

Hybrid Car Radios: Tube Radios Without High Voltage

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Before the Hybrid Car Radio

- Before 1956:
- Most car radios had a tube line-up that looked like household radios.
- Main differences:
 - High voltage (for the plates) was generated with a “Vibrator” power supply.
 - Tuning was usually done with variable inductors (coils) rather than variable capacitors in home radios. Apparently, variable capacitors are not good with vibration, and tended to be “microphonic”.
 - Radios were well shielded and filtered, and designed for a small external whip antenna.
 - Usually had an RF amplifier.

Vibrator Power Supply

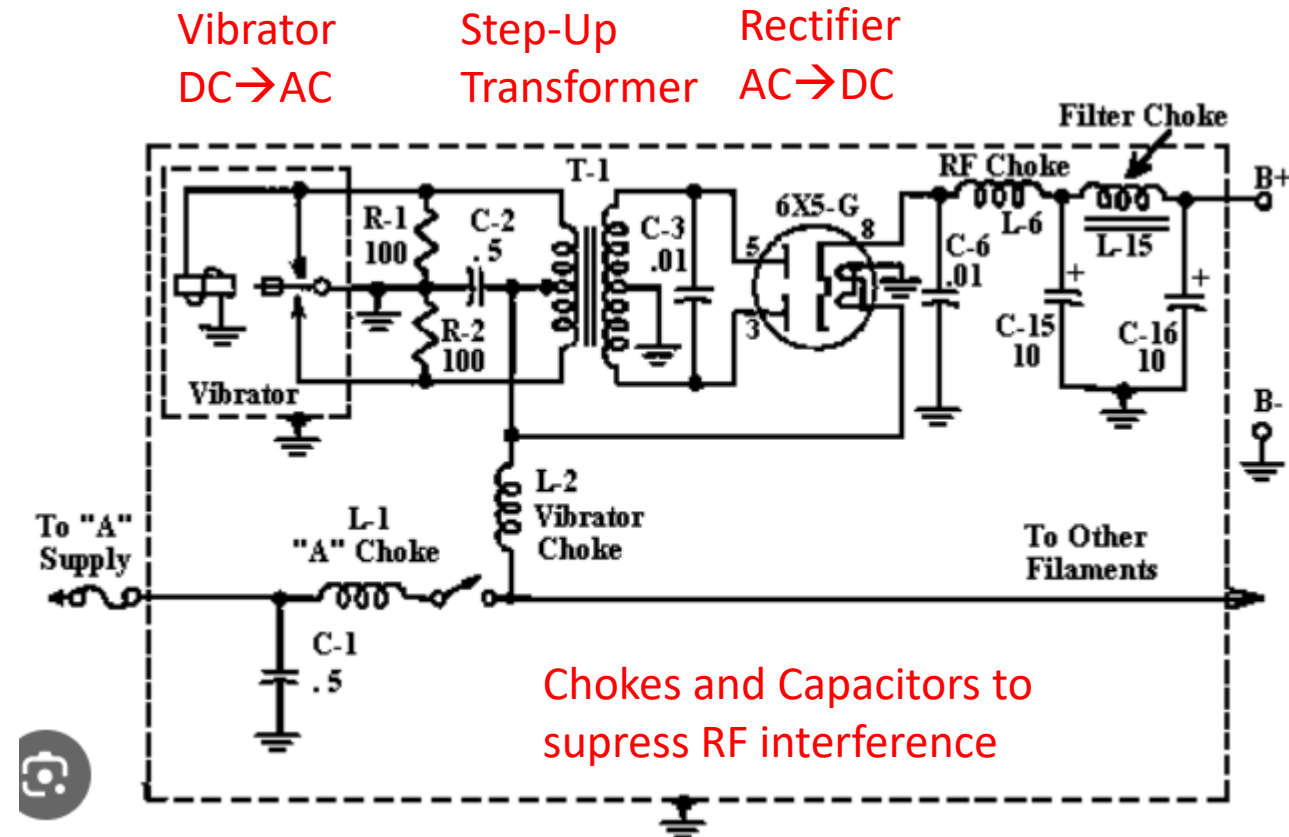
- Cars have 12VDC (or back then, even 6V*) batteries.
- Conventional tubes used >100VDC on the plates.
- The best way to increase voltage is with a transformer. BUT transformers only work on *AC not DC*.
- A vibrator is a device that converts the 12VDC to AC.
- This AC is boosted up with a transformer.
- The high AC voltage is rectified.

* Before about 1955, cars used 6V batteries. The conversion to 12V was apparently done to accommodate larger engines and reduce the amount of copper needed.

Vibrator Power Supply

- A vibrator is an electromechanical device rather like a buzzer.
- A weighted contact, excited by an electromagnet, vibrates back and forth, alternatively making connections to convert DC into square-wave AC.
- Notoriously unreliable, a bit noisy (though not as bad as you might imagine), and they cause a lot of RF interference. Think “spark transmitter”.

Before the Hybrid Car Radio



Vibrator



1956: The First Hybrid Car Radio: Motorola?

Mix of tubes and transistors

- The transistor entered the car radio in 1956.
- The only stage in a 1955 car radio that *really* needed high voltage was the audio output stage.
- By 1956, germanium PNP power transistors had matured enough that they could perform in an audio output stage.
- The audio driver stage *could have* been done with a transistor, but instead the industry resurrected an old idea, the 12 volt “Space Charge Tube” that could provide adequate power to drive a transistor.
- The rest of the radio used more-or-less conventional tubes with 12V on the plates!

