FM – TUNER

Stereo MPX decoder
SCA demodulator

Prof. Yosef PINHASI
The tuner is aimed at receiving commercial FM radio stations broadcasting at the VHF band 88-108MHz. It enables detection of the frequency modulated signals including decoding of stereophonic transmissions and also Subsidiary Communications Authorization (SCA) signals.

The RF stage shown in Figure 1, consists of a broad-band low-noise amplifier (LNA), based on the MPSH10 high frequency bipolar transistor, and followed by the balanced mixer NE602 (or today – SA602). The fundamental parameters of the front-end transistor MPSH10 of the LNA are $\beta = 60, f_T = 650MHz, V_{BE} = 0.6V$ at collector current of $I_C = 1mA$. The bias circuit are the resistors $R_C = 300\Omega$ and $R_E = 10\Omega$ at the collector and emitter respectively and the feedback resistor $R_F = 47K\Omega$ between the collector and base. The emitter current is found from the formula:

$$I_E = \frac{V_{CC} - V_{BE}}{R_F + R_C + R_E} = 10.56mA$$

The collector current is thus $I_C = \beta \cdot I_E / (1 + \beta) = 10.38mA$ and its voltage is $V_C = R_c \cdot I_c = 8.835V$. The small-signal parameters of the hybrid-$\Pi$ model at the quiescent point are:

$$g_m = \frac{I_C}{V_T} = 415mS$$

$$r_x = \frac{\beta}{g_m} = 145\Omega$$

$$C_z \approx \frac{g_m}{2\pi \cdot f_T} = 102pF$$
Substituting these parameters in the expression for the small-signal voltage gain results in:

\[
A_v = \frac{V_{out}}{V_{in}} = \left[ \frac{g_m}{1 + \left( g_m + \frac{1}{Z_p} \right) \cdot R_F} - \frac{1}{R_F} \right] \cdot \frac{R_F R_C}{R_F + R_C} = -12
\]

The input impedance is calculated using:

\[
Z_{in} = \frac{V_{in}}{I_{in}} = \left[ \frac{1}{Z_p + (1 + g_m Z_p) \cdot R_E} + \frac{1 - A_v}{R_F} \right]^{-1} = \left[ Z_p + (1 + g_m Z_p) \cdot R_E \right] \parallel \frac{R_F}{1 - A_v}
\]
The LNA is coupled to the following mixer IC SA602 via impedance matching network composed of two $C_1 = C_2 = 30\, pF$ capacitors and a coil:

$$L = \frac{1}{\left(2\pi f_0\right)^2 \cdot \frac{C_1 C_2}{C_1 + C_2}} = 169\, nH$$

At $f_0 = 100\, MHz$, the networks transforms the $R_c = 300\, \Omega$ impedance to:
as of the input impedance of the SA602.

![Matching Network](image)

**Figure 2:** The matching network between the LNA and mixer.

The mixer circuit in the NE602 down converts the RF signal to an intermediate frequency (IF) of \( f_{IF} = 10.7\text{MHz} \). The tuning of the local oscillator frequency is voltage-controlled by a 100K\( \Omega \) potentiometer. The VCO is built in a Colpitts configuration with components as summarized in Table 1. The oscillator frequency is calculated by:

\[
f_{LO}(V) = \frac{1}{2\pi \sqrt{L_0 \left[ C_V(V) + \frac{C_1C_2}{C_1 + C_2} \right]}}
\]

The frequency of the received radio station is given by \( f_{RF}(V) = f_{LO}(V) \pm f_{IF} \) and shown in Figure 3. The range of the tuning voltage should be set with the two 100K\( \Omega \) trimmers to be between 5.5V to 19V.
Table 1: Components of the voltage-controlled oscillator.

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>10</td>
<td>pF</td>
</tr>
<tr>
<td>C2</td>
<td>10</td>
<td>pF</td>
</tr>
<tr>
<td>C3</td>
<td>1000</td>
<td>pF</td>
</tr>
<tr>
<td>C4</td>
<td>0.8</td>
<td>pF</td>
</tr>
<tr>
<td>L3</td>
<td>0.274</td>
<td>μH</td>
</tr>
<tr>
<td>f1f</td>
<td>10.7</td>
<td>MHz</td>
</tr>
</tbody>
</table>

V C(V) [V] [pF]

| 3 | 8 | K = 16.407663 |
| 25 | 2 | a = 0.6538312 |

V C(V) f(V) [V] [pF] [MHz]

| 7.39 | 4.4371073 | 103.7 | V1/V2 = 0.5121275 |
| 14.43 | 2.8647207 | 114.7 | C1/C2 = 1.5488796 |

Ctotal 4.2 pF f1/f2 = 0.9040975

Figure 3: Received signal frequency as a function of the tuning voltage.
The IF stage and detector is based on the CA3089 (or its equivalent TDA1200) FM radio IF system. The electronic scheme of the IF circuit is shown in Figure 4. Note that the differential 741 amplifier is provided for an Automatic Frequency Control circuit is also shown but not used in this application. A photo of the board of the RF front-end and the IF demodulator is shown in Figure 5.

Figure 4: IF and FM quadrature detector.
The spectrum of the demodulated multiplexed (MPX) signal is shown in Figure 5. It is composed of the monophonic L+R signal at base-band, the 19KHz pilot tone, the double-side band modulated L-R signal at 38KHz, the Radio Data System (RDS) 1187.5BPS data at 57KHz and the Subsidiary Communications Authorization (SCA) FM signal at 67KHz. The decoding of the MPX stereophonic broadcast is carried out by the MC1310 (or NTE801) FM stereo demodulator, and the SCA broadcast is demodulated with the NE565 PLL, as illustrated in Figures 6 and 7.

The layout of the components is shown Figure 8.
Figure 5: The spectrum of the MPX signal of the FM demodulated radio broadcast.

Figure 6: Stereo MPX decoder and SCA demodulator.
Figure 7: The MC1310 stereo MPX decoder system.
Figure 8: Inner look at the tuner layout.