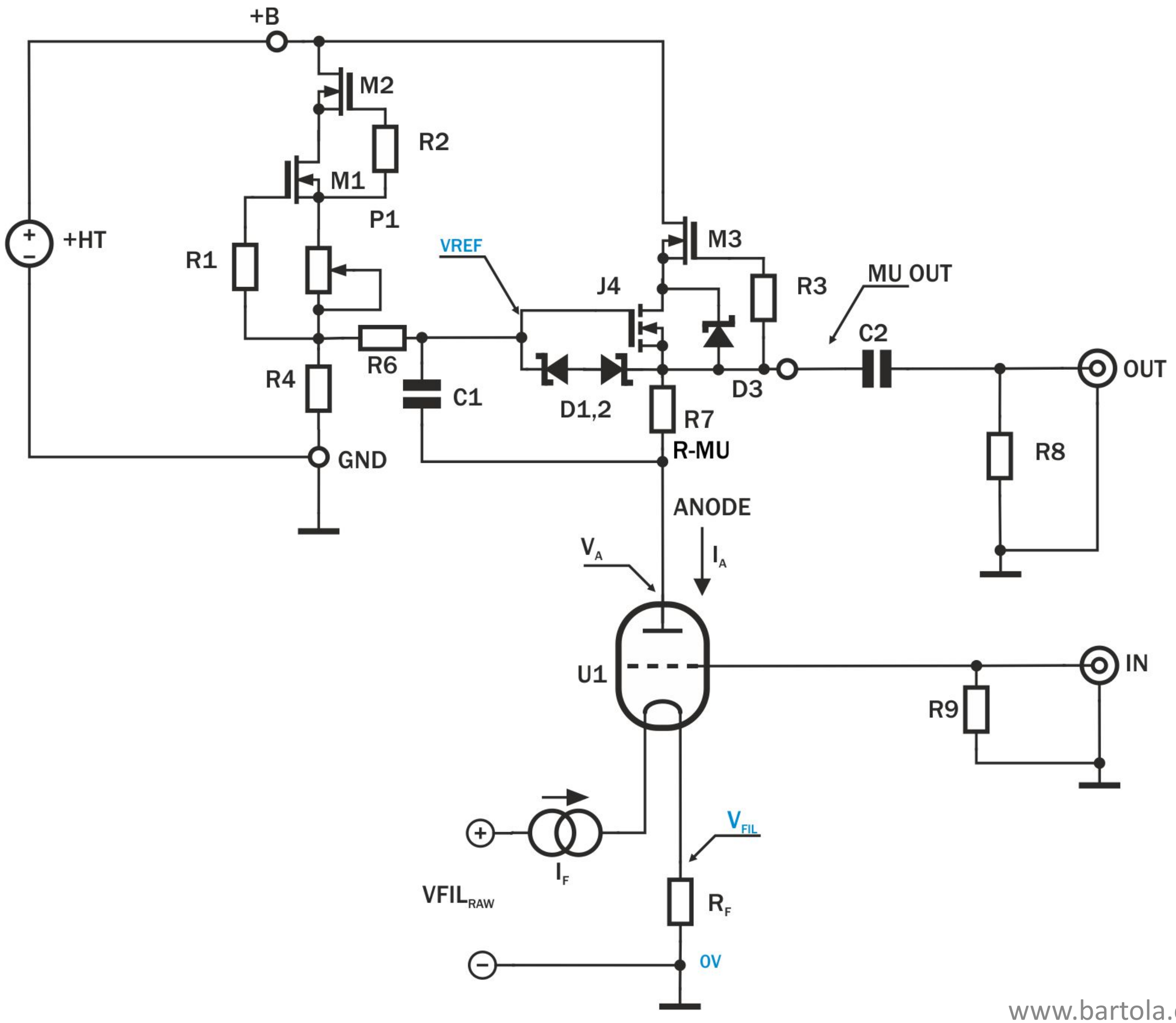
Advantages

- Use of higher gm part:
  - Lower output impedance
  - Lower distortion (Rµ bootstrapping)
- Simplified heater supply