Why Not an All-Transistor Radio in 1956?

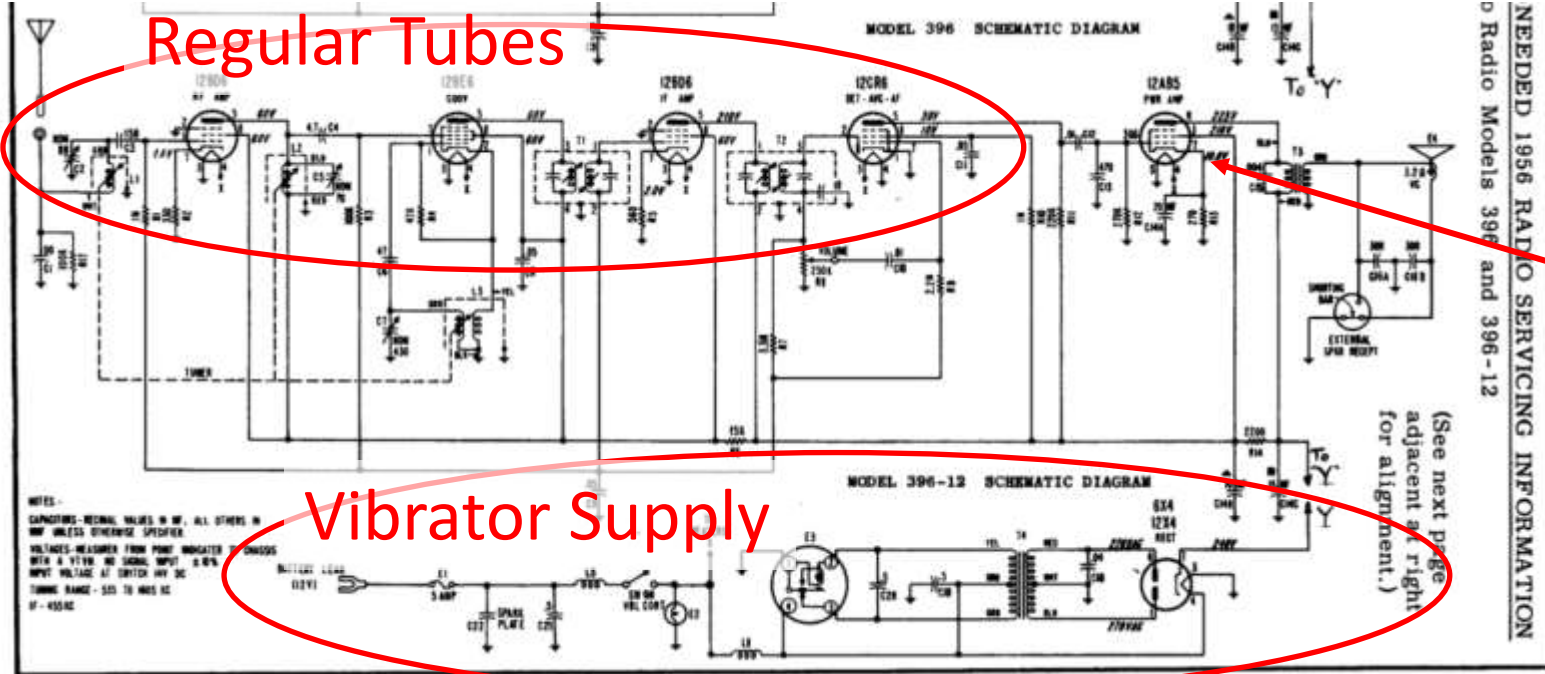
- Portable transistor radios were new but widely available.
- Indeed, transistor car radios appeared circa 1957.
- But they were very uncommon.
 - Transistors were expensive, RF transistors were more expensive than tubes.
 - In the early days, transistors were “binned” depending on their characteristics, and good RF transistors were relatively rare.
 - The conservative auto industry was probably concerned about the transistor’s reliability, and early ones were fragile.
 - Vibration + temperature swings make the car a challenging environment.
 - Early transistors were temperature sensitive.
 - I suspect that there may have been lobbying from tube manufacturers.

Hybrid Radio History

- Tubes optimized for 12V, and 12V space-charge tubes*, were introduced by Tung-Sol, but soon many were available from all the main tube manufacturers.
- From my limited research, Motorola made the first hybrid radio in 1956.
- By 1958, everyone was making them. Car radios with vibrator supply were still made, but about half were vibrator-less hybrid radios.
- In the early 1960's, entirely solid-state car radios started to take over.
- Hybrid car radios were a huge improvement over the vibrator-supply radios, and used clever engineering. But solid-state radios were even more revolutionary.

