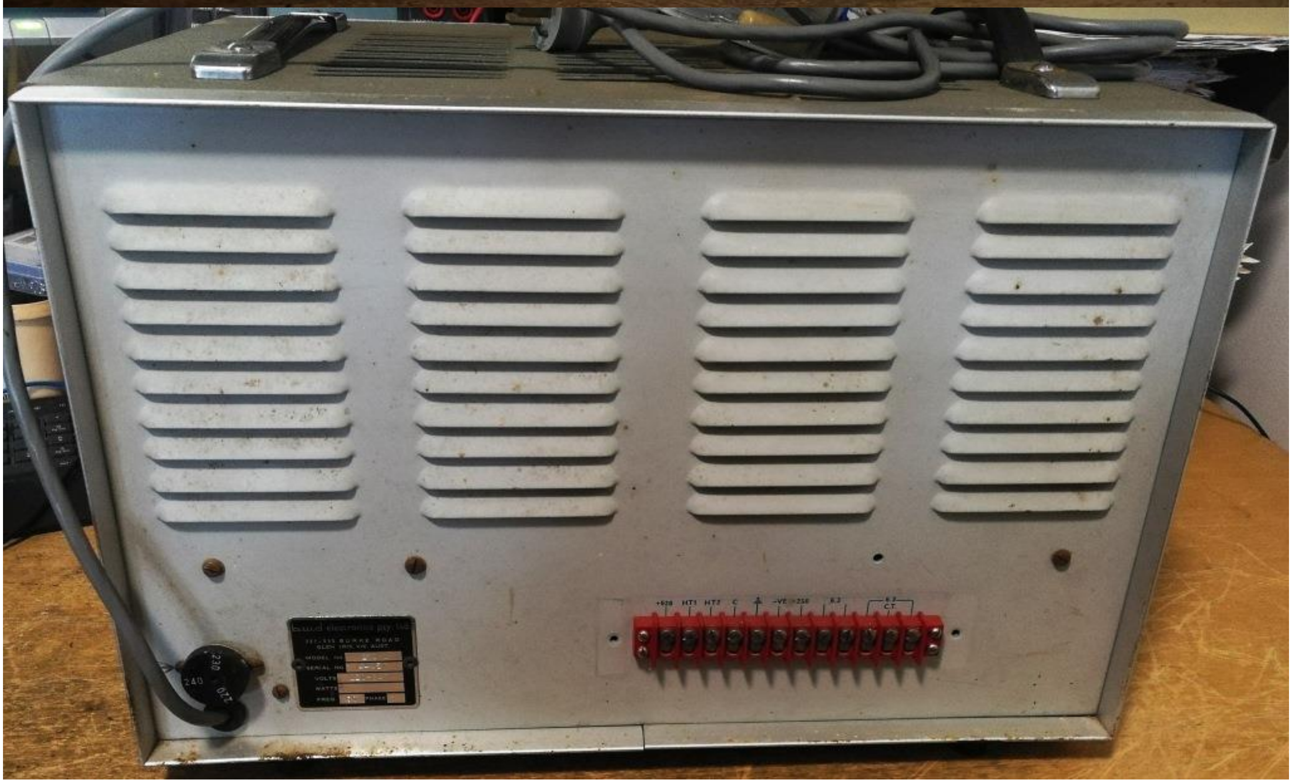
POWER SUPPLY – BWD 210 B

BWD Model 210B – Stabilised Power Supply

S.N. 4405   Operating manual and schematic – Charlie Pandolfo.



2x 500Vdc regulated outputs (300mA, or 180+150mA); 1x 250V regulated 50mA; 2x 6V3 5A. Separate voltage and current meters. This unit S.N.4405 appears to be an Iss.1 from 8/65 as it doesn't include the Iss.2 mods from 4/67 or Iss.3 mods from 7/68, and at least 3 other circuitry differences so far to the Iss.4 schematic. The part date-codes indicate earliest manufacture from July 1966, which is consistent.

POWER SUPPLY – BWD 210 B

As found:

PT Original PT had failed and had been removed - replaced by three PTs
Valves EL34 x5 1x fitted: X11 B1J4
6BL8 x6
85A2 x2
6CW5 x2
6BM8
SS AD149 on h/s
2N3638 712
1N3256T G H Anodeon
1N4254 x4 Anodeon
1N3255 x2 x2 Anodeon
Caps Ducon e-cap 356, 286, 276
Ducon polyester 276, 235
Mustards 046H, 076H, 036H, 085H, 075H
POTs A.G.Naunton 9/28
Resistors Welwyn 05D, C5D
Meters Master Instruments PT35, 300mA FSD, No. N621
Master Instruments PT35, 500V FSD, No. E13895

Issues:

- Power Transformer replaced – 3 replacement PTs retrofitted- RHS 6V3 CT 5A terminals not connected – LHS 6V3 5A terminals connected to 5Vac winding – PT2 has no IR between 300V windings, and one winding is poor – PT1 is under-rated – PT3 has too high HT and too low a heater rating. 3 pots moved to new bracket - mains wires run with secondary side wiring and to voltage selector on rear panel.
- A few e-caps replaced.
- Mains and secondary wiring in close proximity.
- C18 and C17 have degraded capacitance. C1 partially degraded.
- AD149 failed.

