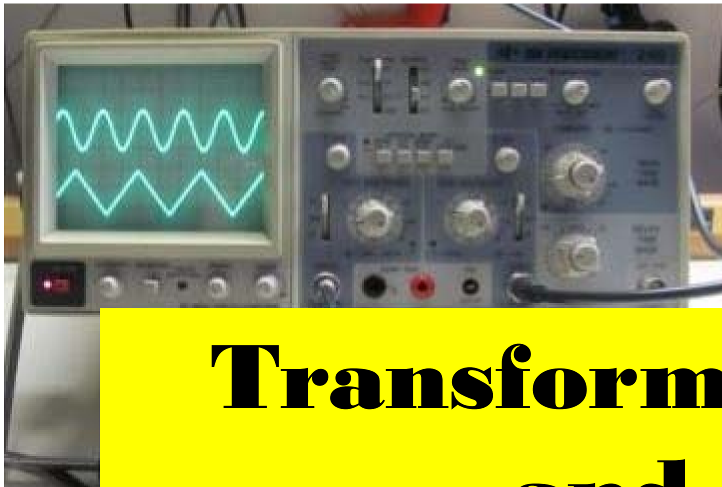


Transformer Replacement and Problems

MAARC RadioActivity-2017

Ed Lyon






In radios and in radio restoration, we run across transformers of several types:

1. In quality A-C operated radios and amplifiers, there are POWER transformers.

2. In many old “3-dialers” and a few later sets we find interstage audio transformers, often just called “AUDIOS.”

3, Many radios, especially those after 1927, use AUDIO OUTPUT transformers.

4. At radio frequencies, there are both R-F transformers and antenna transformers.

5. Most superhet radios have LOCAL OSCILLATOR transformers, and some have BFO transformers.

6. There are interstage I-F transformers in Superhet radios.

What makes it a transformer?

It will have two or more coils or spools of insulated wire arranged so that the magnetic fields of the coils are linked together.   That allows currents in one coil to create voltages in the other coil(s), without any need for the coils to be connected to each other.

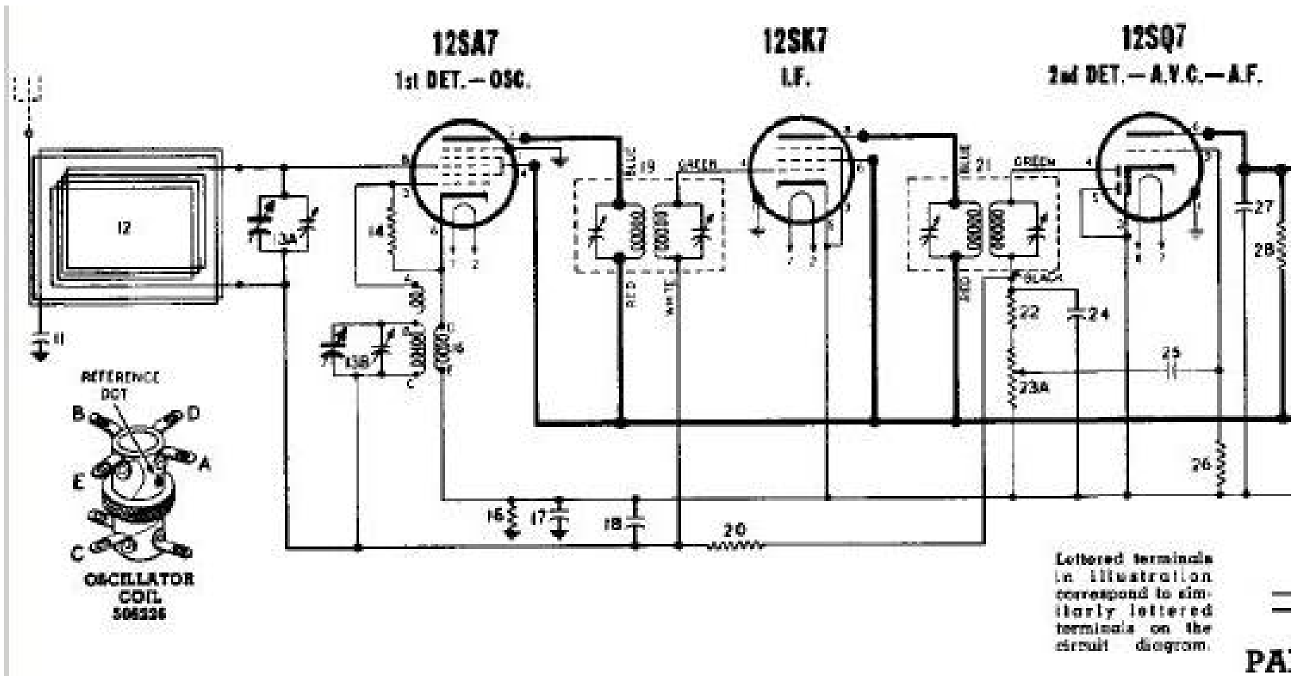
Kind of like Hatfields and McCoys – (or Cabots and Lodges, for those of you from New England).

