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TUBE MATCHING

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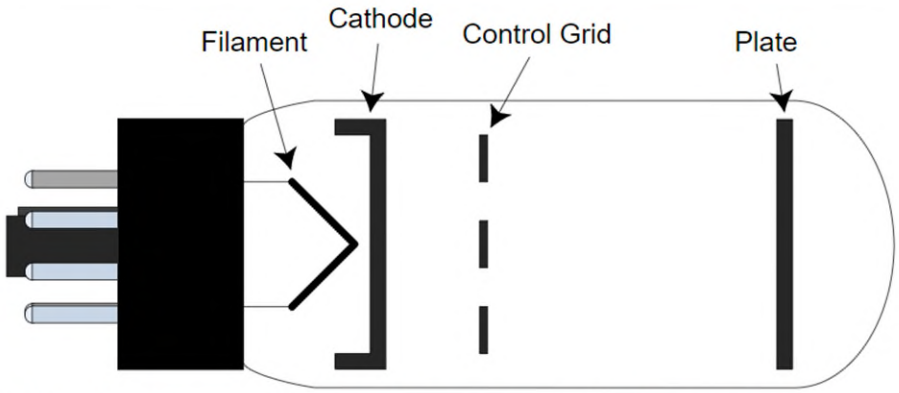
15 July 2018

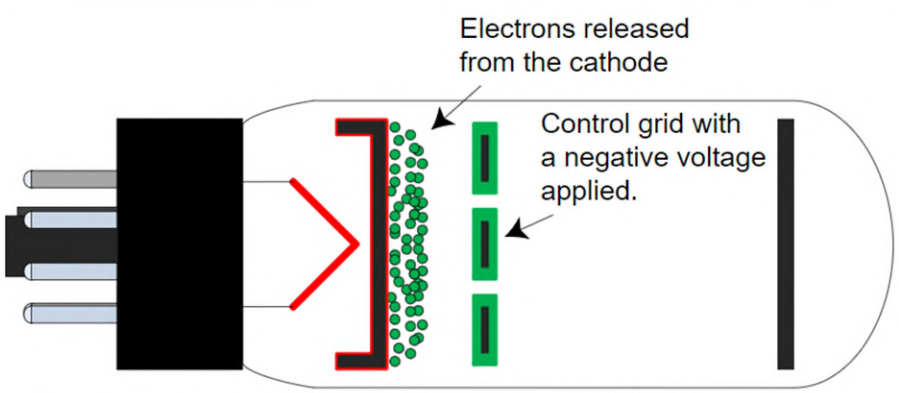
6L6G

WHAT ARE MATCHED TUBES?

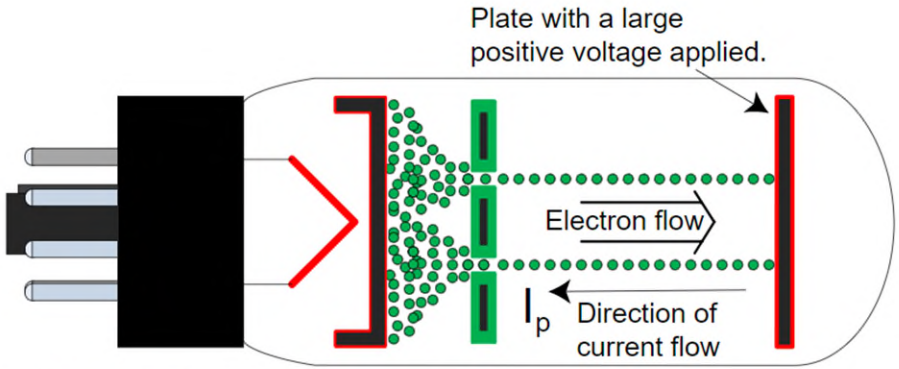
SIMPLIFIED TUBE BASICS



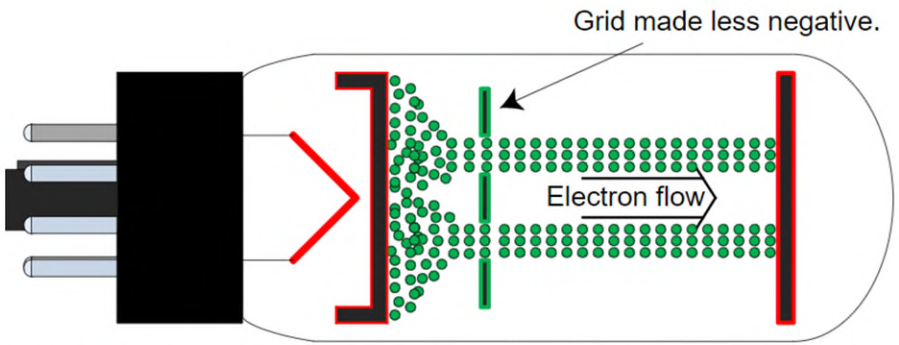
1. The fundamental parts of a vacuum tube drawn as they might be seen on a circuit schematic.



2. The filament receives a voltage allowing it to heat up the cathode freeing electrons for current flow.



3. The plate is given a large positive voltage to attract the electrons while a negative grid voltage restricts electron flow.



