1. Summary

Audio Engineers Williamson amp and preamp. Peter Stinson July 2023

Main amp based on original 1947 WW amp circuit with pot in driver B+ feed, but with RC step filter retrofitted, a 10k input grid stopper (input from preamp chassis), output stage 500k grid leaks, common cathode R21 pot replaced with 330Ω 10W, choke CH1 only 1H. 15Ω speaker winding configuration (4k7 feedback). Chassis pre-drilled with rubber grommets for 807's.

Preamp is original 1947 WW preamp circuit except for modified input, and use of 6AU6 in triode mode.

Main amp chassis

6SN7GT Central Electric B5
6SN7GT Haltron
KT66 GEC WM Z (Dec 1965 Hammersmith)
KT66 GEC WM Z (Dec 1965 Hammersmith)
5R4-GY RCA H4 directly heated cathode
Ferguson PF173 PT 230,240V (5Ω). 425-0-425V 175mA (52+57Ω). 6V3 3A CT. 6V3 2A. 5V 3A. ES.
Ferguson OP25/15 in 15 ohm config (original version with black hammertone finish)
Ferguson CF111 choke, 16H 200mAdc 165Ω spec.
Rola TV306-1 choke, 7 dec 1962 date. 1H 325mAdc spec.
Ducon leaded ecaps 8uF 120, 120
IRC 10W WW - 71 46, 66 05
Mustards 055H, 074H

Mains with 10nF 600V hiseal caps from A, N to gnd.
HT CT through fuse to 0V
B+ with 16uF-16uF/16H/50uF

Step network on input triode.
Driver loads to B+ via 20k balance pot.
driver to output coupling caps changed to 47nF 600V styroseals.

4-pin McMurdo socket: 1x heater, B+, 0V.

Issues:

- Mains caps to gnd.
- PF173 has three pri. taps – two were isolated inside bell end.
- OPT sec gnd to poor gnd location, and two chassis links to 0V.
- Old e-caps, and drifted resistors.
- CT fuse rating 0.5A.
- Zinc whiskers on pots and insulation resistance.
- Step network is 5k4-220pF: start 15kHz; stop 151kHz.
- Driver anode loads with 100k//100k rather than 39k.
- Driver stage balance pot shaft is electrically connected to wiper – dangerous.
- 500kΩ output stage grid leaks (instead of 100k).
- Resistor and coupling cap matching.
- Spare heater and heater grounding/humdinger.

- Very close KT66 pair separation – chassis prepared for 807 anode leads, but wired for KT66s. KT66's shown in 1952 advert. One KT66 rotated poorly for anode thermal radiation. Need to thermally derate, or use different model/package, or angle the valve holders.

Obvious history:
choke CH1, Styroseal caps for C6/C7, and some other parts appear to be from 1960's, so could be replacements.

Testing:
Mains pri to earth 540M at 1kVdc.
OT pri – 75MΩ at 1kVdc to core and sec.
TV306 >2T at 1kVdc; 33R
Driver stage pot insulation to chassis ~65MΩ at 500V.
C5 - both 16uF 350V leakage <50uA at 346V.
5U4 only; 240Vac 0.21A, 580Vdc (C8), 6.4Vac heater.
All valves in: 230Vac, 0.54A; 435Vdc (C8), 36V cathode, 47+48mA. V1 and V2 stage voltages are fine. KT66's warm-up differently – changed pair for closer warm-up match. 12.3Vout 16Ω 9.5W onset of distortion increase.

Output stage with Sovtek's fine. F/b = 16.8dB with existing 7k9, and 20.1dB with 15k//. Distortion trimmed using balance pot.
Pico gain-phase results at 210V mains with 16.8dB f/b, and showed stable response for no-load, but up to +8dB peaking at circa 100kHz.

Initial inductor 4.5T ~0.8uH (no step). Roll off slightly more than step network for 1W 16R no f/b.
Inductor 2.5T ~0.33uH (no step). Roll off about the same as step network for 1W 16R no f/b. Pico squarewave testing – stable for no load and 10nF only, but not 47nF. Squarewave response improved considerably with up to 143pF parallel to feedback R; still stable with no load, but unstable for 10nF and 47nF only.
No step, no L, comp cap, shunt RC across load. RC with 50kHz corner and 20 ohm, so 0.16uF (0.22u used). Unstable for 47nF.
No step, L2, comp cap, shunt RC across load. RC with 50kHz corner and 20 ohm, so 0.16uF (0.22u used). Stable for 47nF only load. Lower margin with lower comp cap.

Feedback: 8k//15k -19.5dB; 15k -12.2dB; 8k -16.5dB.

Step, no L, comp cap, shunt RC across load. Stable with 47n, 100n loads. Lower margin with lower comp cap. Unstable without zobel.