Disadvantages

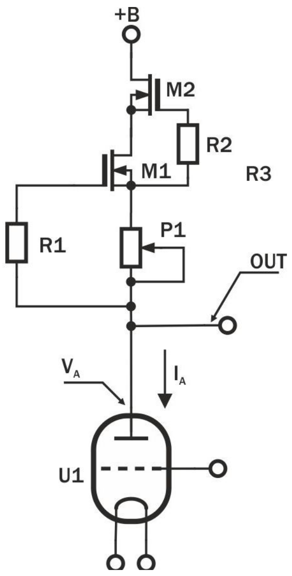
- MOSFETs protection
- Device Unbalance

The Hybrid μ-follower Evolution

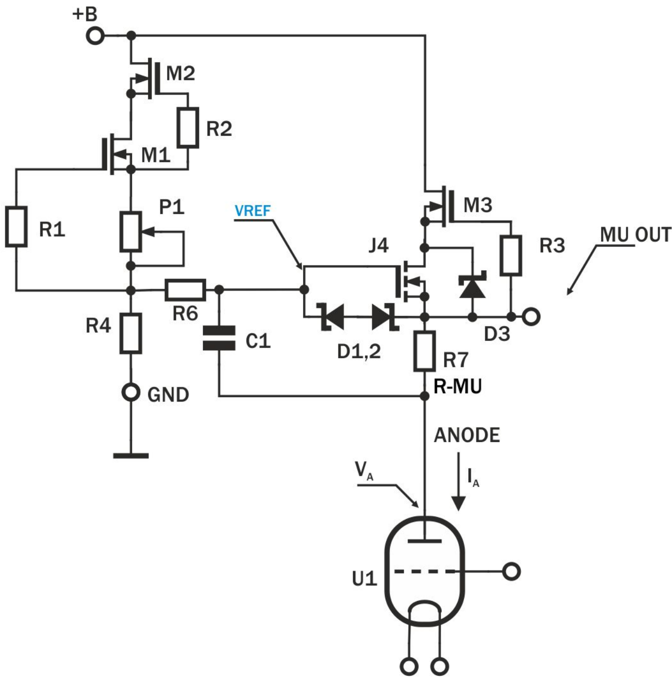


- CCS Voltage reference
  - Power supply isolation
  - Voltage stability
- Cascoded FET pair
- Improved HF response and lower output impedance:
  - J4: high Gfs and low Crss
  - M3: High VGS(off) -> reduce J4 Crss and Coss
- Keeping C1 value low

