1. Summary

A 20W amp using common triode/pentode tube, and a PP UL 6CM5/EL36 output stage. Input stage pentode with direct coupled connection to triode cathodyne PI stage using Jeffrey configuration set for max gain. 6CM5 push pull stage with UL configuration and fixed bias. The amp is powered from a 12Vdc 5-8A switchmode plugpack, using 12Vdc for heaters, and dc/dc to generate isolated B+ of circa 320V as well as -60V bias.

Main aims:

- 12VDC plug-pack supply for mains AC powering.
  - +ve centre pin.
  - 5A model Powertech MP3242 (N287)
  - 8A model LY1208 (N363)
- 12Vdc input 150W inverter step-up switchmode module for isolated B+ and neg bias.
- Use commonly available valves:
  - Input stage and PI options – single valve
    - 6V or 9V heater – use XL4015 buck module
    - Use Jeffery 1947 WW circuit for highest gain
    - Heater can't be elevated as 12VDC plugpack may connect to AC supply protective earth.
    - //dalmura.com.au/static/Prototype%2012AU7%20PP%20with%20Jeffrey.pdf
  - 2x 6CM5 or 2x 6L6G for either PP or parallel SE
    - 2x 6CM5 with 1.2A heater
    - 2x 6L6G with 0.9A heater
- Use commonly available transformer for output transformer:
  - Altronics M1115 line transformer with 8k PP and 42% taps and 8Ω speaker loading ($16.50 altronics) – nominal 15W capability.
  - Alternatives are:
    - Spare Ferguson OP301/8 with 8k PP and 41% UL taps, rated 12W
    - Downlight or other power transformer
    - Vintage SE OT's for low power amps
- Using chassis from Unknown amp #4:
  - Chassis and base cover cleaned and painted.
  - Holes for Octal and noval sockets.
  - Wooden tolex covered box with front opening.

2. Measurements

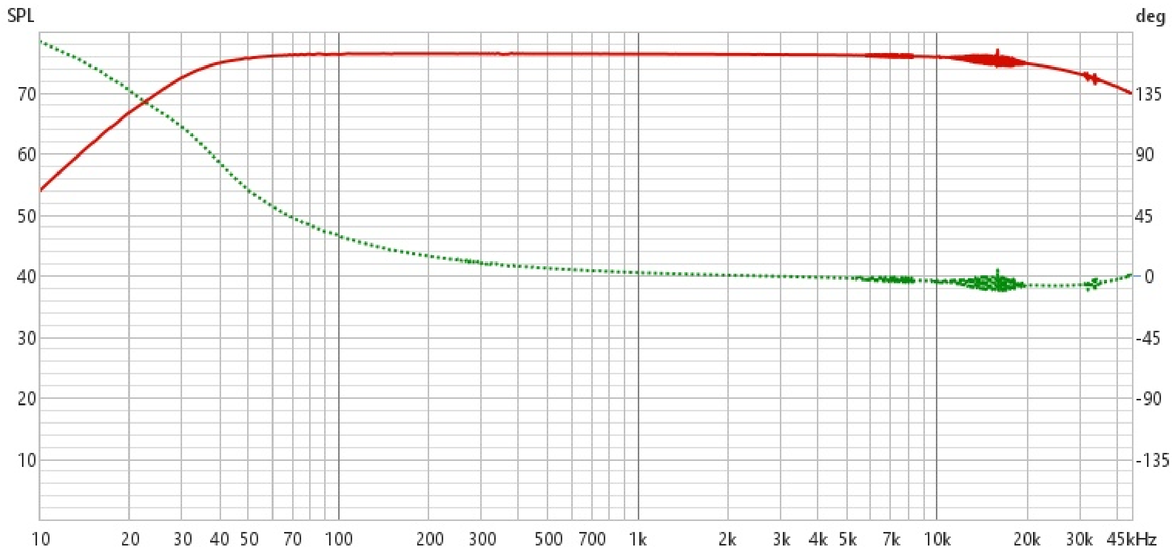
2.1 Jeffery direct coupled modification

Initial testing with 6EA8 and 6U8. Then 6EA8 swapped for PCF80:

