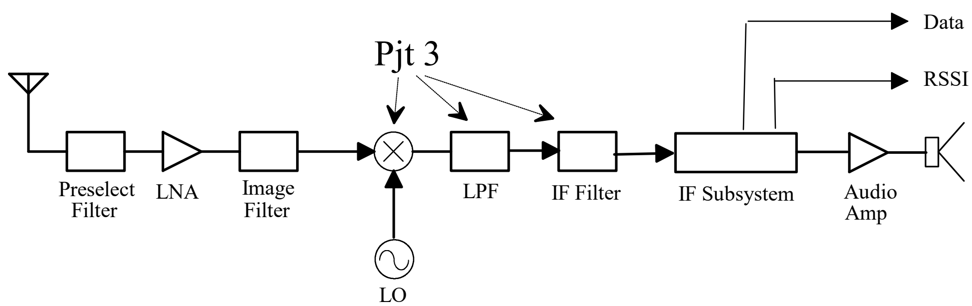
Project 3

Downconversion Mixer and IF Filter

Due Date: Friday, Nov 15 @ COB

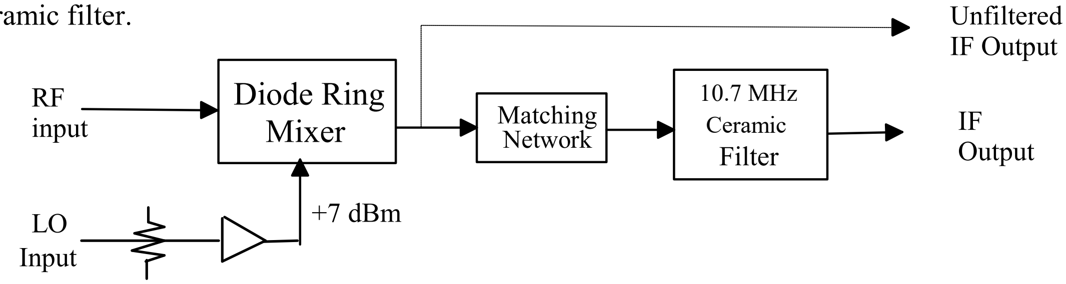
Objectives:

A block diagram for the complete receiver we are building is shown below. In this project, we will design, build, and test the mixer which downconverts the RF signal to 10.7 MHz, and the IF filtering circuits which perform channel selection. A set of measurements (detailed below) will be used to verify and illustrate the downconversion and channel-selection processes.



Circuit topology:

A block diagram of the circuits you are to design and construct is shown below. The downconversion mixer will be built "from scratch" as described in class, while IF filtering will use a commercially made ceramic filter.



Both the RF input and the LO input signals will be brought in on coax cables (which you may need to borrow from your previous projects). Although the diode ring mixer will have 50 Ohm nominal input and output impedances, the technology used in the filter requires it to see approximately 300 Ohm terminating impedances. Hence, a matching network will be needed between the mixer and,

The "Unfiltered IF Output" shown is a temporary output which will require a third coax cable and connector. This output will be used to test the mixer by itself, ***with the filter and MN circuits disconnected***. After the mixer has been tested, this output will be removed and the filter and MN circuits will be tested. The final "IF Output" shown will be made using "twisted pair" wires (i.e. no coax) to better match the 300 Ohm output impedance at this point in the circuit.

NOTE: 6:1 impedance transformers are available in the lab to allow connecting the 300 Ohm final IF output to 50 Ohm test equipment when assessing conversion gain.