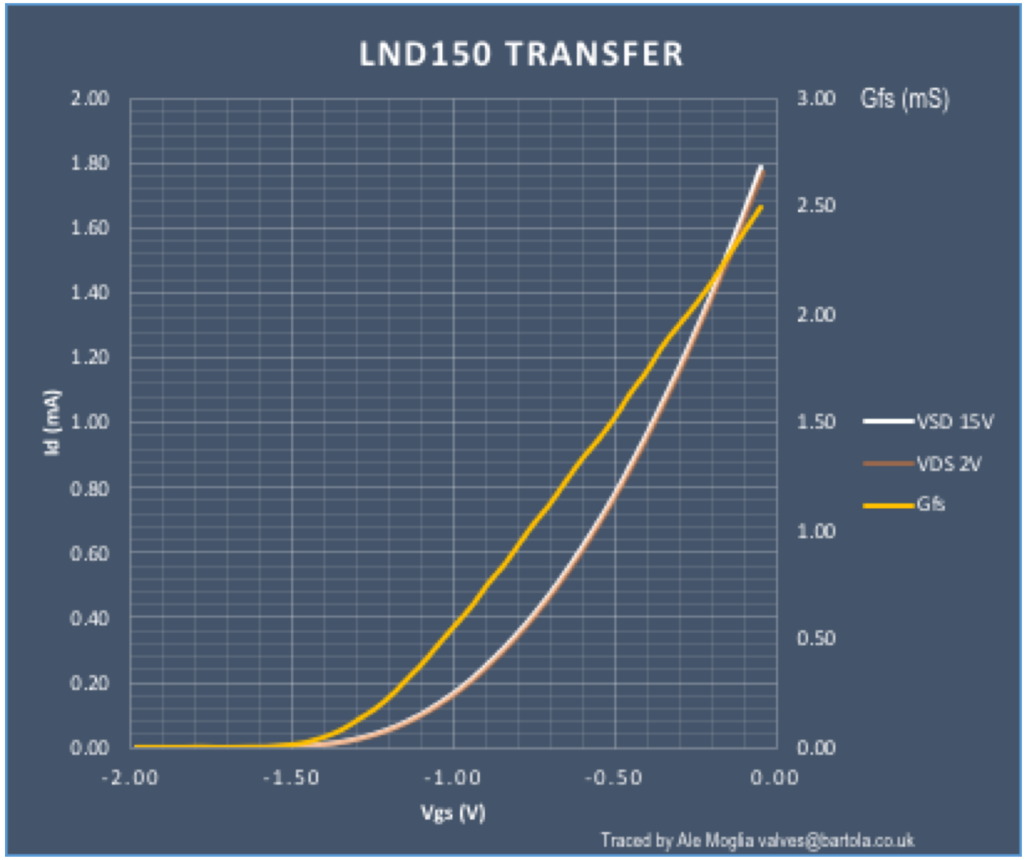
CCS vs Hybrid µ-follower



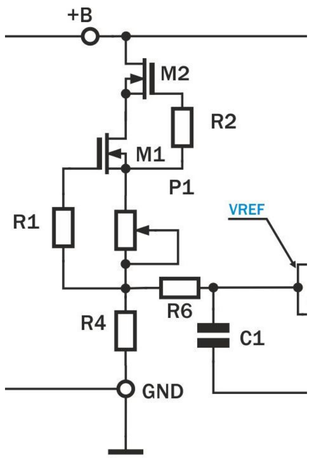
	CCS	Hybrid µ-Follower
Valve parameter fixed	Anode current	Anode Voltage
Output impedance	Mid-High (anode resistance)	Very Low (1/gfs)
Mode	Single-ended	Push-Pull
Complexity	Low	High
Low impedance loads	No	Yes

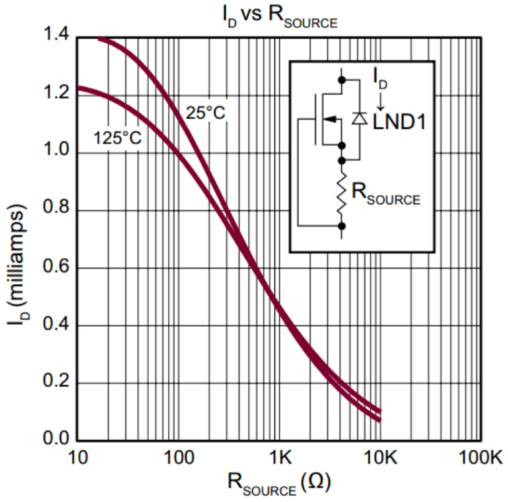


The CCS Reference Voltage

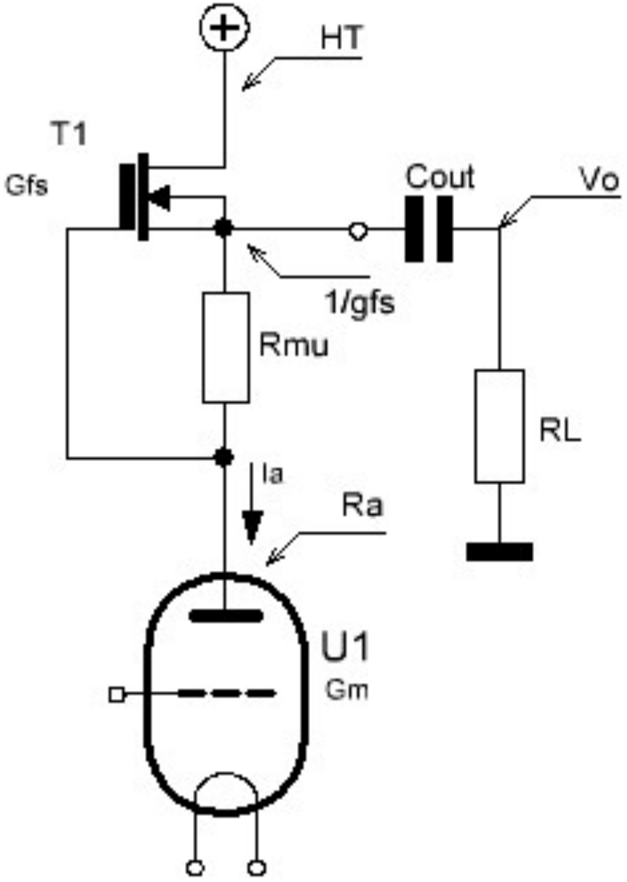


- Lowest TEMPCO [4] for LND150 measured:
  - $Vgs_{off} = -1.6V$
  - $I_{DSS} = 1.8mA$
  - $Vgs_{(0TC)} = Vgs_{off} - 0.63V = 0.97V$
  - $I_{DZ} = I_{DSS} \cdot \left(\frac{0.63V}{Vgs_{off}}\right)^2 = 0.28mA \rightarrow$
  - $Rs = \frac{Vgs_{(0TC)}}{I_{DZ}} = 3.47K\Omega$