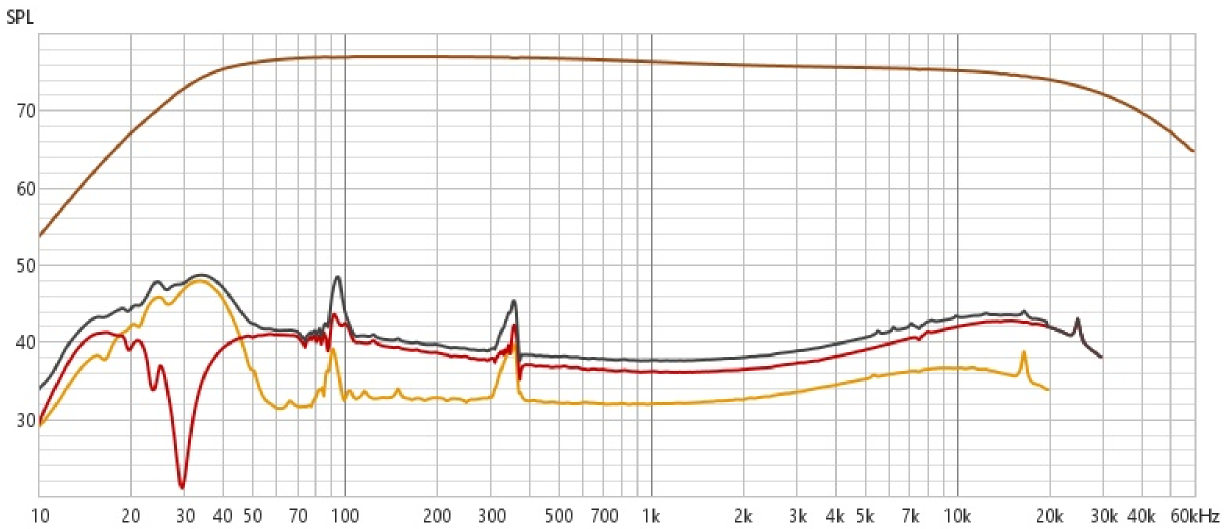
- PCF80 heater voltage adjusted to 9V
- First stage PCF80 pentode screen adjusted and PI output signal distortion and waveform monitored at medium to max signal level. Harmonic distortions reduce as screen voltage lowered, however output waveform at max level showed a compromise of clipping on-set on one sine peak, and broadening on other peak.
    - 20Vrms on PI output had 2% 2HD, and <1% 3HD
    - 40Vrms max had 11% 2HD and 4.3% 3HD at on-set of clipping.
    - About 40Vdc on screen with 10M meter loading, and 102Vdc on anode.

Returned bias to -60V max, then reinstalled 6CM5's and modified bias to 10W nominal idle dissipation per tube for 320V 32mA bias (320mV sense each).

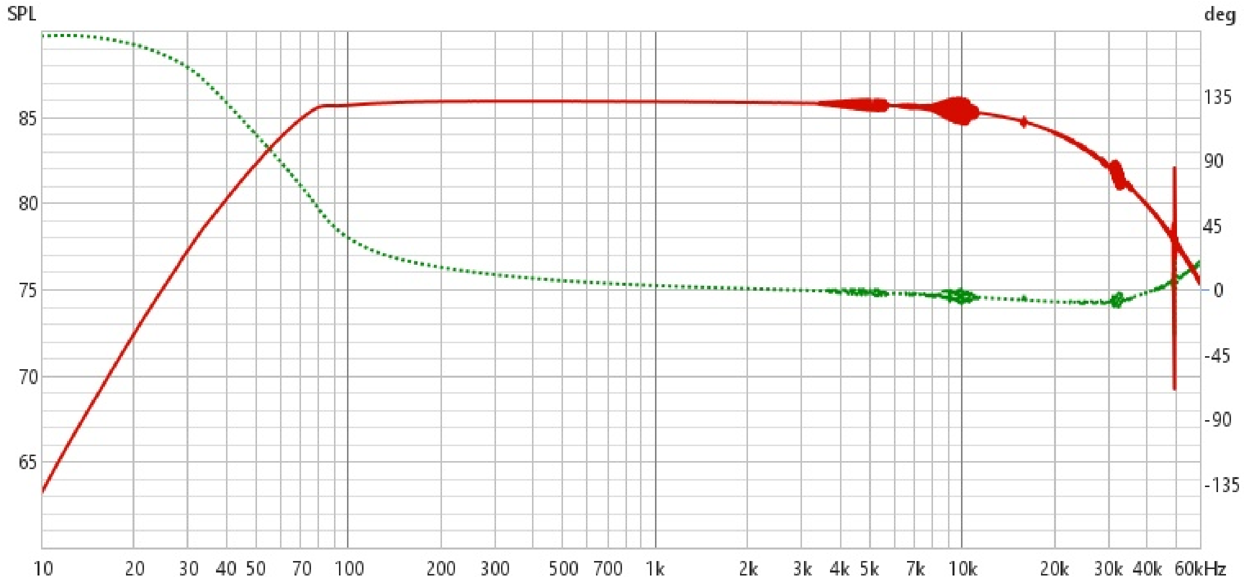
- Feedback 0.918V from 2.0V, so -6.8dB at max Vol, no Tone.
- 2.6mVac noise into 8R at idle with max Vol, reducing to 0.5mV at min Vol.
- 2W power bandwidth extends to -1dB at 50Hz and 20kHz. Harmonic distortion low across bandwidth (2 HD 1.0% at 1kHz).
- 18W power bandwidth extends to 80Hz, and -1dB at 70Hz and 15kHz. Harmonic distortion increases rapidly below 100Hz (2 HD 3.4% at 1kHz).
- 20W staring to clip one side, but HD's still low. VS1 sags from 328V at idle to 320V at 18W clean.
- Gain-phase response at 4V (2W 8Ω) with max Vol setting shows smooth phase roll off above 10kHz, with no transformer resonance till above 200kHz for nominal load, no load, and 47nF only load, so amp appears to be unconditionally stable.



