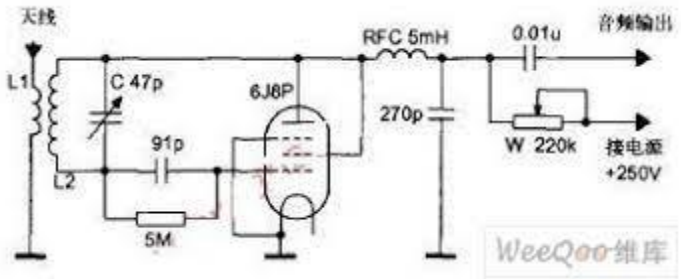
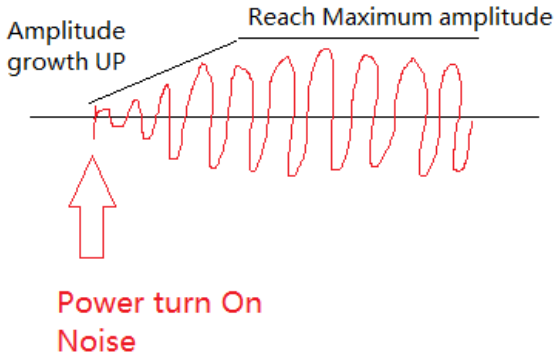
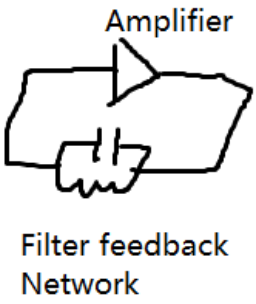
Simple one tube FM super regenerative receiver circuit analysis