Some Math…



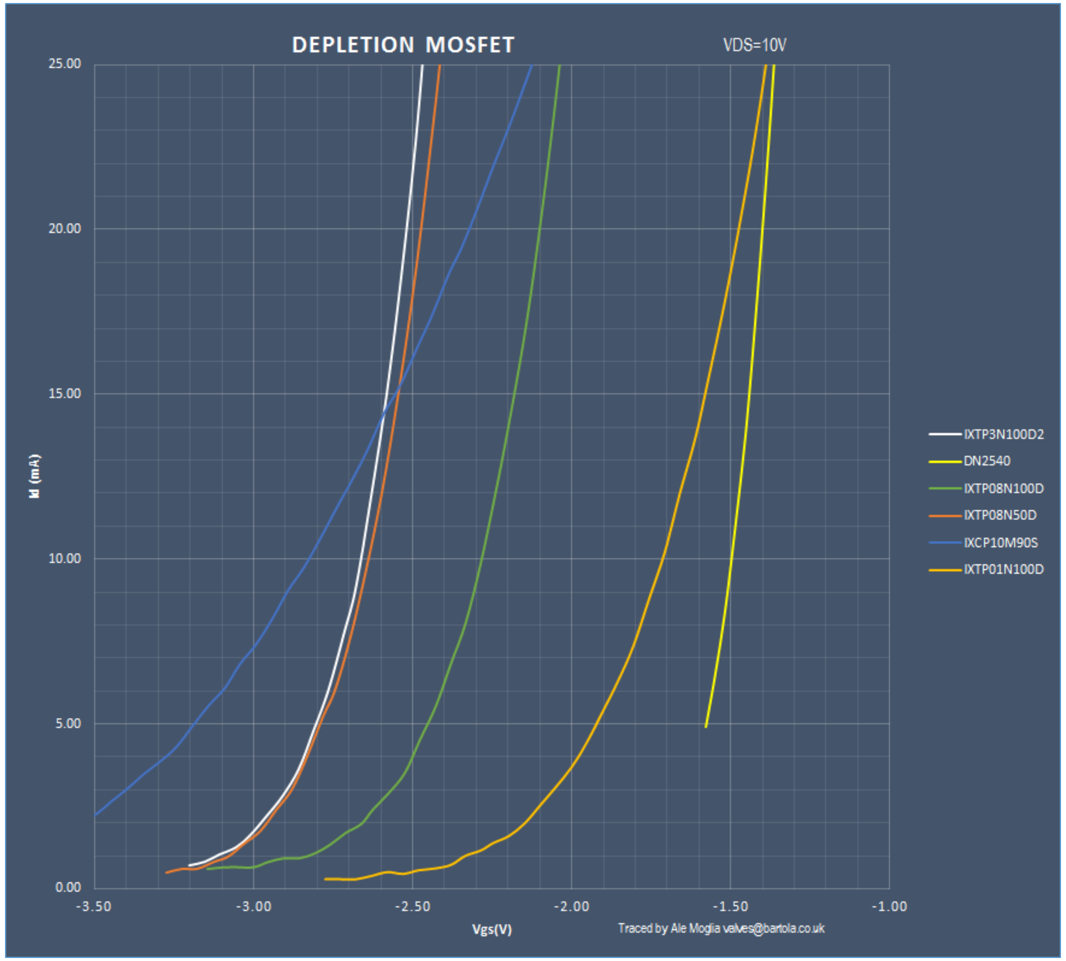
- For totem-pole current balance $g_{fs} = g_m$ so $R_\mu \cong \frac{1}{g_m}$ for current balance in the load

- Output impedance: $Z_O = \frac{R_a + R_\mu}{1 + R_\mu \cdot g_{fs}}$
- For a low R_a then $Z_O \cong \frac{1}{g_{fs}}$

FETs and MOSFETs: an Endless Tale

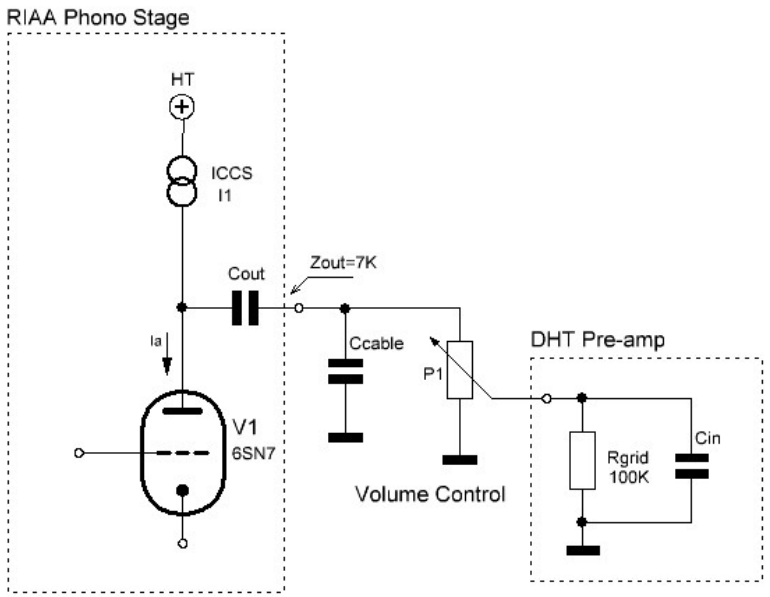
	LSK170	BF862 (*)	BSH111BK	DN2540	BSN20BK	BSP149	RU1C001UN
Ptot (W)	0.4	0.3	0.3	1	0.31	1.8	0.15
VDS	40	20	55	400	60	200	20
VGS off	2	-1.2		-1.5	1	-1.4	
IDSS (mA)	12	25	210	120	265	660	
Gfs (mS) (*)	22	45	640	300	710	800	180
Id Gfs (mA)	18	18	200	125	200	480	100
Id (mA)	10	10	10	10	10	10	10
Gfs @ Id (ms)	16	34	143	85	159	115	57
Ciss (pF)	20	10	19.1	200	20.2	326	7.1
Crss (pF)	5	1.9	1.5	1	2	17	1.7
Coss (pF)			2.7	12	3.1	41	3.3
1/gfs (ohms)	61	30	7	12	6	9	18