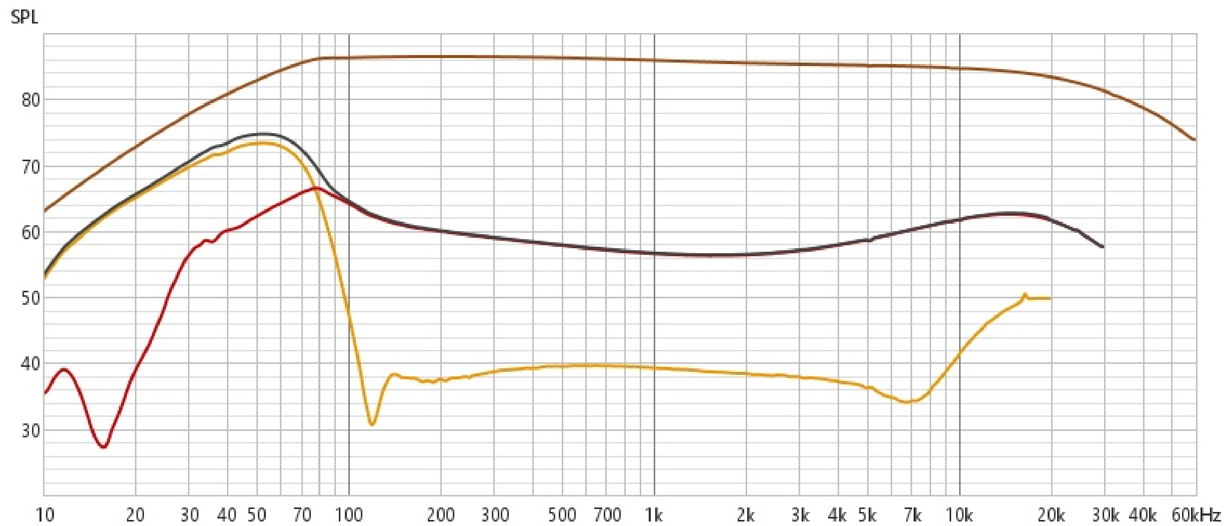
2W 8Ω load frequency spectrum – max Vol, Tone off.