Antenna and RF transformers must operate over the entire band to be tuned by the radio.

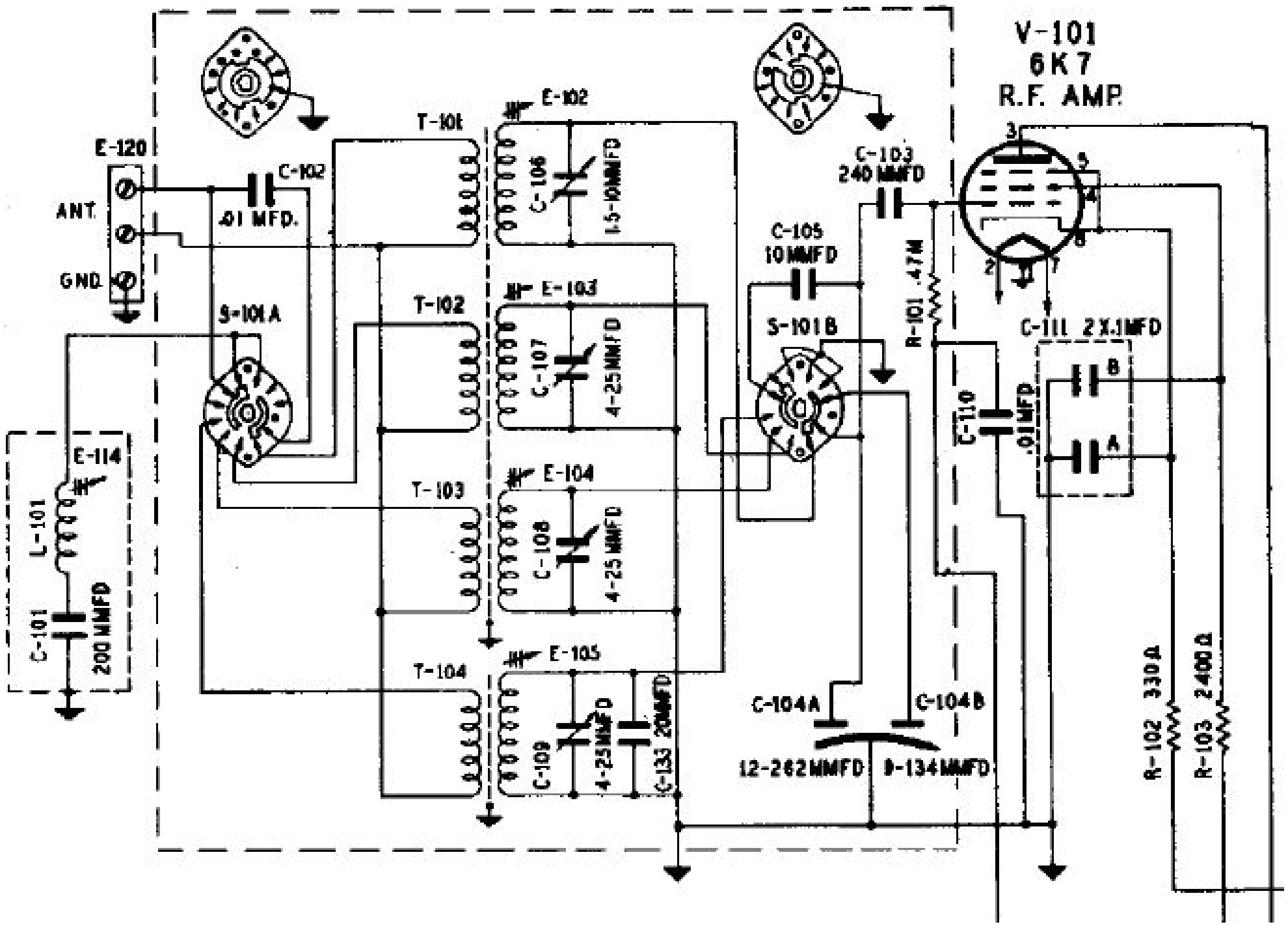
Usually they are tuned by a variable capacitor (but sometimes by a movable transformer core slug)

Note the rather loose coupling between primary and secondary on the one on the right.