HV Depletion MOSFETs (Id vs Vgs)



(*) EOL now, 2SK3557 and CPH3910 instead

Where To Place The Volume Control?

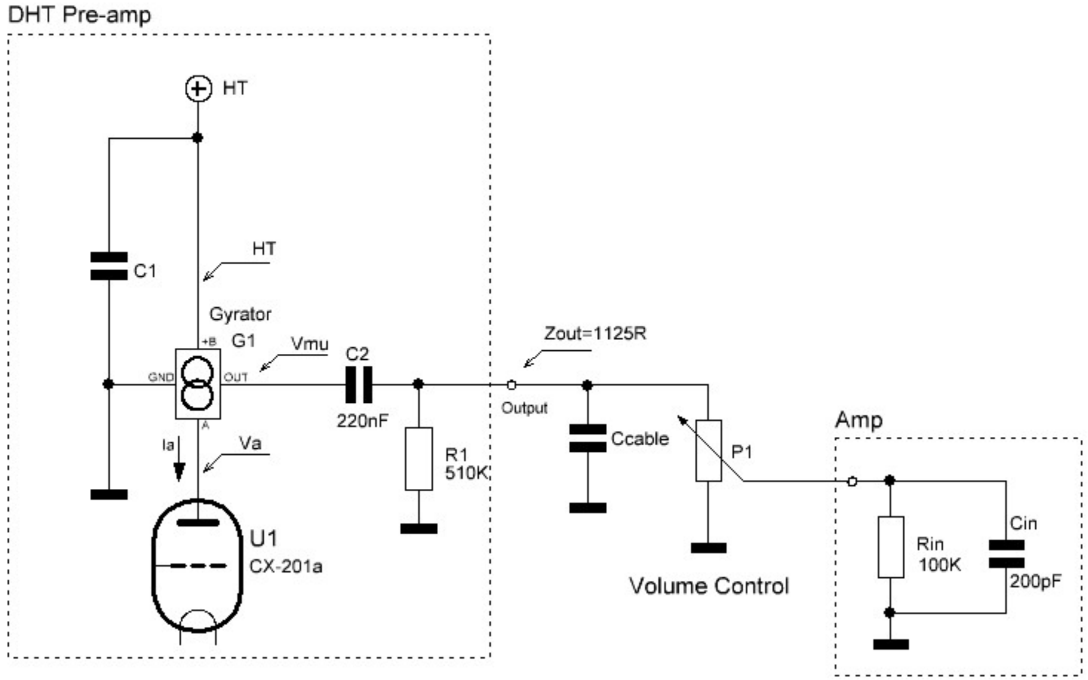


Can we use a 20K vol. control at the input of the DHT pre-amp?

Example 1

- Short interconnect cable ($C_{cable} \approx 200pF$)
- DHT preamp valve is 10/VT-25:
  - $C_{in} = C_{gk} + (\mu + 1) \cdot C_{ag} \approx 70pF$
- If volume control is 20KΩ (90% position):
  - $f_{-3dB} = 123kHz$
- If volume control is 100KΩ (90% position):
  - $f_{-3dB} = 98kHz$

