An Effective Frequency Rejection Circuit

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A novel null-circuit arrangement designed for use as a record-scratch filter in conjunction with a wide-range amplifier.

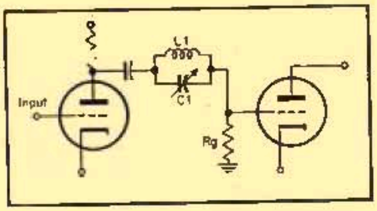


Fig. 1. Tunable rejection circuit which is not particularly sharp, and which offers several constructional disadvantages.

THE SURFACE NOISE heard from the speaker when reproducing a record is a result of a number of factors. The type of pickup, the material and shape of the stylus point, the particle size of the material (especially shellac compounds) used in the record pressing, the surface finish of both the stamper and the pressing made from it, the speaker response curve, the acoustics of the room, and the hearing range of the listener all contribute to the final effect. For any particular combination of these factors, there will usually be some frequency or narrow band of frequencies in the noise spectrum that is both obtrusive and more annoying than the other frequencies.

With the writer's present set-up, these frequencies are centered around 600 cps when playing modern shellac pressings, and the effect is more of a "hiss" than a "scratch". The pickup used is a crystal type with sapphire stylus, which with suitable equalization by an *R-C* network between pickup and amplifier input, has a substantially flat response to 10000 cps, and a usable output up to 12000 cps.

In order to be effective, a scratch filter therefore should be tunable over a range of frequencies. The usual type of tunable rejection circuit shown in *Fig.* 1. and consisting of the tuned circuit L_1C_1 in series with the grid resistor R_g of the following tube, has several disadvantages. Both ends of the inductance and of the variable condenser are isolated from ground, causing both mechanical difficulties and excessive hum sensitivity, while the inductance needs to have a very high Q if a sharp rejection is to be achieved without adversely affecting a wide band of signal frequencies. This requirement makes the filter more expensive than is warranted by the results obtainable. The *R-C* type of circuit such as the twin-T bridge, if it is to be comparable in results with a tuned circuit, requires a multiplicity of variable circuit elements and becomes rather a complex affair.

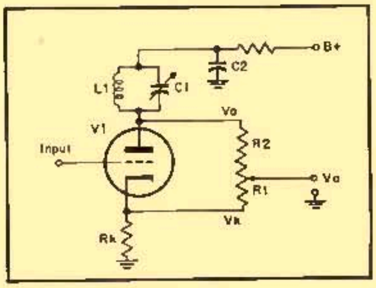
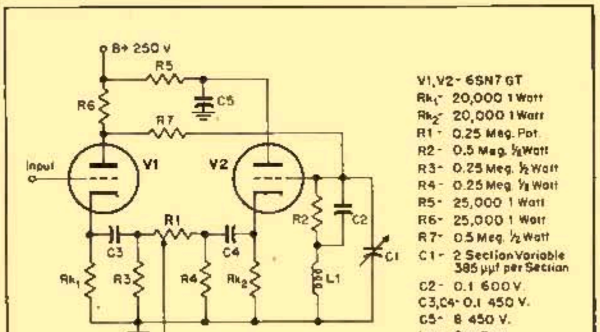


Fig. 2. Circuit arrangement designed to permit adjustment of amount of rejection as well as frequency.

To obviate these difficulties, the following circuit, shown in a basic form in *Fig.* 2, was devised. The tube V_1 has a divided load, the cathode part R_k being resistive and hence having an impedance independent of frequency over the range amplified, while the plate load L_1C_1 is frequency selective. The output signal V_o is taken from the slider of the potentiometer R_1R_2 connected between plate and cathode. At the resonant frequency of L_1C_1, the plate output V_o will be at a maximum, and exactly 180° opposite in phase to the cathode output V_k, so that there will be a point on R_1R_2 that is ground potential, and at this position of the slider V_o will be zero for the resonant frequency. At frequencies far removed from resonance, the plate output will be very small and $V_o = V_kR_2/(R_1+R_2)$ approx. At frequencies slightly above and below resonance, there is a rapid shift of phase angle occurring across a parallel resonant circuit, which considerably sharpens up the rejection curve, so that signal frequencies will be adversely affected only over a narrow band width. The circuit of *Fig.* 2. is not the most suitable for practical application. While the tuning capacitor C_1 can have one end grounded, the L_1C_1 connection being completed via C_2, there is still the plate current of V_1 flowing in L_1, which is also at high d.c. potential to ground. Also, unless R_k is of a high value, there is some output from the plate at lower frequencies, due to the resistive impedance of L_1. Damping of L_1C_1 by the effective anode impedance of V_1 is not serious, due to the negative current feedback effect from R_k, but it is preferable to drive L_1C_1 from an approximation to a constant-current source.

Fig. 3. Preferred circuit for rejection of a desired frequency, arranged for practical construction.



The modified circuit of *Fig.* 3 has a more satisfactory performance, and

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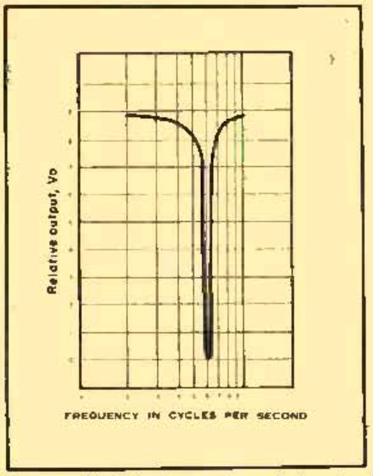

Fig. 4. (A) Relative output of circuit of Fig. 3.