Some Rider's examples of transformers you may find defective – usually a break in a fine coil wire.



And an E.H. Scott multiband set. Note each band uses its own RF transformer rather than try to use a tapped multi-band winding.



Audio transformers are characterized by having laminated iron cores, and many have a small gap in the core.

Interstage, c. 1926

Mic. Input, c. 1960

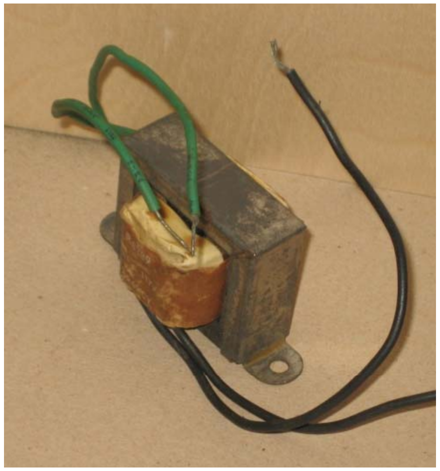
Power transformers, also operating at low audio frequencies (25 to 400 Hz), have iron cores, too, and they are not gapped.

Many have shells held in place by the bolts at the corners. Here we have one in which the bolt-heads are insulated by fiber washers; not so with the other.

Other shell-type power transformers use side-mounting bolts and slotted passages in the laminated core for these bolts. These transformers have fewer hum and corrosion problems than those with corner bolts.

There is not much difference between some transformers intended for power applications and some audio transformers.

A test of the response to severe load changes will show that the average audio transformer will smooth out such effects*. A power transformer blows a fuse, instead. High-end audio transformers are more like power transformers in this respect, without core gaps..



120-to-6V power Xformer

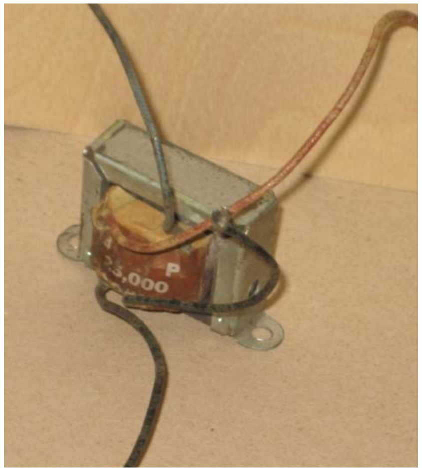
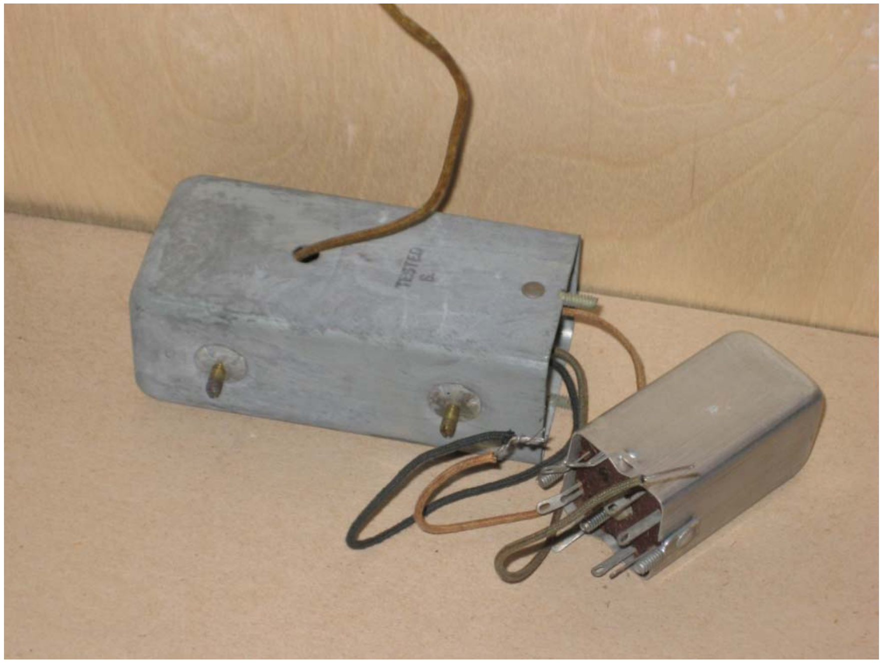