Step 150pF-10k (22kHz-130kHz), no L, comp cap, shunt RC (20R-220n) across load, 12.2dB f/b. Stable with 47n, 100n loads. Lower margin with lower comp cap. Resonant peak of 13dB at 55kHz with 47nF load.

Varying zobel when 47nF only loading. Increasing zobel 0.1u to 0.7uF for 20R reduced 55kHz GP pk by about 2db from 14 to 12dB. Increasing zobel 0.1 to 0.7uF for 10R reduced 55kHz GP pk by about 7db from 14 to 7dB. No feedback GP response with 16R load shows only minor bandwidth reduction for -3dB level when increasing zobel C or reducing zobel R to 10. With 19.5dB feedback, just stable with up to 100nF load, but needed 10R 0.3uF zobel, and full comp cap (120+143pF).

55kHz no load resonance with 47nF aligns with 180uH.

REW testing of frequency response:

- Loopback of EMU0404 with in-situ leads and cal file is flat from 3Hz to 90kHz, with abnormal 60 deg phase shift at 96kHz (0deg at 50kHz, and -20deg at 20kHz), but flat to 3Hz.
- 0.1W, 1W, 4W, 10W into 16Ω for final version of main amp shows <0.5dB amplitude variation out to 90kHz, and phase shift at LF end as frequency descends through OPT LF power limit. HF phase shift due to the amp is not discernible – perhaps due to the inherent calibration file used by REW.

LF power limit is 50Hz at 10W, 35Hz at 4W, 18Hz at 1W and 12Hz -3dB at 0.1Hz. The OPT LF resonance is at 3.5Hz for 0.1W, 2.9Hz for 1W, and appears to be below 2Hz for 4W and 10W.

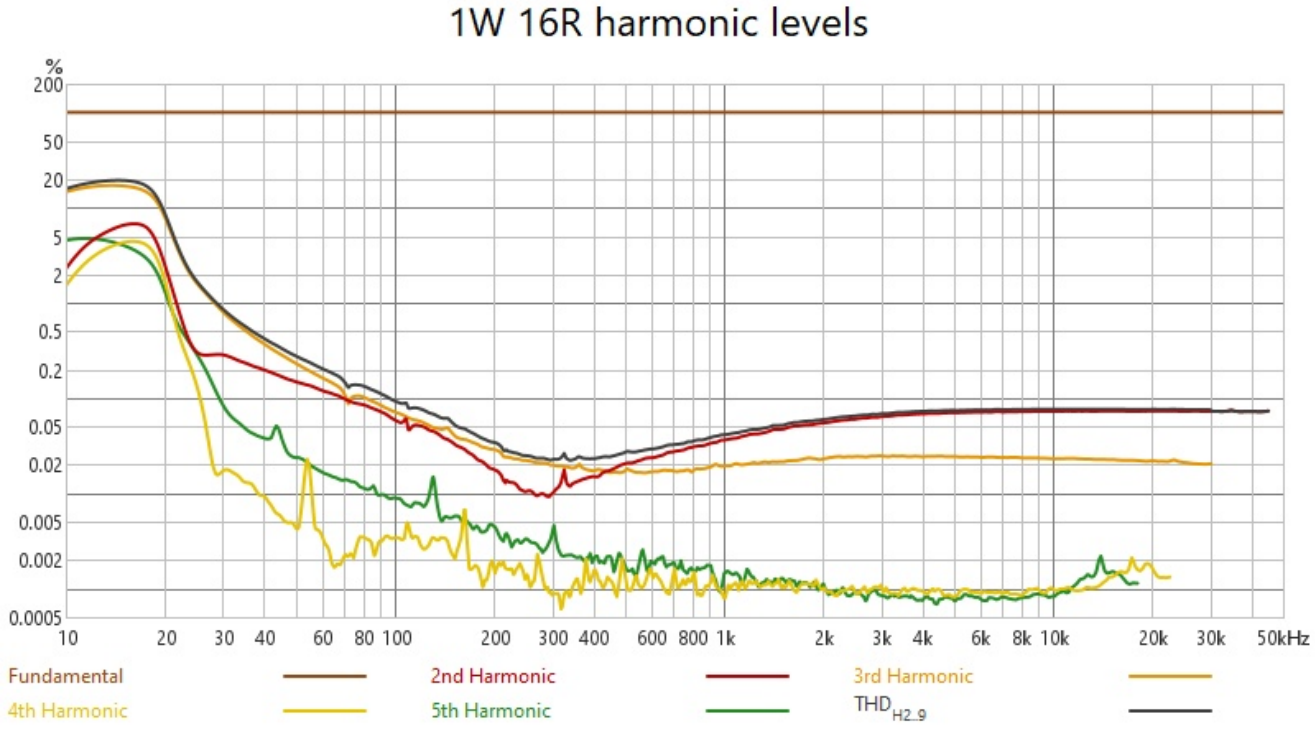
Harmonic distortion is dominated by 2nd and 3rd, with 3nd dominant at 10W as well as higher orders increasing. Up to 4W, the higher orders are at least an order of magnitude lower. At 4W, THD is about 0.11% across the spectrum, rising below 100Hz. At 10W, THD is about 0.2% across the spectrum. Distortion rises markedly at LF as the power bandwidth limit is approached.