Specifications:

RF Input to Wideband Output (using temporary 50 Ohm IF output coax connection)

- RF input frequency — 88 to 108 MHz
- IF output frequency — 10.7 MHz
- LO input power — -6 dBm +/- 3dB
- Conversion Gain — -6 ± 2 dB
- Isolation (LO-RF, LO-IF, and RF-IF) — > 30 dB
- 1 dB RF Input Compression — ≥-3 dBm
- RF, LO, IF port impedances — 50 Ohms*

To Final IF Output

- Conversion gain — -9 ± 3 dB
- 3 dB bandwidth — 200 kHz +- 20 kHz
- Alternate channel selectivity — > 40 dB
- IF output impedance — 300 Ohms*

* Not measured

Suggested Design Procedure:

You should be able to meet the project requirements if you follow the guidelines below. ***Be sure to use the appropriate frequency at each point in the circuit when making your calculations***

- Study the VAM-6 amplifier datasheet and estimate the input pad attenuation needed to achieve +2 to +7dBm out from the specified -6 dBm nominal LO drive level.
- Calculate R for the amp when powering with +5V.
- Design the a double-balanced diode ring mixer using the FT37-67 cores as discussed in class. Make sure the inductance of the windings is sufficiently high. Also, be sure to label the windings with the dot convention to get all polarities right (critical!).
- Design the matching network, using a LOWPASS topology using a T37-2 or FT37-67 core to minimize the number of turns needed (recall you're at 10.7 MHz here when computing L).
- Sketch the full circuit schematic. On the mixer, label the three windings on the transformers with the colors of wires you plan to use in construction. Also, mark the + end of each winding with a dot to assist you in getting the polarities correct during construction.
- CAREFULLY plan your layout, making sure you get the mixer diode and coil winding connections correct. Leave a small amount of space (e.g. 0.3 inches) between the mixer and the rest of the circuits to allow connection of the ***temporary***, "Unfiltered IF Output" coax.
- ***Document your design and layout in your writeup***. As in Pjt 2, there is no preliminary design to turn in this time. Your design work will be graded when the project is complete, along with your measurements. But if you have concerns about your understanding of the design procedures and underlying theory, ask someone for help.

Construction:

Use good RF construction practices, especially in the high frequency parts of the circuit. In particular, try to keep the lead lengths from the transformer cores to the coax and diodes as short as practical and close to the board. In the IF portion, lead lengths are less critical since the frequency is only 10.7 MHz.

When you initially construct the circuit, disconnect the mixer from the matching network so that you can connect the temporary "Unfiltered IF Output" coax to this point. *After the Part A measurements below have been performed, you should remove this coax, and then complete construction and/or connect the rest of the circuit* for Part B.

Measurements:

Part A - Measurements using 50 Ohm output (filtering disconnected)

Mixer Conversion Gain

Connect a 97.3 MHz signal at a level of -10 dBm to the RF input port. Connect a -6 dBm LO signal to the LO port and set it to a frequency to give a 10.7 MHz IF output (using low-side injection). Using an RF probe, verify the level going into the mixer's LO port is reasonable (> + 2dBm, and less than +10 dBm). Then connect the Unfiltered IF Output to the spectrum analyzer.

Observe and plot the resulting unfiltered IF output spectrum over a frequency range from 1 MHz to 500 MHz with a resolution bandwidth of 30 kHz (to decrease the noise level). **On the plot, identify all of the spectrum lines (frequencies) present**. That is, state not just the frequency value, but where the spectral lines are coming from (e.g. downconverted signal, upconverted signal, LO feedthrough, etc.) HINT: Recall the class discussions of how the mixer operates, and how it differs from the ideal mixer (multiplication by squarewave instead of sinewave, LO-to-IF leakage, etc.)

Observe the output power at 10.7 MHz and compute the conversion gain (is it reasonable? If not, troubleshoot and repeat the above.).

Vary the LO power level and make a plot of conversion gain in dB versus LO power in dBm from -30 dBm to 0 dBm in 2 dB steps. Explain the threshold behavior and show that the threshold should occur at approximately the power level that it does.

RF Compression Point

Reset the LO power to -6 dBm. Vary the RF input power from -20 dBm to +10 dBm and compute/plot the conversion gain versus input level. Find the 1 dB compression point referred to the RF input.