Plate-to-v.c audio Xformer

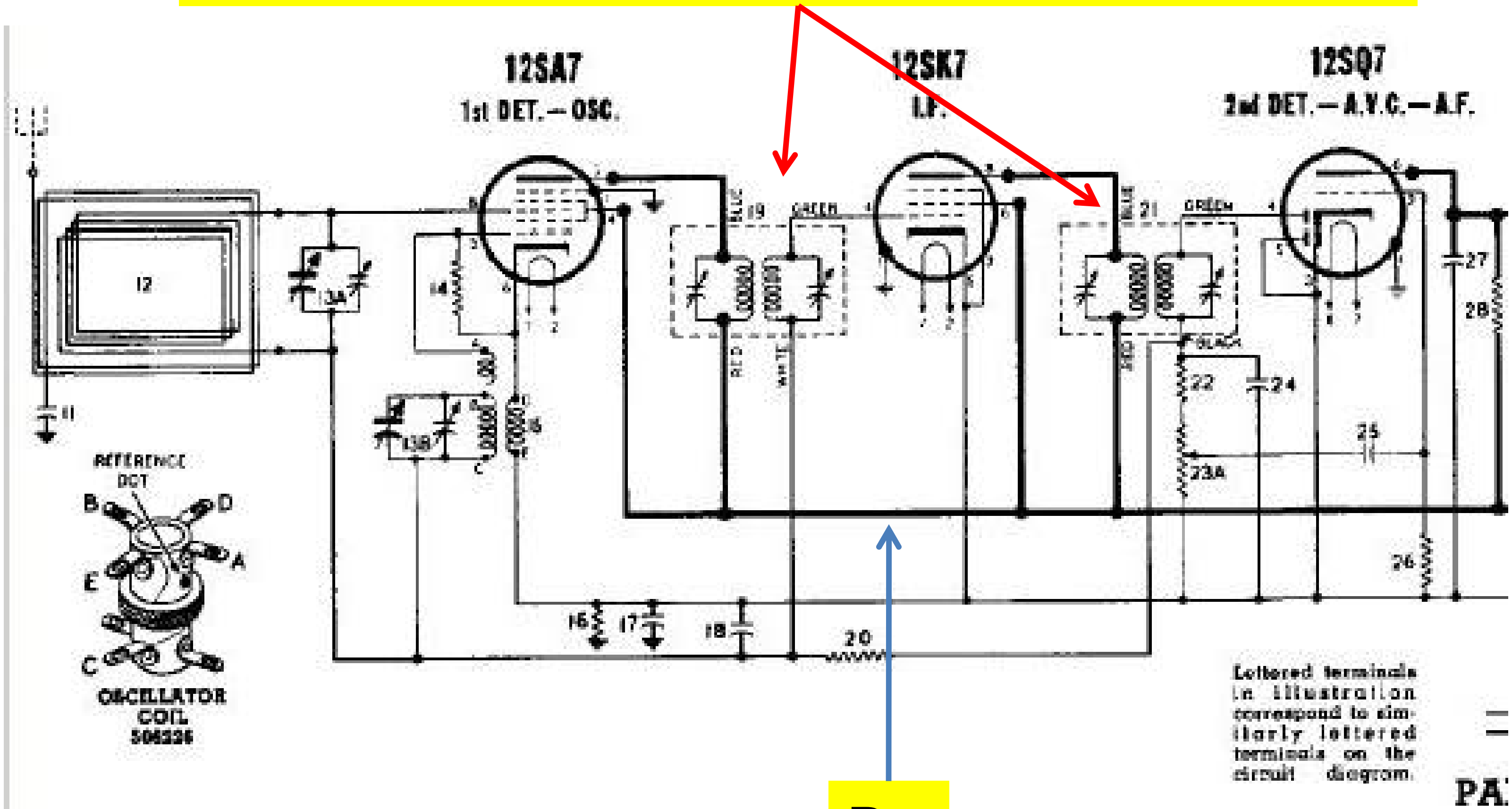
* The miniscule gap in the core of the audio transformer provides sufficient permeability reduction to “absorb” the voltage spikes in audio without saturating the core.