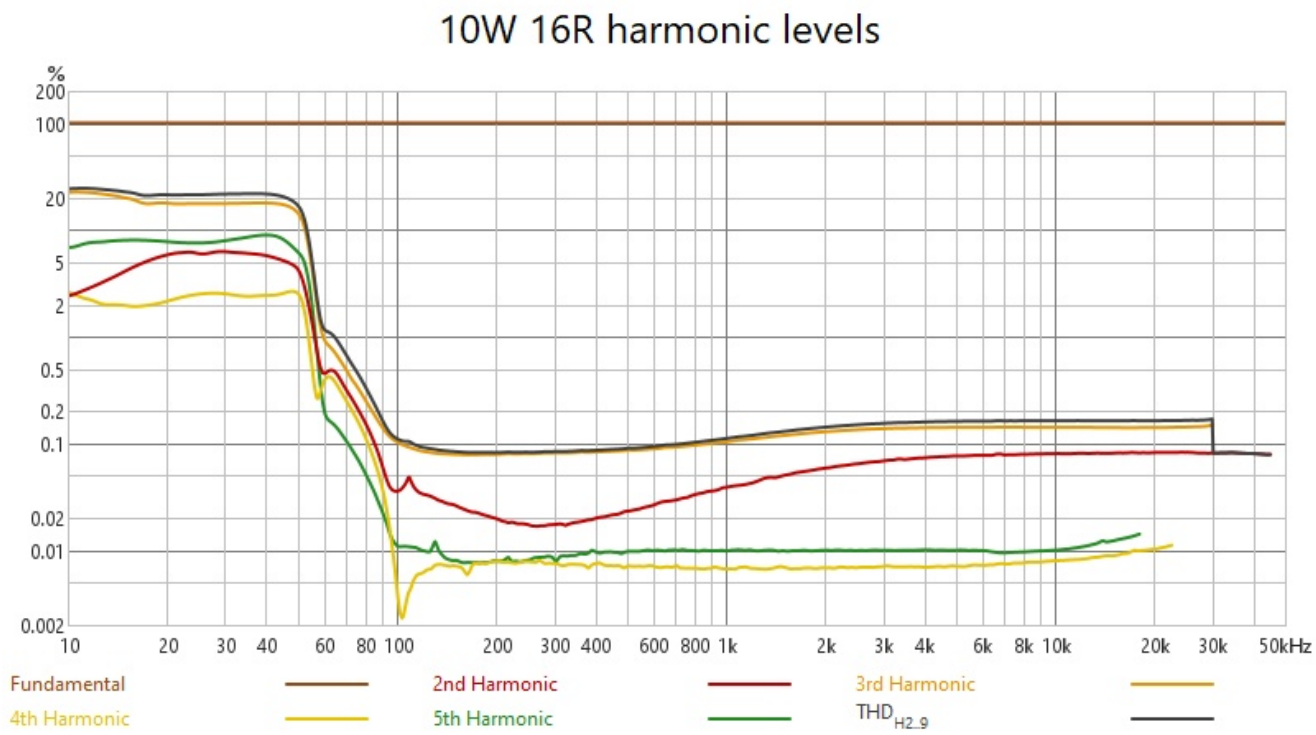
Input sensitivity is 2.76Vout for 0.284Vin at 1kHz. So 10W 16Ω (12.65V) for 1.3Vrms in.

Output harmonic distortion sweeps at 16Ω with no feedback – bias and balance adjust pots:

- Zobel and input stage step still in circuit (but no influence on testing). KT66 pair.
- Testing at 1W 4Vrms sinewave. Measurement sweep to 50kHz but HF not a focus.
- Bias balance at idle measured on 8x meter module – first test setup.
  - Balanced dc currents reduce HD levels.
- Balance adjust pot rotated (with insulated screwdriver) – 2nd test setup.
  - Lowest HD levels for full CCW.
  - Swapped 6SN7's and measured effectively the same.
  - Likely HD improvement from better KT66 balance.

Repeat testing of amp with feedback, and balanced idle dc currents and better ac balance gave 10W HD levels <0.1%. HD levels above 20% may have been modified by REW.





Testing to do:

- Insulation resistance of valve heater-cathodes.
- 4Ω output configuration stability assessment.

Mod options:

- MOV-R's on OPT primaries.
- Adjust total gain and f/b level to make equal to other mono W amps.

