Oscillating Amplifiers

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This article explores a fairly common problem in radio servicing: unwanted oscillations in RF & IF amplifiers. If your radio has whistles while tuning between stations, or picks up no stations, or exhibits "Motorboating" (the name describes the sound that you hear), then you could have an unwanted "parasitic" oscillation.

This article will focus on parasitic RF & IF oscillations in post 1930 superheterodyne tube radios. Earlier TRF (Tuned Radio Frequency) radios are notorious for parasitic RF oscillation and they must be "neutralized" to make them stable (not oscillate), but that topic deserves an article of its own. Audio oscillations can also occur, but this is relatively rare and I won't discuss it further.

What causes oscillation?

True story: 40 years ago, a university professor, Dr. David Roulston, told me "If you want an amplifier, design an oscillator. If you want an oscillator, design an amplifier.". What he meant was that many oscillator designs fail to oscillate and many amplifier designs DO oscillate. I have been reminded about the truth in these words dozens of times. Anyone who has designed a high-performance RF amplifier knows that they can oscillate, and that you must address instability many times during the design cycle. I have been cursed with "parasitic oscillations" so many times during my career, thinking about it almost brings me to tears.

An oscillator is an electronic circuit that produces an AC voltage, generally at a stable and predictable frequency. Oscillators are good and useful things (for example, part of the "converter" tube in a superhet oscillates on purpose), unless you don't want one. It is far too easy to accidentally make an amplifier into an oscillator.

An amplifier takes a small input signal and makes it bigger at the output. If a small fraction of that output signal gets back into the input, it too will be amplified, and be fed back, and amplified, and so on... You can see that this process could feed itself forever if enough of the output signal gets back to the input; that's oscillation.

One of the reasons that triodes are not widely used as RF or IF amplifiers (they were used out of necessity before pentodes were invented, and much work was done to make them stable. Look into the Neutrodyne and the Hazeltine patent) is because the capacitance between the grid (input) and plate (output) is large. That capacitance is a direct path from the output to the input, and can be enough to make a triode amplifier into an oscillator. A triode amplifier with high "Q" (high quality; low loss) tuned circuits at the grid (input) and plate (output) (like an IF amplifier) is especially susceptible to parasitic oscillation. If a triode is used, "Neutralization" or de-Qing (adding loss, often in the tuned circuits) must be employed to ensure stability.

The pentode is a far better tube for an RF or IF amplifier because the screen grid significantly reduces the control-grid-to-plate capacitance, and allows the designer to get far more stable gain out of each stage. Essentially all IF amplifiers in post 1930 tube radios use pentodes for this reason. That does not mean that they cannot oscillate; there are many potential paths from the output pack to the input.

The undesired coupling can be though the air, through capacitive (electrostatic) coupling. IF amplifier tubes are usually shielded to reduce unwanted capacitive coupling. The reason that the control grid connects through the top of early IF tubes is to reduce unwanted coupling to the plate, which i5s accessed at the bottom. If the IF tube has a tube shield, make sure it is grounded well.

The coupling can be through air, through magnetic (inductive) coupling; that is, when the magnetic field from one coil is picked up with another coil. IF transformers are always shielded by metal cans to prevent inductive coupling, and the shields are grounded to prevent capacitive coupling. The coils in a TRF set are often mounted at 90 degrees relative to each other to minimize magnetic coupling.

The coupling can also be through the power supply. Any power supply that is shared between 2 stages in a radio can unintentionally become a path for unwanted feedback. Both the plate and the screen grid (2nd grid) supply voltage are usually shared between 2 or more stages. These nodes always have a capacitor (aptly called a decoupling capacitor or bypass capacitor) to ground, to “short out” any RF that might be present (keep in mind that a screen grid also behaves like a plate; it draws DC current like the plate, yet it is also a grid so controls the flow of electrons). Without that capacitor, the grid or plate from a later stage could induce an AC voltage that finds its way to the grid of an earlier stage.

A similar argument can be made for a grid bias supply shared between stages. RF energy at the detector can find its way back to earlier stages through the AGC line, and the AGC line is sometimes shared between 2 or more stages. Again, the AGC line will have a capacitor to ground to prevent coupling.