4. The grid is made less negative allowing for an increased flow of electrons from cathode to plate

BASIC MATCHING CHARACTERISTICS

- Include:
  - Manufacturing Batch, Matching Date Codes, and/or Appearance
  - Transconductance
  - Idle Plate Current

SYMMETRY IN CONSTRUCTION

- Manufacturing Batch
- Matching Date Codes
- Appearance
- Relabeled Tubes

TUBE VARIABILITY IN THE SAME BATCH

RCA Parameter Limits for New Tubes

	TRANSCONDUCTANCE (μS)					PLATE CURRENT (mA)					
Type	Cust. Min.	Fact. Min.	Bogie	Fact. Max.	Cust. Max.	Cust. Min.	Fact. Min.	Bogie	Fact. Max.	Cust. Max.	Measured at E_p / E_{g2} / E_c
10	-	1350	1600	1900	-	13	18.5	24	-	-	425 V / - / -35 V
12A	-	1300	1600	1900	-	4.5	6.2	8.5	-	-	135 V / - / -9 V
22	-	300	350	425	-	1.2	1.7	2.3	-	-	135 V / 45 V / -1.5 V
24A	900	950	1100	1250	1300	2.8	3.1	4.2	5.0	5.3	250 V / 90 V / -3 V
26	-	875	1075	1225	-	4.0	5.5	7.0	-	-	135 V / - / -9 V
27	815	850	1000	1150	1185	3.1	3.5	5.2	6.9	7.3	250 V / - / -21 V
40	-	300	400	525	-	0.40	0.45	0.90	-	-	135 V / - / -1.5 V
45	1550	1650	2100	2500	2550	20	22	30	38	40	250 V / - / -50 V
50	1550	1700	2100	2500	2550	40	42	55	68	70	450 V / - / -80 V
71A	1450	1550	1700	1850	1950	14.0	15.0	20.0	25.0	26.0	180 V / - / -40.5 V
199	-	350	425	570	-	1.6	2.4	3.5	-	-	90 V / - / -4.5 V
201A	-	600	725	825	-	-	1.7	2.4	3.2	-	90 V / - / -4.5 V
2A3	3200	3450	4000	4550	4800	22.5	28.0	40.0	52.0	57.5	300 V / - / -60 V
6BQ5	8300	8600	11,300	14,000	14,300	36	37	48	59	60	250 V / 250 V -7.3 V
6L6	5400	5550	6000	6450	6600	60	62	72	82	84	250 V / 250 V / -14 V
6L6GB	Same as for 6L6					62	64	72	80	82	Same as for 6L6
6L6GC	5300	5400	6000	6600	6700	58	60	72	84	86	Same as for 6L6
6V6GT	3500	3600	4100	5400	5500	33	34	45	56	57	250 V / 250 V -12.5 V
5881	5500	*	6100	*	6700	65	*	75	*	85	Same as for 6L6
7027A	5300	5400	6000	6900	7000	58	60	72	84	86	Same as for 6L6
6973	3800	4000	4800	5600	5800	57.5	60	65	-	-	250 V / 250 V / -15 V

TRANSCONDUCTANCE (GM OR G_M)

- Transconductance (Gm, g_m, Mhos, or Siemens)
  - Incremental change in **plate current** (measured in milliamps [mA] or microamps [μA])
  - divided by the incremental change in **grid voltage**
  - at a given operating point
  - The main measure of tube gain