Preamp chassis

6X4
6AU6WA RK12
6AU6WA M13
6AU6WA
Ferguson PF269 - no data – pri; HT-0-HT; 6V3; ES.
Ferguson CF103 choke – 30H 60mA 475Ω.
Ducon chassis cap 16u 600V, 16u 600V, 25u 40V; 19
Ducon leaded ecaps 120, 120, 120
Mustard 84H (must have been a replacement)
TCC
AEE microcaps
IRC pot 8E1 B10,
Input dual pot: No. LB1 A [500k CCW] ; app no 11262 G E [450k CW]

Front panel layout L to R: input Vol (replacement knob); Bass rise/fall switch (marked BASS and B C); Bass pot (marked BASS); Treble rise/fall switch switch (marked TREBLE and B C); Treble pot (marked TREBLE); Filter switch (marked 20 13 10 7 5).

Almost exact version of Williamson preamp circuit.

- Input only from ¼" socket. First pot in series with 2nd pot. 2nd pot as standard vol pot. First pot as input series resistance (500k at min pot setting) with output to 2nd pot, and shunted to gnd by 47k (58k) in series with 11nF (which inserts -20dB with 30Hz corner).
- 6AU6 in lieu of EF37. Split load on all 6AU6 triode mode stages, to bring gain down to EF37 level.
- 6X4 in lieu of 6X5 rectifier.
- 25uF 40V in can - not used.
- 4-pin McMurdo provides extension powering of tuner etc.
- Chassis top terminals for 6Vac heater.
- Output shielded signal cable with 2501 microphone plug to match amp chassis input.

Issues:

- Mains cable rubber poor. Mains cable earth purposely disconnected. No switch or fuse.
- S4 assembly with missing link to S4d, and incorrect connections to external circuitry. Cap values with wide tolerances, but ok matching, except for C40. Drifted resistors.
- Bad choke. Replacement options: RCS Filter choke type TC 70; Rola 14/60; Rola CH22; ; 2 Jul 1954; Bramco FC2.
- Somewhat leaky C19 (0.25uF 500V), so replaced.
- Volume pot knob not original.
- Filter -3dB frequencies significantly lower than rated 5, 7, 10, 13kHz.

R49=590k; R55=133k; R54=129k;

CLC 16uF/30H/16uF filter on 6X4. Output to 4-pin tuner socket. 50k/8uF filter to input stage B+, and 33k/8uF to output stages B+.

50k/0.25uF/50k split anode load to pins 5/6 of input stage 6AU6 (plate, screen) to 100k and bass switch, and to mic cap and treble switch. Input signal socket to dual gang vol pot to 6AU6 pin 1 grid. 6AU6 suppressor to cathode to RC to gnd.

Treble pot end to next 6AU6 input grid. plate and screen to B+ through split load 51k/47nF/51k. 47nF to multi-switch RC networks feeding pin 1 input grid of final 6AU6A, again with 50k/nF/50k split anode load (from plate/screen) back to multi-switch and then to signal output lead.

Heater loading: 3x 0.3 = 0.9A plus 0.6A for rectifier. Likely additional 0.6A for Radio Tuner, so likely 2A heater rating.

PT:- 86Ω pri; 500MΩ 1kVdc; 245+264Ω HT sec; 240Vpri 50mA for 280-0-280V and 6.6V unloaded. Choke: 500MΩ 1kVdc. Open circuit – no obvious break internally, but signs of high resistance.

R42=10k (not 6k8). C23=425pF (not 1nF). Perhaps causes +/-1dB non-flat response.

Testing:

- Frequency response from 10Hz to 20kHz depending on tone setting. 10Hz likely due to larger cathode bypassing caps and 0.33uF coupling cap. +2dB at 16kHz.
- Gain of 7.8 (not 1.9/0.2=9.5 as per schematic).
- Adjusted to 10x with 50k//56k – 50k on first stage. 0.045% H2 at 1kHz, rising to 0.32% at 10kHz.
- First stage gain 1.50/0.1 = 15 and 0.28% H2. 2nd stage output 1.61V
- Hum (50Hz) minimised with humdinger into noise floor.