And, then there are I-F transformers (or “cans”) used in interstage coupling in I-F amplifiers and in discriminator stages in FM or PM circuits.



These are usually (but not always) in shield cans, which help keep stray radio interference signals from entering these high-gain stages.

The two IF transformers here are not identical to each other. In better radios, the output IF "can" has a lower impedance secondary because it has to feed a load (the detector diode and volume control, for example)'



B+

The primary advantage of superhets is that most of their amplification of radio signals takes place at a primarily fixed frequency, the I.F. This allows optimization of the I-F transformers rather than live through the compromises in designs of RF transformers (e.g., the AM B-C band spans a 3:1 frequency spread).

A bench test shows that even high-priced RF transformers are trimmed down and made loose in coupling between the two windings, to be equally mediocre at all frequencies in their band.

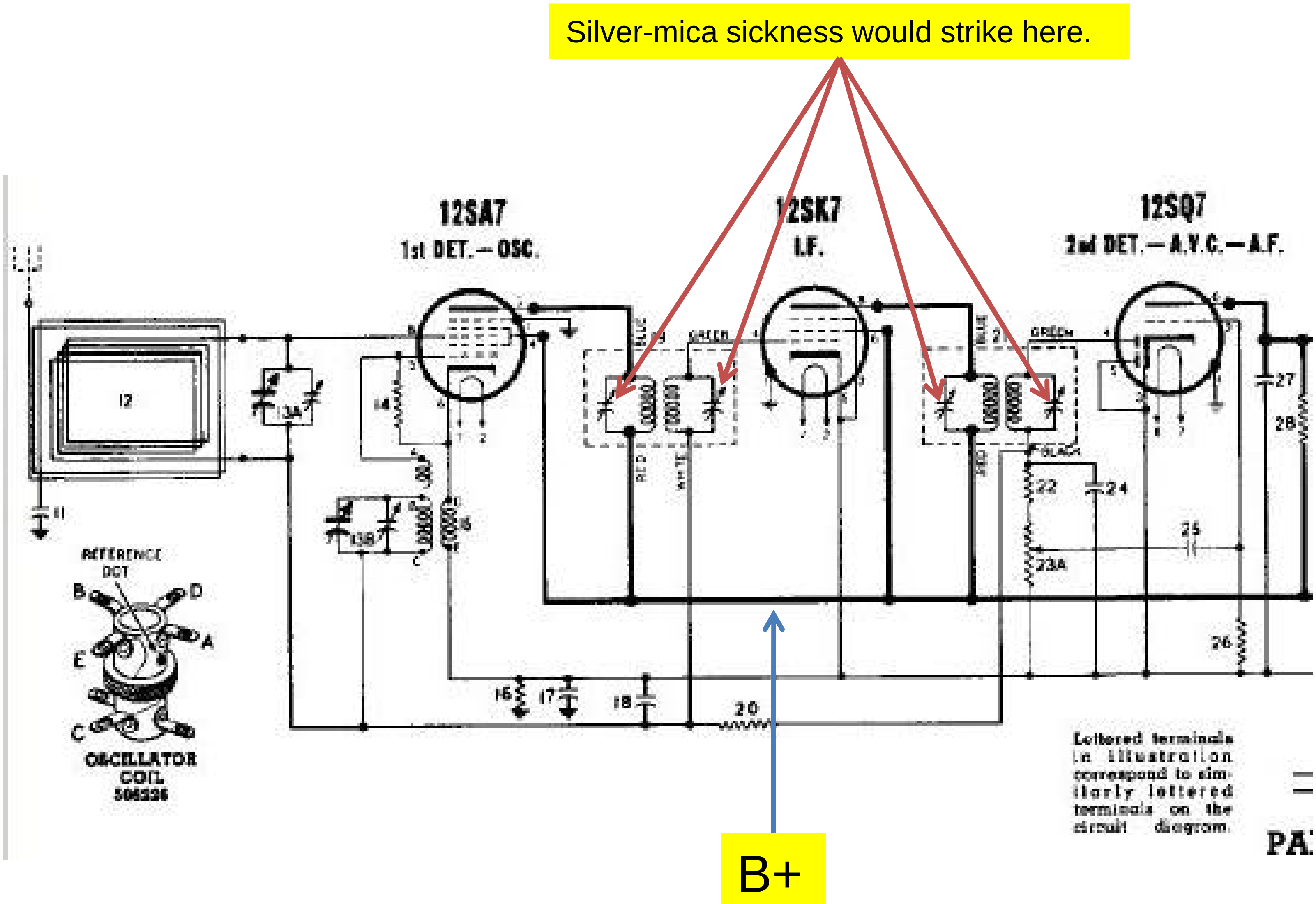
One often-neglected example of a transformer that operates over a wide band of frequencies is the local oscillator (LO) in the superhet. These are like RF transformers but often use a Hartley circuit that has a single tapped winding, in which the bottom portion (below the tap point) drives the upper portion by means of the magnetic coupling.