Circuit differences (apart from Iss.2 and Iss.3 changes):

- Anodeon 3256T G H (1N3256) diode between output 0V and internal Output 2 rail.
  - Perhaps a pre-cursor to D12 location
- V14A/6 doesn't have 1M to +180V; the 1M is from input grid 2 to screen pin 9.
- V14B/9 has 1k to spigot to or/wh to 0.22uF (was in parallel with 0.1uF??, and was not original), and to 0.1uF to S7, and to yel to RV10 wiper.
- R61 is 10k (not 33k in schematic).
- AD149 (instead of AD139)

Past owner modifications:

Failed PT replaced by retrofitted 3x PT, and parts moved to accommodate PT2:

- PT1, Largest PT replaced original PT, Red Line: COM,200V,230V,240V (9Ω); 400V,CT,400V (63+68Ω); Shield; 6.3V 3A; 5V 3A; 2.5V 5A
  - 1948 ARW pricelist: stock #13, type 15403, 400/400V 150mA
  - Original HT rectifier modified to full-wave
    - HT voltage is 10% low, and current rating is 150x1.5= 225mA (ie. 75%)
  - 6.3V 3A heater is being used on c-c ~6A demand circuit.
    - Heater tested at 4.5A and appears ok
  - Given no suitable replacement, and 27VA of heater not used, then retain this PT.
- PT2, Mid-size PT located on chassis by moving some parts/pots: 0-200-230-250V; 0-300V (230DCR); 0-300V; 6.3V; 6.3V; 5V; 2.5V. 2x 6.3V in parallel - via gry and gry/blk to terminal strip, then gry and blu to V8-V9 heaters (b-b). Mounting by two feet only - a bit wobbly. 5V taken to front panel 6.3V 5A terminals via yel and yel. 0-300V taken to C1 and diodes. 0-300V taken to C2 and diodes.

  - Testing showed this PT was not ok – so swapped out with PT of equivalent footprint.
- PT3, Smallest PT – fitted to ceiling frame: 0-225-240V (22Ω); 240-0-240V (76+82Ω); 6.3V; 5V; ES. 5V unused. only 240-CT used. 240V mains tap used. Ex-radio with 2x 6M5, 6A?8, 6V4. 0-200V used for screen supply. 6.3V for V5-6-7 heaters.
  - HT voltage too high, and heater rating too low.

Mains AC input:

Active red to front panel fuse to S1 to voltage selector then brn to PT1, then to PT2, then to PT3 terminal strips

Neutral blk to S1 to PT1, then to PT2, then to PT3 terminal strips.

Front panel indicator take-offs from S1.

e-caps replaced:

- C16 replaced by 22uF 450V under chassis (was 32uF 450V) and chassis hole used for cabling
- C6, C7 replaced by 1000uF 35V under chassis (were 1000uF 16V) and chassis holes used for cabling

Parts moved to accommodate PT's:

- V16.
- C22 replaced by 22uF 400V (this is in series with poor C13 sections).

Latest modifications

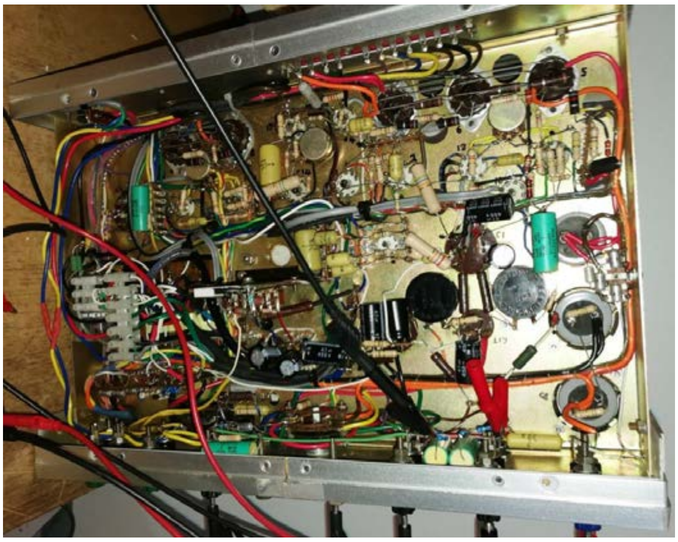
- Mains side wiring: removed voltage selector; sheathed DC wires to front panel fuse.
- PT2 replaced. 0-240V (17Ω); 0-300V 50mA (126Ω) pur-pur; 0-300V 75mA (118Ω) wh-wh; 6.3V
- Front panel dc fuse rewired to full-wave rectifier CT. CT taken via fuse to C9 direct, with other 0V taken to C18 tab. Full-wave rectifier output taken to +620Vdc node on Veroboard.
- Faulty AD149 regulator for V2 heater replaced: doubler caps with 12k bleeds, and LM317T .
- PT secondary fuses added to
  - PT2 300V 75mA (125mA T 5x20)
  - PT2 300V 50mA (125mA T 5x20)
  - PT3 200V 75mA (125mA T 5x20)
- 100k 2W bleed on screen C3.
- 1N4004 across C1B and across C2B for reverse polarity protection.
  - Also protects C2A.
- RV11 wiper made fail-safe.
- R89/90/91/D13 added.
- C1,C16,C17,C18 replaced.
- 2M bleeds added across C26 and C27 (output 1 & 2 terminals). 1M bleed added across C25 (0 to -250V terminals).
- Added 5V+2.5V PT1 windings in series with UF5406 (back to back) and 165mΩ (2// 330mΩ 3W). This new winding added in parallel to existing PT1 6.3V winding, and contributes 2.8Arms to 5.4A total c-c heater loading.