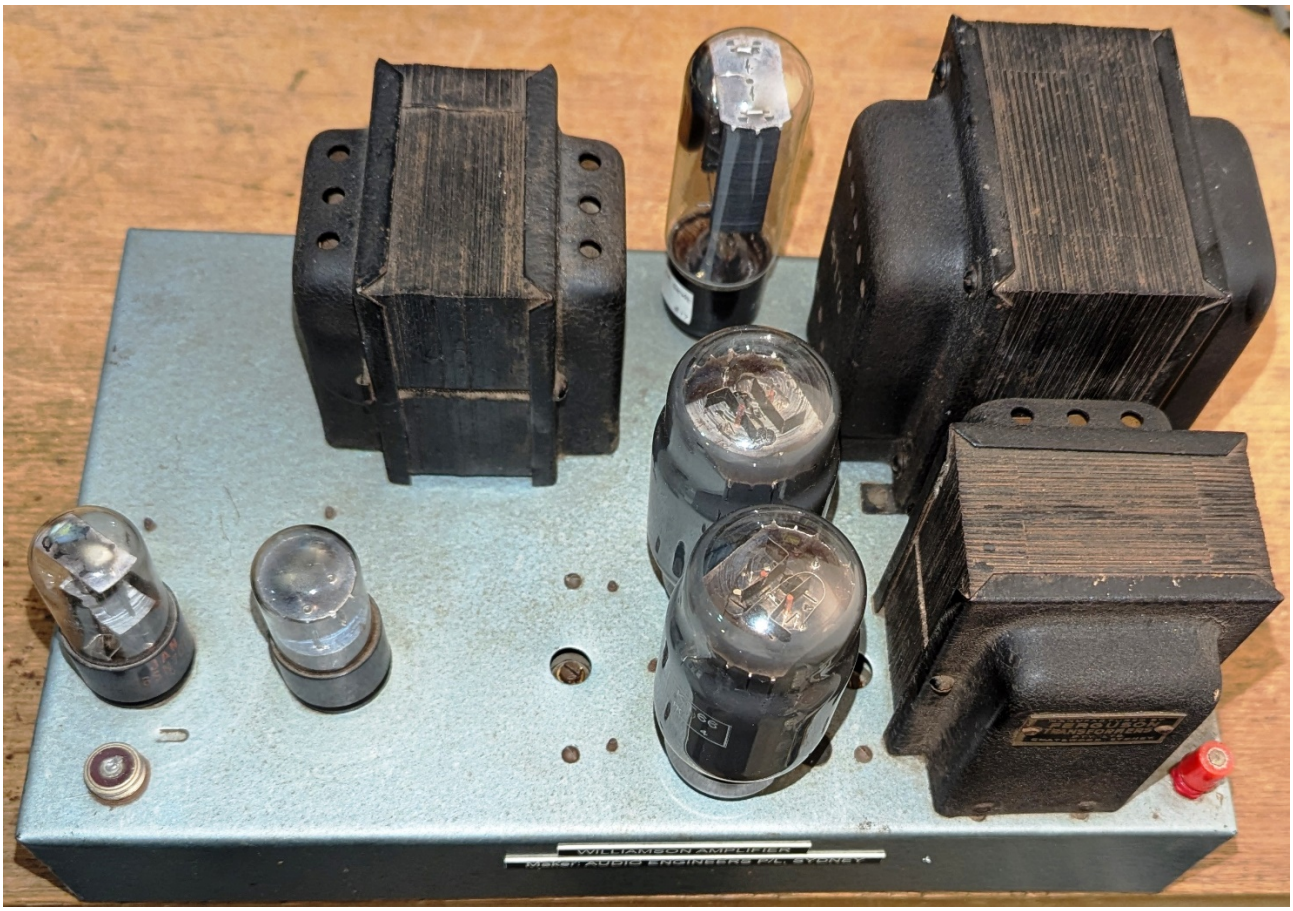
- Filter position response at -5dB: #1 (5, CW) 3.5kHz; #2 (7) 5.2kHz; #3 (10) 8.2kHz; #4 (13) 10kHz; #5 (20) 18kHz.
    - So noticeably shifted from advertised 5, 7, 10, 13kHz, and 20kHz.
    - Measured values of capacitances were often significantly different from Williamson derived values, and are the likely cause of parallel-T filter differences.
    - Posel (1956) indicates response may be influenced by Miller effect, which may be influenced by use of 6AU6 with split load.

