CARLETON UNIVERSITY

FINAL
EXAMINATION
April 2012

DURATION 3 HOURS — No. of Students 7

Department Name & Course Number: Electronics ELEC 5705
Course Instructor(s): Prof. John W. M. Rogers

AUTHORIZED MEMORANDA: Calculators, Course Notes

Students MUST count the number of pages in this examination question paper before beginning to write, and report any discrepancy immediately to a proctor. This question paper has 5 pages.

This examination question paper MAY **be taken from the examination room.**

Information and Instructions:

1. Attempt all questions.
2. Show all analysis.
3. The exam marks total 100.

Potentially Useful Equations:

$$v_{DS\ Sat} = v_{GS} - V_T,\ V = IR,\ C = \frac{q}{V},\ i_D = \frac{1}{2}(\mu C_{ox})\left(\frac{W}{L}\right)(v_{GS} - V_T)^2$$

$$v_{DS\ Sat} = v_{GS} - V_T = \sqrt{\frac{2 i_D}{\mu C_{ox}}\left(\frac{L}{W}\right)},\ E = mc^2,\ c = \frac{1}{\sqrt{\mu\varepsilon}}$$

$$r_{DS} = \frac{1}{\lambda I_{DS}},\ i_{nd}^2 = 4kT\left(\frac{2}{3}\right)g_m,\ \text{kT} = 4\cdot10^{-21}\text{W/Hz at T=290K, q} = 1.6\cdot10^{-19}\text{C}$$

$$g_m = \sqrt{2\mu C_{ox}\left(\frac{W}{L}\right)I_{DS}},\ \Gamma = \frac{Z_L - Z_o}{Z_L + Z_o},\ \nabla \times \vec{E} = -\mu\frac{\partial \vec{H}}{\partial t}$$

$$a = \frac{dv}{dt} = \frac{d^2x}{dt^2},\ Money = Power = VI = I^2R = \sqrt{Evil},\ R_{on} = R\cdot\frac{L}{W}$$

$$\alpha = \frac{1}{(1+\Delta A)\cos(\phi_e)},\quad \Delta A = \frac{-2(Q_d Q_{im} + I_d I_{im})}{I_d^2 + Q_d^2},\quad \phi_e = 2\tan^{-1}\left[\frac{Q_d I_{im} - I_d Q_{im}}{Q_d^2 + I_d^2}\right]$$

$$\beta = -\tan(\phi_e)$$

Question 1 (Total 25 Marks)

(a) A nonlinear amplifier with $k_1 = 1$, $k_2 = 0$, and $k_3 = 0.01$ is driven with:

$$v_{in} = \cos\left[2\pi \cdot (10\ MHz\ )t\right] + 0.8\cos\left[2\pi \cdot (11\ MHz\ )t\right]$$

Make a plot of amplitude versus frequency and plot all the components that come out of this amplifier.