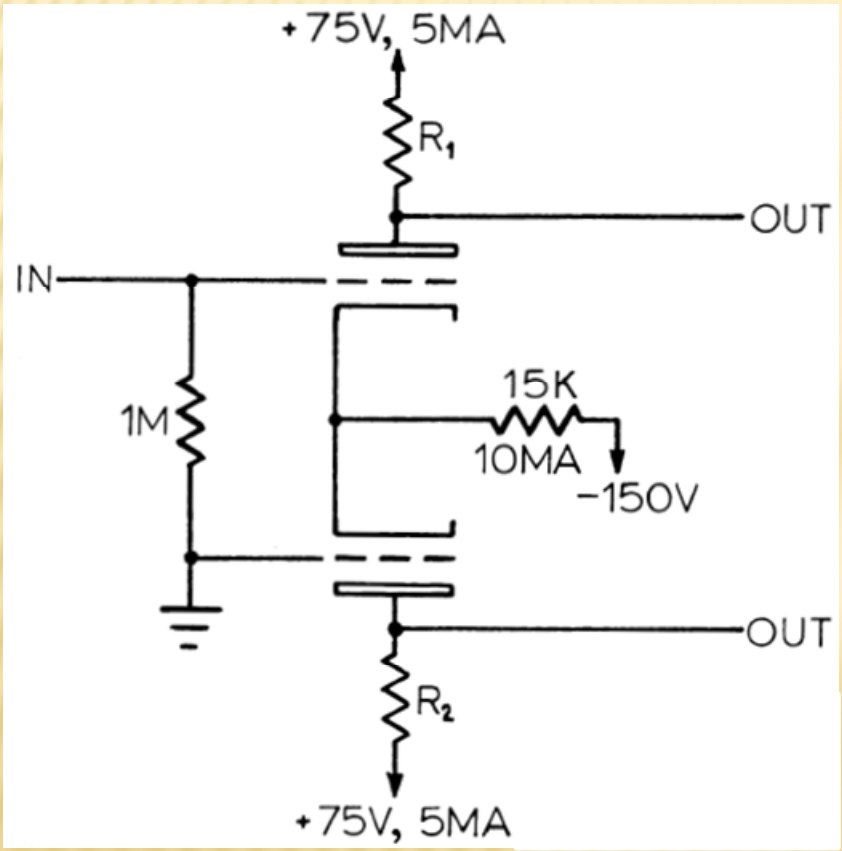
IDLE PLATE CURRENT

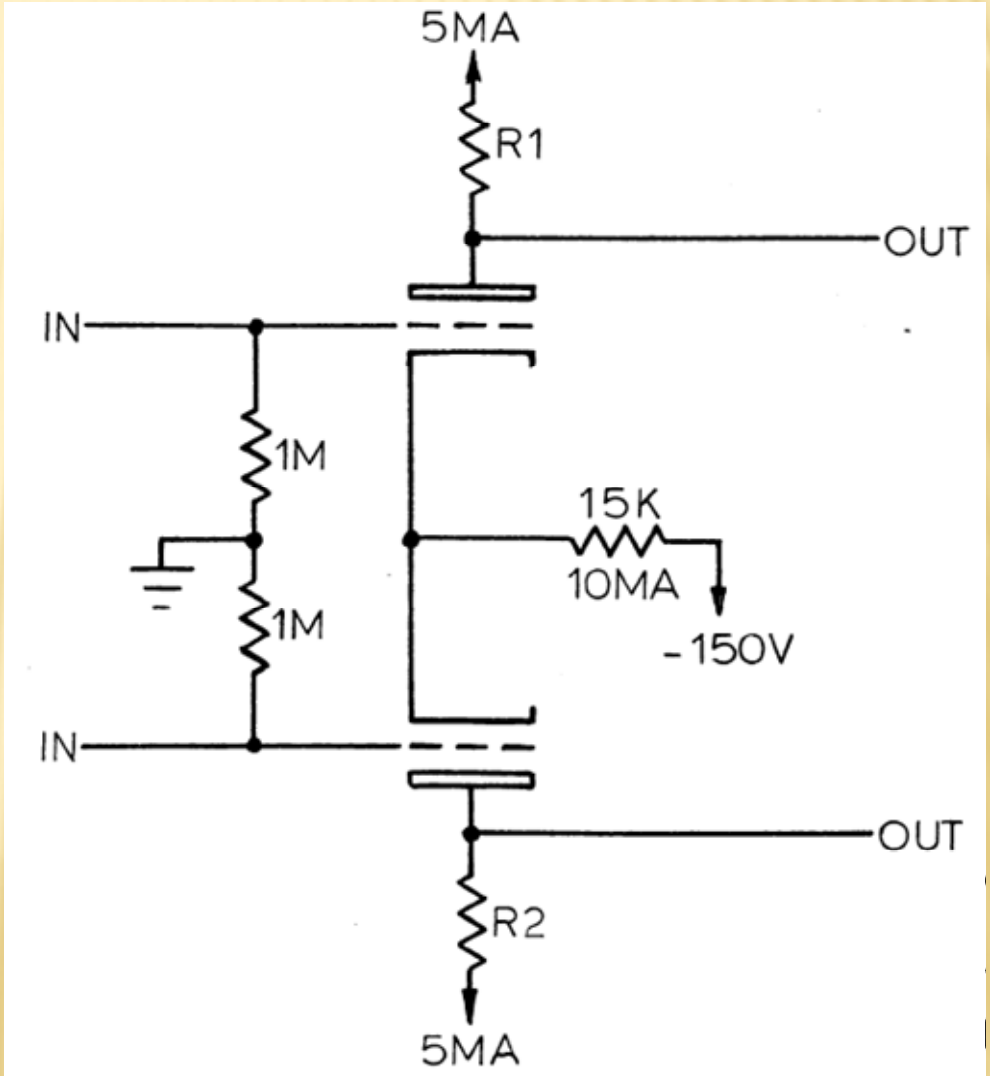
- Amplifier tubes have an Idle Plate Current
  - low-level driver
  - output tubes)
- Determined by:
  - Positive DC plate voltage
  - Negative DC grid-to-cathode bias voltage
  - Other characteristics of the tube itself
- In certain applications, matching Idle Plate Current very is important

THE NEED FOR MATCHED TUBES

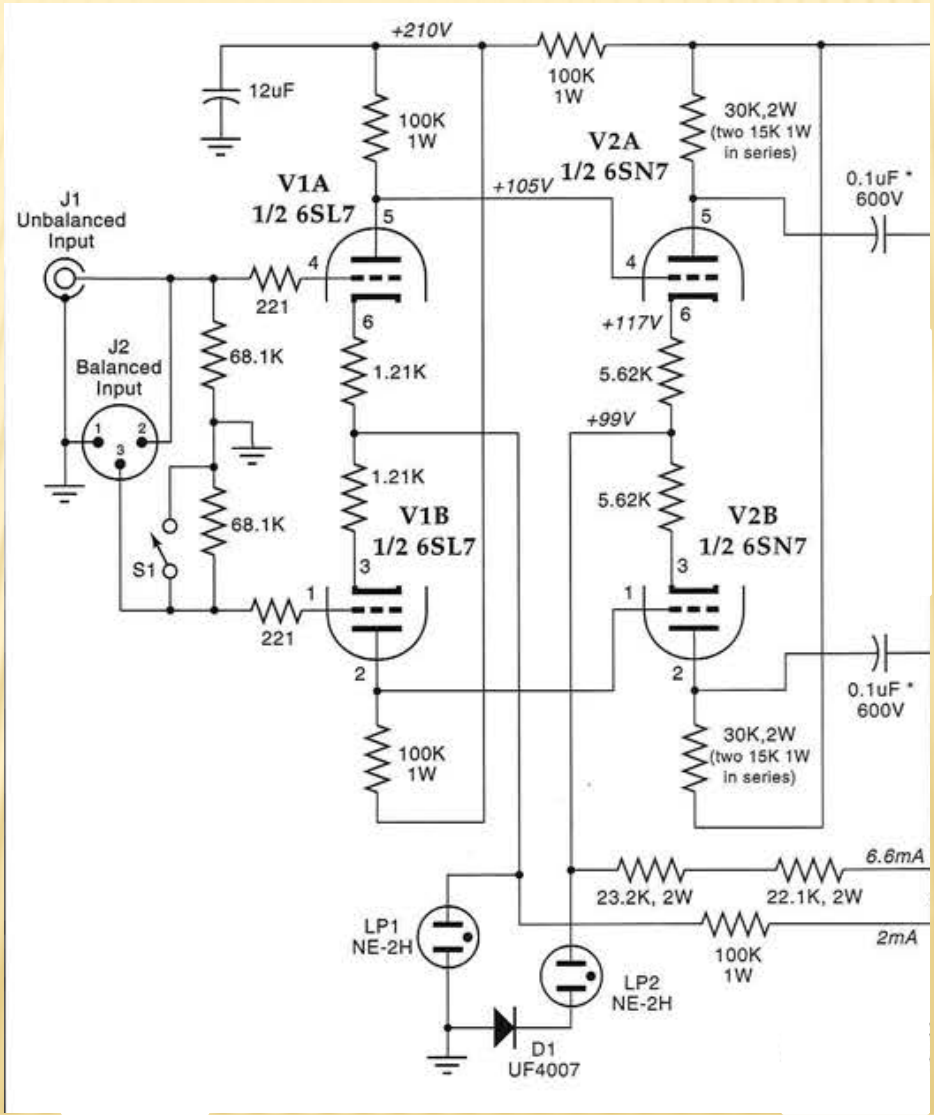
- Circuits that do need matching often need only certain matched parameters
- Circuits needing some matching include:
  - Balanced DC Amplifies
  - Differential Amplifiers/Phase Inverters
  - Paralleled tubes
  - Push-pull output stages