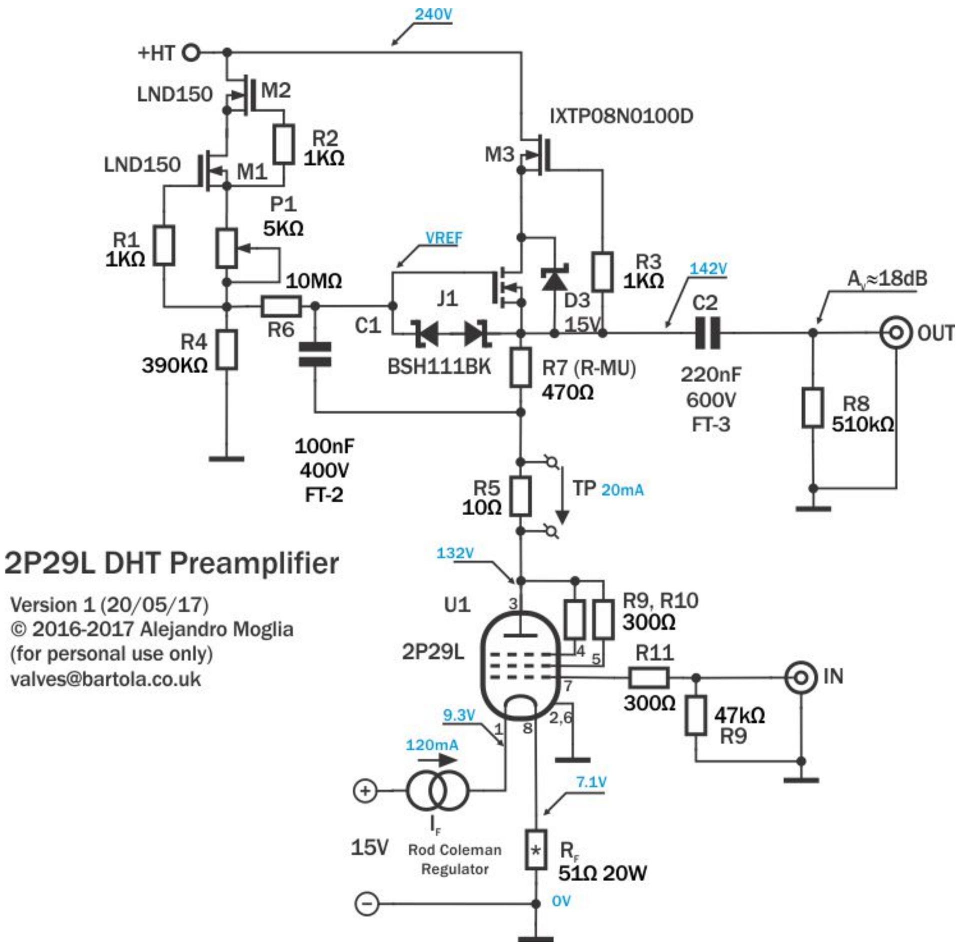
Can You Drive Me?