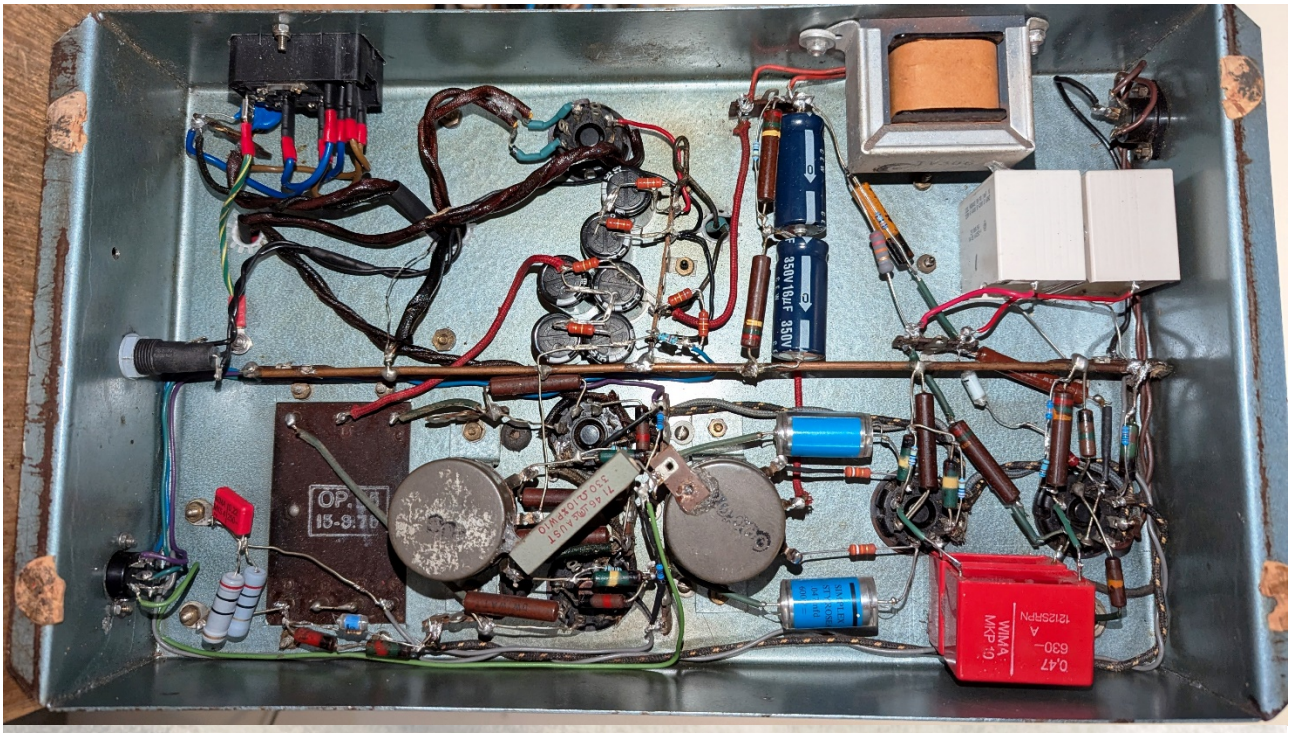
FR of first 2 stages up to R47 is flat for just a bit of treble and rise setting, but -3dB down at 13kHz for no treble and cut setting; with input pot at max. Flat for either Bass setting and no bass. Input pot below max starts to roll off HF response, which can be partially offset by increasing treble boost, but roll off still starts about 20kHz.

Last stage filter introduces about a +2dB lift for all settings. Article indicates a small peak of 1-2dB.

Testing to do:

- Combined pre and main amps – noise floor – mains hum/loop.

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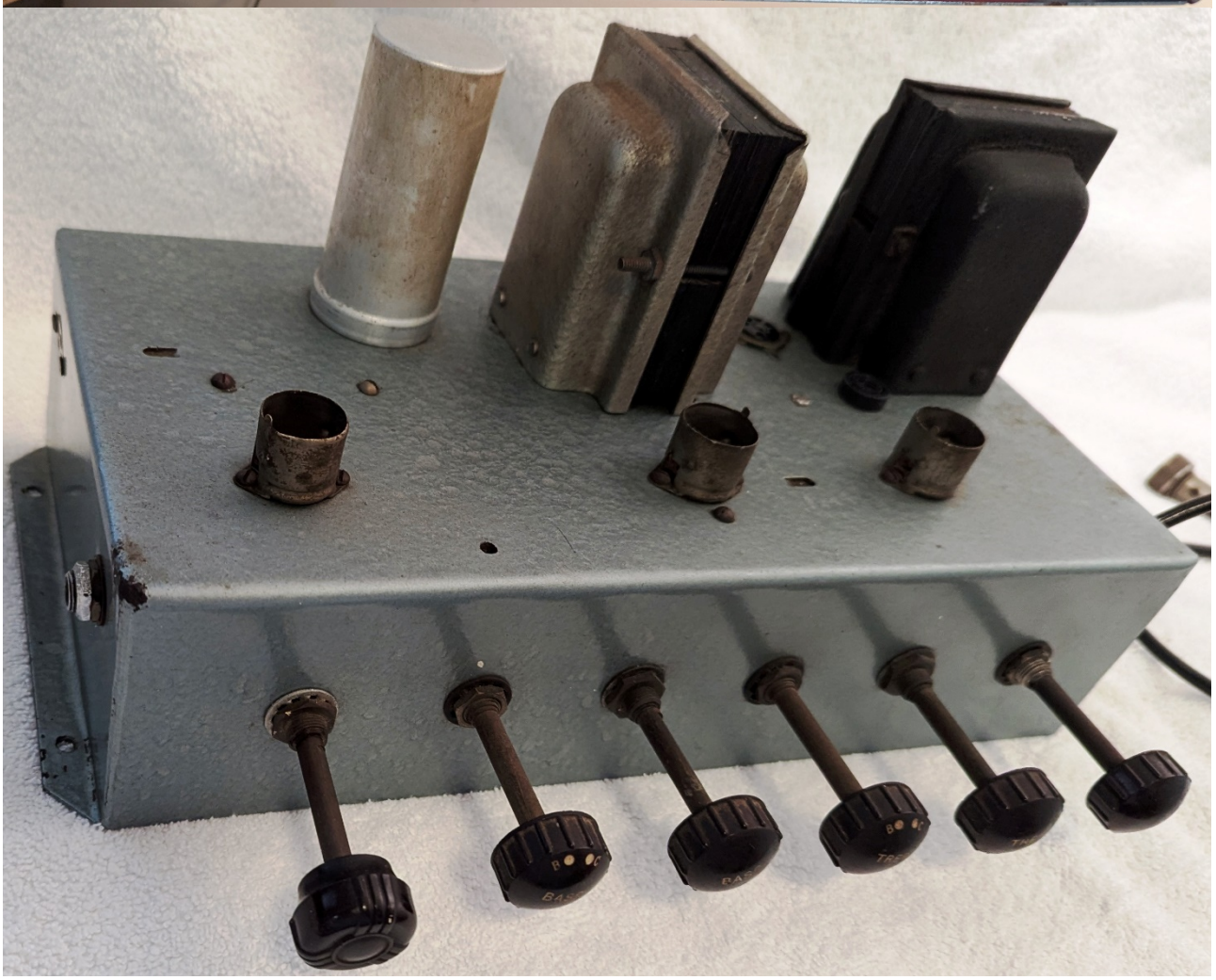