DC AND DIFFERENTIAL AMPLIFIERS

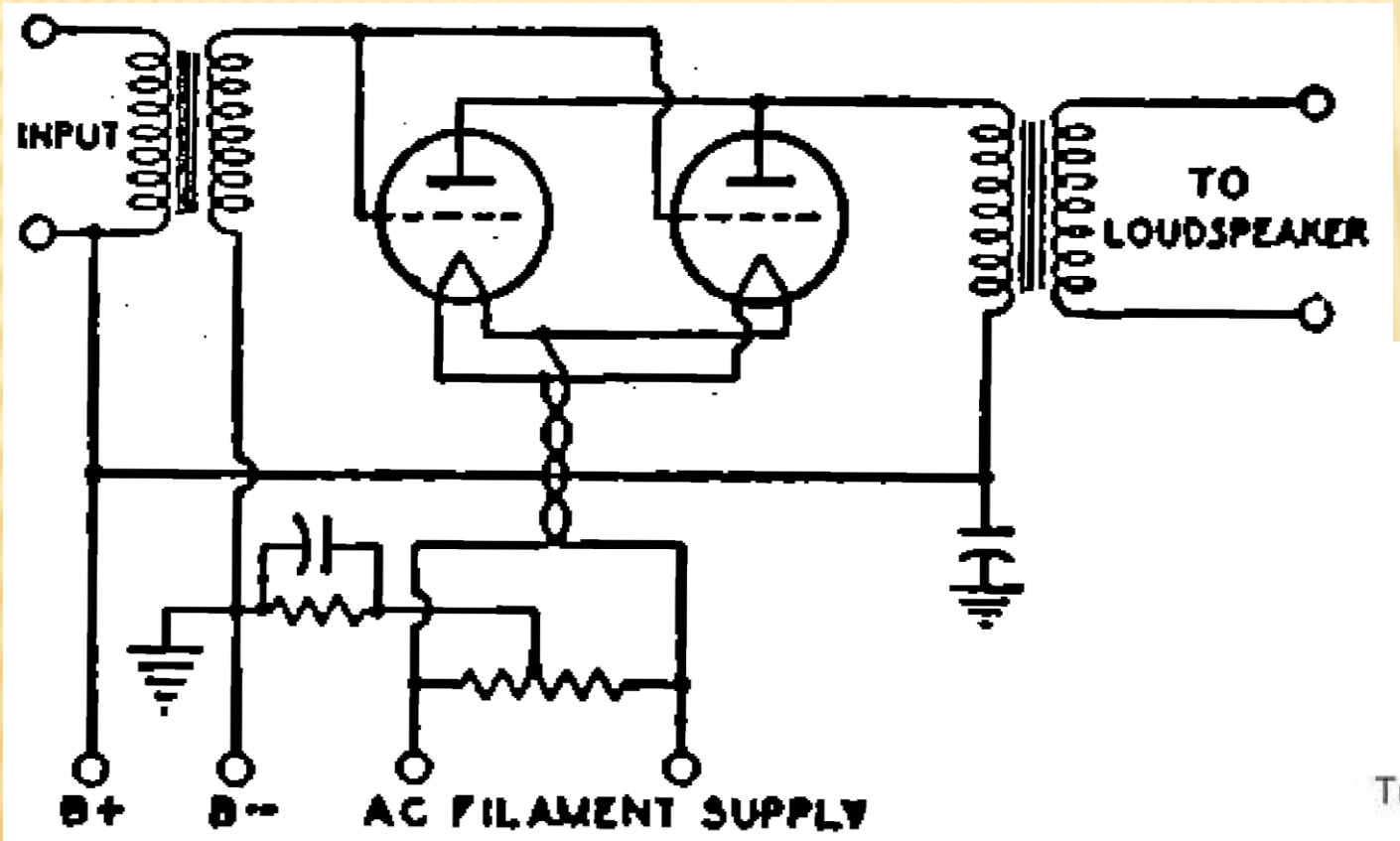


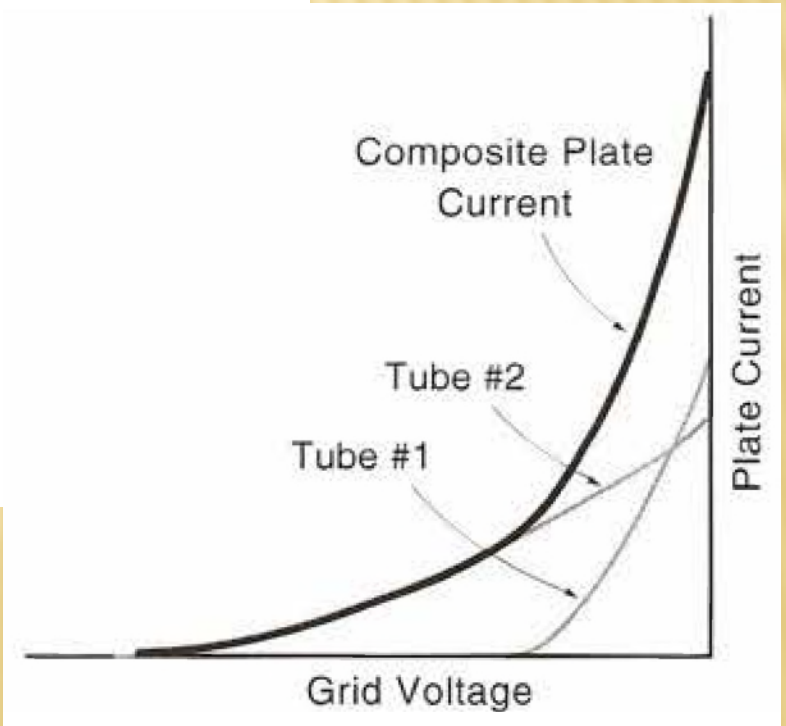


AUDIO PHASE INVERTER AND DIFFERENTIAL AMPLIFIER

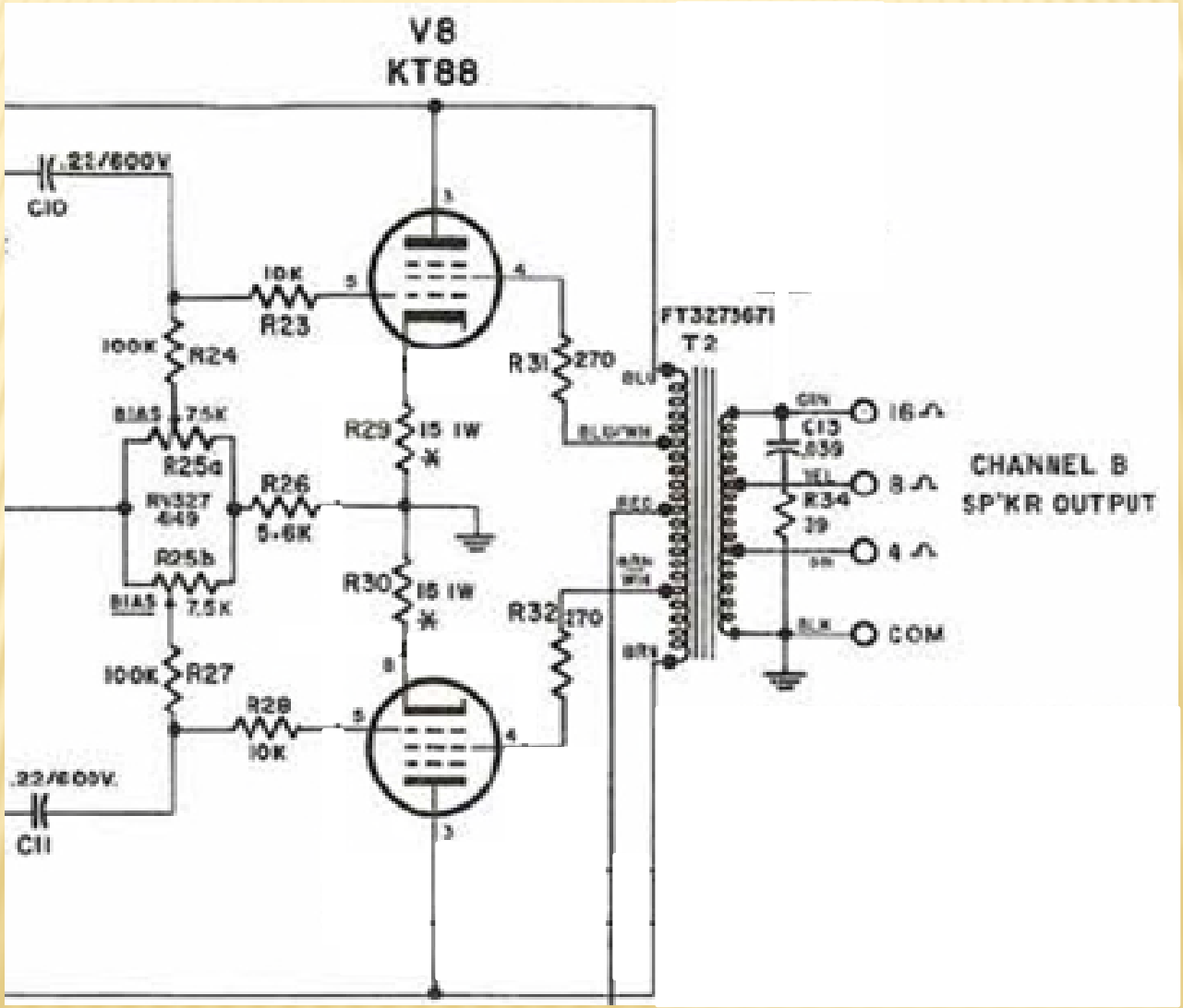


POWER AMPLIFIER WITH TUBES IN PARALLEL





PUSH-PULL CIRCUITS



CANCELING DC FLUX IN THE OUTPUT TRANSFORMER