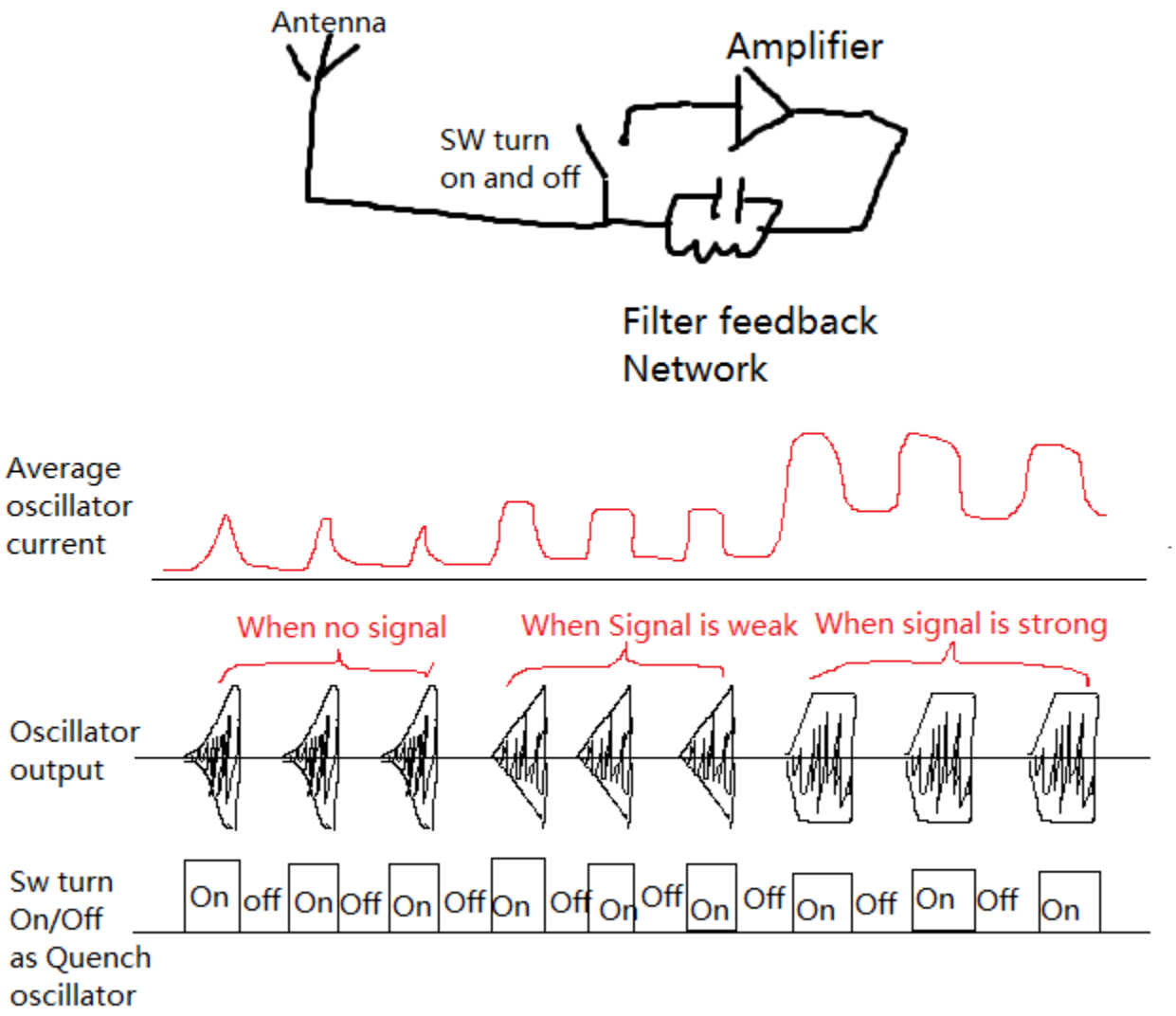


We often found the simple FM super regenerative receive circuit like above. I couldn't find any webpage explain how it work. I did build it it work, but when I try to modify something or change voltage it stop working. So I decide to find out the theory behind.Super regenerative consist of a main oscillator and Quench oscillation which to make the oscillator on and off and the average of the current will be the Audio.

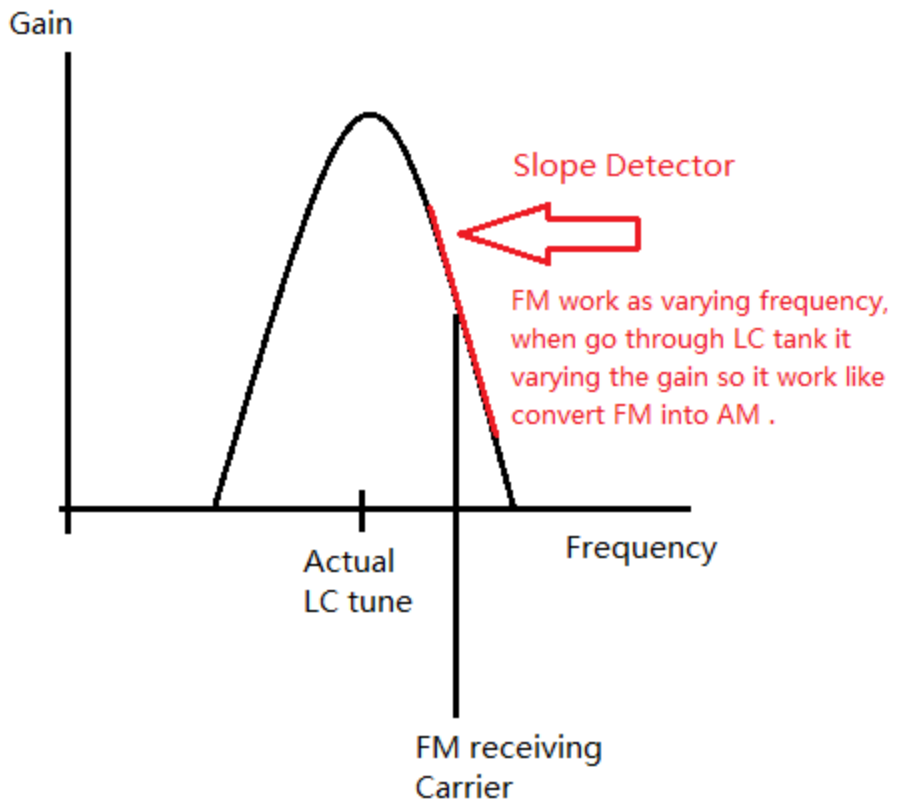




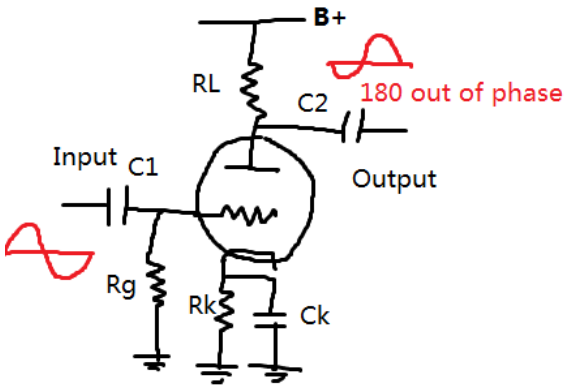
During power turn on, the Random noise will go into amplifier input, and amplifier amplify the signal and go into Filter network to remove all frequency signal except that frequency which resonant with LC tank able to pass and feed into amplifier input and amplify again over again Until the amplitude reach the maximum. The growth up time can reduce either by increase the loop gain or there is external feed in the signal with same frequency as LC tank resonant. When we know that when oscillator stop oscillate the current either close to 0 or with maximum depend the oscillation configure.



