CSE4377 (Spring 2026)
Lab #1 (Modulation)

This lab is due by February 24, with a 20% penalty per week day for being late.

For this lab, you will need a breadboard, a TM4C123GXL board, a baseband arb generator, an RF signal generator with external IQ modulation inputs, an oscilloscope in XY mode, and an RF spectrum analyzer.

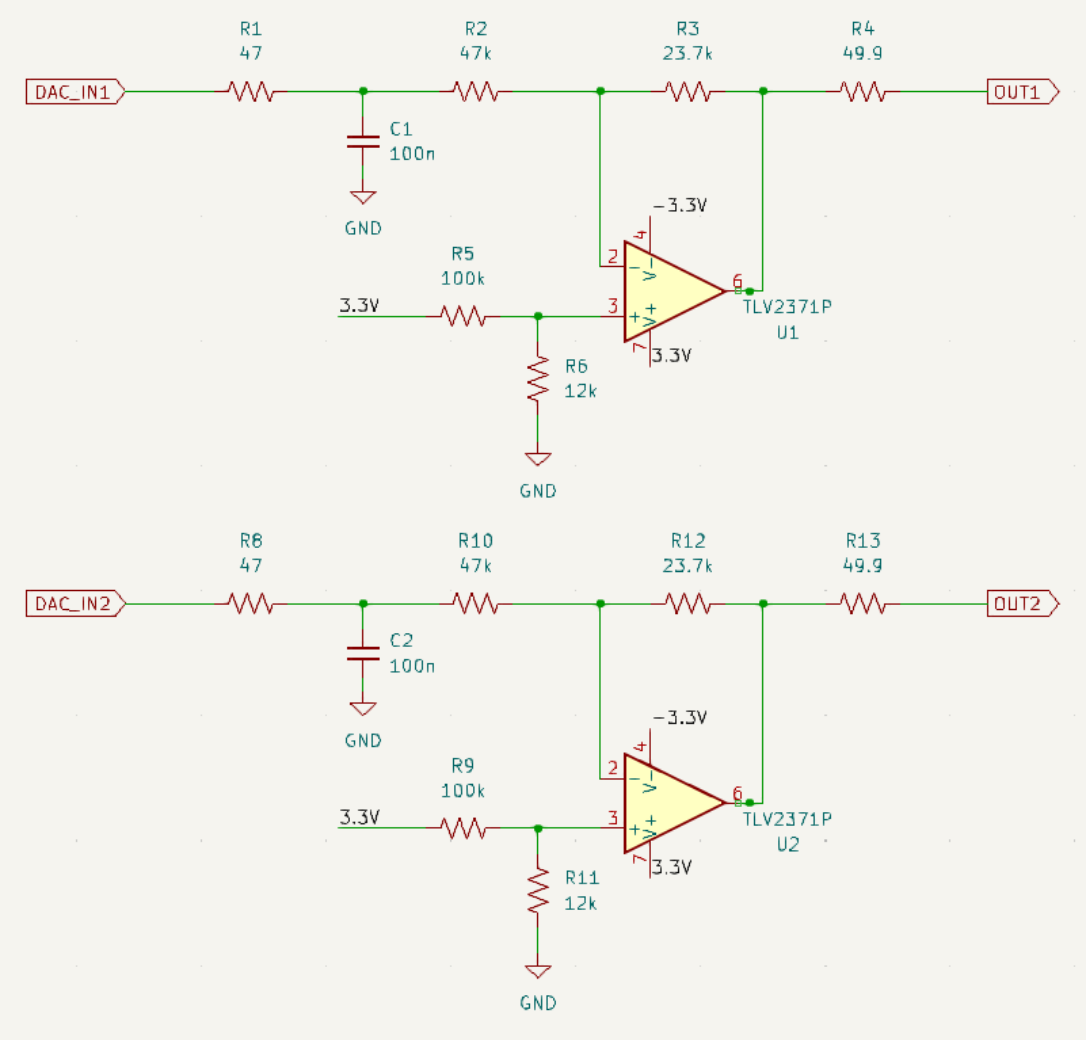
External IQ Source

1. Connect the CH1 and CH2 outputs of the arbitrary generator (10 kHz cosine and sine, 0.5V p-p, 50 ohm output mode) to the IQ inputs of a signal generator with frequency set to 27.1 MHz and the power output set to -30dBm with RF output enabled. Connect a BNC cable to ensure that the reference frequency of the generator and spectrum analyzer are the same. Connect the generator to the spectrum analyzer. Set the center frequency of the oscilloscope to 27.1 MHz with a span of 100 kHz.
2. Now turn on external IQ modulation (IQ button) and enable modulation (button on lower right of instrument). Note how the frequency shifts up 10 kHz in frequency. This is single-sided (upper sideband) modulation.
3. Reverse the I and Q input and observe the results. This is single-sided (lower sideband) modulation.
4. Now connect only the I input (Q is left unconnected) and observe what happens to the output. This is double-side modulation.

Circuit build

5. Using the white breadboard, TM4C123GXL board, and MCP4822 SPI dual DAC, build a circuit that takes the 0 to 2.047V outputs of the DAC and converts this to signals with a range of +/- 0.5V using a TLC072 op amp. Place diodes across this output to prevent a higher output and verify that the voltage does not exceed this range. A voltage of less than 0.5Vrms is needed on the signal generator IQ inputs to avoid damage.

   The circuit that converts the DAC signals to the +/- 0.5V levels is shown below:



6. Write software to write a voltage pair to the DAC outputs and verify the operation is as intended.

Basic modulation tests

7. Add a command line option to output a test cosine and sine functions with 0.5V amplitude and 10 kHz frequency.

8. Connect the DAC outputs to an oscilloscope in XY mode and take a picture of the plot.