MAIN CONCERN REGARDING TRANSFORMER SATURATION – RED PLATING

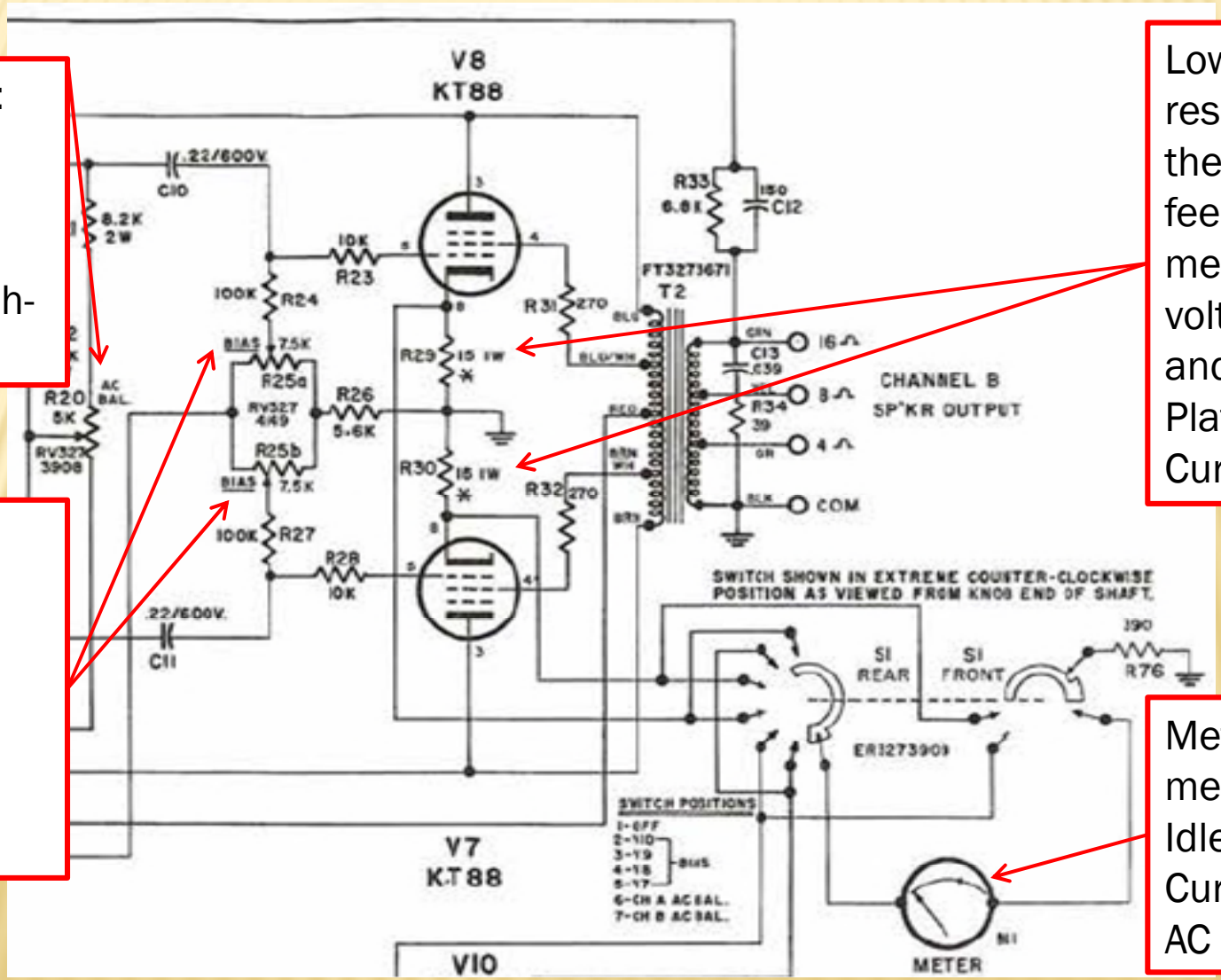
DEGREE OF MATCHING REQUIRED FOR PUSH-PULL OUTPUT TUBES

- Depends on the sophistication of the bias and drive circuits
- Considerations include:
  - Bias Adjustment (individual tube) or Bias Balance Adjustment (DC Balance)