Above show a simplified Oscillator and a turn on and off switch as quench oscillator. As we know if there is a signal same frequency feed from antenna the oscillator will growth faster. By turning on and off and measure the average current from oscillator we can know the signal strength. So super regenerative are work on AM (Amplitude Modulation). They can work on FM through the LC tank slope detection.

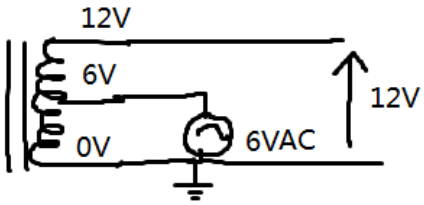


Above show how the Slope detector work, the LC tank convert FM into AM, Since we know FM is Frequency modulation, so the amplitude of carrier should be equal and the frequency is modulate up and down by audio signal. When the frequency modulate go down when close to the LC tank center resonant frequency it the output of amplitude will be larger, when the signal frequency go higher the gain will go lower. So by using LC tank slope detector, can convert FM signal into AM and let the Super regenerative do the high sensitivity AM demodulation.

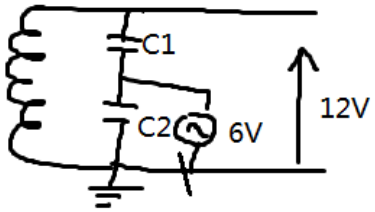


A standard Class A amplifier

Above is a standard class A amplifier, which have a voltage gain. The Rk will provide the bias voltage to set the tube operate at middle and Ck is decoupling act like short circuit for AC signal to Cathode. And Rg will be provide grid bias , since grid always negative so there is no current flow to grid Even Rg is 100K ~1M the voltage across Rg will be 0V. so Rg also act as the input impedance for the previous stage. RL will be the load resistor , it can but plot from Tube characteristic curve. Tube are operate at Voltage control current source, so the gain in gm or know as transconductance which is in mA/V , the number of mA/V will represent 1 volt vary on grid and the amount of current vary on plate. Tube are non-linear device so the gm vary when at different plate voltage. RL is convert the plate current into voltage swing. Theoretically larger RL will get more gain but also it bring down the plate voltage as voltage decrease tube gm also decrease.



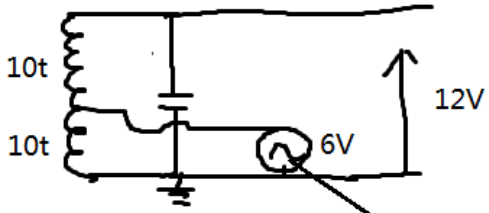
Autotransformer



C1 and C2 are same value

Source frequency are same with LC resonant frequency

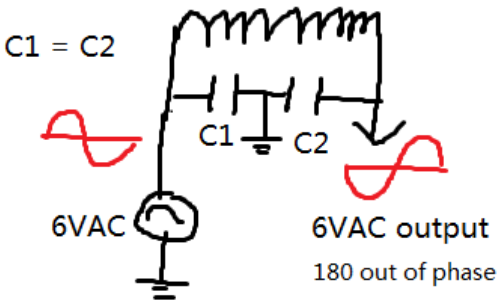
Colpitts Network



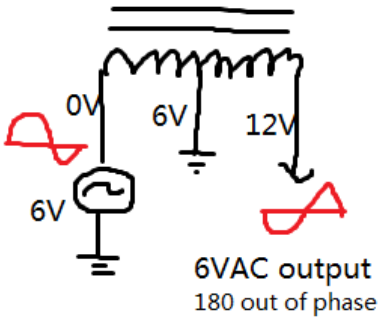
Frequency is same as LC resonant frequency

Hartley Network

Above show the 3 type of step up transformer, the Autotransformer is typical we use in power transformer to step up the voltage like above example. When we 6V input and output we can obtain 12V. Both input and output phase are in phase or same phase. Also we can do same thing for Harley Network, they are same except the source frequency is same as LC resonant, So we can step up with this way as well. For Colpitts network are same as Hartley instead of tap at center tap on coil , it tap the center tap at capacitor. When Both C1 and C2 are same the step up ratio will be 2. The only thing different with coil is the larger then capacitor equal to less turn on coil. When C2 is larger then C1, it make more output voltage. The input and output are in phase or same phase.