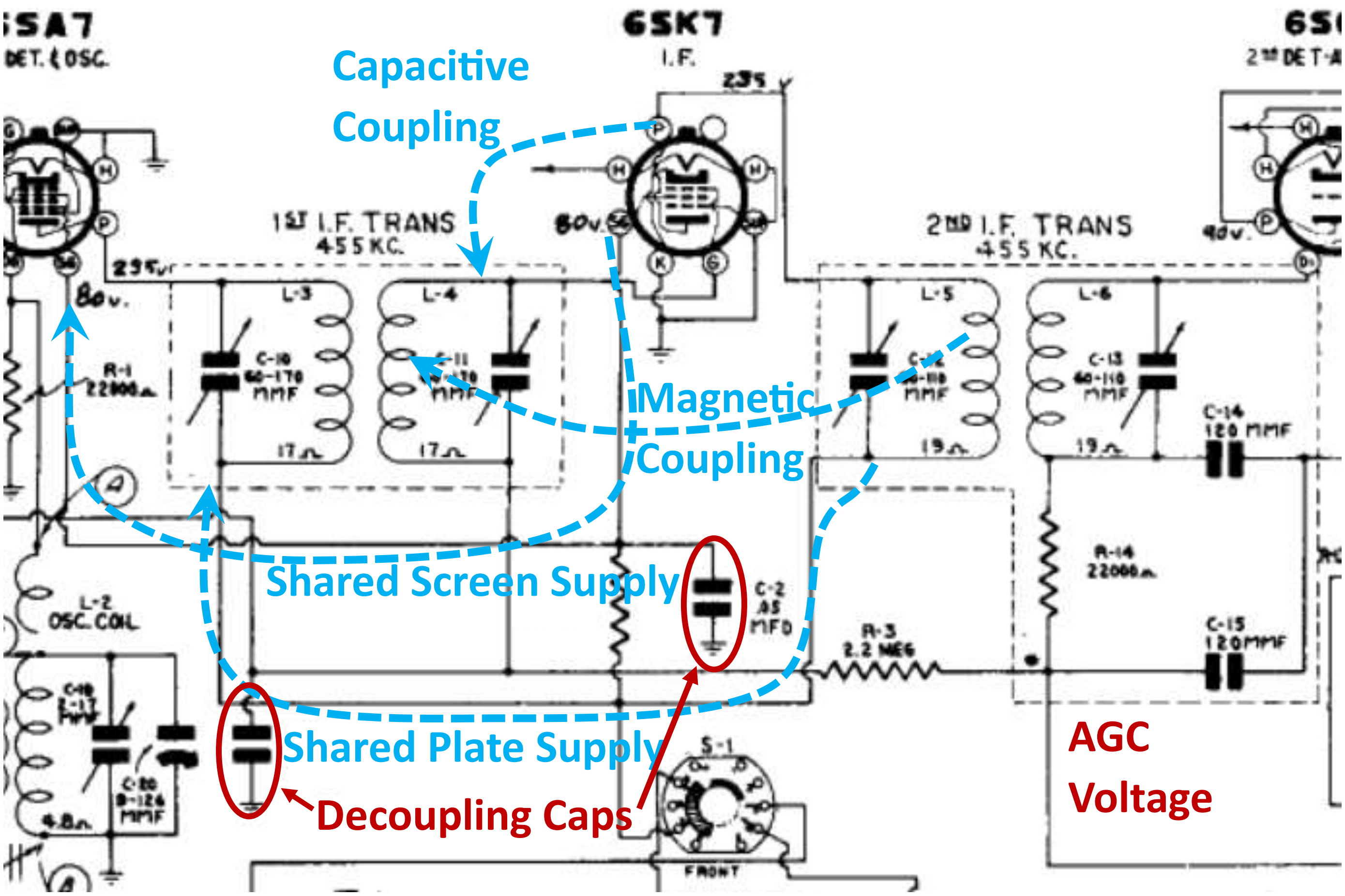
The coupling could be through the pentode tube itself if the screen grid is not effective, and to be effective, it needs a decoupling capacitor to ground. Coupling can even be through a (bad) shared ground.

How do you know if you have an RF oscillation?

Oscillations can occur in the RF or IF amplifier of any radio, and possibly even the converter tube. My experience is that these oscillations are usually caused by a bad or missing decoupling capacitor. Your best diagnostic tool is to place a known good capacitor in parallel with each of these decoupling capacitors to see if the oscillation stops. If you have an oscilloscope, look at the RF voltage across these capacitors, there should be none!

AGC (Automatic Gain Control) voltage can indicate that an oscillation is occurring in the IF amplifier. The AGC voltage is the DC voltage out of the detector, that is fed to the magic eye (if there is one), and is also fed back to the control grid of the IF and maybe RF amplifiers. With the radio not tuned to a station, this voltage will usually be low, less that 1 V (negative WRT ground). If the IF amplifier is oscillating, this voltage could be -10 or -100 or more volts. If you see this, try removing or disconnecting the IF, converter, and RF amplifier tubes to localize the problem.

If the radio "sort of" works, but there are whistles as you tune through stations, that's another sign of an oscillation. You may be able to use an oscilloscope to check that the supplies are clean, but just connecting a known good capacitor (say 0.05uf, with short leads) from the plate or screen supply to ground may show you where the problem is.



Motorboating (named by the sound it makes) can be caused by an AF oscillation on top of an RF oscillation. An RF oscillation can be so strong that it builds up a DC grid bias voltage that is large enough to turn off the oscillating tube. This stops the oscillation until the DC bias voltage decays, and allows the oscillation to start again, and this can repeat at an audio rate, causing a “growl” or “putt-putt” sound.

Fixing an oscillating radio

Parasitic oscillation is usually fixed by either grounding shielding (or installing missing shielding), or by replacing a decoupling capacitor. Decoupling capacitors are not critical (they are usually 0.005uF to 0.1uF), but should be installed close to the circuit they are decoupling, with short leads. An extra capacitor won’t hurt! Sometimes, oscillation can be fixed by dressing wires appropriately; the grid circuit of a tube should not be routed close to the plate circuit; possibly wires were moved on an earlier repair. Some early radios had neutralization in the IF amplifiers. I’d be reluctant to play with this except as a last resort!