

# 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.

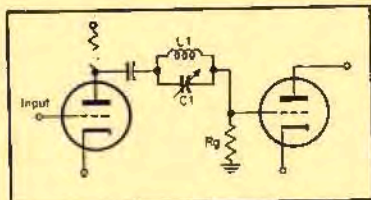


Fig. 1. Tunable rejection circuit which is not particularly sharp, and which offers several constructional disadvantages.

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

tentiometer  $R_1R_2$  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  $180^\circ$  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.

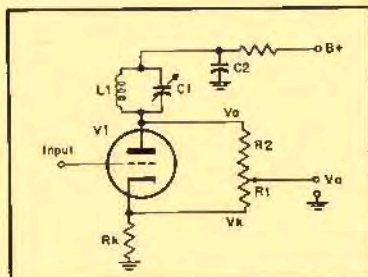
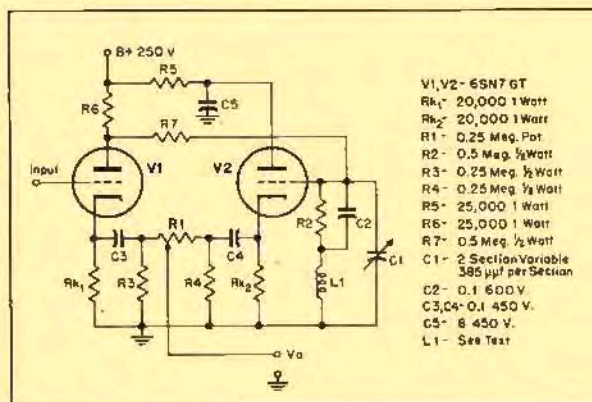


Fig. 2. Circuit arrangement designed to permit adjustment of amount of rejection as well as frequency.

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



- V1, V2 - 6SN7 GT
- Rk<sub>1</sub> - 20,000 1 Watt
- Rk<sub>2</sub> - 20,000 1 Watt
- R1 - 0.25 Meg. Pot
- R2 - 0.5 Meg. 1/2 Watt
- R3 - 0.25 Meg. 1/2 Watt
- R4 - 0.25 Meg. 1/2 Watt
- R5 - 25,000 1 Watt
- R6 - 25,000 1 Watt
- R7 - 0.5 Meg. 1/2 Watt
- C1 - 2 Section Variable 385  $\mu$ f per Section
- C2 - 0.1 600 V
- C3, C4 - 0.1 450 V
- C5 - 8 450 V
- L1 - See Text

of variable circuit elements and becomes rather a complex affair.

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 output  $V_o$  is frequency selective. The output signal  $V_o$  is taken from the slider of the po-

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.

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

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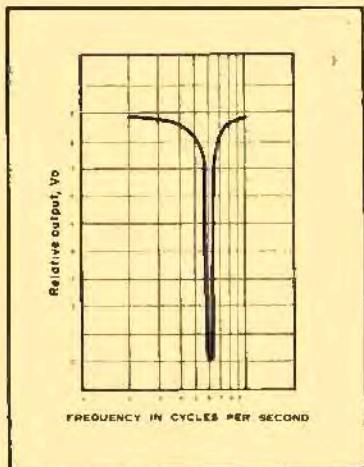


Fig. 4. (A) Relative output of circuit of Fig. 3.

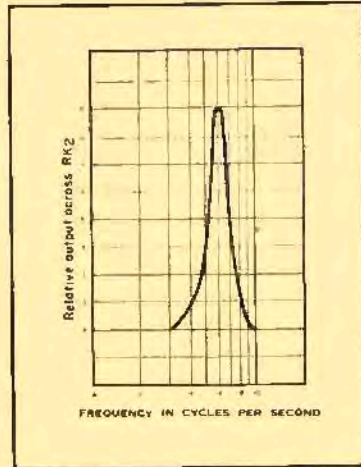


Fig. 4. (B) Output from cathode of  $V_2$  in Fig. 3.

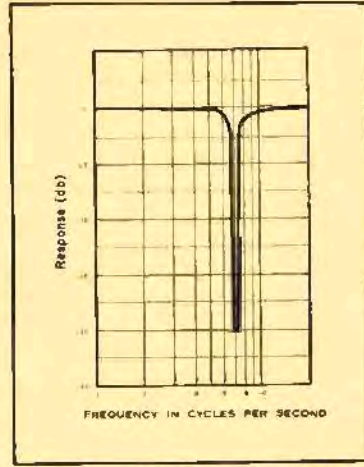


Fig. 5. Response of circuit of Fig. 3, plotted in db.

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  $C_3$ ,  $C_4$ ,  $R_5$ , and  $R_4$ , though not strictly necessary, are inserted to prevent noisiness 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  $\mu\text{f}$  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  $V_0$  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  $V_0$  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  $LC$  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.