Note on present status:

- PT2 heater for a-a: limited to 2x EL34 (not 3x)
- PT3 heater for b-b: limited to 1x EL34 (not 2x)
- Front panel 6.3Vac 5A terminals not connected
- Front panel 6.3Vac CT 5A terminals not connected
  - Heater option is to include additional PT like Trimax TP4349.
- Change front panel dc fuse to 500mA T 3AG.
- Fit spare AD149 from Charlie P and confirm ok operation
  - Check start-up conditions and fault/stress levels and identify protection.
- PT option:
  - ~335VA resistive loading
  - Rated winding voltages at rated load currents

POWER SUPPLY – BWD 210 B

- Confirm each winding using PSUD2
- A failed PT would still identify most winding DCRs, wire diameters and turns.
- Ed D info has identified original C-cores. The PT has dual C-cores, with total height (chassis to top of frame) of ~5 ¼" (13.5cm) and chassis mounting holes of 87 x 107mm.

Testing:

Reform and check leakage current on all e-caps.

Top chassis C1 – 32+32uF 450V Ducon; ∆ 27uF 1.6Ω & D 25uF 1.9Ω 1kHz MCP
∆ 115uA leakage 450V, 26uF 1.6Ω 1kHz MCP
D 150uA leakage 450V, 25uF 2.0Ω 1kHz MCP

Top chassis C2 – 32+32uF 450V Ducon; ∆ 37uF 0.67Ω & D 34uF 0.97Ω 1kHz MCP
∆ 180 uA leakage 445V, 36uF 0.78Ω 1kHz MCP
D 160uA leakage 450V, 34uF 1.1Ω 1kHz MCP

Top chassis C3 – 100uF 350V Nitto
~123uA leakage at 350Vdc; 122uF 0.22Ω 1kHz MCP;

Top chassis C8 – 200uF 350V Elna; 200uF 0.18Ω 1kHz MCP
~70uA leakage at 350Vdc; 201uF 0.18Ω 1kHz MCP;
154kΩ ok

Top chassis C9 – 200uF 350V Elna : 290uF Aneng; 235uF 0.17Ω 1kHz MCP;
~100uA leakage at 350Vdc; 238uF 0.185Ω 1kHz MCP;
153kΩ ok but solder joint was suspect

Top chassis C17 – 32uF 500V Ducon; 21uF, 0.72Ω 1kHz MCP
~320uA leakage at 495Vdc; ~60uA leakage at 430Vdc so ok; 21.5uF 0.35Ω 1kHz MCP;

Top chassis C18 – 32+32uF 450V Ducon: ∆ 17uF 1.3Ω & D 13uF 2.2Ω 1kHz MCP
∆ 200uA leakage 450V, 17uF 1.4Ω 1kHz MCP
D 190uA leakage 450V, 13uF 2.3Ω 1kHz MCP

C13, C14, C15, C20, C23, C24, C26, C27 >2GΩ 500V, and cap value ok

SS diode PIV leakage:
D1 A-D 1N3254 400Vpiv - >2GΩ 500V each
D6-D7 1N3255 600Vpiv - >2GΩ 500V each
D8-D9 1N3255 600Vpiv - >2GΩ 500V each

Mains side insulation resistance:
A/N to PE: 1kVdc 1200MΩ with only PT1. 170MΩ with only PT1 & PT2. 390MΩ with only PT1 & PT3. 150MΩ with PT1, PT2, PT3. 225MΩ with PT2 (150MΩ A/N to sec).

POWER SUPPLY – BWD 210 B

- PT2 IR very low between each 300V winding, and one 300V winding has a poor connection. This PT is not usable.

PT1 Red Line 6.3V 3A heater:
240Vac mains = 6.49V @ 4.3A;
Wire gauge 1.0mmD (compared to 2.5V 5A wire gauge of ~1.35mmD)
Equal current sharing with 5V+2.5V in series with UF5406 (back to back) and 165mΩ (2// 330mΩ 3W), which increases heater voltage to 6.78V 4.5A.
  - Could use 5+2.5V (with diodes and 165mΩ) as additional heater capacity option to power up 5x EL34.

PT2 (swapped unit) 6.3V heater:
- 6.32Vac 1.5Ω (4.2A); 6.56Vac 3Ω (2.2A); 6.8Vac no load; 240Vac mains
  - Should be fine with 3A heater load, but 4.5A likely too much.

PT3 6.3V heater:
- 6.4Vac 3Ω (2.1A); 6.8Vac no load; 240Vac mains
  - Should be fine with 1.5A heater load, but 3A likely too much.

0 to -250V 50mA rail:
- Shorted V16; maxed RV11; shorted V15/7 to 0V; C2A and C2B in parallel so use variac
  - -250V 30mA rail is linked to R79-RV11 divider – so C1 down to -50Vdc.
- Winding fuse 125mA T 5x20 inserted at PT2 terminal strip.
- PT2 only energised, 160Vac mains, 188Vac winding, 250Vdc output
  - Only quickly went to 300Vdc due to RV11 dissipation.
- See later for full test.