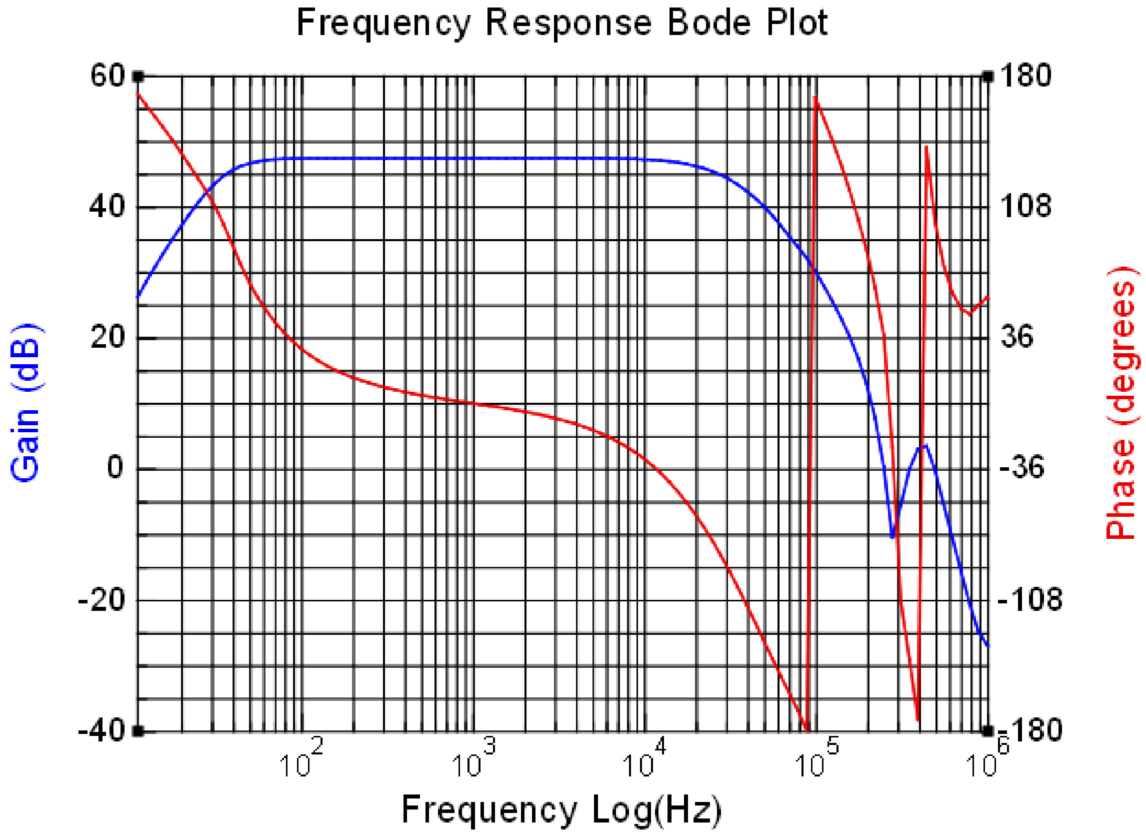
2W 8Ω load distortion spectrum – max Vol, Tone off.



18W 8Ω load frequency spectrum – max Vol, Tone off.



18W 8Ω load distortion spectrum – max Vol, Tone off.



Gain-phase response at 2W with 8Ω load, no Tone and max Vol setting from 11Hz to 1MHz.