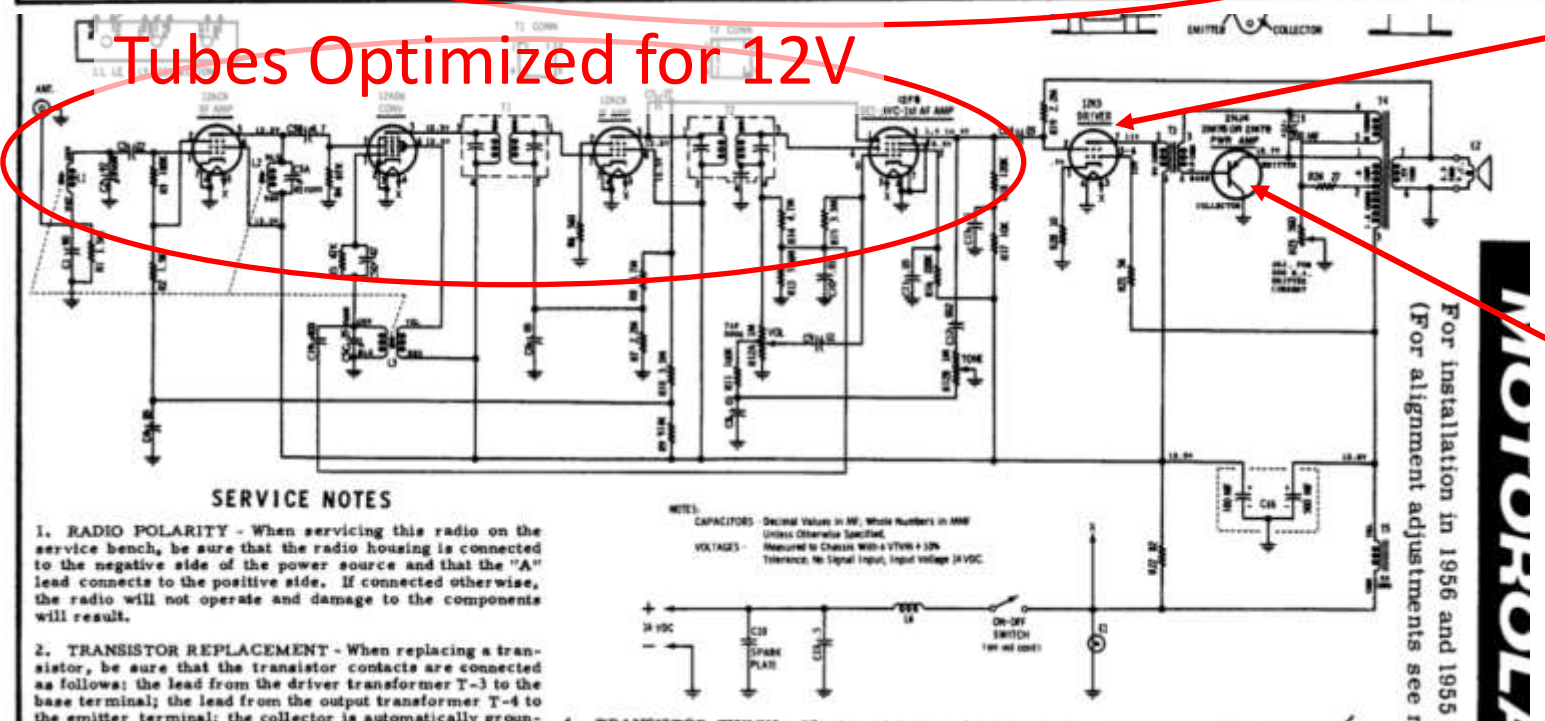
*More later

Regular Tubes



Vibrator Supply

Tubes Optimized for 12V



Compare!

Conventional Radio with
beam power Vibrator
output tube Supply

Space-Charge tube
(transistor driver)

Hybrid Radio
Transistor output stage

Pretty similar, right?

Deconstructing a 1961 “Hybrid” Car Radio

- Delco 988413 (Chevrolet: General Motors)
- Very typical 1960’s “Hybrid” Radio. Made in Canada (Oshawa?).
- No vibrator power supply. 12V is the highest voltage anywhere in the radio.
- Uses 4 tubes, all with 12V plate voltage.
 - 12DZ6 RF Amplifier
 - 12AD6 Converter
 - 12EK6 IF Amplifier
 - 12DS7 Detector, Audio (Space charge tube)
 - Germanium PNP power transistor for final audio amplifier