9. Connect the DAC outputs to the IQ inputs of a signal generator with frequency set to 27.1 MHz and the power output set to -30dBm with RF output enabled. Connect a BNC cable to ensure that the reference frequency of the generator and spectrum analyzer are the same. Connect the generator to the spectrum analyzer. Set the center frequency of the oscilloscope to 27.1 MHz with a span of 100 kHz.

10. Now turn on external IQ modulation and enable modulation. Note how the frequency shifts up 10 kHz in frequency. This is single-sided (upper sideband) modulation.
11. Reverse the I and Q input and observe the results. This is single-sided (lower sideband) modulation.
12. Now connect only the I input (Q is left unconnected) and observe what happens to the output. This is double-side modulation.

Streaming symbols without filtering

13. Build an array of data values in memory that will be converted to streams of bits for transmission.
14. Provide a command line option to specify the type of modulation (bpsk, qpsk, 8psk, or 16qam) and provide a command line option to accept the transmission rate in symbols/second.
15. Build a streaming loop that takes bits from the array of values and creates a series of digital modulated IQ samples using the modulation type and symbol rate above. Provide a command line option to run and stop this streaming.
16. Connect the output of the IQ generator to the oscilloscope in XY mode and verify that the correct symbols are being sent.
17. Put the oscilloscope in FFT mode and take a picture of the plot. Note the bandwidth of the signal at baseband as a function of the symbol rate.
18. Connect the output to the IQ inputs of the signal generator and enable IQ external inputs and modulation. Adjust the frequency to 27.1 MHz and the power output to -30dBm and connect the output to the spectrum analyzer. Set the center frequency of the oscilloscope to 27.1 MHz with a bandwidth as appropriate. Take a picture of the plot and note the bandwidth of the signal at RF frequencies as a function of the symbol rate.

Streaming symbols with RRC filtering

19. Now, add a command line option to enable RRC filtering. If filtering is enabled, convolve the symbols with the filter prior to outputting the result to the DAC.
20. Repeat steps 17-19, noting the differences.

Report

21. Document the results in a brief 2-4 page document (with pictures and data), along with your code, and email to the TA for the course.