1.1 Dating and history:

Electrosound made PA amps as well as:

- Williamson amp identified in advert R&H Nov 1948.
- The Model RW amp, based on Radiotron A515 Williamson, with separate output stage and power supply chassis and using 807's, and what appears to be Ferguson OP25/15. R&H July 1949 advert.
- the ML20-5, an amp and preamp chassis pair with 20W rating using KT66 PP pentode mode (R&H advert Sept 1952).

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- formerly Electrosound Special Equipment (a division of Electrosound P/L) before June 1950.
- Same advert photos as Model RW – R&H advert Aug 1950.
- The Williamson 'our latest model' with separate tone control chassis – as per this amp. R&H advert May 1952. Same chassis layout and with KT66.
- R&H advert Oct 1952 and Jan 1953 for new series ML20-5.
- Arrow Electronics appears to be a subsidiary, and advertised from late 1959.

AEE Microcaps were advertised from Aug 1953.

2. Modifications

Amp chassis done:

- Removed AC primary side caps.
- Replaced AC mains cable/tag strip with IEC fuse switch combo and 1.6A T IEC 5x20.
- Reverted 500k output stage grid leaks to 100k.
- Paralleled resistors that had drifted high.
- Insulated chassis through holes and separated PT windings.
- HT CT to 315mA 5x20 T fuse.
- Replaced B+ filter caps with 41uF (2x 82uF 350V), and 82uF (4x 82uF 350V) after choke, to provide adequately damped PSUD2 response to step load disturbance. C9 with 2x 110k Pro2 bleeds. C8 with 2x 110k Pro2 bleeds.
- Removed 1350R 10W dropper to end-wall 4-pin McMurdo socket.
- Single 0V busbar link to chassis at signal input socket.
- V5,V6 cathodes with individual 10R 0.25W current sense.
- 5-pin socket for common cathode, PP currents, B+/100.
- Only use 5U4 rectifier (not 5R4).

To do:

- CT fuse changed to lower rating.
- MOV-R for each half-primary.

Heater CT – possibly to divider as part of C5 bleed. PT shield to gnd. Star gnd nodes for C5, C8, C9.

Preamp chassis done:

- Replaced AC mains cable with IEC fuse switch combo and 0.8A T IEC 5x20, and 300Vac MOV, and PE connection to chassis.
- Added 80mA IEC 5x20 T fuse/holder to PT sec HT CT link.
- Added 1N4007 in series with each 6X4 anode.
- Replaced B+ filter caps with 15uF 450V for all 4x caps. Provides adequately damped PSUD2 response to step load disturbance. 150k PRO2 bleed added.
- Insulated chassis through holes and separated PT windings.
- Installed replacement 15H 550Ω choke, and disconnected open CF103.
- Paralleled resistors that had drifted high.
- Replaced 0.25uF 500V coupling cap, and 25uF 40V ecaps for cathode bias.
- Input volume control now with 47k-11nF disconnected.