3. Design Info

3.1 Jeffrey input configuration

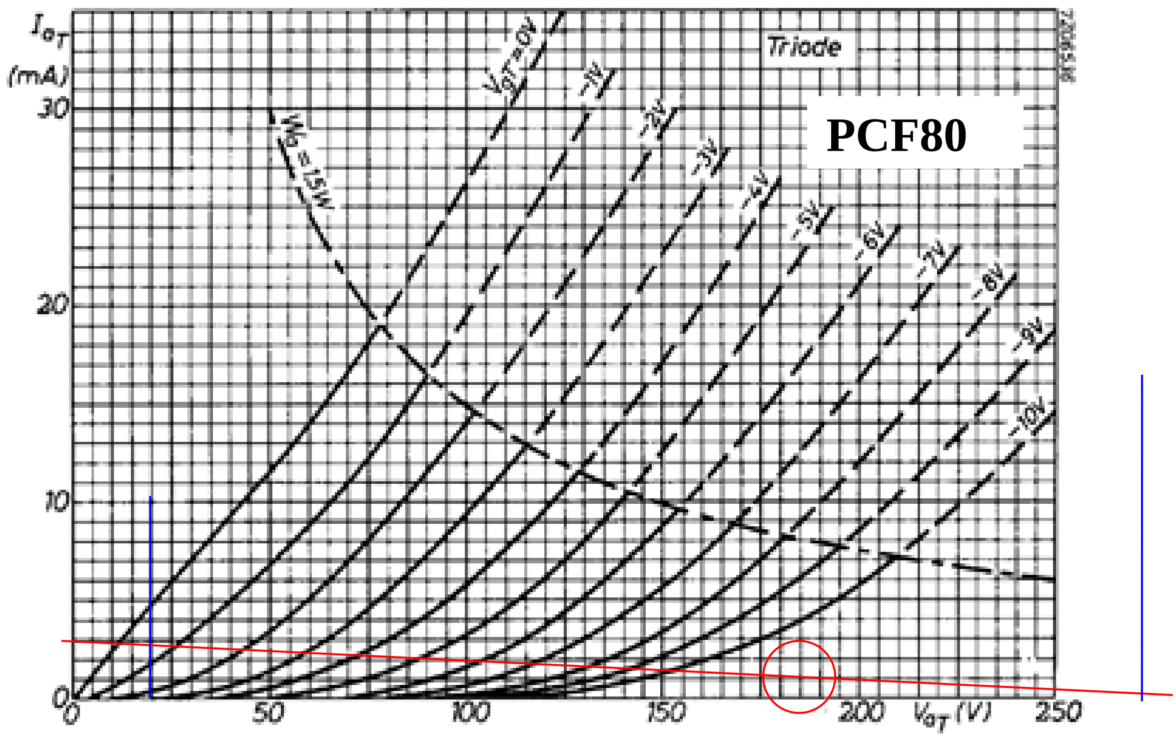
The input stage pentode uses a cathode bypass of 100uF and 1k to provide a suitably low 1.6Hz corner. The screen voltage is set by 820kΩ + 1MΩ trimpot, and also suitably bypassed.

For the cathodyne with a nominal 320V B+ and 40V minimum anode-cathode voltage, along with a 33+66=100k DC loadline, indicates the max current swing is from 0mA to (320V-40V)/100k = 2.8mApp. For a centre-biased cathodyne, assume idle at 2.8mA/2 = 1.4mA, the cathode voltage is 66kx1.4mA=92V, the anode at 320-(33kx1.4mA)=274V, and Vak=274-92=182V. Vak has swing limits of 320V and 40V (ie. 280Vpp), so a 140Vpk swing away from 182V Vak idle. Triode curves compress towards cutoff and will round off a sine peak, whereas peak of sine will show clipping when approaching saturation.

Measured idle Vkt=96V, falling to 94.5V with 10MΩ meter loading on Vap=83V, for VS2=327V, which indicates the triode idle Vgk~12V.

PI grid stopper used to tame any overdrive.

Pentode input stage with fixed screen voltage, which is relatively high (circa 80V) for this Jeffrey config due to the 66kΩ asymmetric cathodyne resistor. The idle anode current is about (320-80)/220k = 1.1mA. The very high gain of the pentode, due to the almost infinite anode load, means the anode voltage loadline is horizontal, with a lower limit close to 0V and an upper limit bootstrapped to the cathodyne cathode positive excursion limit of nearly 140Vpk. This indicates the pentode anode swing to near 0V, or about 80Vpk is likely to be the limitation on the Jeffrey configuration.



Adjustment of the pentode screen voltage down to about 40Vdc (loaded with 10M meter) allowed lower 2H and 3H harmonic distortion, and a compromise PI output at 40Vrms that started clipping on one peak whilst other peak was not too rounded. The pentode anode voltage was measured at 102Vdc with 10M meter loading. This indicates the compromise of pentode anode voltage swing along with triode PI swing.

3.2 Output stage – push pull, ultra linear, fixed bias

Two 6V 1.25A heaters in series no issue for 12VDC plug-pack supply, but need to confirm series heater balance during power-on and steady state (especially given valves unlikely to be NOS from same batch).

UL PP option:

- http://home.alphalink.com.au/~cambie/6AN8amp/Grant_Wills_6CM5amp.htm
- B+ of 340V should be ok given example amps from Grant Wills and Patrick Turner.
- Use feedback as a gain and presence adjust.

OT is Altronics 15W Line Speaker Transformer, MM1115 as 8k PP with 8 ohm output.

M1115	Power (W)	Vrms (8 ohm)	Vratio (100V)	Zratio	Zpri (rel to 8ohm)
	1.25	3.16	31.62	1000	8000
	2.5	4.47	22.36	500	4000
	5	6.32	15.81	250	2000
	10	8.94	11.18	125	1000
	15	10.95	9.13	83	667
	0	0.00	0.00	0	0

Fixed bias to minimise power loss and use available -60V from switchmode module.

