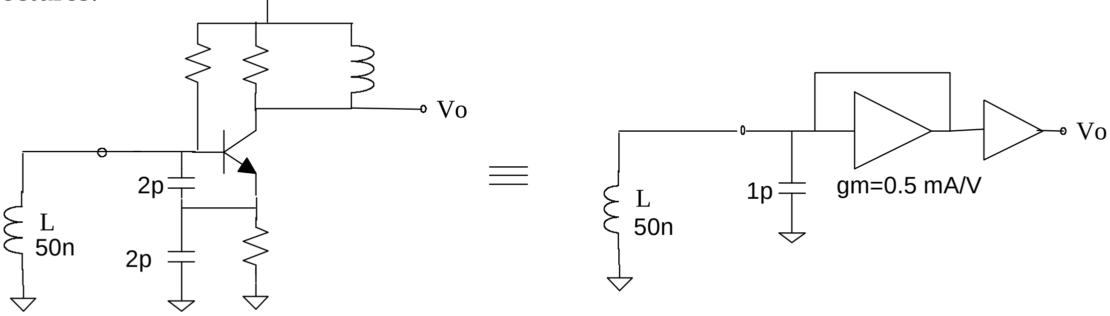
EECE 690/890
Digital Radio Hardware Design
HW #3
Due Tuesday, 9/15/98

** indicates a problem that is optional for students registered for 690

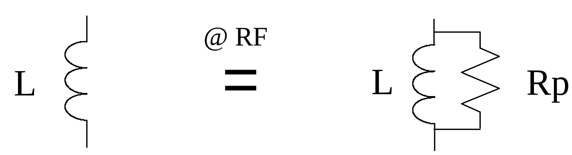
1. The circuit shown below is a common-collector Colpitts Oscillator - one of the most often used circuit configurations for RF oscillator implementations. A detailed analysis of this circuit is somewhat involved (see EECE662 class lectures), but the circuit can be simplified as shown below to a form matching the basic configuration discussed in class lectures.



a) Find the frequency of operation of this oscillator (in MHz), given the values shown.

b) Modify the inductor value to make the circuit operate at 928 MHz.

c) Real-world inductors at RF act not as ideal inductive elements, as the usual schematic symbol suggests, but rather as inductors in parallel with resistances as shown below:

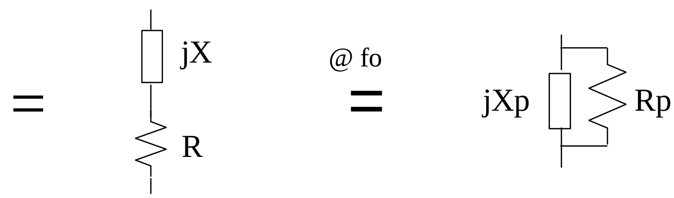


Ideally the parallel resistance Rp is infinite, but in practice, it is found to be Q times the inductor's reactance at the frequency of operation, where "Q" is called the inductor's "quality factor" and may range from 10 for a poor inductor, to >100 for a very good one. If the inductor's Q is too low, an oscillator may not oscillate. This occurs when the parallel combination of the inductor's resistance and the oscillator's negative resistance ($-1/g_m$) is no longer a negative number, or equivalently, when g_m Rp < 1. For the oscillator of part (b), find the lowest inductor Q that can be used.

2. ** Many RF circuits are designed to work at, or very near, a single frequency (e.g. 902 to 928 MHz ≃ 915 MHz) - unlike audio circuits that must work over a wide range of frequencies. This allows some useful “tricks” to be played at RF.

For example, the impedance Z of an RF circuit (at some specified frequency f_o) can be represented in two ways - by its “series-equivalent” form and by its “parallel-equivalent” form, as shown below:

$Z = R + jX$



a) Show that the parallel form is equivalent to (has the same impedance as) the series form if the values of Rp and Xp are taken to be:

$$Rp = (1+q^2)\,R \qquad \text{and} \qquad Xp = \frac{(1+q^2)}{q^2}X$$

where

$$q = \frac{X}{R}$$

HINT: Write an expression for Z for the parallel circuit and show that it reduces to R+jX.

b) The input impedance of the RF Micro Devices RF2502 oscillator is shown on the data sheet to be -55 - j170 Ohms at 900 MHz. Convert this to an equivalent parallel form consisting of a negative resistance in parallel with a capacitive reactance.

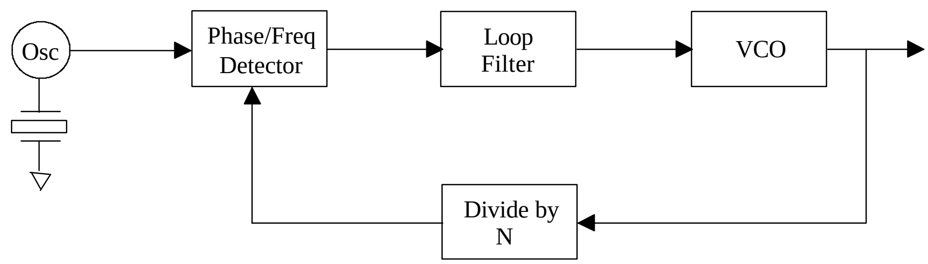
c) Based on your result in part (b), find the inductor value needed to create a 900 MHz oscillator with an RF2502 IC. Assume that no additional capacitance is added. The only component attached to pin 2 (other than a series blocking cap) is an inductor. (Hint: Convert the Xp value found above to a capacitance value and find L to resonate with this C).

d) Based on your result in part (c), and on the discussion of inductor Q in problem 1, find the minimum inductor Q that can be used with the RF2502 at 900 MHz.

e) Assume that the circuit shown on page 14 of the RF2502 data sheet is built, and that the varactor diode shown has a capacitance that varies from 2.5 pF down to 1.5 pF as the control voltage varies from 1 to 3 volts. This changes the effective inductance value by subtracting off some of the inductor’s reactance. Find the minimum and maximum frequencies of operation of the circuit assuming the PC board adds 2pF of capacitance from pin 2 to ground. (For simplicity, you may assume that the C value found in part (c) is the same at other frequencies. You can check this assumption if you like.)

f) What is the approximate “VCO constant” in MHz / Volt for the oscillator of part (e)?

3. For some wireless applications (such as remote keyless entry, wireless headphones, etc.), a single channel (frequency of operation) may be sufficient. In this case, it may be possible to build a very simple synthesizer such as that shown below. For this synthesizer, find the crystal frequency needed to give an output frequency of 915 MHz, assuming that the divider ratio N = 128.



4. A frequency synthesizer similar to that we will use in our cordless phone is to be built using a National Semiconductor LMX1602 chip. A TCXO (temperature compensated crystal oscillator) supplies a highly stable reference frequency of 34.300000 MHz to pin 2 of the chip, and the desired frequencies to be synthesized range from 902 to 928 MHz in 100 kHz steps.

a) Find the divisor that must be programmed into the 12-bit "R counter" to achieve the desired 100 kHz step size. Give your answer in decimal (base 10) form.

b) Inside the block labeled "16-bit Main N Counter" is a dual modulus divider control circuit like that discussed in class, which includes an "A counter" and a "B counter". Find the values of A and B needed to achieve a frequency of 902.3 MHz. Give your answer in decimal (base 10) form.