The BFO and the AR-88 receiver

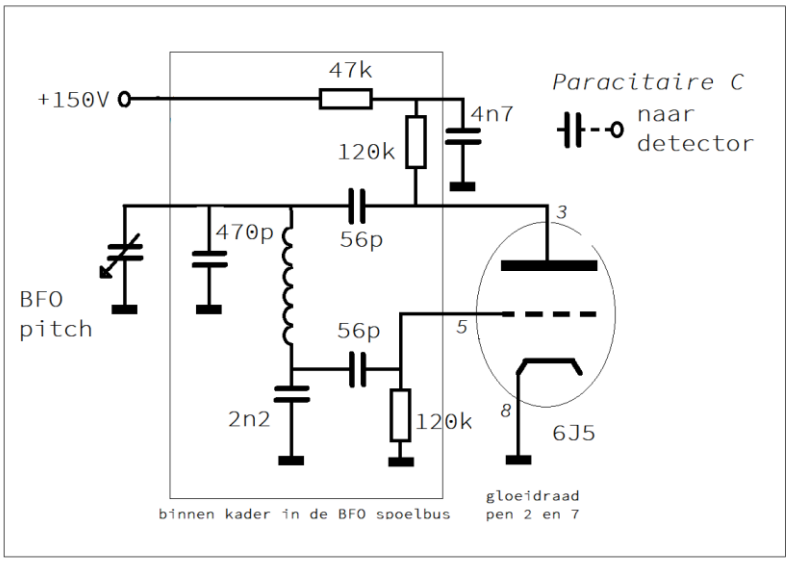
What a beautiful radio, that RCA Victor AR-88! I was allowed to repair one and that is - except for the 50kg that you have to turn over all the time, sigh - a real pleasure!
And then that wonderful tuning knob with fantastic flywheel action: unfortunately you don't have to tune often, because the radio is rock stable. But what a wonderful gear train!
You'll have to turn the tuning knob a long way each of the six bands several times from bottom to top when trimming the set; and also always back... The frequency readout of the tuning dial is not precise, but the repeatability is incredibly good due to the double logging scale.
And that audio that comes out of a good speaker connected to the set, wow!
Great to just listen to broadcasting. Or an AM network.

Arrghhh, but that **low BFO injection**, really a terrible circuit! How did they come up with something like that! Just does not work for me, while the valve does oscillate... And I am not the only one.

The original BFO and detector

Well, that's how they did it in those days, a free-running oscillator with a triode. In the AR-88 that is a steel octal valve, the 6J5. One of these is also in the local oscillator. Such a BFO was then coupled with the IF signal, so that in the detection diode (a 6H6) the CW signal became audible as a difference frequency due to non-linearity. Other products also became audible, namely every strong signal within the IF passage. This not only mixes with the BFO, but also results in a distorted audio signal through the envelope detector, or intermodulates with other components present, if the interfering signal was strong enough. And that was soon the case. Because there is far too very little BFO signal available on the detection diode. After all, if the BFO is linked too strongly with the IF, the frequency of the BFO is pulled along. And that is not allowed. So tighter coupling is no solution.

In the AR-88 the BFO was therefore very loosely coupled: a wire to pin 4 of the 6J5, a pin that has nothing attached to it inside the valve, so purely parasitic. That wire then runs through a short wiring harness to the IF transformer between the 2nd and 3rd IF amplifier. There, too, the wire is connected to an "empty pin" on that IF transformer. The weak BFO signal is boosted a bit by the 3rd IF valve and thus ends up at the detection diode. See figure for the circuit of the original triode oscillator. Al this is a worthless construction! Completely parasitic and undefined! No ISO-9000 so to speak... Both the two coupling capacities (*in* and *out*) and the capacity to ground in the wiring harness. Uncontrollable! If the wires run slightly differently, almost all the signal leaks out there. Or with a valve of a different make, the question is what happened to the undefined pin.