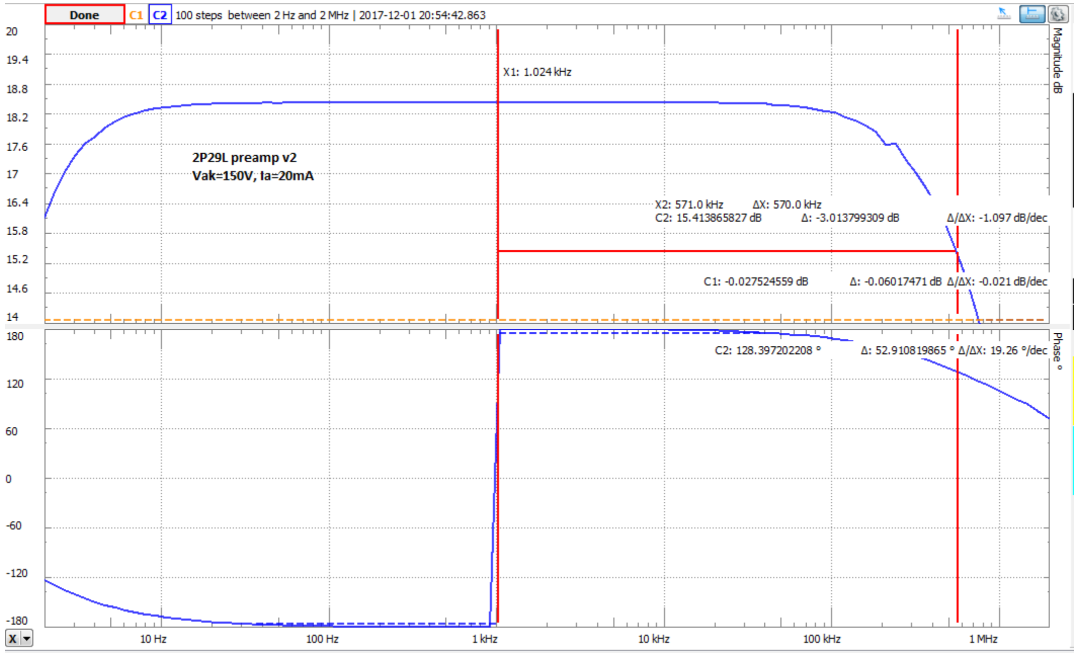


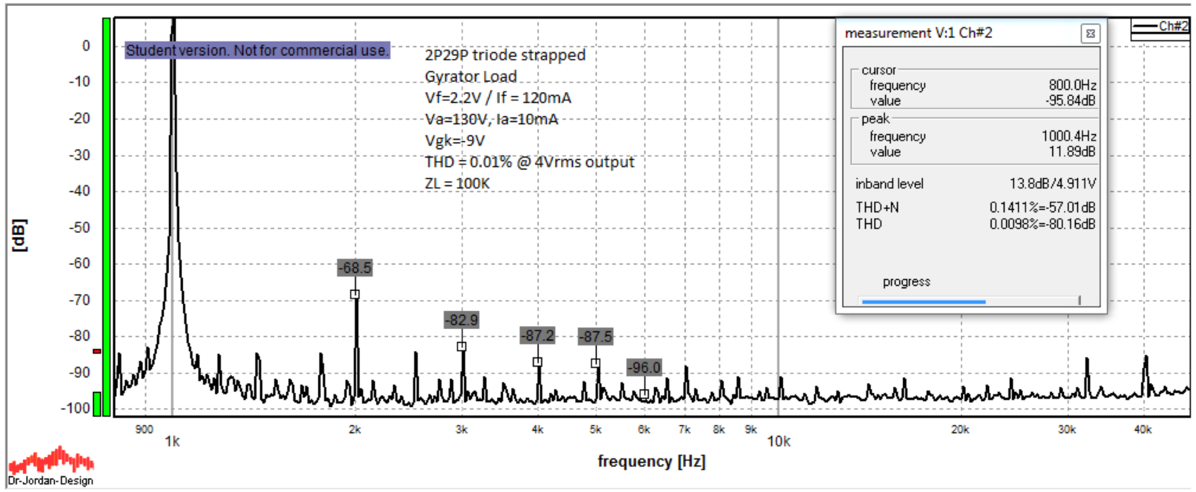
Can the DHT Pre-amp drive 5m cable?

- 5m interconnect: ($C_{cable} \approx 1.1nF$)
- CX-201a follower $R_{OUT} \cong 1125\Omega$ for $R_\mu = 470\Omega$ and $G_{fs} \cong 20mS$ @ $I_a = 3mA$
- If volume control is 20KΩ (90% position):
  - $f_{-3dB} = 118kHz$
  - However, $C_2 \geq 1\mu F$ for $f_{-3dB} = 9Hz$
- Slew rate limitation:
  - $I_C = C \cdot 2\pi \cdot f \cdot V_{peak}$
  - If $I_A = 3mA$ and $V_{peak} = 10V$ then $f_{max} = \frac{I_A}{C \cdot 2\pi \cdot V_{peak}}$ =36kHz
  - For $f_{max} = 100$kHz then $I_A = 8mA$.
  - Source or cathode follower solution

A Practical Example: 2P29L







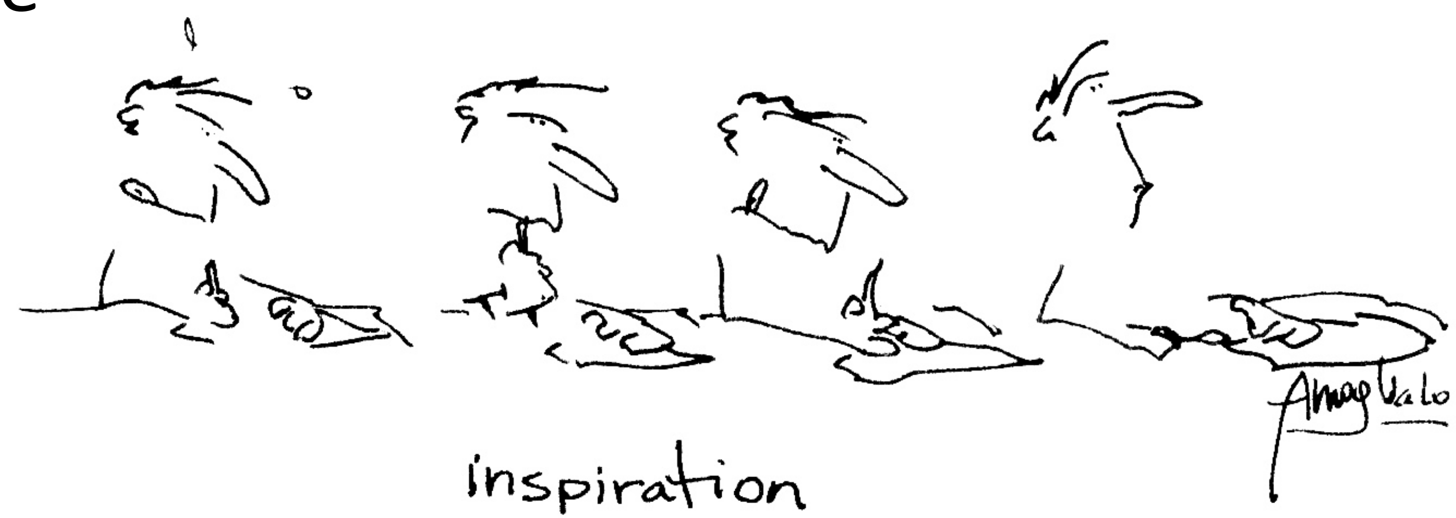
Valve	Timbre & Detail	Microphony	Current Drive	Gain	Notes
801a 10-Y VT-25	●●●	🟡	🟢	M	• Challenging for filament bias (heat) but doable • Thoriated-tungsten filaments • ER801a a great option!
01a	●●●	🟡	🔴	M	• Be careful with old valves and microphonic devices • Great for filament bias • Thoriated-tungsten filaments
2P29L	●●	🟢	🟢	M	• Still cheap and plentiful • Remove the aluminum can and use it naked! • Great for filament bias
Aa / Ba	●●●	🔴	🔴	H	• Rare and expensive • Ba picks too much hum – needs shielding • Good for gain but needs SF/CF stage
4P1L	●●	🔴	🟢	M	• Still available • Easy to match pairs • Can be very microphonic
26	●●	🟡	🟡	M	• Be careful with old valves and microphonic valves
199	●●●	🔴	🔴	M	• Very microphonic • Old and scarce, Variance between samples • Short pin UV99/199
45 / 46	●●	🟢	🟢	L	• Bias levels prevents filament bias use • Low gain
112a	●	🟡	🟢	M	• Better current drive than 01a, but lack of thoriated tungsten filaments
RE-804	●●	🟢	🟡	H	• Hard to find in NOS. Valvo brand is best.
71a	●	🟢	🟢	L	• Low µ and anode resistance. Ideal for line stage when gain isn't needed