Mixer Isolation

Reset the RF power to -10 dBm. At the IF output, observe the output power at the LO frequency and at the RF frequency. Compute/record the LO-to-IF isolation and the RF-to-IF isolation.

Disconnect the Unfiltered IF Output and terminate this cable with a 50 Ohm load. Then connect the spectrum analyzer to the RF port. Observe the power at the LO frequency and compute/record the LO-to-RF isolation.

Downconversion of "Off-the-Air" Spectrums

Observe the operation of the mixer under actual "off-the-air" reception conditions as follows:

- Connect the outside antenna routed through a 20 dB preamp to the spectrum analyzer and measure/plot the spectrum from 85 MHz to 110 MHz (25 MHz span centered on the FM broadcast band). To get a good display on the spectrum analyzer, set the Reference Level to -10 dBm and set the resolution bandwidth "RES BW" to 30 kHz.
- Disconnect the amplified antenna signal from the spectrum analyzer and connect it to the RF input of your mixer.
- Connect a signal generator to the LO port of your circuit and set it at -6 dBm and 86.6 MHz (the frequency that will convert a station at 97.3 MHz to the center of your IF (10.7 MHz).
- Connect the Unfiltered IF output of your circuit to the spectrum analyzer and plot the spectrum from 1 MHz to 25 MHz. Is the entire FM spectrum downconverted as expected?
- Widen the span to 1 MHz to 500 MHz and plot the response. Identify where the various spectral lines are coming from? (Mixers in general will create output frequencies given by $|N*f_{RF} \pm M*f_{LO}|$ where N and M are integers

Part B - Measurements using Filtered Output

Full Circuit Operation

Disconnect the unfiltered IF output coax and remove the cable from your circuit. Connect the filter circuits to your mixer's output and connect the normal (filtered) IF output to the spectrum analyzer using one of the 6:1 impedance transformers in the lab.

Full Circuit Insertion Loss

Connect -10 dBm, 97.3 MHz RF input and -6 dBm, 86.6 MHz LO signals to your circuit as in the Mixer Conversion Gain test, and connect the filtered IF output to the spectrum analyzer through the 6:1 transformer. Measure and record the insertion loss. ("Insertion loss" in dB is the negative of the gain in dB.) It is recommended to use a reasonable span like 1 MHz for this test.

Selectivity

With the same setup as used in the insertion loss measurement above, vary the RF frequency over a range of 500 kHz either side of center and record the <u>*gain*</u> (negative of insertion loss in dB) at each frequency. This allows you to create a plot of the filter response.

Plot this gain in dB with enough points to create a smooth curve. If the output falls below the noise-floor of the spectrum analyzer at any frequency, note this and record the resulting maximum attenuation level you can actually measure, stating that attenuations beyond this are "noise limited". Then find and record the 3 dB bandwidth, 6 dB bandwidth, and the attenuations at + - 400 kHz (relative to the peak gain)**.** Compare with the filter datasheet.

Third Order Intermods and Intercept Point

Follow directions given/discussed in class to assess the third-order intercept point of your mixer. Do this with and without your project 1 circuit connected in front of your mixer.

Downconversion of "Off-the-Air" Spectrums

Setup your mixer to convert your favorite radio station down to to 10.7 MHz, and plot the output. Confirm that this station is the only one at the output of your board by observing with a 1 MHz span to see the modulation, and then from 0.1 to 25 MHz to look for other stations getting through the filter.

Writeup:

As always, photos are encouraged to help in documenting what you did. Also, as before, this is a team project with a team writeup. One person should do the design writeup and another do the measurements part. However - since there are a lot of measurements, person 1 could also do some of the measurement part - e.g. through conversion-gain measurement in Part A, if both teammates agree this is a good plan...

Summary:

At the end of your writeup for this project, provide a summary of your circuit, your measurements, and how the measurements compared to the specifications. If you failed to meet any specifications, discuss possible reasons.