Now let’s look at problems encountered with transformers

RF transformers, namely those with air cores or ferrites, are usually made with very fine (#36-46 AWG enameled wire) which may have suffered corrosion or vibration problems that broke the wire, or caused a turn-to-turn short circuit.

Among RF transformers used as antenna-to-front-end coupling often have “open” primary windings caused by antenna wires collecting high voltages WRT the radio circuit.

I-F transformers’ fail mode is often primary-to-secondary shorts, due to the voltage difference there. A problem in radios of the 1940s-1950s that have silver-plated mica in their built-in trimmer capacitors is “silver-mica sickness” – tiny whiskers of silver that have grown out of the silver plating, which intermittently short out the coil involved. Symptom is crash-static that doesn’t go away, despite re-capping the radio, new resistors everywhere, prayer, anything you do except replace the IF transformers..


Silver-mica sickness would strike here.
12SA7
1st DET.—OSC.
12SK7
I.F.
12SQ7
2nd DET.—A.V.C.—A.F.
REFERENCE DOT
OSCILLATOR COIL 506226
Lettered terminals in illustration correspond to similarly lettered terminals on the circuit diagram.
B+

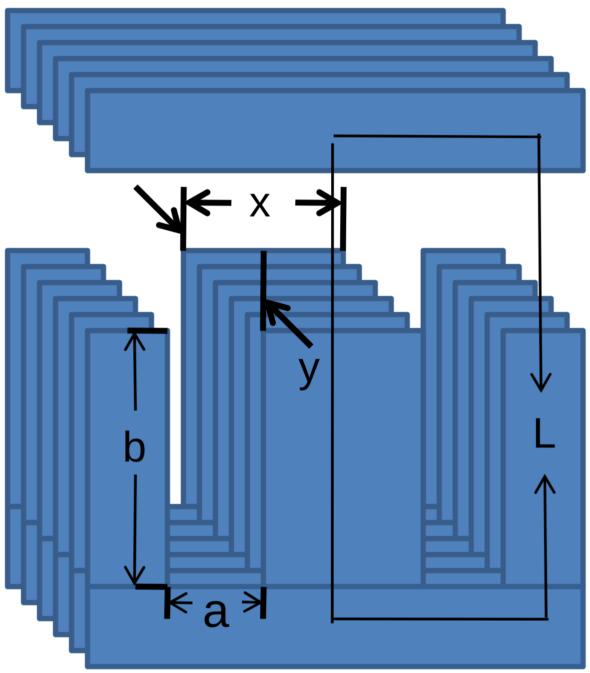
Power transformers and audios fail due to the voltages present and the currents they carry, which are usually sufficient to promote electrolytic corrosion and/or heating, which results in expansion and contraction with periodic use. Having no core gap, they are unforgiving if a secondary winding has a load that gets short-circuited, like a failed electroilytic cap in the B+ line, or a shorted audio output tube's plate-to-ground capacitor.

Repairs can be made, but are quite difficult to do, as the manufacturer was never generous with available space.

Let's see what determines a power transformer's characteristics, just in case you discover a good-looking (but unlabeled) example in the old junk box that just might work out in a replacement situation.

Power Transformer Basics-1

Note: "I" part lifted away from "E" part of core for visibility. Imagine it to be lowered to touch the "E" laminations, with no gap between them.



In the type of core shown, L is the magnetic path length and (a) times (b) is the window area, which must hold all the wire turns.

RMS Voltage equation:

$V = 2 \Pi f N B A$

Where:

N is number of turns of wire

B is magnetic flux density, Wb/m^2

A is area of magnetic core, m^2

2 Π is, of course, 6.28; f is frequency

And, A = (x)(y), the cross-sectional area of the central core pillar.