Total:

- Combined audio testing to dummy load showed no indication of hum artefacts down to general noise floor of -80dB below 4V. Distortion was noticeably higher than amp only level, so preamp distortion contribution is substantial.
- Combined audio testing with 8Ω (don't have hi-fi 15Ω) speaker and CD signal source, using 2k2-2k2-10k log pot stereo to mono mixer and vol pot. Negligible hum and noise. Interdyn P2 with nominal 90db SPL 1W sensitivity was plenty loud. Need to have mixer/pot or preamp inserted before power up to avoid connection transients.

3. Design - amp

A full-wave centre-tapped rectifier with 425-0-425V windings provides a no-load voltage of circa 600V.

The effective source resistance is comprised of the reflected power transformer primary resistance = 5Ω x $(425/240)^2$ = 16Ω; plus the secondary resistance = 52Ω min; which sums to 68Ω.

Idle (and max signal) loading is about 140mA, based on 60mA per KT66, and 20mA downstream.

Only 5U4G is ok to use, but needs all filter caps and bypass caps to survive initial 580V start.

- A 5R4-GY rectifier provides about 440V, with steady state 0.55Apk, and hot-start of circa 2.4Apk. Although steady state peak is adequately below design limits of 0.65A, the hot-start peak is way too high. The secondary Vac, and 140mAdc load appear to be adequately below design limits, but limits are not aligned.
- A 5V4 is marginal for Vac and Iap ratings – would need added Rs and ss diodes. 5V4 shown in 1952 advert.
- A GZ34 is ok, but not for hot-start – would need added Rs.
- A 5U4G rectifier is fine, although it is directly heated and so initial B+ will be circa 580V.

Voltage rating of filter and coupling caps (modified updated version):

- 2x series 350Vdc caps used for C9, C8 and C5, with 110k PRO2 balancing resistor across each
- C1 and C2 were 525 Vp old e-caps. Replaced with 10uF 600Vdc ICEL MAB802 polys.
- C6, C7 are 47nF 600V Simplex Styroseals
- C3, C4 are 47nF 400V mustards. Replaced with 470nF 630V Wima MKP10 to reduce LF phase shift.

The main choke drops about 23Vdc at 140mA.

PSUD2 indicates no resonance response for step dynamic load change for 41uF first filter and 82uF after the main choke. First filter ripple current is about 200mA, and suitably below the 0.35x1.53=0.5A rating for Panasonic EEA 82uF 350V (2x in series).

Bleed resistance is 220k//220k//500k ~ 90k (~4.4mA).

The continuous fuse current in the CT link is about 241mA nominal, which may be too close to 250mA. For a hot turn-on with 140mA load, the continuous load following data indicates a 0.315A T 5x20 is ok. 500mA T 3AG fitted.

Simulate period in PSUD2	**10ms**	**20ms**	**50ms**	**150ms**	**600ms**	**continuous**
Simulated RMS current		1.2A		0.79A	0.43A	0.24A
Multiplier (for 0.315A fuse rating)		3.8		2.6	1.4	0.76
IEC 60127-2 **T** min limit multiplier		10		4.0	2.75	1

Monitoring via 5-pin McMurdo socket for 8x meter module. Common cathode voltage is nominally 125mA x (150//150 +250) = 40V, so use 8x meter module with 300VFS common cathode and 4k7 0.6W protection. 10R current sense per cathode. 180k+180k+3k6 for 100:1 monitoring of 450V rail to output stage.

4. Design - preamp

A full-wave centre-tapped rectifier with 280-0-280V windings provides a no-load voltage of circa 390V, indicating 450Vdc rated filter caps and 400Vdc rated coupling caps should be ok.

The effective source resistance is comprised of the reflected power transformer primary resistance = 86Ω x $(280/240)^2$ = 117Ω; plus the secondary resistance = 245Ω min; which sums to 362Ω.

Original idle loading is about 5mA, based on (350-170)V/100k=1.8mA for first stage. Likely designed to also run radio and any pickup preamp. Bias about 1.8x3k3=6.0V.

Voltage rating of filter and coupling caps:

- All supply rail e-caps with 450Vdc rating.
- C19, C25, C34 with at least 600Vdc rating.

The choke drops about 2.5Vdc at 5mA.

PSUD2 indicates no resonance response for step dynamic load change after the main choke. First filter ripple current is about 20mA, and suitably below the 300mA rating for Nichicon CS 15uF 450V.

Bleed resistance is 150k (~2.3mA).

The continuous fuse current in the CT link is about 22mArms nominal for 10mA dc load. For a hot turn-on, the continuous load following data indicates a 80mA T 5x20 is ok. Fuse parameters for 80mA fuse are different from standard 125mA to 6.3A range.

Simulate period in PSUD2	**10ms**	**20ms**	**40ms**	**200ms**		**continuous**
Simulated RMS current	0.39A		0.28A	0.14A		0.022A
Multiplier (for 0.08A fuse rating)	4.9		3.5	1.75		0.28
IEC 60127-2 **T** min limit multiplier	10		4.0	2.75		1

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