

“Tube” circuit provides linear tuning

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Parallel LC circuits that you tune by changing capacitance have a non-linear frequency-versus-voltage or frequency-versus-shaft-position characteristic. The frequency of an analog-tuned circuit is proportional to the reciprocal of the square root of the tuning capacitance. When you tune a bandwidth that is say, 5% or less of the center frequency, the fre-

quency-versus-capacitance over this limited band is essentially linear. Because the frequency is proportional to capacitance, it's desirable to have a linear capacitance-versus-shaft-position or capacitance-versus-voltage characteristic. A mechanical variable capacitor can provide a linear capacitance-versus-rotation characteristic. However, mechanical tuning capacitors are

expensive and large and have limited reliability.

You frequently use varactor diodes for voltage control of capacitance. But their capacitance-versus-voltage characteristic is approximately logarithmic, not linear. In the days of vacuum tubes, designers used reactance-tube circuits for automatic frequency control in FM receivers and for

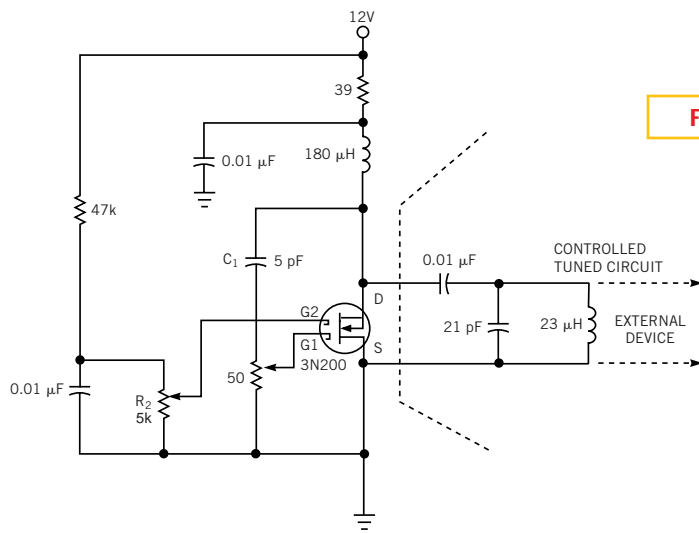


Figure 1

Use Grandpa's circuit without a filament to heat the room for linear frequency tuning in a regenerative radio receiver.

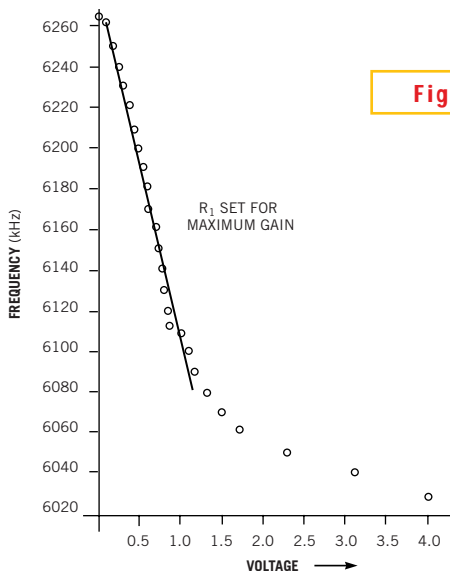


Figure 2

The frequency-versus-voltage characteristic is linear when you use voltage control in Figure 1's circuit.

modulating FM transmitters. It's possible to make the capacitance of the circuit proportional to the transconductance (g_m) of the tube. Over a certain bias range, the tube's g_m is proportional to the grid bias voltage. You can build such a reactance circuit using FET or bipolar transistors (Figure 1). The current in the drain circuit is in quadrature with the drain voltage because of the feedback elements R_1 and C_1 . As a result, the drain circuit emulates a capacitor.

You can control the capacitance using voltage, via potentiometer R_2 , or by adjust-

ing R_1 's shaft position. (You should set the unused potentiometer to maximum.) The L and C values in this controlled tuned circuit are chosen for a frequency range in the vicinity of the 49m short-wave band. The controlled LC circuit serves to tune a regenerative-type receiver. The tuning dial for this radio is linear—a feature uncommon in analog receivers. A modern version of the regenerative receiver can

provide performance comparable with that of a simple superheterodyne receiver. Regenerative receivers are unique in that they require only one LC resonant tuning circuit. A superhet requires at least two resonant circuits that must track each other as you tune the receiver.

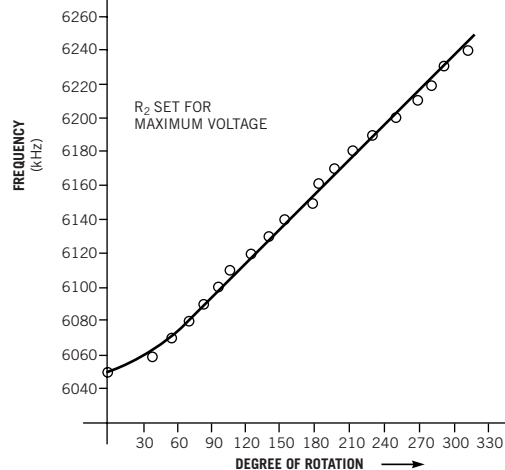
You can change the frequency band of a regenerative receiver by switching a single two-terminal inductor. You could also use Figure 1's controlled tuned circuit to tune an RF amplifier, a filter, or an oscillator. The reactance circuit

produces a maximum capacitance of $C_R = g_m \times R_1 \times C_1$. R_1 is the total resistance of potentiometer R_1 . The reactance of C_1 should be much larger than R_1 at the frequency of interest: $X_{C1} \gg R_1$. Figure 2 shows the result of using voltage tuning via potentiometer R_2 . The curve is linear from 0.1 to 1.3V. The change in frequency that accrues in this voltage range is 6.2 to 6.07 MHz for a 190-kHz bandwidth.

Figure 3 shows the results of shaft tuning. The bend at the lower end of the curve comes from the potentiometer characteristic. The curve is linear throughout the entire tuning range, which is 210 kHz wide. In the reactance-“tube” circuit, it's desirable to use a transistor with high output impedance. In this respect, a pentode vacuum tube with an output impedance of approximately 750 kV is superior to a transistor. However, MOSFETs have a considerably higher g_m than tubes. The transistor's g_m determines the amount of change in capacitance that is possible. The maximum g_m of a 3N200 MOSFET is 15,000 μmho , and the output impedance is 13 kV. (DI #2267).

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Figure 3



A rare feature in analog receivers, shaft (dial) angular position is linear with respect to frequency.