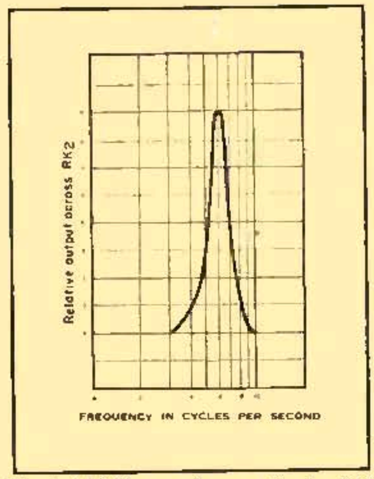

Fig. 4. (B) Output from cathode of V_2 in Fig. 3.

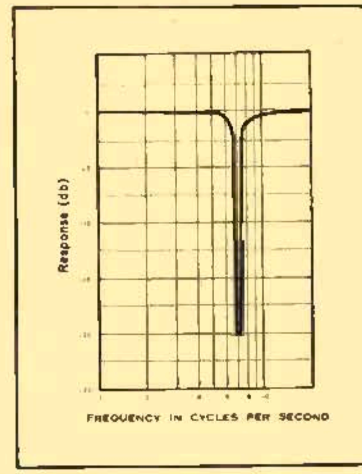

Fig. 5. Response of circuit of Fig. 3, plotted in db.

gives a low impedance feed to both ends of R_1, while both L_1 and C_1 can have one terminal grounded. The components C_3, C_4, R_3, and R_4, though not strictly necessary, are inserted to prevent noiseness of R_1, that may result due to current flow if connected directly between R_{k1} and R_{k2}. The resistors R_6 and R_7 supply grid bias for V_2, while C_2 and all stray capacitances form part of the L_1C_1 circuit. It has not been found necessary to shield L_1 or C_1, there being no audible hum pickup by either component, when the level of the output signal has a maximum of approximately 0.5 volts.

Owing to the non-availability of toroids and such like, so plentiful in the United States, L_1 was made up by winding sufficient turns of No. 30 B. & S. enamelled copper wire on a small alloy core of E and I laminations, assembled in two complete blocks with a 1-mm air gap, to give an inductance of approximately 1.5 H. This coil tunes from 5000 cps upwards with a two-section variable capacitor of 385 µµf per section. Final setting of the frequency range is made by adjusting the width of the air gap in the core. The resulting inductance has a rather low Q, as shown in *Fig.* 4(B), where the resonance curve at 6000 cps of L_1C_1 measured at the cathode of V_2 with R_1 disconnected, is compared with the curve of *Fig.* 4(A) obtained from V_o when R_1 is set to a position of complete rejection for 6000 cps.

The improvement that is possible over a simple LC rejection circuit is well illustrated, the effective Q of the tuned circuit being considerably increased. The higher the Q of L_1, the sharper will be the initial curve for L_1C_1, so that excellent results should be obtainable with a suitable inductance of high Q.

Figure 5 shows the response in db with R_1 set to give a rejection of 20 db at 6000 cps.

If the cathode loaded circuit causes too much drop in signal level, then both tubes can be plate loaded as suggested in *Fig.* 6, V_2 having an unbypassed cathode resistor for degenerative feedback.

It is possible that the employment of negative feedback taken from V_o to a preceding stage would make the rejection band even narrower, but it would require exact setting of the null point, since the output at resonant frequency on the R_{k2} side of the null point is of such phasing as to give positive feedback.

A suggested application of the circuit is the use of it as a frequency-selective element in a negative feedback path to give a peaked amplifier of higher selectivity than would be obtainable with a given L-C circuit, and at the same time retaining the advantage of requiring only one variable circuit element for frequency setting. Such an amplifier could even be made regenerative to give an increased gain and selectivity by advancing R_1 slightly past the null-point and towards R_{k2}.

Operation as a Scratch Filter

The method of adjustment used by the writer is to back off R_1 sufficiently to be able to set C_1 to the required frequency. On either side of the correct setting there is a noticeable accentuation of the "hiss" level, and by slight adjustments of R_1 and C_1, a point can be found where only the lower frequency scratch is apparent.

The effectiveness of the circuit is best judged by setting it to the null point for the most annoying frequency component of the scratch heard when playing a passage recorded at a low level, and then advancing R_1 right to the R_{k1} end, while at the same time keeping the audio level approximately constant by adjustment of the volume control. There will be apparent a quite noticeable alteration in both level and tone quality of the scratch frequencies.

As a non-technical listener remarked, with the unit in operation "the music (especially the violins) seem to ride above the scratch" whereas, without it, the opposite appears to happen, so that the scratch and hiss especially at low levels, are quite dominant.

R_1 can be set finally at any point between the null point and the R_{k1} end, depending on the amount of suppression desired.

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Fig. 6. Arrangement of circuit for greater output of rejection circuit.