The above equation can be re-written in terms of coil turns N per volt V,

$N/V = 1/(6.28 f B A) = 6.63$

What we're trying to do here is develop a safe maximum value of magnetic flux density, B, in the core. For iron core material, that safe value is 1.0 Weber per square meter of core cross-section, A. This is equal to 0.000001 Weber per square mm. We do this ny solving for the primary winding's turns per volt, N/V (how many wraps of wire per applied volt).

Using the formula given for turns per volt and some representative numbers, like 20mm X 20mm for the core area, A; and standard 120-volt, 60 Hz power, where $2\,\Pi f = 377$;

From last slide, $N/V = 1/(2\,\Pi f\,B\,A)$ = 6.63 turns per volt
This means we wind 6.63 turns per applied RMS volt. So, for 120 volts a-c, the primary would need 796 turns of wire for a transformer that will have a safe flux in its core. Note this is determined only by the core area and the applied voltage and frequency.

(Note that if this transformer were for an aircraft-mounted radio, where the power is at 400 Hz, the turns per volt would be only 0.99 (rounded to 1.0), so we would need only 120 turns of wire, or else we could reduce the core area to about 7.75 mm square, rather than 20 mm square).

NEXT STEP: We know the primary's number of turns of wire, but need to know how much current is required to set up the full magnetic field strength, or flux. This "magnetizing current" is determined by three things: The permeability of the iron core, µ, the, magnetic path length, L, and the total flux, (B) times (A).

This total flux, remember, is our target 0.000001 Weber per sq. mm multiplied by our core area, which is 20 mm X 20 mm, thus 0.0004 Weber.

Most iron core material has a permeability (µ) value of 0.000628.

The magnetic path length enters the picture because it affects the Reluctance*, whose symbol is $\mathcal{R}$ (a script R), of our core, with its 150mm magnetic path length, is given by: $\mathcal{R} = L / (\mu \times A) = 600{,}000$, approximately.

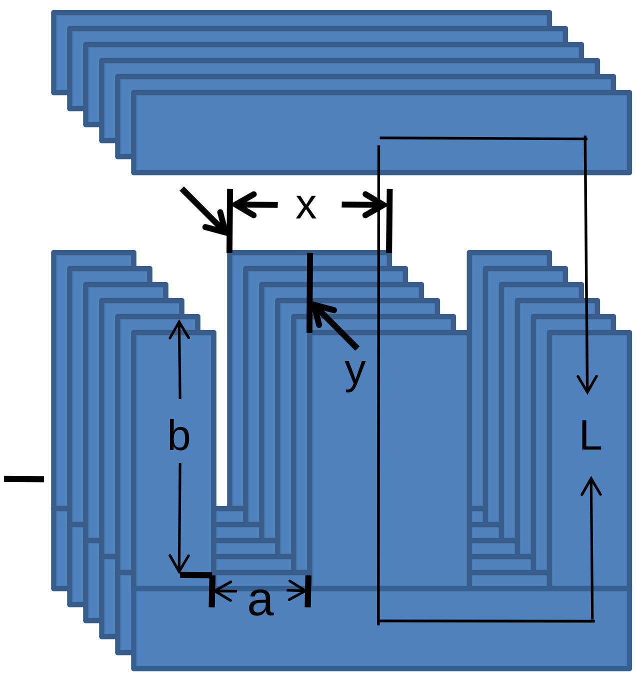
The total magnetization, often called the magneto-motive force (mmf), is simply our flux (0.0004 Weber) multiplied by $\mathcal{R}$: and comes out in ampere-turns:
Mmf = flux X $\mathcal{R}$ = 240 ampere turns, and for our 796 turn primary, is 240/796 = 0.302 amp (or 302 mA) primary current, all inductive, and not costing anything on the electric meter.

From Ohm's law for inductive reactance is 120 volts/0.302 amp, or 397 Ω
Which means our primary has just about 1.2 Henrys inductance.
* Remember that 1950's GE phono pickup cartridge, the *Variable Reluctance Cartridge?*

Power Transformer Basics-2

Making our transformer do something, like make some power

Let's make it a 6-volt filament trans-former, as an example. The secondary will therefore need 40 turns of wire (simply proportional to the voltages) If the 120-volkt primary had 796 turns, the 6-volt secondary needs 6/120 of 796, or 40 turns.