  - AC Balance
  - Single Bias Adjustment per Channel or No Bias Adjustment

AC BALANCE AND BIAS ADJUSTMENT

AC Balance: Pot altering AC Signal Balance to the two Push-Pull Tubes

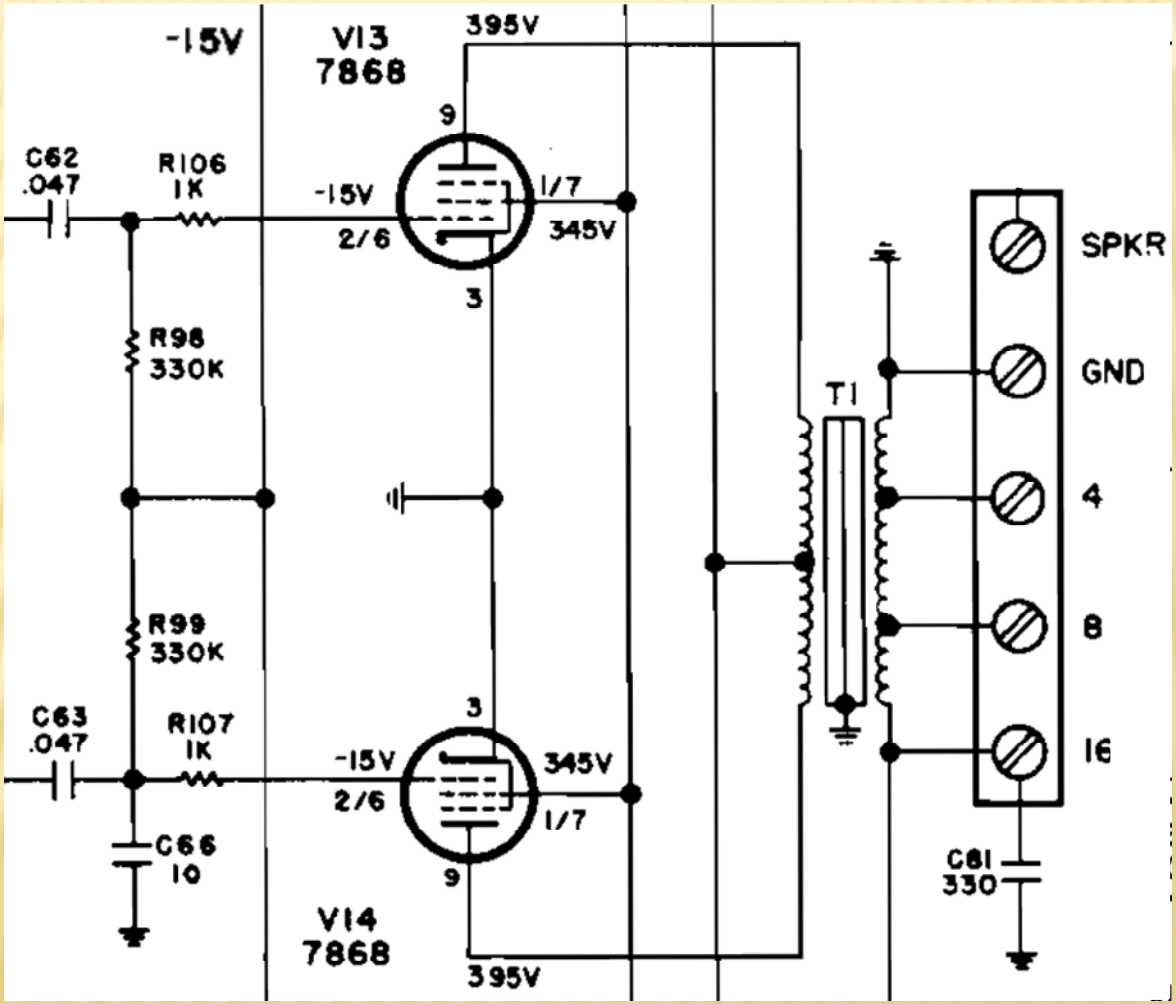
Bias Adjust: Two Pots individually adjusting DC Bias to each Push-Pull Tube