240Vdc screen rail:
- EL34 screen current at 250V is not well defined – datasheet indicates it could be 13-15mA
  - 75mArms winding current is exceeded when total load exceeds 33mA and voltage has sagged to 260V (ie. 6.6mA screen current for each EL34, and 8kΩ 10W loading)
- PT3 only energised. C3 bleed of 100kΩ added.
- PT3 secondary voltage is 240V loaded, which is +20% (ie. too high)
  - Adding a buck 15+15+5=35V also adds about 85Ω DCR.
- C3 voltage is 340Vdc with no EL34 screen loads and 240Vac mains.
  - C3 voltage is 330Vdc+0.3Vrms with 8.2k load (40mA) and 240Vac mains.
- NE2 (B2) voltage increases from 60 to 64V, with operating current of (340-64)/180 = 1.5mA.
  - Some current will bypass the NE2 via R58 (64V/470k=0.14V for EL34 Vgk=0V).
  - NE2 current should be <0.8mA. 240Vdc will just reach 0.8-1.0mA.
    - Will reduce if 180-200V winding available.
- Arlec 7577A inserted as 15+15V buck voltage in addition to 5V heater.
  - Unloaded screen voltage reduced to 270Vdc (ie. NE-2 operates at ~1.1mA).

+620Vdc rail:
- V4 6BM8 initially removed.
- R19-20-23, 270k+270k+220k to -250V rail. This will raise the -250V rail above 0V 5- R19-20-23, 270k+270k +220k to -250V rail. This will raise the -250V rail above 0V initially.
- R19-20-23, 270k+270k+220k to -250V rail. This will raise the -250V rail above 0V.
- R21-22-53, 270k+270k+220k to -250V rail. This will raise the -250V rail above 0V
- R89-90-91, 180k+100k+100k to -250V rail, with D3 path – these are later mods – not yet added.
- Loading on +620V rail is (150k+150k)//760k//760k = 170k.
- Disconnect PT2 and PT3 and PT1 c-c heater.
- 1N4004 added from -250V to 0V for reverse bias protection (across C1B).
- Mains 240V generates 423V-0-423V and 581Vdc with 170k loading.

  - a tad low, but ok for testing

Valve testing:

- 13x 6BL8 and 5x 6CW5 tested for:
  - Rh-k @100Vdc (pos and neg)
  - static Va levels in test circuit, including input grid leakage.
  - Bogey valves selected for use in 210B: 6x 6BL8 from #1,4,2,8,13,5

+180Vdc regulated:

- connect c-c heater on PT1. Remove V1, V2, V3, V10, V11, V12, V13, V14, V15.
- V4, V16, V2 heater doubler energised.
  - -250V rail pinned to 0V by added protection diode.
  - 0 to -250V rail pinned to 0V by added protection diode
  - V4B grid normally pulled to -7V by -250V rail.
    - Need to temporarily connect variable negative supply (-12V via 100k).
    - Link 0V to earth to keep 0V at earth for temporary negative supply.
- Regulation ok at 149V (given -12V bias) with V4b grid at ~ -2.6V.
  - Repeated with another 6BM8 – effectively the same - so original looks ok to use.
- 180Vdc set ok in next section.

-250V 30mA rail:

- PT1 energised: connect c-c heater and 440V on PT1. Remove V10, V11, V12, V13, V14, V15.
  - V4, V16 fitted and energised, V2 heater doubler energised.
- PT2 energised, 300V 75mA winding wh-wh only connected;
  - 300V 50mA and 6.3V b-b disconnected.
  - 300V 75mA winding fuse 125mA T 5x20 inserted at PT2 terminal strip.
  - V1, V2, V3 fitted and energised.
- D14 (Iss.3 mod) fitted.
- Link 0V to earth to keep 0V at earth for temporary safety.
- Swapped out C1A/C1B for individual 47uF 450V.
- R9 set to 1.59M to trim +180 to +180.0V (steady from 200 to 240Vrms mains.

0 to -250V 50mA rail regulation:

- Winding fuse 125mA T 5x20 inserted at PT2 terminal strip.
- PT1 and PT2 energised. Anti-phase 300V windings.
- Instal V1,V2,V3,V4,V14, V15,V16.
- RV10 adjusted for -250.0V max (V15 anode at +128V). Min is just positive 0V (V15 anode at +379V).
- V14 cathode at -83V.
- Added 560k 2W bleed to C2A.
- Cleaned RV10 and other accessible pots – no change to noise.
- RV11 wiper not connected to end – fixed - noise fluctuations much less now.

Output 1 and 2, 500Vdc energisation:

- PT1 and PT2 energised.
- Instal V1,V2,V3,V4,V14,V15,V16.
- Fit R89/R90/R91/D13 mod.
- Fit internal Output 1 reverse diode to 0V (similar to D12 for reverse polarity protection).
- Fit C16/17/18 replacements.
- Link +620Vdc rail to Output 1 and 2 rails each using 1k (as current sense)
  - Loading by 200k from filter cap equalisation; voltmeter; output regulator voltage setting arm
  - Same current when each voltage setting pot at max, and output 1 + 2 is set.
- Outputs 1 and 2 have 0.1uF output decoupling with no bleed - hazard.

POWER SUPPLY – BWD 210 B

  - 2x1Meg 0.5W provides up to 0.25mA bleed and 0.2 sec TC.
- Confirmed C16/17/18 energise ok and voltmeter is accurate for all settings.