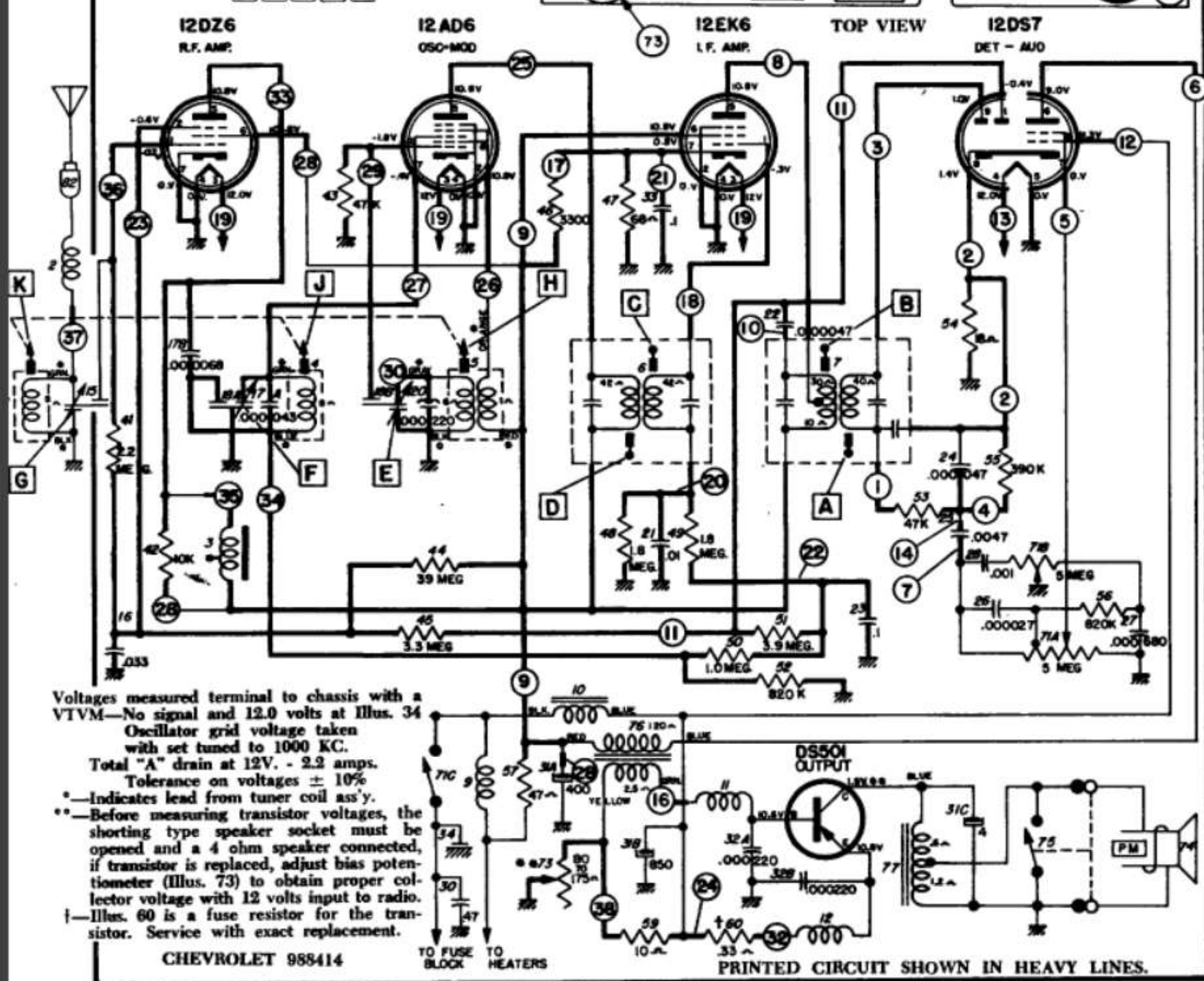
RF
Converter
IF
tubes

Permeability-
tuned

Detector
1st audio
tube
(space-charge)

262kHz IF

Germanium PNP
transistor audio
output



Voltages measured terminal to chassis with a VTVM—No signal and 12.0 volts at illus. 34
Oscillator grid voltage taken with set tuned to 1000 KC.

Total "A" drain at 12V. - 2.2 amps.

Tolerance on voltages $\pm 10\%$

- *—Indicates lead from tuner coil ass'y.
- **—Before measuring transistor voltages, the shorting type speaker socket must be opened and a 4 ohm speaker connected, if transistor is replaced, adjust bias potentiometer (illus. 73) to obtain proper collector voltage with 12 volts input to radio.
- †—illus. 60 is a fuse resistor for the transistor. Service with exact replacement.