The window size determines how much power we can get, for a given core area. It actually determines how much wire of a given gauge can be stuffed through the windows.

A rule of thumb is that you can get 1.55 ampere turns through each sq. mm of window. Our window is 400 sq. mm in area.

For our 400 sq. mm window area, we get 620 ampere-turns. We must share the window equally between primary and secondary, half and half, yielding 310 Amp-turns each.*

For our 796-turn primary, that's 0.39 amps primary current and for the 40-turn secondary, it gives 7.75 amps secondary current. This is a 46-watt transformer.

This portion of the primary current, 0.39 Amp (390 mA) is real, in-phase current that you pay for. The total primary current is the resultant of the 302 mA reactive current and the 390 mA real current, for a total primary current of 0.49 amps (490 mA). The wire size is judged by this current value.

This exercise was intended to show how to analyze a transformer you may find that appears to be useful as a replacement or new-construction power transformer or audio.

Some pointers:

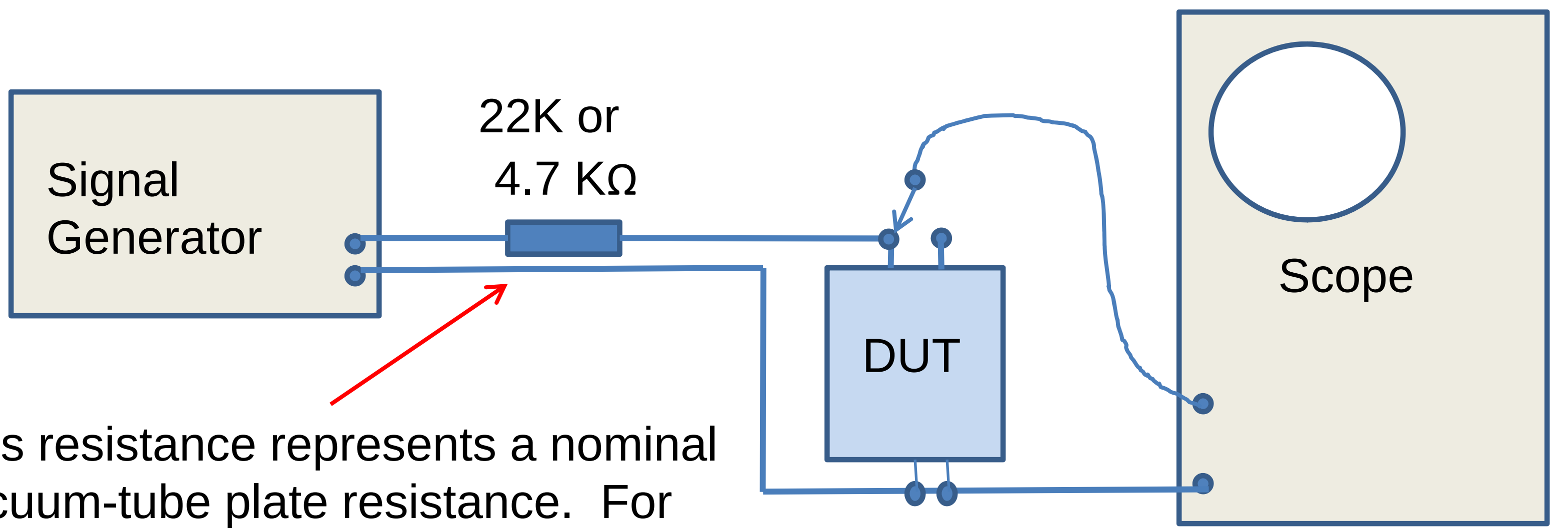
1. Always share the primary's occupied window area with that of the secondary (or secondaries), on an equal basis, Primary has to do as much work as all the secondaries combined, so their shares are equal. If our example secondary had been two identical 6-volt windings, each would be able to claim ¼ of the window area, while the primary got ½.

2. These equations work well with toroidal iron-core transformers, too. The open center of the toroid is the window area, and the dimensions of the toroid cross section determine the pillar area.

ENOUGH Hi-Tech Math!!   Snooze time is over!

Let's do some measurements on transformers.

Basic measuring setup for most all tests:



This resistance represents a nominal vacuum-tube plate resistance. For realism, you would increase it to 47K to 100K to represent pentodes, and leave it at 4.7K to 10K for triodes.