Output 1 500Vdc regulation initial:

- PT1, PT2 energised. PT3 not yet energised.
- Instal V1,V2,V3,V4,V12,V13,V14, V15,V16.
- No connection to C16/17/18 so they are pulled low to -250V rail, but clamped to ~0V with added reverse-bias protection diode.
- Checked heater voltage.

Output 2 500Vdc regulation:

- PT1, PT2 energised. PT2 provides b-b heater.
- Instal V1,V2,V3,V4,V8,V10,V11,V14, V15,V16.
- Output 1&2 switch setting to enable triode mode.
- RV4 used to set 0V lower limit. Upper limit constrained by 620Vdc rail being lower than designed, and triode mode voltage drop.

Output 1 500Vdc regulation:

- PT1, PT2 and PT3 energised.
- Instal V1,V2,V3,V4,V5,V12,V13,V14, V15,V16.
- Output 1&2 switch setting to enable pentode mode.
- RV8 trimmed for 500V max, but min goes just below 0V.
  - R88=282k; R69=32.5k; R70=15.2k; RV8=4k9.
  - Added 1k2 in series with R70, then trimmed RV8 to give 500Vmax to 1V min range on RV7.

Heater c-c current:

- PT1 only. Heater load only. 240Vac mains. 22mΩ current sense (0.1V drop at 4.5A)
- Without V10/V11: 6.23V 4.5A from c-c heater; 6.03Vdc V2A heater; 0.182A mains
- All valves in: 6.03V 5.4A from c-c heater; 5.88Vdc V2A heater; 0.204A mains
- Need to bolster this c-c winding with 5+2.5V windings.
  - Added 5V+2.5V in series with UF5406 (back to back) and 165mΩ (2// 330mΩ 3W)
    - This parallel winding contributes 2.8Arms to 5.4A total heater loading.

Meter calibration:

Panel V meter	Aneng AN9009	Panel I meter	Aneng AN9009
100	+100		
206	+200		
318	+300		
422	+400		
500	+481		
99	-100		
205	-200		
260	-250		

Nominal voltage levels: 240Vac mains, no external load, O/P 1 set for 200V; 1x EL34:

620Vdc rail= 539V	V12/7,8= -83V	C1=250+101= 351V	C3=266V
V4B/6= +480V	V4B/9= +148V	V14/6= -25V	V14/7= -82.4V
V10/3= -2.6V	V10/6= -0.86	V10/7= -11.7V	V10/8= -114.1V
V12/3= -3.8V	V12/6= +144V	V12/7= -63V	V12/8= -84V

Step load needs at least 600Vdc off rating, or protected to that level.

- Use step load test jig with LMC555 output to MIC4427 then driving SPP20N65C3 650V 20A 190mohm TO220. 12V isolated battery power.

POWER SUPPLY – BWD 210 B

- Load step of 17mA at 150V (9k 30W), and 28mA at 250V.
- O/P1, -250V and 0-to-250V rails tested
    - O/P1 shows nominal 20mV step (ie. ESR of ~ 20mV/17mA = 1.2Ω)
        - Applied load step showed simple recovery
        - Disconnected load step appears to show some overshoot but no noticeable ringing
    - -250V shows nominal 10mV step (ie. ESR of ~ 10mV/28mA = 0.4Ω)
        - Either load step showed no abnormal recovery behaviour.
        - Approx 5mVpp 50Hz ripple
    - 0 to -250V shows nominal 15mV step (ie. ESR of ~ 15mV/17mA = 0.9Ω)
        - Either load step showed no recovery behaviour.
        - Approx 5mVpp 50Hz ripple

Output rail AC noise levels:

- -250Vdc rail at ~1mVrms
- 0 to -250Vdc reg rail at ~3mVrms - RV11 WW wiper causes some jumpiness.
- Reverse voltage protection for degraded e-caps C8/9 and C16/17/18 due to cap imbalance.
- Need to use capacitor coupled signal into soundcard, as DC coupled requires 1000:1 probe.
    - CR corner frequency to be below 50Hz (ie. use 100nF and 47k)
- -250Vdc rail output noise reduced from 8.7mvrms to 0.7mvrms when RV1 f/b pot min to max
    - Scope plots and spectrum plot show suppression of ripple.
- Still to update V14/V15 circuitry to latest.

Design notes

The output 1 & 2 regulator circuits provide a relatively large voltage swing in the negative direction on the grids of the series regulator tubes for a slight voltage change in the sampled output in the positive direction, and vice versa. Each regulator section (for output 1 and output 2) comprises two 6BL8, where the triodes are connected as a differential amplifier, and drive a second differential amplifier of two pentodes, as a form of two stage differential amplifier. One side of the triode differential amp is connected to a common -85V reference voltage through an RC filter with a 1.6Hz corner frequency (but is prone to grid leakage). The other side of the triode differential amp is connected to the dc sensed output voltage rail, as well as coupling high-frequency content directly through C14/C28. The triode anodes are RC coupled to reduce high frequency gain as the corner frequencies of circa 880Hz (8k2/22n) and 2.8kHz (10k/5n6) are approached.

The pentode directly driving the EL34 grid voltage has a screen voltage that can feed in AC ripple voltage from the unregulated +620Vdc rail, with feedback level provided by 50k RV3/RV6 trimpots (no feedback of ripple when trimpot sets screen voltage to 0V) to minimise output mains ripple to negligible level.