TO FUSE BLOCK
TO HEATERS

Volume/Tone Control

Output Xfmr

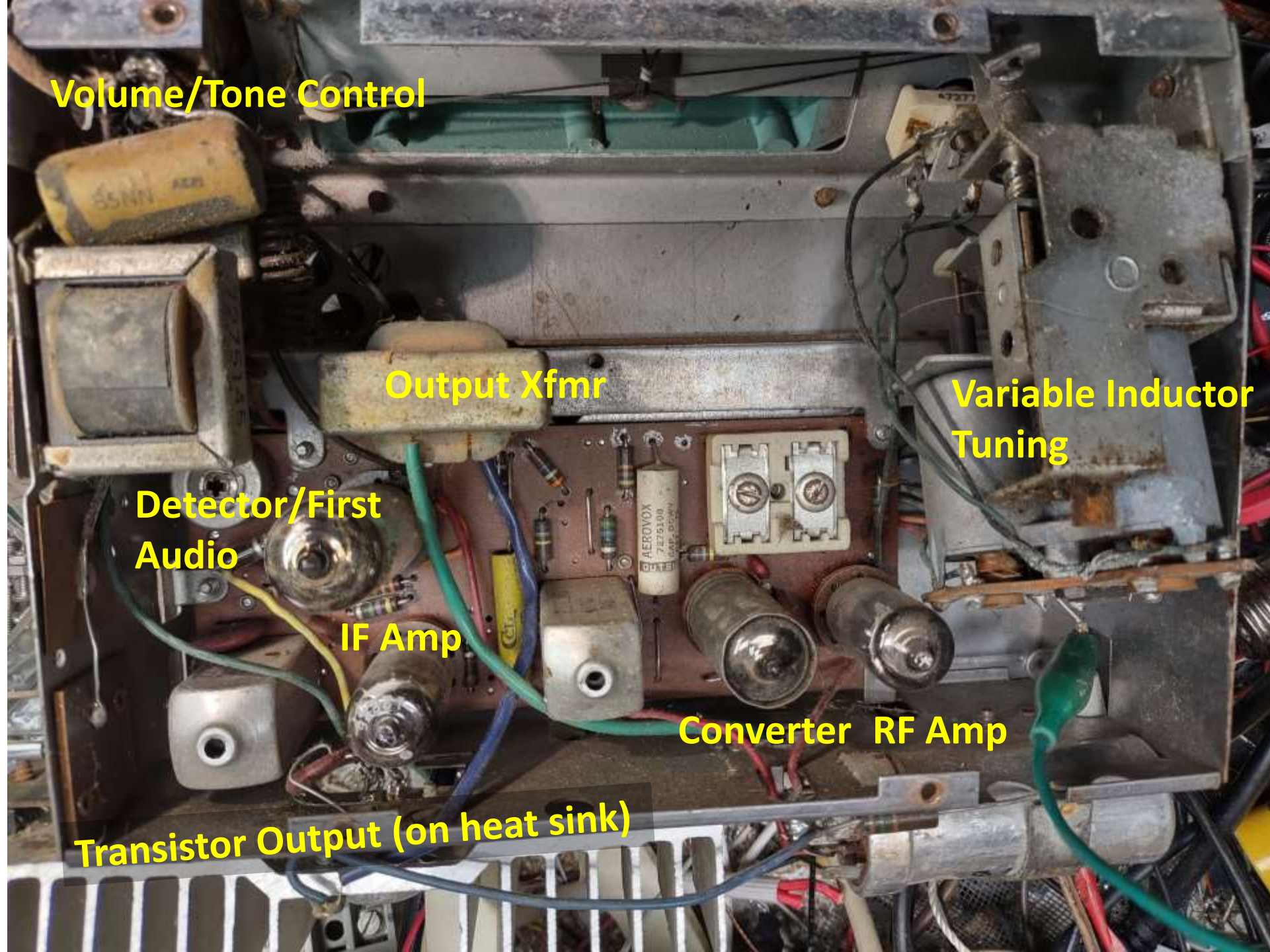
**Variable Inductor
Tuning**

**Detector/First
Audio**

IF Amp

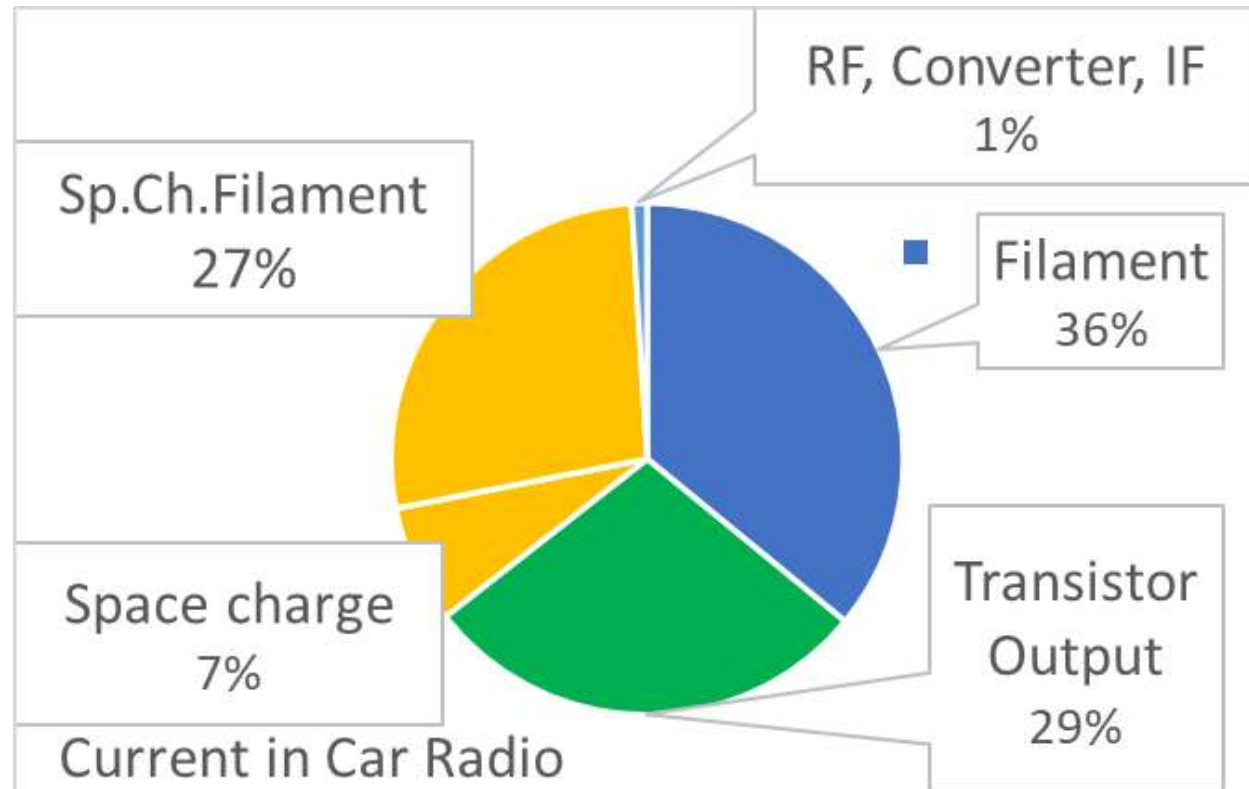
Converter RF Amp

Transistor Output (on heat sink)