In any case, in the AR-88 on my table, there was no BFO-action on the detector at all, nothing, nada, zero! Although the oscilloscope indicated that the triode did oscillate very well! It took me a while to realize that. At first I thought the BFO itself was broken, so little BFO injection there was. In later series of this receiver, it seems, a "real" capacitor was used in the factory, I think in the vicinity of 2...3pF. But teven hat was not enough in my case either. And the BFO suffered from "pulling" with higher C.

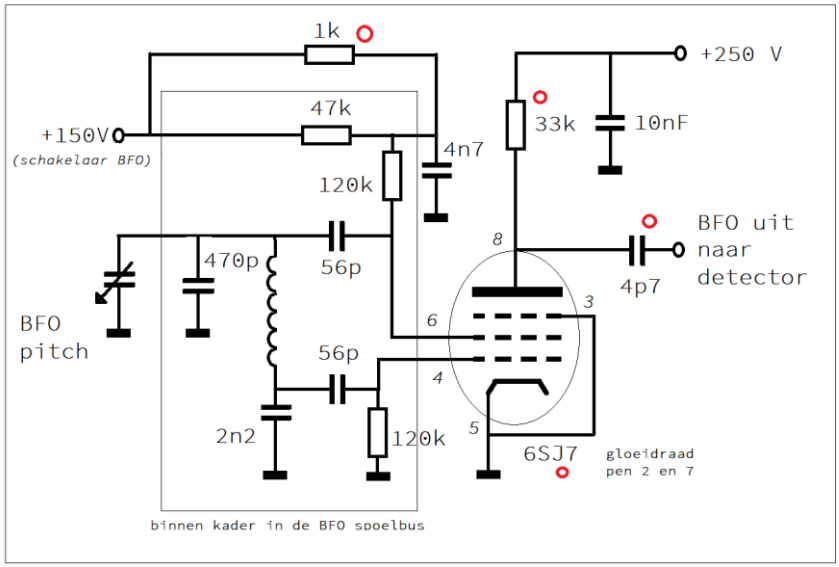
Note: the mixing circuit together with the local oscillator on the RF-deck, also a triode with a 6J5, does work very well. Because a multi-grid mixing valve (6SA7) and a truly defined coupling capacitor are used. The 6SA7 provides good separation between RF and LO signal: no pulling and good mixing.

Some Possible Solutions to the BFO Problem

There are several solutions. **One of them** is to oscillate the BFO at half frequency and then use the second harmonic in the detector. Then you can probably couple without pulling. That was done in the R1155, among others, and it works. So engineers knew of the problem! A disadvantage is that you run more risk of harmonic whistles, because there are now twice as many of them. And you need a lot more BFO signal, the second harmonic is some dB down. That doesn't help against whistles either.

Another possibility is to offer the BFO signal all the way to the input of the IF amplifier via a very small C. At that point, the IF signal is still far too small to pull the BFO. The IF-strip also amplifies the BFO signal. But, if you turn the BFO pitch, the amplitude of the injection signal at the detector changes, because the IF amplifier is selective. And it certainly doesn't get through the crystal filter. And the dynamic range of the IF amplifier is impaired because there is always a strong BFO signal present in the chain. No, this is not a noce solution either.

A third possibility is the use of an Electron Coupled Oscillator, the "ECO". That circuit was well known at the time at the end of the thirties when the AR-88 was developed. It has already been used in the VFOs of transmitters to place an almost free-of-costs buffer between the oscillator and the output stage, often doubling the frequency in the anode circuit. For the ECO, see figure.