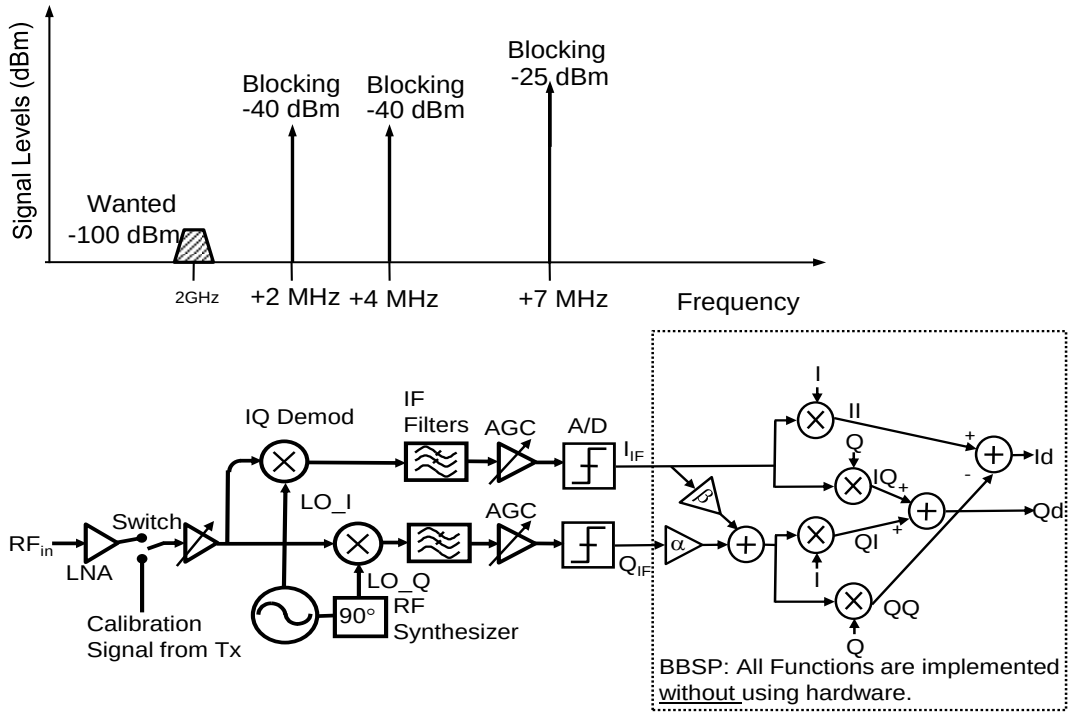
(b) A 2GHz VCO has a phase noise that falls at 20dB/decade. The phase noise of this VCO is measured to be -70dBc/Hz at 100kHz offset and the amplitude is $1V_{rms}$. The VCO (which can drive 50Ω) is attached to an amplifier with a noise figure of 20dB and a gain of 1. Sketch the phase noise profile that would be measured at the output.

(c) A signal is modulated with 16QAM and has an RF bandwidth of 10MHz. If the received power level is -80dBm what is the BER? What is the data rate?

(d) A receiver is using two antennas and is listening to a transmitter. The losses from the transmitter to antennas 1 and 2 are $\gamma_1 = 0.01$, and $\gamma_2 = 0.01j$. The transmitted power is 1mW. In the bandwidth of the signal 1μW of noise is received by each antenna. Use maximal ratio combining to achieve the best possible SNR for this link.

Question 2 (Total 25 Marks)

The following signals are fed into a low IF radio receiver. The bandwidth of the signal is 100kHz.

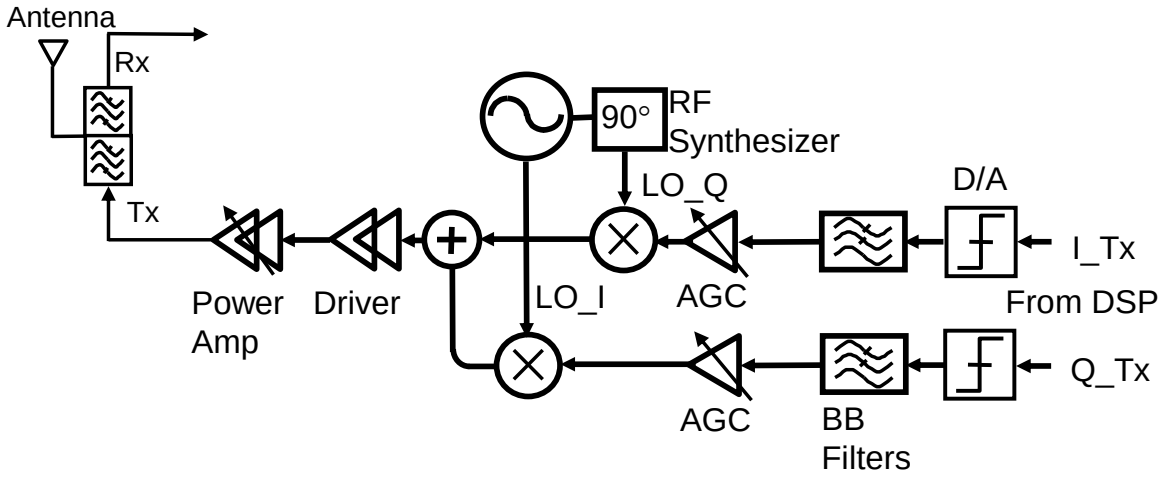


You must design the components of the radio to deliver a signal to the base band with a SNR of at least 20dB. The IF is chosen to be 1MHz. Reading the baseband output data during a calibration test it is found that: I_d = -0.445, Q_d = 1.488, I_{im} = 0.151, Q_{im} = -0.0326. In order to do this fill in the following table at a minimum:

Component	Parameters
LNA	Gain: 15 dB NF: _____dB IIP3: _____dBm
RF Mixer	Voltage Gain: 3 dB NF: 10 dB IIP3:_____dBm
IF Filter	Insertion Loss: 0dB Passband: 1MHz Bandwidth: 200kHz Attenuation at 2MHz offset: 30dB Attenuation at 7MHz offset: 80dB
IF Amplifier	Voltage Gain: _____ dB NF: 15 dB IIP3: _____dBm
ADC	Input voltage: 1Vpp Sampling frequency: 10MHz Number of Bits: 10
Base Band Settings	α= _____ β= _____

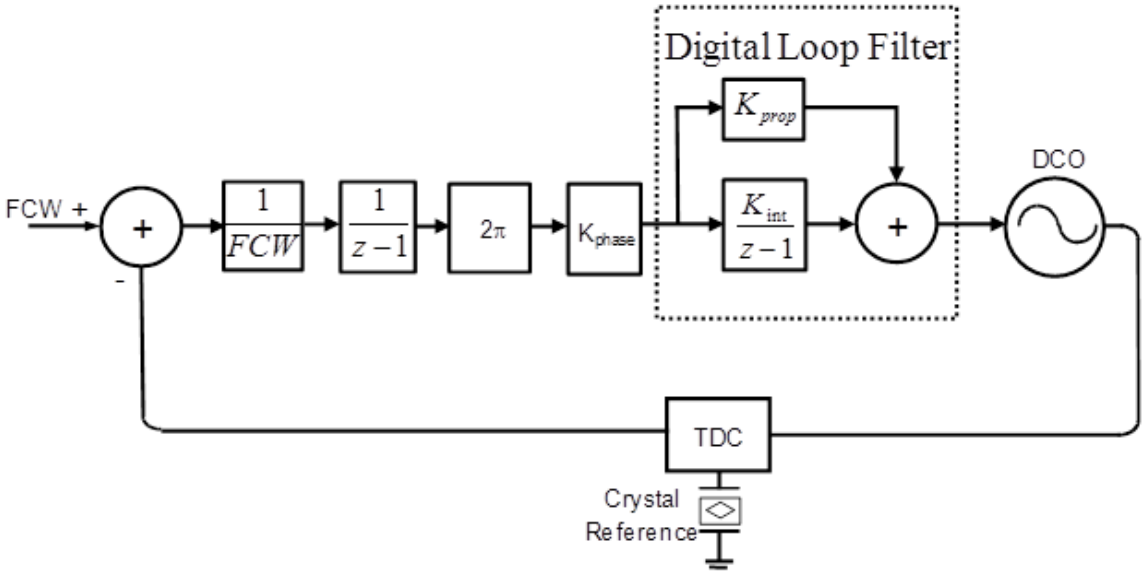
Question 3 (Total 25 Marks)

A transmitter of a full duplex radio must be designed. The transmit frequency is 2GHz and the receive frequency is 2.1GHz. The receiver must receive signals at -80dBm with an SNR of 10dB. The transmit power is 10dBm. A OFDM modulation is used with 64 subcarriers and EVM is required to be 1% or lower. The channel bandwidth is 10MHz. Power leakage into adjacent channels cannot be greater than -40dBm. Determine the transmitter linearity, LO phase noise, IQ matching, transmitter gain, and duplexor isolation requirements.



Question 4 (Total 25 Marks)

Consider an all-digital phase locked loop like the one shown below.



We need to design an ADPLL for an application where the output is 5.2-5.4GHz. A reference of 25MHz needs to be used and the channel spacing is 15MHz. A phase noise of -100dBc/Hz is required at 100kHz offset and the settling time needs to be less than 20us. Determine the resolution of the DCO, the resolution of the TDC, the loop filter components, and list all settings for the FCW to tune the design to every channel.