Low Ohm resistors in the Cathode feed line for measuring voltage drop and resulting Plate Idle Current

Meter for measuring Idle Plate Current and AC Balance

NO BIAS ADJUSTMENT OR SINGLE BIAS ADJUSTMENT PER CHANNEL



PRINCIPAL TECHNIQUES FOR MATCHING

- Burn-In Requirements
- Matching methods include:
  - Tube Testers
  - Static DC Measurements
  - Curve Tracing

TUBE TESTER MATCHING

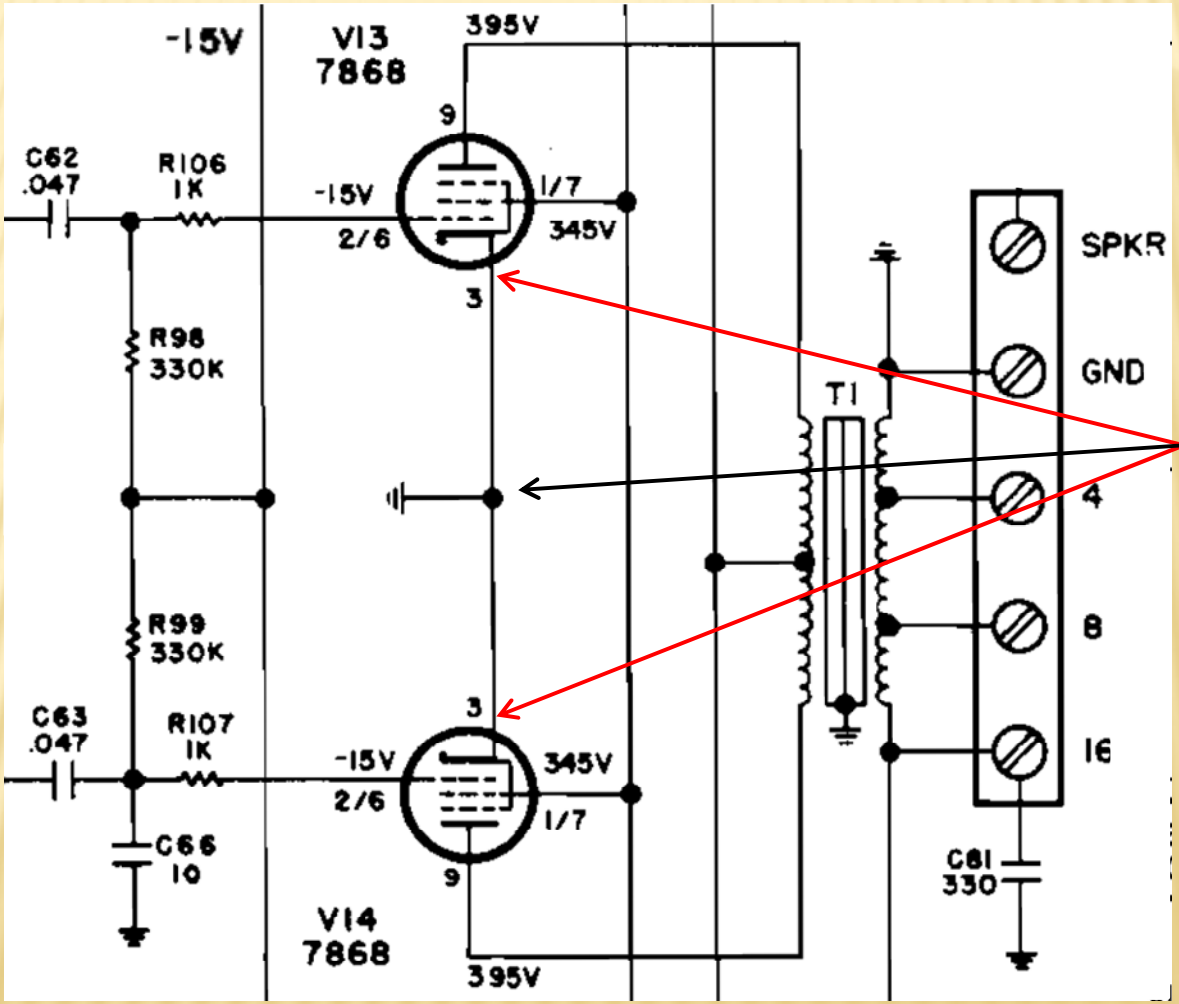
Hickok 6000

USM-118 Cardmatic

Western Electric
KS-15750
{made by Hickok)