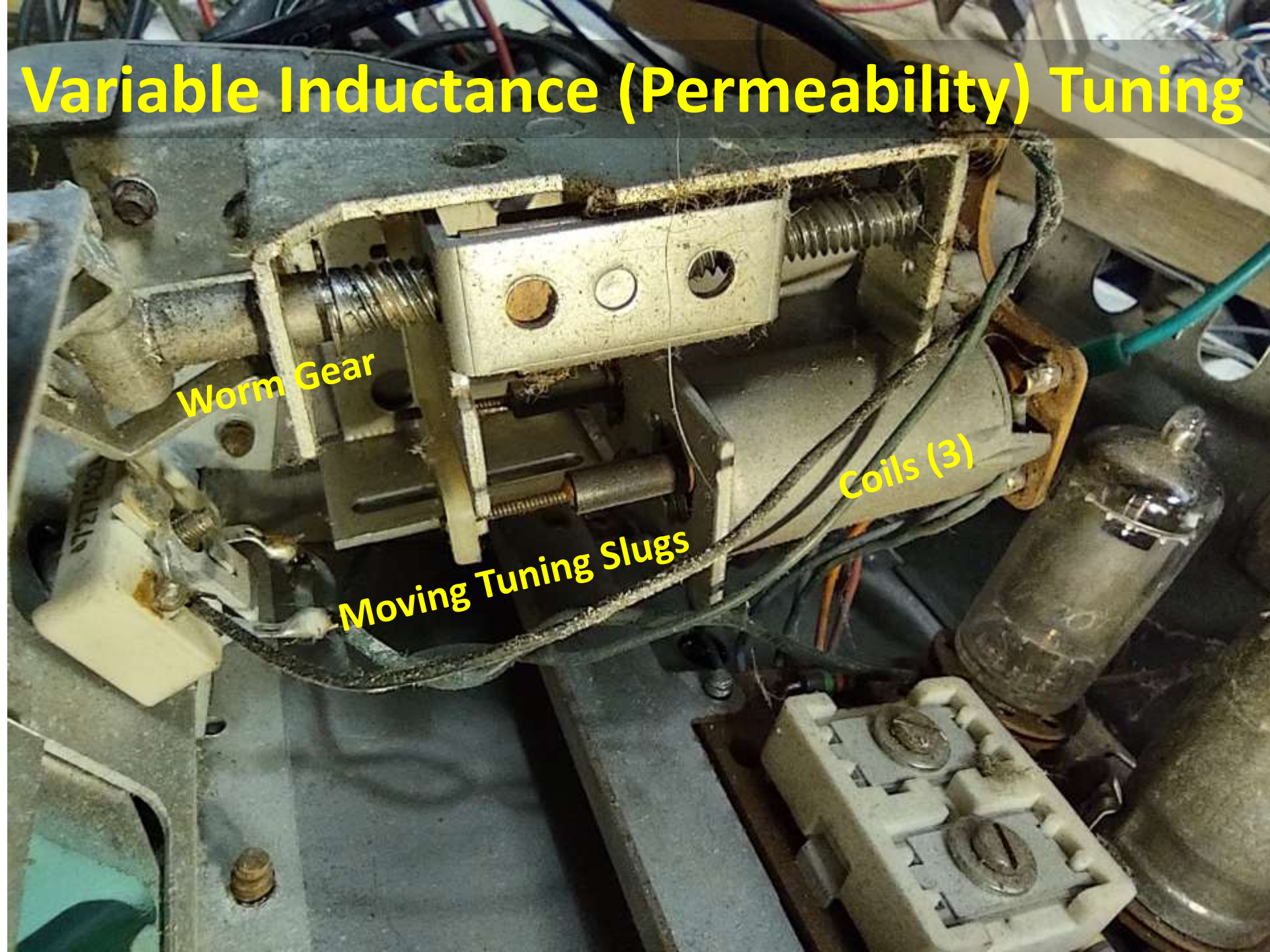


Delco Hybrid

- Like most car radios, this uses “permeability tuning”. Rather than a variable capacitor, it uses variable (moving slug) inductors.
- Apparently, this is less microphonic and is considered more robust. Better for a high-vibration environment.
- Well shielded.
- Never run the radio with speaker terminal open-circuited!



Variable Inductance (Permeability) Tuning



Worm Gear

Moving Tuning Slugs

Coils (3)