The secret of the ECO is that by using a penthode (or, very popular with 6L6 VFO/driver in a MoPa transmitter) you have both the oscillator and the buffer in one valve. The oscillator consists of the triode formed by the *cathode*, the *first grid* as the control grid and the *second grid* as an anode. This "triode" modulates the electron flow to the anode. Between the inner triode (k, g1, g2) and the anode is the supressor grid (g3) which has a little extra shielding effect. So it is actually a disguised cascode of two triodes. The grid of the second triode at RF-ground, provides excellent shielding between the oscilator and the output at the anode. If you include a resistor or chokes in the anode circuit, you get the BFO signal out there. And "what you do there" has much less influence on the

BFO frequency, the first triode section. So you can couple much tighter into the detector diode without the danger of pulling. This works well as a BFO.
(components with red dots are not in the original AR-88)

Why didn't RCA do that? I can think of two reasons, I don't know if they are correct. One of them is that the ECO's circuit may have been known, but it was not used in receivers. In receivers, oscillators were traditionally triodes: "That is the way we do it"... So the circuit was known but people simply did not think of it (?) Another reason may be that the penthode, patented by Philips in 1927, may have been a relatively expensive valve to use because of the rights (?)
But I don't know for sure, none of us were there when this legendary receiver was designed. How nice it would be to have a glance in that kitchen!

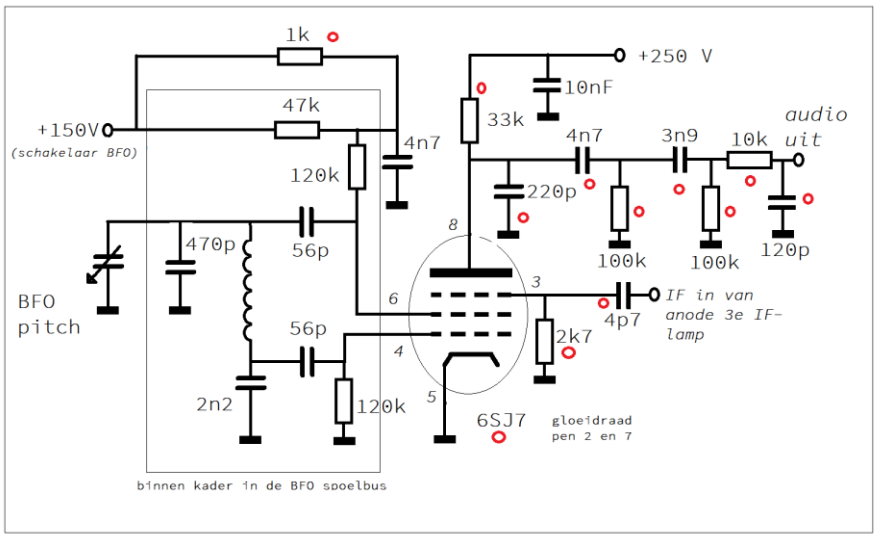
Yet another solution is a crystal-controlled BFO, but that is not just expensive, but also inflexible, you can no longer tune the BFO, which was almost a must in those years back then.

One step further, the product detector !

Just because a circuit is known for one application does not mean that it is thought of for another. An example is the *product detector*. It is a lot better than the BFO/diode combination. Because with a good product detector, you get rid of intermodulation of signals in the diode and AF output by detecting the envelope. All the ingredients for a good product detector were already known. *They are even present in the AR-88 (!!)*, namely the mixer (6SA7) with the local oscillator (6J5). The mixing stage was even often called "first **detector**", how is it possible! But to actually use that as a product detector apparently didn't occur to anyone. We had to wait until well after the Second World War for that.

Even then the Hammarlund SP600 and Racal RA17, both top receivers from the end 1950s, did not have a product detector, allthough they were certainly used for CW. Even while such a product detector has so many advantages: Less distortion, final bandwidth is never more than twice the AF bandwidth, you can completely separate detection and AGC (so AGC is possible for CW and SSB) you can easily keep BFO and IF signal separate. No one had to explain how a mixing valve worked, that was well understood. But they hadn't thought of using it as a product detector at the time. At least, that's what I suspect now.