- -85V regulator output can be better buffered for hum and noise, which could then allow the 1M grid resistors to be lowered in value to reduce their contribution to noise and any voltage from grid leakage current. This option wasn't tested.

heater dc supply for V2 only: c-c winding through doubler then regulator,
one end grounded, other end likely -6.3V.
regulator needs - 250V rail to turn-on
regulation tweaked by R86 (SOT)
Q2 base at -0.4V (germanium)
base current ~ (6.3-0.4)/3k + 250/100 = 2.0 + 2.5 = 4.5 mA.

AD149 with shorted C-E; option is to use 2SB474, but simpler to initially use LM317T
LM317T option needs 1.8V headroom. 0.45A x 3Vdrop = 1.4W diss; T0-220 Rjc ~4C/W
TO-220 tab to negative doubler; Vin to 0V rail of 6BL8 heater
Series sense resistor is 1.25V/0.45A = 2.8Ω (0.6W) (ie. 5R6//5R6)

POWER SUPPLY – BWD 210 B

Measured 11.6Vdc doubler; 5.5V 0.44A heater (<1mVac); 1.36Arms 6.6Vrms feed.
6BL8 Vhk limit is 100V; heater is at ~0V due to c-c and doubler; 6BL8 cathodes are > -85V.
Doubler caps had no bleed resistors (eg. if V2 is pulled out).

-250V rail regulation:

V1, V2, V3
C1a voltage ~352Vdc + 3.6Vac no external load; 330Vdc+6.6Vac 9kΩ (28mA) external load
Output terminal voltage: no Vdc change with 28mA external load; Vac rises from 1mV to 1.7mV
RV2 sets 250V by V2B: RV2 midpoint at -99V;
V2B g-k ~ -6V for 2mA and 90V Vak, but maybe some grid-leak voltage
V2 cathodes at ~-83V. R6 current ~(250-83)/56k= 3mA.
RV1 sets V2A - V1 feedback, and sits V2A screen at up to ~100Vx50/1050 = +5V
(ie. Vsk= 83+5 = 88V)
RV1 max setting suppresses 50Hz ripple to negligible level (<1mVrms).
R7-C5 filters 85V ref by 2Hz corner.
Iss.3 mod D14 pulls up +180 rail to ignite V16 and locate -250V rail based on 430V raw supply
R1 drops ~ 350-250 = 100V (so D14 reverse biased by ~80V).
V1 pulling positive rail towards 0V and suppressing ripple
V1 idles at ~Vak=100V, with Vsk=180V.
V3 operating current ~(250-85)/27k= 6.1mA
250V loading via V1 ~ 6.1+2x165/56k+2x85/150k+2x165/150k = 6.1+5.9+1.1+2.2 = 15.3mA

180V rail design:

180v rail loads: V16 regulator (180-85)/6k8= 14mA; V1 screen ~2mA
R12 current ~(539-478)/3k9 = 15.6mA.
V4A Vak = 478-180= 300V
V4A triode mode with 3k9 loadline and 539-180= 360V Vak (92mA)
close to cut-off (triode mode curves)
Vgk~ -36V for 16mA and 300V; ~5W pentode diss, so 2W below limit.
V4B triode with input grid set to (180+85)x0.75/2.55= -85+78= -7V
470k loadline from +180V and 0.38mA, with 0.1mA anode at ~Vgk=-3V
Possibly some grid leak
+180V has some tolerance in voltage setting
R8-R9 possibly SOT for Vak~ 180-45 = 135V, to achieve +180V reg.

0 to -250V 50mA regulated supply design:

300Vac secondary winding half-wave rectified and filtered
Replacement PT DCR = 234Ω.
381Vdc +0.85Vac unloaded; 360Vdc+3.6Vac 125V 6kΩ 21mA; 339Vdc+6.2Vac 250V 6kΩ.
250V/42mA = 6kΩ 11W
negative rail is -250V variable output, and C2B and C25 capacitor decoupled to 0V.
Positive rail is pulled to 0V by V15 (6CW5), with screen at +180V and cathode at 0V.
V15 input grid is controlled and pulled below 0V by V14A anode with 1M loadline to +180V.
V15 anode could conduct up to 50mA, and drop from 400V to 325-250=75V
6CW5 anode saturation voltage at 50mA is ~20V
6CW5 pentode plate curve at 50mA requires about -15Vgk at 400V drop & Vsc=180
6CW5 pentode plate curve at 50mA requires about -13Vgk at 150V drop
6CW5 anode limit of 12W, so Vak drop limited to <240Vav
The 0-250V supply is not formally specified for output current limit except for front panel 50mA label and schematic 50mA label.
Vak could be ~325Vmin, so output current needs to be derated between 0 to -85V.
Or output current limited to <35mA for full 0-250Vdc range.
V14A and V14B used as differential pair
V14B grid has manually set input by RV11, with RV10 setting range.

POWER SUPPLY – BWD 210 B

-250V output gives RV11 wiper at 85-(15/65)x(85+250)= 85-77 = +8V.

V14B grid ~8 - (192/435)x(8+250)= 8-114 = -106V.

-0V output gives RV11 wiper at 0V.

V14B grid ~ -(192/435)x250= -110V.

Assume V14 cathode tail at -125V, so 56k with 2.2mA

V14B grid ~-130V for 1.1mA idle

V14A anode current up to (180+120)/1M=0.3mA, and screen current could exceed 1mA.