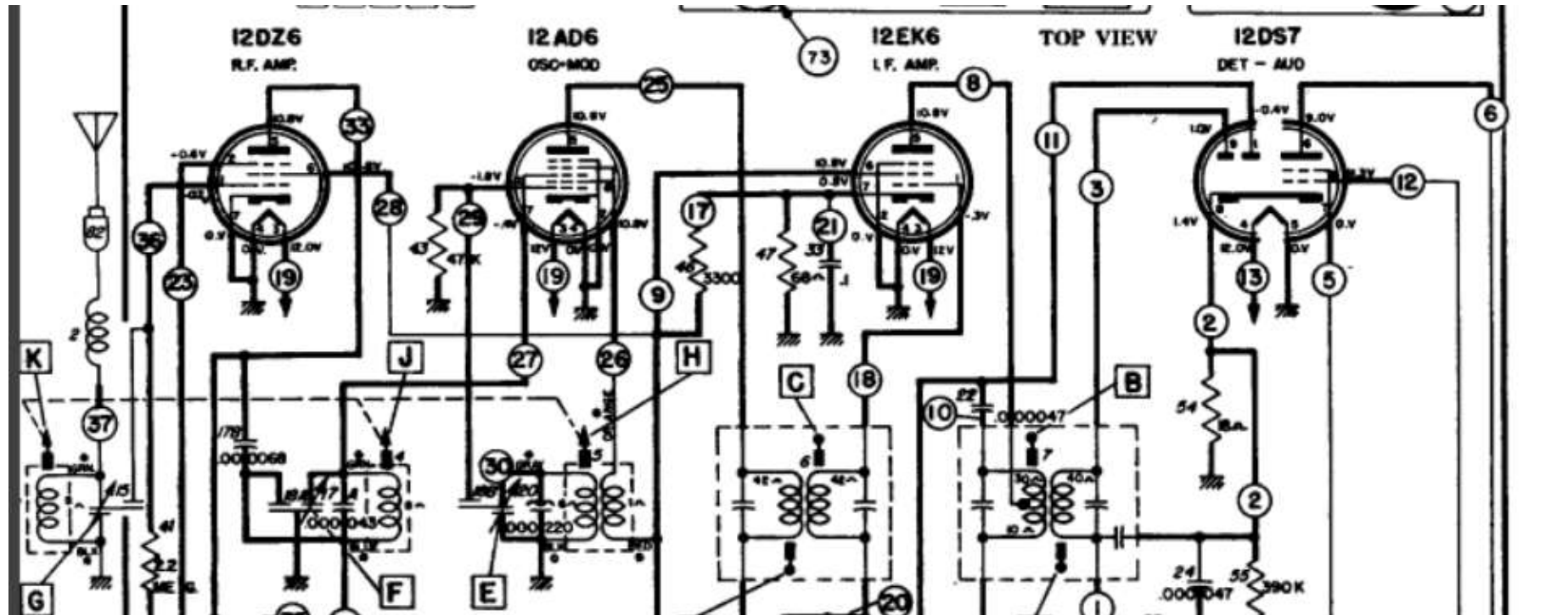
The Tubes in my Delco

Regular tube,
12V on plate

Regular tube,
12V on plate

Regular tube,
12V on plate

Regular diodes.
Space-charge
tetrode, 12V on
G1 and plate



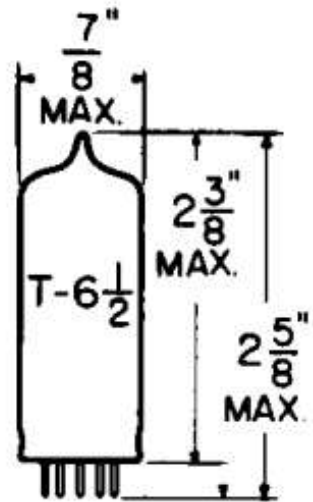
Space Charge Tubes vs. 12V Plate Tubes

- There are sources on the internet that claim that all these tubes are “space-charge” tubes. They are not.
- The RF amplifier, Converter, and IF amplifier are “Conventional” tubes optimised for 12V operation.
- You can replace these tubes with conventional tubes (12BA6, 12BE6), and *the radio still works!* I tried it; not quite as loud, but acceptable.
- The only tube that is truly a space-charge tube (with a space-charge grid) is the audio driver that drives the transistor output stage. The output transistor needs appreciable output power that is impossible to achieve (with 12V) without a space-charge tube.

What is a “Space Charge” Tube?

- A true space charge tube has the first grid at a fixed DC positive potential (12V in the case of the 12K5/12DS7 in a car radio). The second grid is the “control” grid.
- The positive grid attracts electrons out of the space charge (cloud of electrons around the hot cathode).
- The electrons accelerate towards the grid.
- Many of the electrons hit the grid (cause grid current), but some (20-30%) miss the grid and go flinging towards the distant (but also positive) plate.
- It allows significant plate current to flow even when only 12V is present.

A TRUE SPACE CHARGE TUBE



GLASS BULB

SMALL-BUTTON NOVAL
9 PIN BASE E9-1

OUTLINE DRAWING
JEDEC 6-3

12DS7

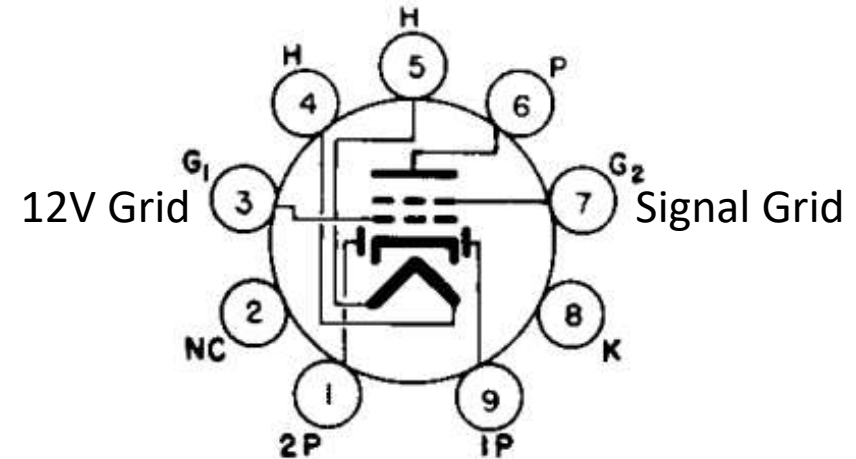
HEATER

12.6 VOLTS 0.4 AMP.

AC OR DC

ANY MOUNTING POSITION

SPACE CHARGE GRID TETRODE



BOTTOM VIEW

BASING DIAGRAM
JEDEC 9JU

THE 12DS7 IS A TWIN DIODE-POWER TETRODE IN THE 9 PIN MINIATURE CONSTRUCTION. IT IS INTENDED FOR USE IN AUTOMOBILE RECEIVERS WHERE THE TUBE AND TRANSISTOR ELECTRODE VOLTAGES ARE OBTAINED DIRECTLY FROM A 12 VOLT BATTERY. IN THIS APPLICATION THE DIODE UNITS ARE BASED FOR AM SIGNAL DETECTION AND AUTOMATIC VOLUME CONTROL. THE TETRODE UNIT IS USED AS THE DRIVER FOR THE TRANSISTORIZED AF POWER OUTPUT STAGE.