The screens connect to 40% turns ratio tapping's. Using a 100 ohm 0.4W stopper as a poor mans fuse, and to minimise any chance of oscillation.

Using 12k grid stopper for each pentode, as should be able to achieve overdrive, and to avoid instability.

Effectively using 11nF coupling (22nF in series) cap to provide faster recovery from blocking distortion due to grid conduction.

400V coupling cap on its limit (340V + 60V).

Plate DC voltage will be lower than VS1 by an amount up to ~6V; ie. OPT half resistance of about 108Ω with a peak current of up to about 0.055A.

The maximum output valve bias current allowed is dependant on the maximum recommended plate dissipation of up to 20W, + 3W for the screen: Ibias(design) = 70% Pd / Vb = 15W / 300V = 50mA.

3.3 Power Supply

Mains AC plugpack 12VDC output current budget:

- Valve heaters = 0.45 + 1.25 = 1.7A at 12Vdc
  - 6EA8 heater (0.45A) dropped using 2x 33Ω 5W in //, to provide about 5.5V heater. But then modified to use XL4015 buck module
  - 6CM5 heaters (1.25A) had 4.7V and 6.9V at power up; stabilised to 5.5V and 6.1V.
- Plug-pack supply at 3.63A at 11.6V (42W)
  - 6CM5 cathodes at 31mA each.
  - VS2 at 12V/4k7 = 2.6mA.
  - Dc/dc module output at idle = 317V x 0.065A = 20.6W
  - Heaters at ~1.7A = 19.7W
  - Dc/dc module loss ~ 42 – 40.3 = 1.7W
    - Dc/dc input current ~ 22.3W/11.6V = 1.9A
  - Plug pack supply just exceeds 5A at 20W cranked output.
- Higher power plugpack – 12V 8A regulated – aim for class 1 (with earth pin).
  - 200W PC supply likely to have separate 6A and 12A supplies.
  - 12V 6A FH1206000 was $38
  - Element14 VES90PS12 7.5A $70
  - MeanWell GST90A12 6.7A, hiccup from 110%, negative not connected to FG.
  - Supplies for LED strips may be ok, with a CV and CC characteristic, but output negative floating (cap to FG), such as MeanWell HLG-120H.

The 150W module may benefit from increased switching frequency mod, as modules are early vintage.

Concerns:

- Ripple current of doubler and main local filter caps, given small physical size is required.
  - Use 4.7uF 400V KMG United Chemicon 10x16, ripple rating of 50mA 120Hz, with 1.75 multiplier.

  - Check actual levels with CT probe.
- Constraining switching ripple to just module:
  - Use buffer low value resistors for B+, 0V and bias connections at module.
  - Added 100uH PKB0809-101J radial, 700mA, 0.62 ohm.

Original module with doubler and full-bridge, and neg bias.

12.0Vdc, 2.9W;	339V, no external loading, 0W.	2.9W loss
12.0Vdc, 9.0W;	329V, 21.1kΩ external loading, 5.13W.	3.9W loss
11.83Vdc, 31W;	320V, 3.66kΩ external loading, 28W.	3W loss

Original module with doubler and full-bridge, and neg bias. Modified RT=3k9.