Let's look at the figure, you'll see the ECO with a 6SJ7 is almost like a product detector. The supressor grid now not only acts as suppressor for secondairy emission electrons, but also as a control grid for the IF signal. There is a small (unwanted) coupling between second and third grid, so between oscillator and IF signal. If you want to reduce that, you could take a 6AS7, which is specially designed as a mixing valve and it just fits in the same base.
I didn't have that valve in the box, but there was this 6SJ7 doing nothing.



Is this circuit new? I don't think so. But I had never seen it built or used as a BFO & product detector in a single pentode. While going from triode to ECO, the idea presented itself to try to offer

the signal to the third grid. It worked. And the nice thing is that you can always return the AR-88 to the old state easily. You don't do anything irreversible.

The result
It works! Pick up the IF signal at the output of the 3rd IF with a small C and feed it to the third grid of the 6SJ7. Place a high and low filter in the anode circuit for the audio signal. And the whole thing sounds amazingly well! Of course you shouldn't add too much IF signal, but it is far better then with the orignal BFO/Diode detector. You got to take back RF-gain on CW/SSB and advance it for AM detection: a AM diode detector requires a large signal. And with 2x RF, 1x mix and 3x IF, there can be a bulky signal there at the output of the 3rd IF amp.

The 2k7 resistor and the 4p7 capacitor ensure that there is not too much signal on the product detector. It is good to experiment with this to your own taste. The 2k7 is also a DC path from the surpressor grid to ground, which is necessary! And the 4p7 capacitor must be able to withstand enough voltage. An old Philips NP0 ceramic tubular C is nice for that.

Switching the audio from the envelope detector (AM) to the product detector (CW/SSB) is done with a relay that was lying around: the thing wanted 110V coil voltage, and you get that via a resistor (value depending on the relay coil resistance) from the 150V supply voltage for the original BFO. So "BFO on" = "pull relay" = "switch audio". All this without an extra switch in the front plate! The 150V also switches on the BFO/product detector at the screen grid, g2.

Everything is made in such a way that it can be built back completely to the original situation in half an hour. If you look at the chassis you don't even see anything special as long as you don't read what is printed on the valve. And the front plate remains completely original. Only underneath the chassis you see some aditional parts. But well, the leaky oil and paper Cs have all been replaced anyway with almost every AR88. I did put a small warning on a sticker on the 6SJ7: "Don't use a 6J5 for the BFO, but a 6SJ7". Best not to accidentally plug in a 6J5.

If you really want to do it right, take a 6SA7 instead of the 6SJ7 and a small LF interstage transformer or choke instead of the resistor in the anode. Then you probably have more audio, even more separation from the BFO and you can work with more IF signal. By the way, if you now turn on the BFO while listening on the AM detector, you hardly hear any detection by the BFO signal on the diode detector. So insulation BFO to the AM/AGC detector is fine. The AGC only responds to the IF signal and not at all to the BFO, while there is enough BFO present in the product detector for an undistorted reception of SSB. *So you get AGC while the BFO is ON, teriffic!*

Hope all this will get many an AR-88 in good CW/SSB condition.

best 73 and warm valve greetings!
Gert,
pa3crc

PS-1: for the real purists and conservators of historical heritage among us: RCA has published a BFO and SSB-AGC conversion for the AR/CR88 series. And transistors, mosfets and diodes were used in it! So that's a real original and official RCA modification, with silicon! But *that* is really too much for me, you have to draw a line somewhere... (even though that RCA mod will probably work very well)

PS-2: on the diagram and in the AR-88 I could not find any fuse. That's scary! But well, electrical safety of most American radios is scary. So I added a line fuse.

PS-3: the RME69, a general coverage receiver that was produced until 1939, does contain an ECO as a BFO! So it was not completely unknown. But yes, that RME69 also has a Lamb Noise Silencer instead of a simple clipping ANL. Those people at RME apparently walked unbeaten paths. But even there, a product detector was just a step too far at the time.

By the way, who has a schematic of the Noise Silencer option for the RME69? Because then I can finally start overhauling this beautiful old receiver.