Closing Note

- DHTs sound is unique and worth the trouble
- Don’t underestimate role of power supplies
- Right topology for your system
- Don’t be afraid of sand ☺

Acknowledgements

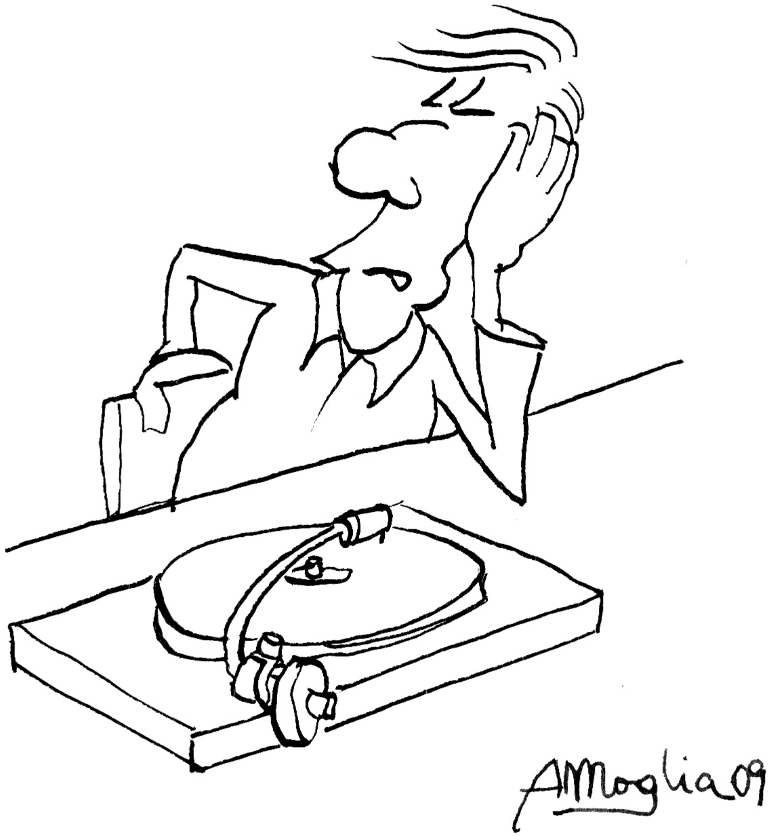
- Morgan Jones
- Rod Coleman
- Andy Evans & Tony Rees
- Tom Browne



References

1. Alan Kimmel’s ”Mu Stage Philosophy” - http://www.fetaudio.com/wp-content/uploads/2003/09/Mu-Stage.pdf
2. Gary Pimm’s website (archived)
3. Morgan Jones’ “Building Valve Amplifiers”
4. Linden T. Harrison’s “Current Sources & Voltage References”
5. Steve Bench’s “Directly Heated Triodes operated with lower voltage on the filaments”
6. SRPP theory and evolution:
    1. John Broskie’s “SRPP deconstructed”, “SRPP+”- www.tubecad.com
    2. Merlin Blencowe’s “The Optimised SRPP Amp” - http://www.valvewizard.co.uk/SRPP_Blencowe.pdf

Thank You!



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