CARLETON UNIVERSITY

FINAL
EXAMINATION
April 2013

DURATION 3 HOURS — No. of Students 3

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:

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

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

$$r_{DS} = \frac{1}{\lambda I_{DS}},\ i_{nd}^{\ 2} = 4kT\left(\frac{2}{3}\right)g_m,\ kT = 4\cdot 10^{-21}\text{W/Hz at T=290K},\ q = 1.6\cdot 10^{-19}\text{C}$$

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

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

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

Question 1 (Total 25 Marks)

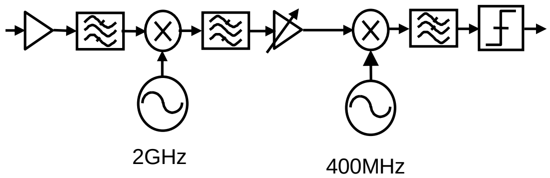
(a) A nonlinear amplifier with $k_1 = 2$, $k_2 = 0$, and $k_3 = 0.02$ is driven with:
$v_{\text{in}} = x \cdot \cos[2\pi(10MHz)t]$
If the amplifier is matched to 50Ω at the input and the output at what value of *x* will the amplifier reach its 1dB compression point? What will be the value of the output 1dB compression point in dBm?

(b) Write an expression for a 1GHz LO with a 1V peak amplitude and spurs at -60dBc at 40MHz offset.

(c) A signal is modulated with 64QAM and has an RF bandwidth of 1MHz. What power level can be received with a BER of 10^{-3}?

Question 2 (Total 25 Marks)

A simple superhertodyne radio is shown below.



You must design the components of the radio to deliver a signal to the base band with a SNR of at least 10dB. Channels have a bandwidth of 20MHz and can have power levels from -80dBm to -30dBm. Image signals can be as high as -10dBm. In order to do this fill in the following table at a minimum:

Component	Parameters
LNA	Gain: 15 dB NF: _______dB IIP3: _______dBm
Image Filter	Insertion Loss: 0dB Passband: 2.1GHz Bandwidth: 200MHz Attenuation at 3GHz:________
RF Mixer	Voltage Gain: 5 dB NF: 10 dB IIP3:_________dBm
IF Filter	Insertion Loss: 0dB Passband: 400MHz Bandwidth: 20MHz Attenuation: ________dB
IF Amplifier	Voltage Gain Range: ______ dB NF: 15 dB IIP3: -20dBm
ADC	Input voltage: 1Vpp Sampling frequency: 40MHz Number of Bits: 10 Clock timing jitter: ____________

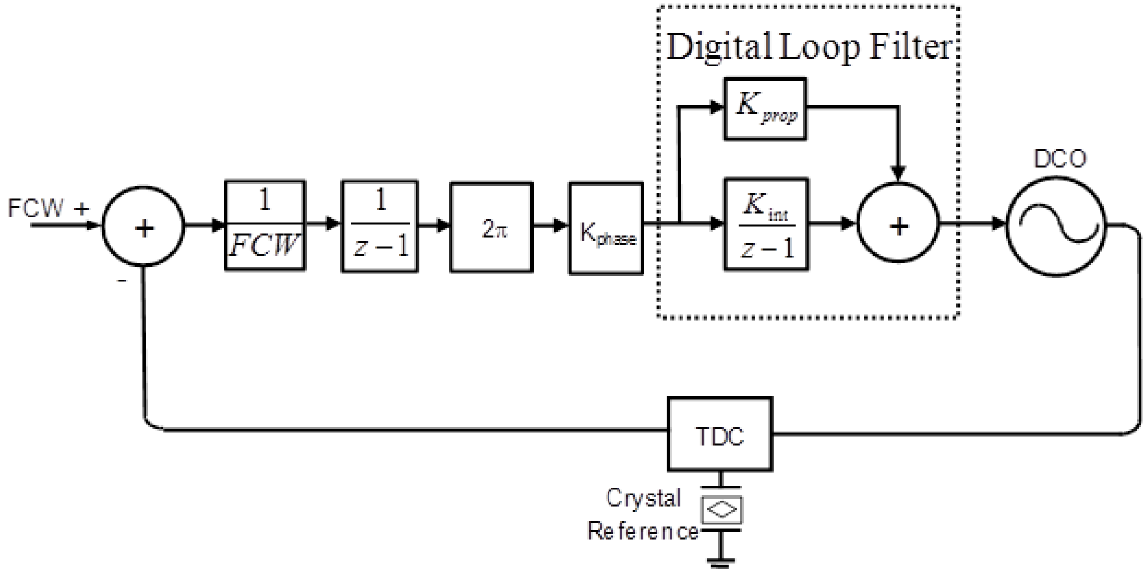
Question 3 (Total 25 Marks)

A transmitter is designed to put out a power of 33dBm. At the same time a receiver is expected to receive a signal at -70dBm at a frequency 100MHz away. The phase noise of the transmit LO is -160dBc/Hz at 100MHz offset. 16QAM OFDM modulation with 64 subcarriers is used with a bandwidth of 10MHz.

(a) Specify the performance level of the duplexor for this radio.
(b) What is the required linearity of the transmitter to have an EVM of 25dB?
(c) What is the required linearity of the transmitter to provide an ACPR of -40dBc?
(d) What is the in band phase noise requirement of the LO?

Question 4 (Total 25 Marks)

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



(a) What phase noise would be required for the radio in question #2?
(b) If a 1MHz reference is used what is the required TDC resolution?
(c) What resolution is required for the DCO?
(d) If the natural frequency of the loop is set to 200kHz, and Kphase = $10^{-3}/2\pi$ and K_{DCO} = 200MHz/unit design this loop.