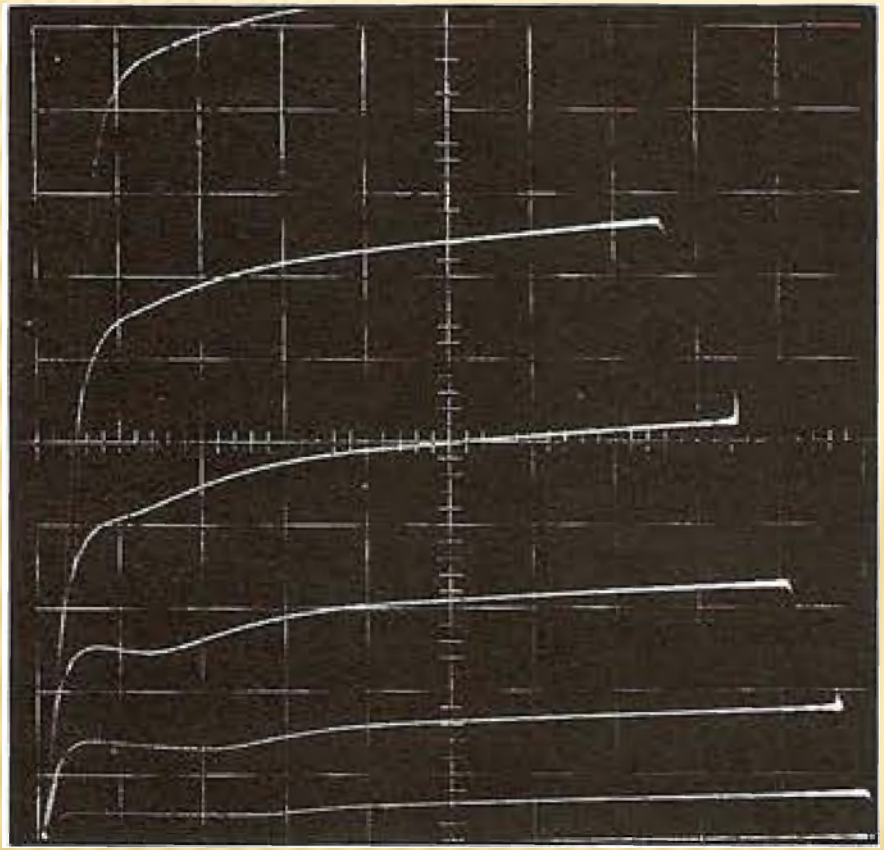
STATIC DC MEASUREMENTS

INSTALLING A CATHODE RESISTOR FOR IN-SITU TUBE MATCHING

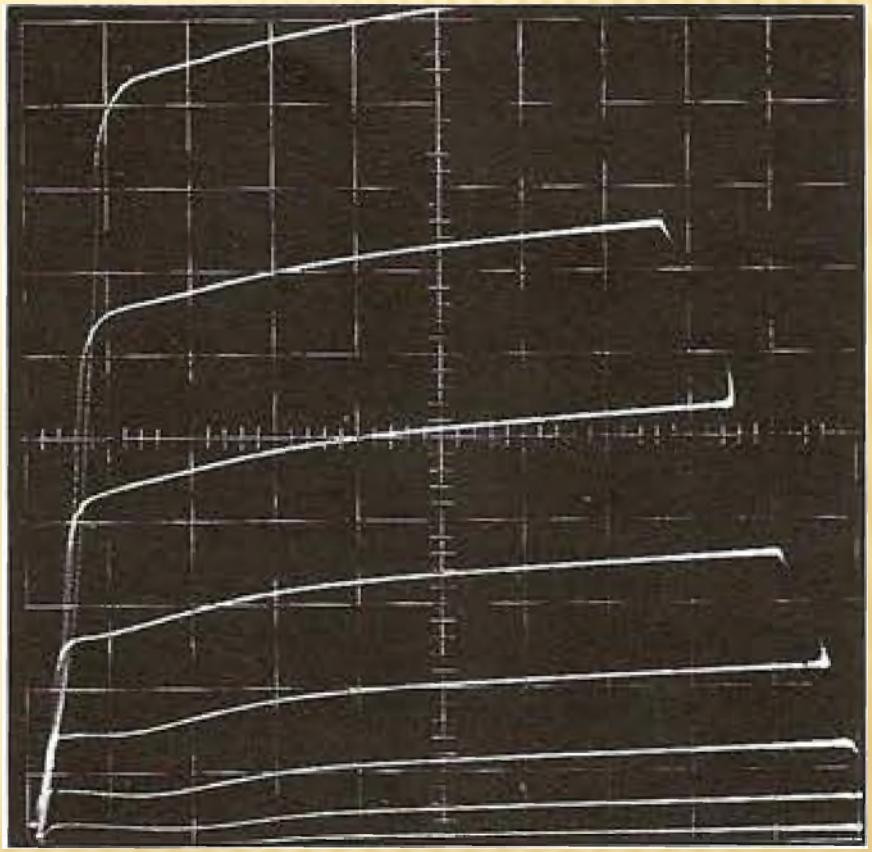


Insert two 10 Ohm Precision Resistors and Measure Voltage Drop between Tube Terminal and Ground

CURVE TRACERS



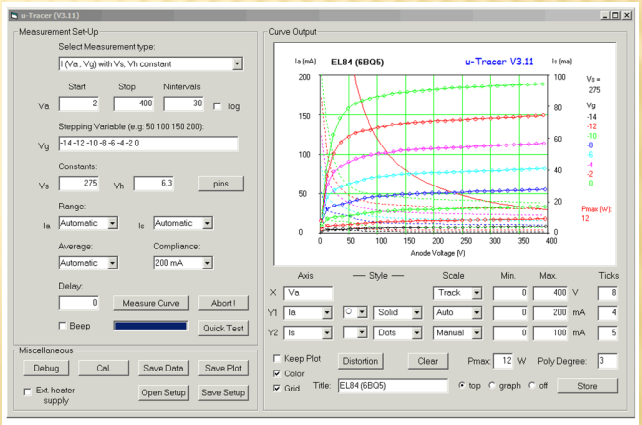
British KT66 (grey carbon inner coating)



Mid-1970s? GE 7581/KT66

SOURCING CURVE TRACERS

Tektronix 570



µTracer 3+ and PC GUI

MaxiMatcher II

Amplitrex AT1000

PURCHASING MATCHED TUBES

IN SUMMARY

- Not a black art, nor necessary in every application
- Small low-level tubes seldom matching
  - Except DC amplifier or fully-balanced circuits
- Closely-matched output tubes only needed for amps without DC bias controls

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