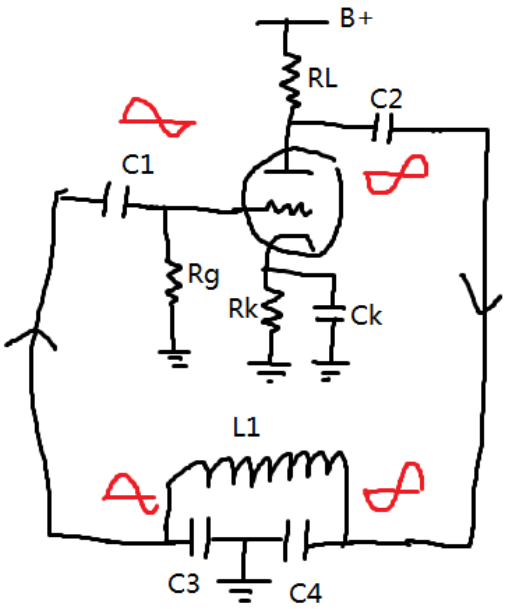


Colpitts Network

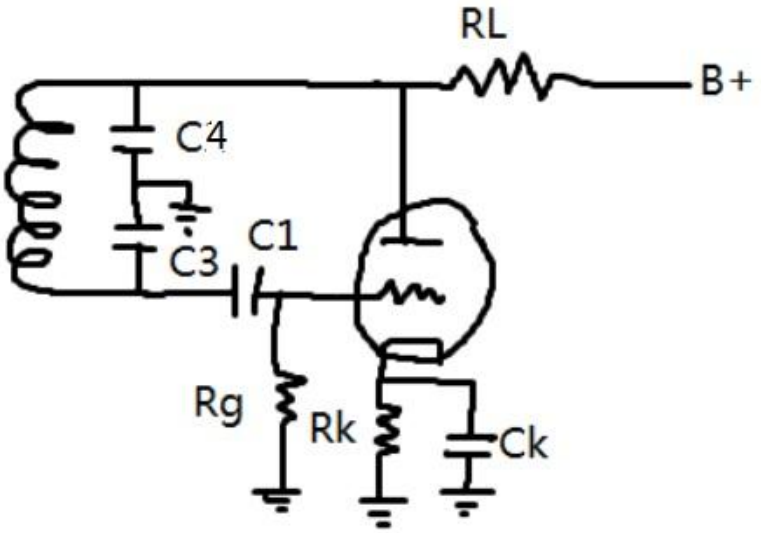


Autotransformer

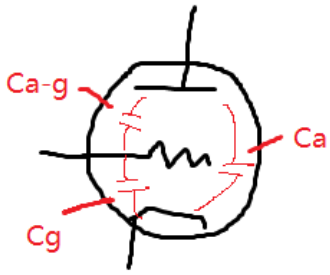
Another way of connection it can also use as Inverting the output, which the input and output is 180 degree out of phase



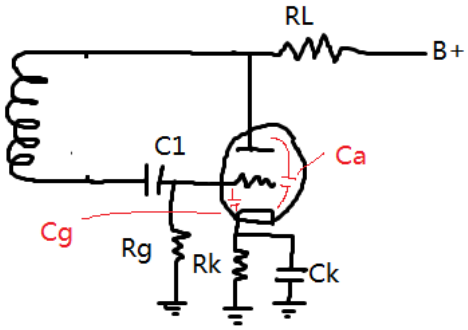
In order to make an oscillator work, We need to have an amplifier to make sure the total loop gain greater then 1 . It can be amplifier have 200 gain and the colpitts network have 0.01 and it sum up the total loop gain is 200 x 0.01= 2 , so 2 is greater then 1 so it will oscillate by amplify the noise can be from 1nV to 2nV to 4nV and so on. Also the total loop phase must be 0 or 360 degree like circuit above the amplifier having 180degree out of phase or phase shifted 180degre and the colpitts network have another 180 phase shifted so total phase shift is 360 degree or 0 degree. With this 2 condition the oscillation will start . The more the loop gain the shorter time it growth to full amplitude, also too much loop gain it will amplify unnecessary phase noise. Sometime when we load it the oscillation stop is due to the loop gain barely to 1 and any load will cause the loop gain less then 1, so we need to make sure to have sufficient. The last thing will be if to oscillate very high frequency need to make sure the amplifier at that frequency still have gain.. because amplifier will suffer from miller effect which act like a single pole Low pass filter. If you design oscillator network at 100Mhz and your amplifier having 200gain at DC and at 100Mhz the gain only 20 and your colpitts network let say attenuate 0.01 at 100Mhz due to Miller effect , then at 100Mhz your loop gain only 20 x 0.01 = 0.2 which is less then 1 the oscillation wont oscillate.



