Optimization of the L_D/L Ratio of a Selectivity-Enhanced Germanium-Detector Crystal Radio

Ramón Vargas Patrón
rvargas@inictel-uni.edu.pe
INICTEL-UNI

Our article *"On the Reduction of Detector Diode Losses in a Crystal Radio"* described a simple feedback technique for reducing the zero-crossing conductance of a germanium crystal diode. The present report will show how to maximize the signal voltage across the diode at resonance while still maintaining improved selectivity. This will also give maximum detected audio output from the receiver.

Under the assumption $A_1 \omega L_D \left(1-k^2\right) << 1$ the aforementioned article showed that:

$$I_{IN}\left(j\omega_R\right) = V_A\left(j\omega_R\right) \cdot \left[A_1 \left(1 - \sqrt{\frac{L_D}{L}}\right)^2 + \frac{1}{R_L} \right] \qquad \ldots(1)$$

where $\omega_R = 2\pi f_R$ is the radian resonant frequency of the tuning tank.

The diode's anode-cathode voltage drop is:

$$V_A\left(j\omega_R\right) - V_K\left(j\omega_R\right) = V_A\left(j\omega_R\right) \cdot \left(1 - \frac{M}{L}\right)$$

$$= V_A\left(j\omega_R\right) \cdot \left(1 - \sqrt{\frac{L_D}{L}}\right)$$

assuming a coupling coefficient $k \approx 1$.

Substituting Eq.(1) into the expression for the diode's voltage drop we obtain:

$$V_A\left(j\omega_R\right) - V_K\left(j\omega_R\right) = I_{IN}\left(j\omega_R\right) \cdot \frac{\left(1 - \sqrt{\frac{L_D}{L}}\right)}{\left[A_1 \left(1 - \sqrt{\frac{L_D}{L}}\right)^2 + \frac{1}{R_L} \right]}$$

$$= I_{IN}\left(j\omega_R\right) \cdot R(x) \qquad \ldots(2)$$

where $x = \sqrt{\frac{L_D}{L}}$. We call *R(x) the detector diode's transfer resistance at carrier frequencies*.

Maximizing expression (2) will yield stronger detected RF currents. Therefore, optimization of the $\frac{L_D}{L}$ ratio of the receiver proves itself a necessary task.

A typical graph for *R(x)* is shown in Fig.1, where sample values for A_1 and R_L have been chosen as $\frac{1}{A_1} = 40k$ *ohms* and R_L = *100k ohms*. The independent variable $x = \sqrt{\frac{L_D}{L}}$ takes values between zero and unity. A maximum in the graph may be seen to occur at:

$$x = x_M = 1 - \frac{1}{\sqrt{A_1 R_L}} \qquad \ldots(3)$$

that is, at $x_M = 0.3675$.

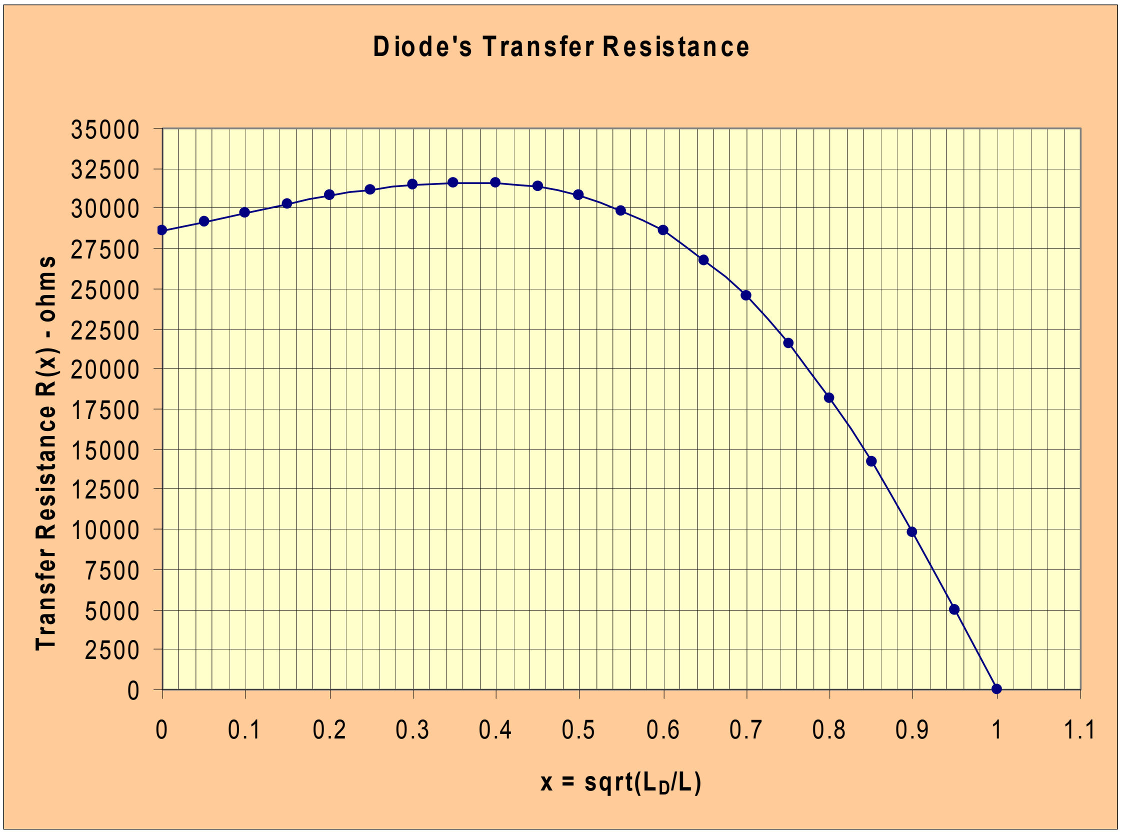

Fig.1 Typical diode transfer resistance graph when $A_1 = \frac{1}{40}$ *mmhos* and R_L= *100kΩ* .

This is exactly the value of x for which the modified zero-crossing conductance of the diode equals the conductance of the tuned circuit at resonance, according to the maximum power transfer principle, i.e., :

$$A_1(1-x)^2 = \frac{1}{R_L} \qquad \ldots(4)$$

or:

$$x_M = 1 - \frac{1}{\sqrt{A_1 R_L}}$$

$$= \sqrt{\frac{L_D}{L}}_{\,OPTIMUM}$$

The maximum of the curve in Fig.1 is given by:

$$R(x_M) = \frac{(1-x_M)}{A_1(1-x_M)^2 + \dfrac{1}{R_L}}$$

$$= \frac{\dfrac{1}{\sqrt{A_1 R_L}}}{A_1\left(\dfrac{1}{A_1 R_L}\right) + \dfrac{1}{R_L}} \qquad \ldots(5)$$

$$= \frac{1}{2}\sqrt{\frac{R_L}{A_1}}$$

For the said sample values of A_1 and R_L, $R(x_M) = 31.623k\ ohms$. The net parallel resistance across the tuning tank at resonance is $R_{NET} = \frac{R_L}{2} = 50k\Omega$.

Ramón Vargas Patrón
rvargas@inictel-uni.edu.pe
Lima-Peru, South America
May 25nd 2009