97.455 Exam Solutions for 2001

Note: 97.455 2001 Final Exam Questions have been corrected so make sure you download the latest version on my web page

Question 1 $Yin = 0.1m + j1m$, BW = 100kHz, $f_o = 1$ MHz.

a) R=10 kΩ and C=159.155pF.

b) $\frac{N_1}{N_2} = 0.0707$, $R_{TOT} = 5k$, $C_{TOT} = 318.310$ pF, $C_{ADD} = 159.155$ pF, $L = 79.577\mu H$.

c) If $Q_L = 100$, $R_p = \omega L \times 100 = 50k$, center frequency remains the same but bandwidth increases to 110 KHz (10%).

d) L=112.26 μH and C=65.36 pF.

Question 2

a)

- Filter 1 BW $\geq$ 19.8 MHz, f_0 at 98.1 MHz
- Filter 2 BW $\simeq$ 0.2 MHz, f_0 at 10.7 MHz
- $f_{LO} = f_{RF} + 10.7$ MHz, nominal 108.8 MHz.

b) Image frequency is $f_{RF} + 2f_{IF} = 119.5$ MHz, Any signal or noise at this frequency will also mixed down to our frequency of interest. The image reject filter removes it.

c) Adjacent channels are also mixed down tot the 10.7 MHz region e.g. 89.9 - 10.0 and 98.3 to 10.5 MHz. IF filter removes these.

d) Intermodulation by any two frequencies with Δf between them where one is Δf away fro the RF signal. e.g. At Δf and $2\Delta f$ away e.g. 98.3 and 98.5 MHz, remove by making circuit linear.

Question 3

a) RF input need to be more linear than the LO input to avoid intermodulation of multiple RF inputs. LO is a known frequency and harmonics can help switching. High linearity can be achieved by degeneration resistance in series with emitters as shown in class. Linearity estimated from $V_{max} = i_{bias} \cdot (R_E + r_e)$.

b) Two signals added amplitude A,B. A=4 and B=1, $f_A = 2$ MHz and $f_{mod} = 50$ kHz. separated by $2f_{mod}$ e.g. signals are $f_c \pm 2f_{mod}$ where f_c is suppressed. so 2 MHz and 2.1 MHz or 1.90 MHz and 2 MHz.

Question 4 Conducts for 10 μs , off for 40 μs, $I_{peak} = 10$ mA, $V_{CC} = 10$ V, n=2.

a) $\Theta = \frac{\pi}{5} = 36^o$, T = 50 μs, input frequency is 40 kHz.

b)$I_p = 52.36$ mA, $I_{DC} = 1.3244$ mA, $P_{DC} = 13.244$ mW, $I_2 = 2.2564$ mA, $P_{2,max} = 11.2821$ mW.

c) $\eta_{max} = \frac{P_2}{P_{DC}} = 85.19\%$

Question 5 PLL for LO generation for FM receiver

Need $f_{RF} + f_{IF}$ or (88.1 - 107.9 MHz) + 10.7 MHz in steps of 200 kHz or 98.8 - 118.6 MHz in steps of 200 kHz.

a) Block Diagram (Done in class)

b) Choose $\xi = 0.707$, then settling time is $\omega_n t \approx 4.5$

$$\omega_n = \frac{4.5}{t} = \frac{4.5}{1m} = 4500\, rad/sec$$

c) Channel at 98.1 has $f_{LO} = 108.8$, or N=544 switching to N=545 for 200 kHz step of 200 kHz/545 = 366.97 Hz or 2305.76 rad/sec. Phase error from graph is peak at:

$$\frac{\epsilon}{\frac{\Delta\omega}{\omega_n}} = 0.46 \;\; or$$

$$\epsilon = 0.46 \times \frac{\Delta\omega}{\omega_n} = 0.46 \times \frac{2305.76}{4500} = 0.2357 \;\; rad$$

Will lose lock if $\epsilon = 2 \cdot \pi$ for three state detector.

$$\Delta\omega = \frac{\epsilon\omega_n}{0.46} = \frac{2\pi \times 4500}{0.46} = 61465.9 \;\; rad\,\text{sec} = 2\pi \times 9782.6 \;\; Hz$$

At output 544 times higher on $2\pi \times 5.32$ MHz.

d) $\omega_n = \sqrt{\frac{K}{N\tau_1}}$ or $\tau_1 = \frac{K}{\omega^2 N} = \frac{0.4 \times 2\pi \times 10M}{4500^2 \cdot 545} = 2.277 \;\; ms$

$\xi = \frac{\omega_n \tau_2}{2}$ or $\tau_2 = \frac{2\xi}{\omega_n} = \frac{2 \times 0.707}{4500} = 314.2 \,\mu s$

e) Plot and explanation already done in class

Question 6

$N_{o,add} = 0.5 N_{o,src}$ given.

$F = \frac{N_{o,tot}}{N_{o,src}} = \frac{N_{o,src} + N_{o,add}}{N_{o,src}} = \frac{N_{o,src} + 0.5 \cdot N_{o,src}}{N_{o,src}} = 1.5$

$NF = 10 \cdot log_{10}(1.5) = 1.76$ dB.

Question 7

a) Open Loop gain larger than 1 at 0^o point.

- Moves C.L. poles into RHP which guarantees startup and oscillation with finite (nonzero) amplitude.
- Aiming for exactly gain of 1, small oscillating amplitude at best, at worst errors may make it marginally stable.

b) Function of crystal: behave like an inductor, replace an inductor in an oscillator. inductor over narrow frequency range only.
Advantages: very narrow frequency of operation, precisely defined frequency, low noise, drift, and simple.