V14A anode voltage down to ~-115V, so V15 in deep cutoff.

V14A screen taken to V15 plate to 0V divider via feedback trimpot RV9.

Screen voltage could range from 400+125= 525V, to 75+125=200V.

6BL8 pentode screen rated to 550V with no current, but voltage limited at >0mA.

0 to 500V output 1 regulated supply design:

Original 440V secondary winding bridge rectified and via 2A fuse to cap filter (~620Vdc + ripple)

Negative rail is 0V.

Positive rail is series pass reduced to 0-500V variable output by V5-V9 (EL34).

EL34 operating current monitored from anode and screen stoppers.

EL34 screen 240Vdc from 200V secondary and full bridge rectifier and cap filter.

Indicator neon is internal.

O/P 1 set to 300Vdc – no load; external 9kΩ - 1x EL34 only

+620v rail: 540Vdc +0.61Vac unloaded; 528Vdc+1.2Vac loaded.

O/P 1: 300Vdc 0mVac unloaded; approx. -10mVdc change when loaded, no Vac.

O/P 1 set to 200Vdc – no load - 1x EL34 only

EL34 Vgk= -46V

20 to 500V output 2 regulated supply design:

440V secondary winding bridge rectified and via 2A fuse to cap filter (~620Vdc + ripple)

Negative rail is 0V. Output with diode clamp to 0V.

Positive rail is series pass reduced to 20-500V variable output by V8-V9 (EL34).

EL34 operating current monitored from anode and screen stoppers.

EL34 operated in triode mode.

V10B and V11B used as differential triode pair with 8k2/220n anode-anode (88Hz).

V11B triode grid has manually set input by RV5, with RV4 setting range.

+500V output gives V11B grid ~(32/150)x(500+250)= -90V.

+20V output gives V11B grid ~(32/50)x(20+250)= -77V.

V10B triode grid to -85V reference.

V10B-V11B cathode idle at ~V, from 121k anode loads and common 150k to -250V.

Vk ~-83.5V. Vgk ~-1.5V. Ik ~(250-84)/150k= 1.1mA. Va ~0.55x121= -67V. Vak ~-17V.

V10A and V11A used as differential pentode pair driven by V10B-V11B diff output.

V10A anode drives EL34 grid with 330k loadline to Vout.

Vout ~20V requires V8-9 near cutoff, and V10A near saturation.

V10A in saturation forces ~(20+250)/(330+150)= 0.56mA, Vk~-120V..

V10B saturated and anode ~-85+1+10 = -74V, so V10A grid down to ~-73V.

V10B cutoff and anode up to 0V.

V10B anode voltage does no align with V10A grid voltage ???t

V11B in cutoff and anode ~0V, so V11A grid up to 0V

V10A-V11A cathode could be ~0V, so 250/150=1.7mA

V10A saturated at 1.7mA needed to force anode ~+550V.

V11A screen to 0V and anode to Vout and input grid driven negative, with 0V max.

V10A screen to midpoint (620V to -250V) with RV3 feedback to 0V.

V15 input grid is controlled and pulled below 0V by V14A anode with 1M loadline to +180V.

V14A and V14B used as differential pair

POWER SUPPLY – BWD 210 B

V14B grid has manually set input by RV7, with RV8 setting range.
V13A screen taken to 0V; V12A to midpoint voltage via feedback trimpot RV6.

620Vac supply design:

PSUD2 indicates 620Vac is unloaded level. Sagging to 580V at 300mA load with 23Vpp ripple.
EL34 anode dissipation is up to 580Vx60mA =35W, but could be higher if not all EL34 in.
Need to identify PT effective resistance, and fuse rating (as a function of # of EL34).

Fuse now in full-wave CT with 400-0-400V
Idle dc rail load ~ 300k//540k//540k//280k = 90k (~6mA) plus cap reform current plus ~20mA (for +180V rail) with ~26mA total load (0.026 x 600= 16W).
Rated dc rail continuous load ~300+17+5 = 320mA mA

Initial turn-on – no load.

Simulate period in PSUD2	**10ms**	**20ms**	**50ms**	**150ms**	**600ms**	**continuous**
Simulated RMS current		2.5A		1.1A	0.5A	0.025A
Multiplier (for 0.5A fuse rating)		5		2.1	1.0	0.05
IEC 60127-2 **T** min limit multiplier		10		4.0	2.75	1

Simulate period in PSUD2	**10ms**	**20ms**	**50ms**	**150ms**	**600ms**	**continuous**
Simulated RMS current	3.1A		1.8A			0.54A
Multiplier (for 0.63A fuse rating)	4.9		2.9			0.86
IEC 60127-2 **F** min limit multiplier	4		2.75			1

Continuous operation – max load 320mA

Simulate period in PSUD2	**10ms**	**20ms**	**50ms**	**150ms**	**600ms**	**continuous**
Simulated RMS current						0.55A
Multiplier (for 0.5A fuse rating)						1.1
IEC 60127-2 **T** min limit multiplier		10		4.0	2.75	1

So better to use 500mA T fuse with proviso of not loading more than about 250mA DC HT outputs.

Screen 240V rail
200Vac winding causes >240Vdc. Try and find 180-185V. PT3 240V winding too high.