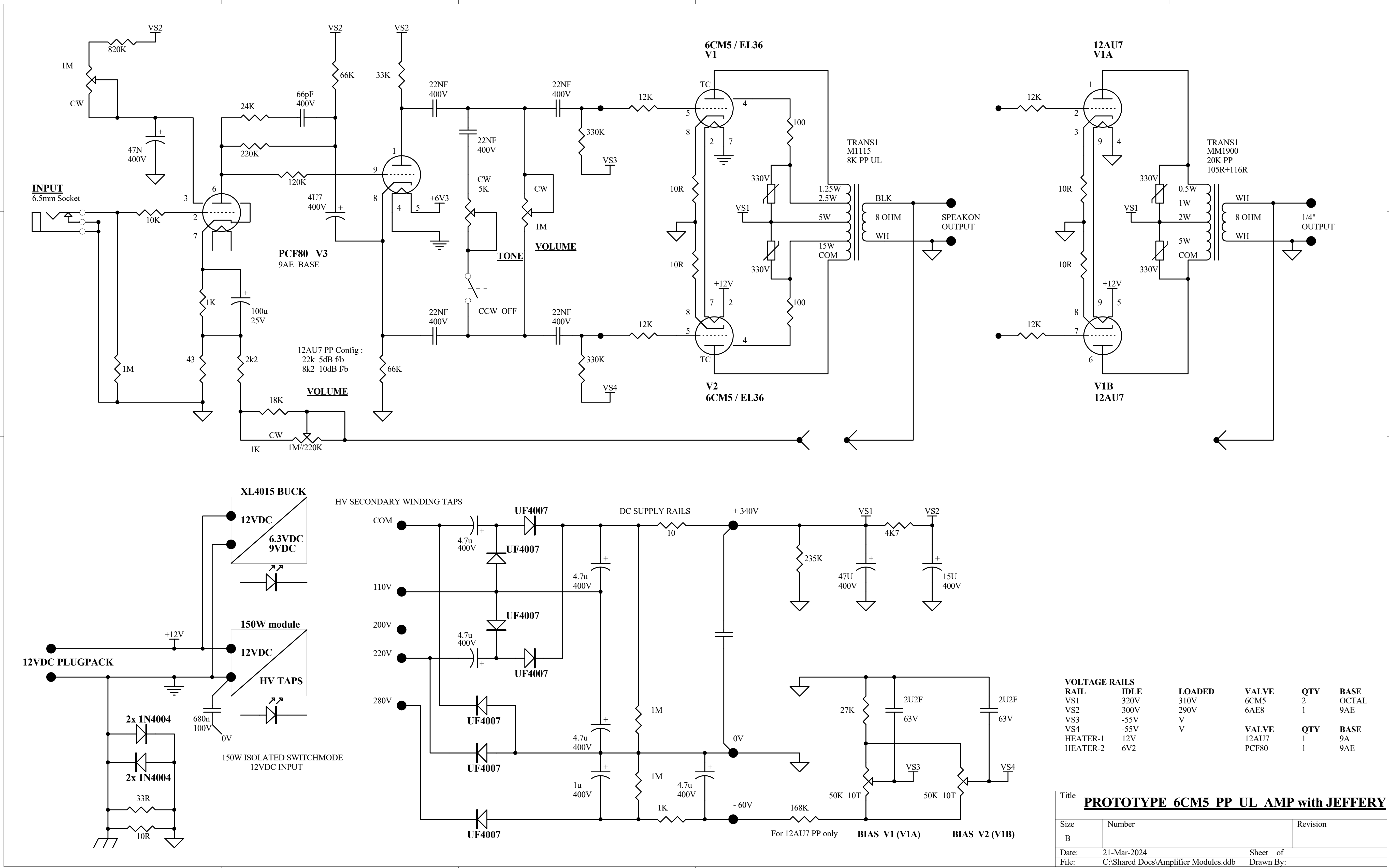
12.25Vdc, 2.6W;	354V, no external loading, 0W.	2.6W loss
12.16Vdc, 7.7W;	334V, 21.1kΩ external loading, 5.3W.	2.4W loss
11.80Vdc, 30.7W;	320V, 3.66kΩ external loading, 27.8W.	2.9W loss

Meters: Aneng AN8009. MPR-5W 0.1Ω sense resistor (cal at 0.0996 at 2.6A, 0.68W with Aneng).

Idle: 324V 38+39mA (12.5+12.6W); 11.8V heater; 6.3V heater; 0.41A mains, 87.0mV shunt (4A).

3.4 6.3V heater dc/dc

Small dc/dc buck module based on XL4015E1, with input voltage range:4~38VDC. Output voltage regulated and adjustable with pot, and set for 9.0V. 0VDC passed through, so no elevation of V3 heater.



VOLTAGE RAILS

RAIL	IDLE	LOADED
VS1	320V	310V
VS2	300V	290V
VS3	-55V	V
VS4	-55V	V
HEATER-1	12V	
HEATER-2	6V2	

VALVE	QTY	BASE
6CM5	2	OCTAL
6AE8	1	9AE

VALVE	QTY	BASE
12AU7	1	9A
PCF80	1	9AE

Title: **PROTOTYPE 6CM5 PP UL AMP with JEFFERY**

Size	Number	Revision
B		

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