A TRUE SPACE CHARGE TUBE

TYPICAL OPERATING CONDITIONS AND CHARACTERISTICS

12DS7

CLASS A₁ AMPLIFIER

A true space charge tube

HEATER VOLTAGE ^A		12.6	VOLTS
HEATER CURRENT		0.4	AMP.
PLATE VOLTAGE		12.6	VOLTS
GRID #2 (CONTROL-GRID) VOLTAGE: DEVELOPED ACROSS A 2.2 MEGOHM RESISTOR		-0.5	VOLTS
GRID #1 (SPACE-CHARGE-GRID) VOLTAGE		12.6	VOLTS
PLATE RESISTANCE (APPROX.)	→	500	OHMS
AMPLIFICATION FACTOR, GRID #2 TO PLATE	→	8	
TRANSCONDUCTANCE, GRID #2 TO PLATE	→	16 000	μMHOS
PLATE CURRENT	→	35	MA.
GRID #1 CURRENT		75	MA.

A TUBE OPTIMISED FOR 12V OPERATION

12AF6

MINIATURE TYPE

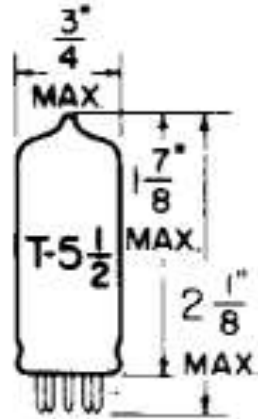
COATED UNIPOTENTIAL CATHODE

HEATER

12.6* VOLTS 0.15 AMP.

AC OR DC

ANY MOUNTING POSITION



GLASS BULB



BOTTOM VIEW

MINIATURE BUTTON
7 PIN BASE

7BK

Not a space charge tube

THE 12AF6 IS A MINIATURE PENTODE INTENDED FOR USE AS A RADIO-FREQUENCY OR INTERMEDIATE-FREQUENCY AMPLIFIER IN AUTOMOBILE RADIO RECEIVERS. THE TUBE IS SPECIALLY DESIGNED TO OPERATE WITH PLATE AND SCREEN VOLTAGES SUPPLIED DIRECTLY FROM A 12-VOLT STORAGE BATTERY.

A TUBE OPTIMISED FOR 12V OPERATION

TYPICAL OPERATING CONDITIONS AND CHARACTERISTICS CLASS A₁ AMPLIFIER

12AF6

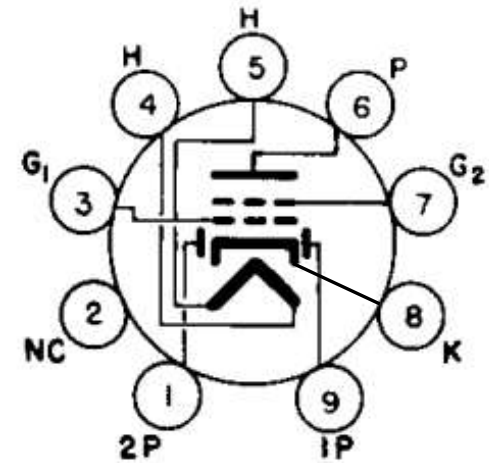
Not a space charge tube

HEATER VOLTAGE	12.6	VOLTS
HEATER CURRENT	0.15	AMP.
PLATE VOLTAGE	12.6	VOLTS
SUPPRESSOR VOLTAGE	0	VOLTS
SCREEN VOLTAGE	12.6	VOLTS
GRID #1 SUPPLY VOLTAGE	0	VOLTS
GRID #1 RESISTOR (BYPASSED)	2.2	MEGOHMS
PLATE RESISTANCE (APPROX.)	→ 0.35	MEGOHMS
TRANSCONDUCTANCE	→ 1500	μMHOS
PLATE CURRENT	→ 1.1	MA.
SCREEN CURRENT	→ 0.45	MA.
GRID #1 VOLTAGE (APPROX.) $G_m = 40 \mu\text{MHOS}$	-2.7	VOLTS
GRID #1 VOLTAGE (APPROX.) MEASURED * WITH GRID #1 TIED TO GRID #3, $R_{g1} = 0, G_m = 10 \mu\text{MHOS}$	-3.5	VOLTS

Space Charge Tube Substitute

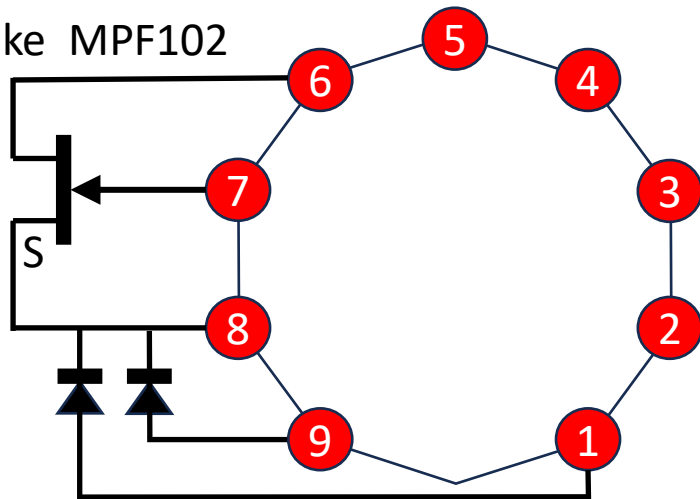
- A space charge tetrode can be replaced with a common n-channel JFET like a MPF102. I tried it, it works.
- Source → Cathode ; Gate → Grid 2 ; Drain → Plate ;
No connection to G1

12DS7



(Bottom view)

N-ch JFET
like MPF102



GE diodes
like 1N34A

(Top view)