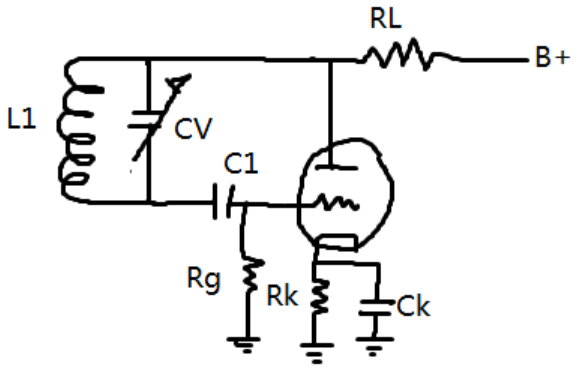
From above colpitts oscillator circuit, we can remove the C2 since we only need C1 to block the Plate voltage go into Grid. So we can further simplified the colpitts oscillator in this way.



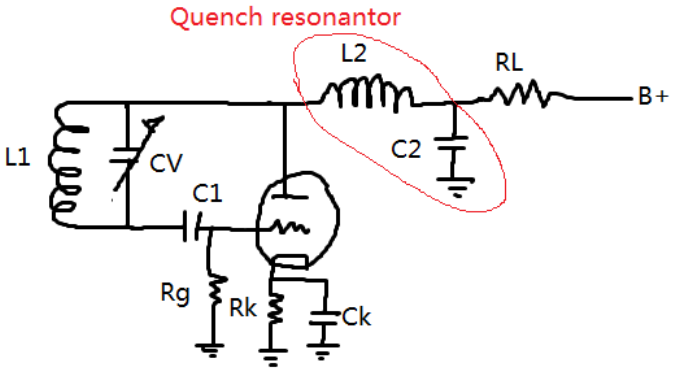
As we know tube having internal electrode capacitor, like above diagram. There is Cg , Ca and Ca-g which is miller capacitance. When C3 can replace by Cg , and C2 can replace by Ca . When C1 and CK is much more larger then Cg and Ca . So the colpitts further simplified.



To make it frequency adjustable add a Capacitor across the inductance , it will act like parallel with C2 and C3 or Cg and Ca.