- Use 5V winding to buck 240V.
- Add another small PT (Arlec 7577A) with 30V 100mA sec to buck 240V.

Fuse fault current limited by 82Ω 1W to 1.3Arms (ie. abt 10x fuse rating).

Initial turn-on – no load.

Simulate period in PSUD2	**10ms**	**20ms**	**50ms**	**150ms**	**600ms**	**continuous**
Simulated RMS current		1.2A		0.52A	0.24A	0.025A
Multiplier (for 125mA fuse rating)		9.6		4.2	2.0	
IEC 60127-2 **T** min limit multiplier		10		4.0	2.75	1

Perhaps 160mA T would be best.

-250V output rail (300V 50mA winding)
PT2 replacement winding pri=18 , sec= 122 + 192Ω ; use 122Ω winding for 75mA supply.

POWER SUPPLY – BWD 210 B

Fault via C2A; or C2B via V15 and shorted 0-250V terminals.

Initial turn-on – no load – different fuse limits for 100mA

Simulate period in PSUD2	10ms	20ms	40ms	150ms	200ms	continuous
Simulated RMS current	1.1A		0.60A		0.29A	0.025A
Multiplier (for 100mA fuse rating)	11		6.0		2.9	
IEC 60127-2 **T** min limit multiplier	10		4.0		2.75	1

Better to use 125mA T fuse, due to more onerous 100mA fuse limits. 125mA T ~3.5Ω cold.
Shorted DC output would force 1.0A (ie. 8x fuse rating).

0 to -250V regulated rail (300V 75mA winding)
Fault via C1A; or D14 to shorted 180V, or via V1 and shorted output terminals. See other 0-250V winding.

BD149 regulated heater for V2.
Current through BD149 would be limited by doubler and BD149 conduction.
Current from c-c would be fused by each diode if a doubler capacitor shorted.

Original PT VA rating

- a-a: 6.3V 4.5A = 29VA
- b-b: 6.3V 3A = 19VA
- c-c: 6.3V 5.4A = 34VA
- d-d: 6.3V 5A = 32VA
- e-g: 6.3V 5A = 32VA
- 200Vx75mA x2 = 30VA
- 440Vx300mA x2 = 264VA
- 300Vx75mA x2 = 45VA (but less due to half-wave)
- 300Vx50mA x2 = 30VA (but less due to half-wave)
- Total = 515VA (assuming 2x for rectified)
    - 29+19+3x32+15+132+22+15 = 330

EL34 over-current protection options:

- If an EL34 fails 'on' then the current and voltage meters would indicate a problem, but only if selected. Ensuring correct metering is observed is likely the best form of protection.
- If O/P1 is shorted then regulation control will force Vgk more positive towards 0V to reduce Vak.
    - Likely that EL34 V-I will follow Vgk=0 curve for given screen voltage. If it is a bolted or heavy short, Vak will likely reach and pass through the knee region, and current would fall (likely with screen current rising). The screen voltage is high enough for each EL34 to well exceed a 60mA continuous limit, so worst-case dissipation would be a load that allows about 250V at >300mA.
- Protection circuitry powered from a-a or b-b heater using capacitor input doubler or half-wave rectifier would need to sense cathode current (ie. added sense resistor)
- Global O/P1 protection by dropping screen voltage by relay contact inserting series winding resistance.
- Anode stopper voltage drop up to 10x60mA = 0.6V nominal.
    - Use an optomos to switch when stopper voltage exceeds circa 1.0 to 1.3V (100 to 130mA).
    - Gross overload protection.
    - Connect optomos switches in parallel to turn off a relay coil, powered from 6V heater winding. Use a relay contact to latch off the coil (ie. power needs to be removed to unlatch relay).

EL34 alternatives:

- Socket orientation has the EL34 hotter anode sides facing at about 45deg from each other.

POWER SUPPLY – BWD 210 B

- Socket pin 1 is connected to pin 8 (cathode), and pin 6 is used as a link, so alternative needs pin 1 to be not connected internally or to a shield (ie. can't use 7027A or metal 6L6 or KT66 or KT88).
- EL34 heater current is 1.5A, so higher is a concern (ie. 6550A is 1.6A).
- Socket spacing is 5.1mm (2"), with 18mm bulb spacing
    - larger diameter bulbs are a concern (eg. 6L6GC only has 11mm spacing)

Tube	EL34/6CA7	6L6GC	6550A	7027A	7581A	KT66	KT77	KT88
Pdiss	25W	30W	42W	35W	35W	25W	25W	35W
Heater	1.5A	0.9A	1.6A	0.9A	0.9A	1.3A	1.4A	1.6A
Pin 1	g3	NC	NC	=pin4	NC	Internal	NC	Shield
Pin 6	NC	NC	NC	=pin5	NC	NC	NC	NC
Pin 8	K	K+g3	K+g3	K+g3	K+g3	K+g3	K+g3	K+g3

6L6GC are not rated to the same voltage as EL34, so there is risk.
6550A is adequately rated, except for small glass separation when multiple are used, and the hotter anode sides are facing each other directly.
6CM5/EL36 would need an adaptor and be operating beyond datasheet limits for screen voltage, and unsure about grid voltage compatibility.
807 would need an adaptor.
Sovtek 6550A regulates 0-500V on O/P1 with V12/6=163V (ie. Vgk= -37V) for 200V O/P.

Photos of other unit in original condition: