# CARLETON UNIVERSITY

FINAL
**EXAMINATION**
December 2014

DURATION 3 HOURS — No. of Students 10

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.**

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Information and Instructions:

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

Potentially Useful Equations:

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

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

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

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

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

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

**Question 1** (Total 25 Marks)

(a) What SNR is required to detect a 64QAM signal with a BER of $10^{-3}$?
(b) If the 64 QAM signal has a BW of 1MHz and a power of -70dBm what NF can a receiver have and still achieve this performance level?
(c) An LNA has an IIP3 of 0dBm an IIP2 of 20dBm and a gain of 10dB. Determine $k_1$, $k_2$, and $k_3$ to model this device.
(d) What are three uses of subcarriers in an OFDM signal?
(e) What is a cyclic prefix?

**Question 2** (Total 25 Marks)

Design a superheterodyne radio receiver. The bandwidth of the 64 QAM 64 subcarrier OFDM signal is 1MHz. The input signals at 10GHz. The lowest signal level is -85dBm and the highest signal level is -20dBm. The first LO will be at a frequency of 9GHz. Expect signals in the 8GHz band to be as high as +10dBm.

Fill in the table to meet these specifications:

| Component | Parameters |
|---|---|
| LNA | Gain: 10 dB<br>NF: _____dB<br>IIP3: _____dBm |
| Image Filter | Insertion Loss: 0dB<br>Passband: 10GHz<br>Bandwidth: 100MHz<br>Attenuation at 9GHz: _____ |
| RF Mixer | Gain: 5 dB<br>NF: 10 dB<br>IIP3: _____dBm |
| IF Filter | Passband Gain: 0dB<br>Adjacent channel rejection: _____ |
| IF Amplifier | Gain Range: _____<br>IIP3: -20dBm |
| Base Band Gain | 20–30dB |

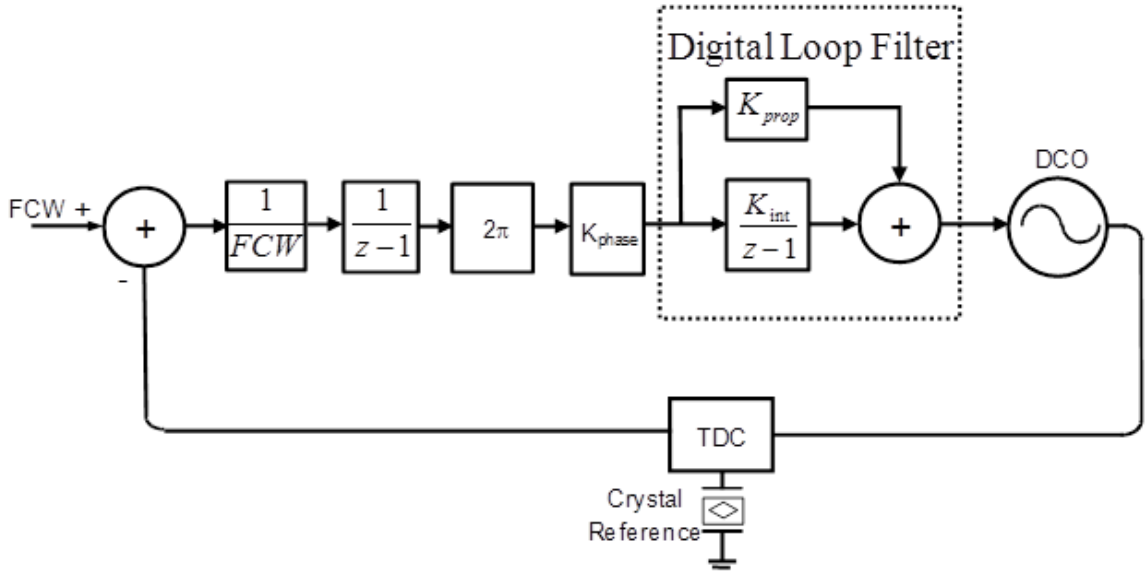
**Question 3** (Total 25 Marks)

A direct conversion transmitter is designed to work at 10GHz with a 64QAM 64 subcarrier modulation with a bandwidth of 1MHz. The transmit power is 30dBm.

a) What is the required EVM to achieve a BER of $10^{-3}$?
b) Design the PA so that the ACPR is less than -40dB.
c) What is the PA linearity requirement to meet this EVM?
d) What IQ mismatch can be tolerated?
e) Describe how you would deal with a phase shift and amplitude shift in the base band filters to avoid EVM degradation.

**Question 4** (Total 25 Marks)

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




Assume that the synthesizer must work with the radio described in Q2 and Q3. The reference frequency is 40MHz.

a) What is the close in phase noise requirement of the synthesizer?
b) What is the phase noise requirement at the adjacent channel offset?
c) What is the resolution requirement on the TDC?
d) Set the loop bandwidth to be 1MHz. Assume that the DCO can tune from 10 to 10.1GHz in 1000 steps. $K_{phase} = 10^{-3}$.