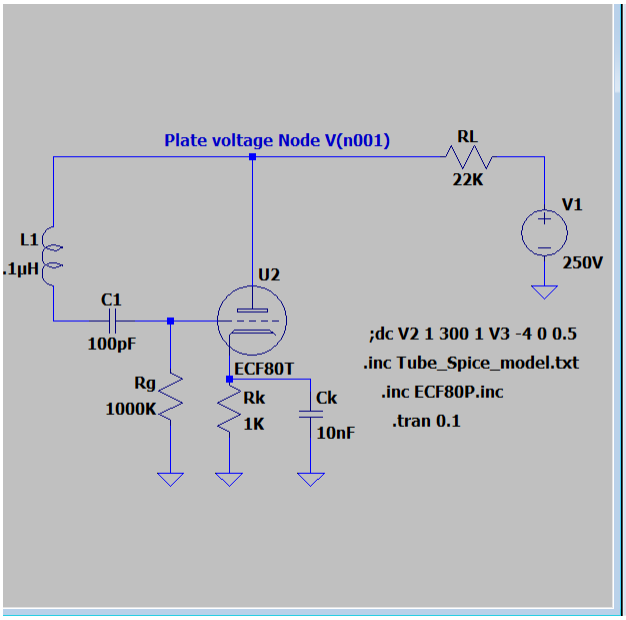


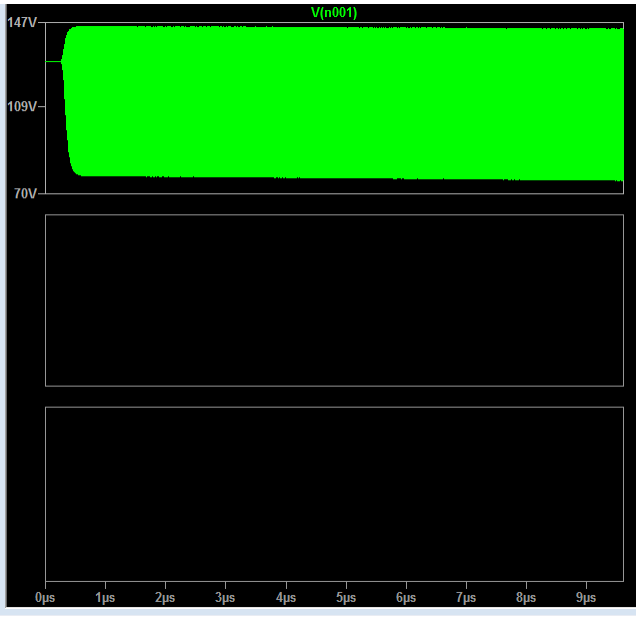
The simplified colpitts oscillator circuit with Variable capacitor show above. As we know Super regenerative need to have Quench oscillation to turn the Oscillator on and off. Above colpitts after turn on power the oscillator will continue oscillate at constant amplitude. We can either make a self-quench oscillation or external-quench oscillation. For here we talk about self-quench type. In order to make it self-quench we need to add a LC tank resonant at plate.



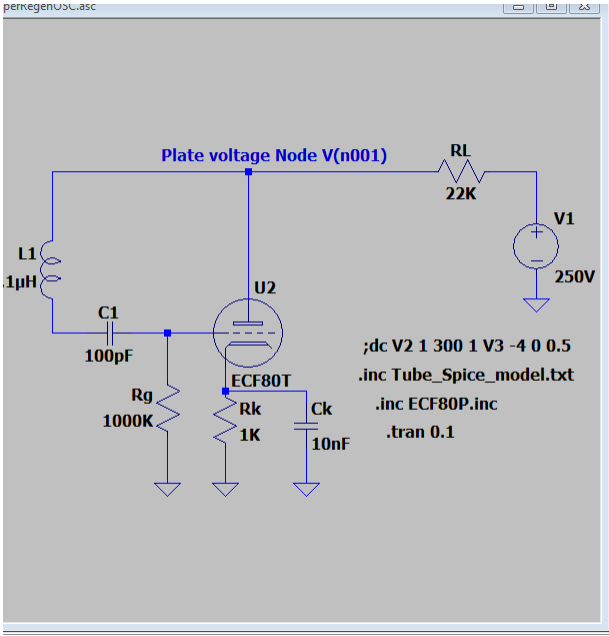
Above circuit show the L2 C2 form a quench LC tank to resonantor. From the first circuit the L2 is 5mH and C2 is 270pF , by using LC resonant frequency formula we can get the frequency is 139.9Khz the quench must oscillate above audio range to prevent noticeable. The first circuit they are remove RK CK to make the tube work in class C and Rg is connect to L1 to give the gird bias in positive to push the tube have more gm gain.. the RL will be the 220K adjustable potential meter .

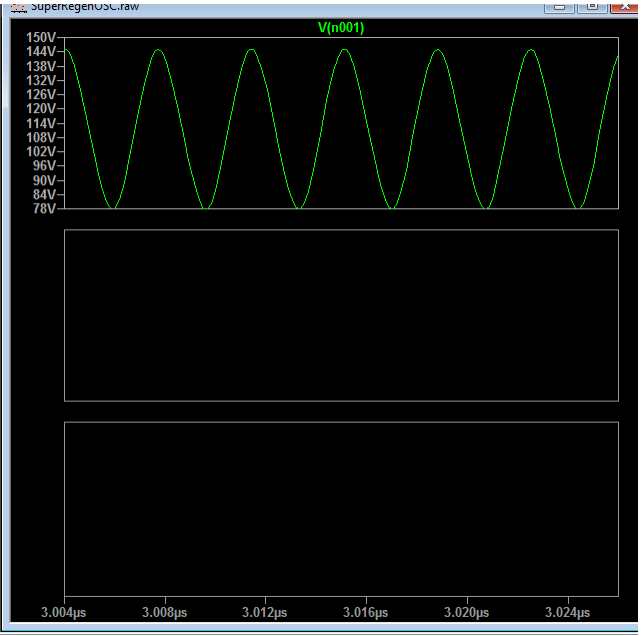
Below showing the simulation from LT spice.





Zoom in plate voltage waveform.





By add in the LC quench .