Wideband Feedback Amplifier
UCSB – ECE218A – Winter 2007

Goals:
1. Understanding of the dual feedback wideband amplifier.
2. Develop prototyping skills for RF circuits.
3. Learn to use the spectrum analyzer for measurement of power, gain compression, and harmonic distortion.
4. Understanding the concepts behind gain compression and harmonic distortion.

Precautions:

This circuit will have bias voltages on both the input and output. You <u>MUST use DC blocking capacitors</u> at both input and output to prevent these DC levels from being applied to either the network analyzer or spectrum analyzer. You will create very expensive damage (in the thousands of dollars) if you neglect this important requirement.

Complete the Spectrum Analyzer orientation before attempting to use this instrument.

Amplifier Design

This lab project involves the design of a wideband dual-feedback amplifier. You should use a combination of shunt and series feedback as illustrated in Chapter 2 of the Stanford notes, "Series-Shunt Feedback Amplifier Design". Sections 2-1 through 2-6 are directly relevant to this design[1].

Specifications:

Gain	6 dB minimum
Bandwidth (3 dB)	600 MHz minimum
|S11|, |S22|	-10 dB maximum at 600 MHz
Lower 3 dB frequency	10 MHz
Gain Peaking	Less than 1 dB

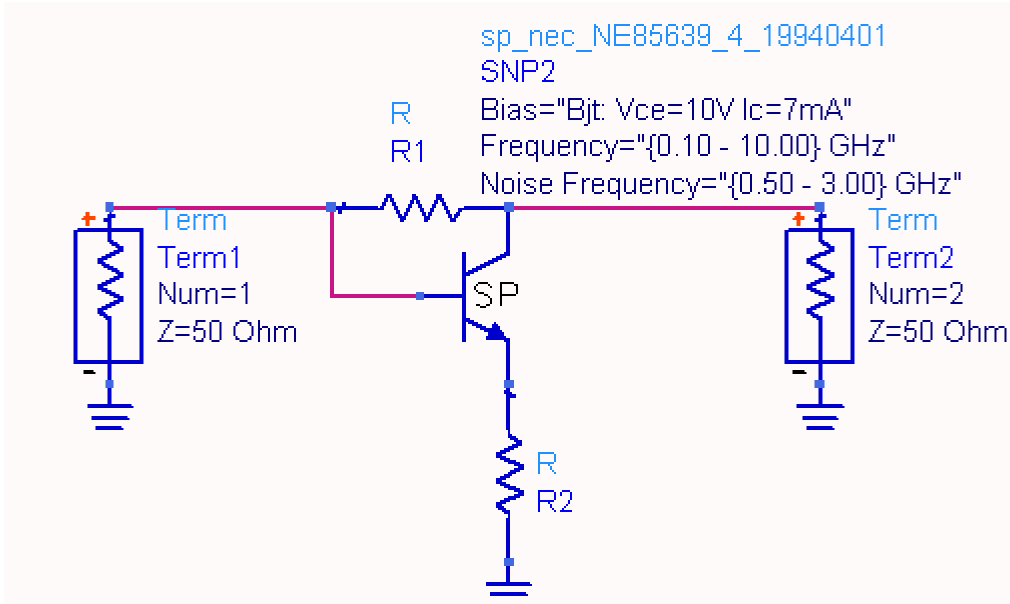
The device you will use is the NEC 85639. There are models for this device in the ADS component library.

Model type	Library	Sub-Library	Model name
S-parameter	S Parameter Lib.	NEC	sp_nec_NE85639_4_19940401
Nonlinear	RF Transistor Lib.	Packaged BJTs	NE85639_19960601

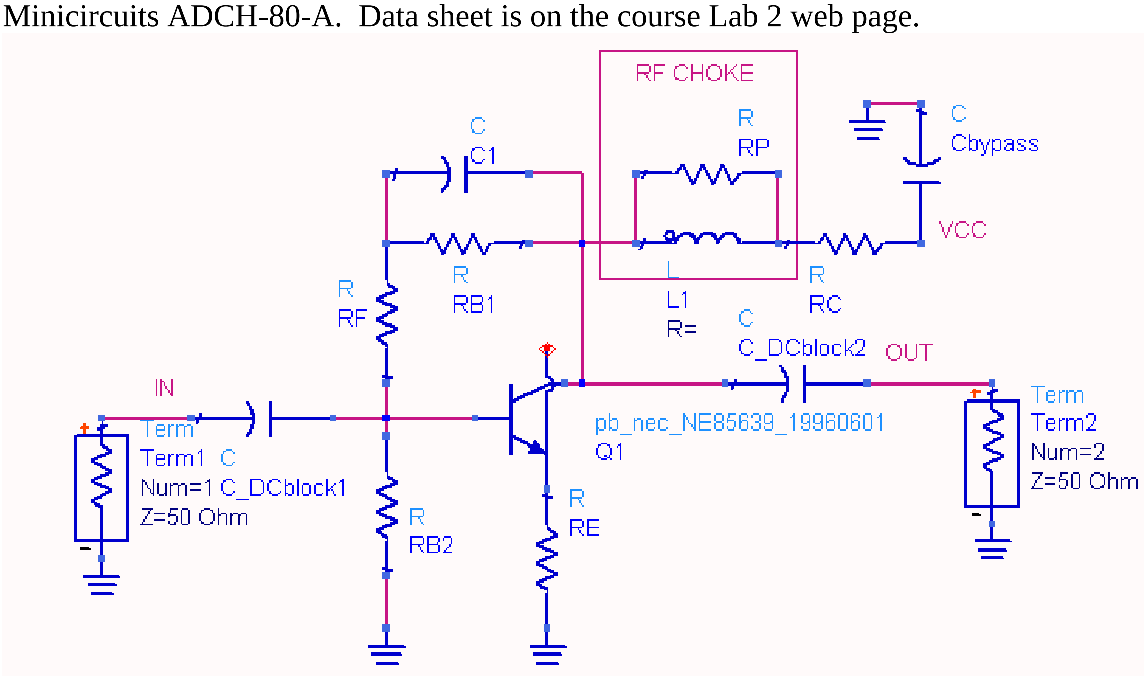
1. First, use the analysis equations to design R_E and R_F. Simulate the AC circuit using the S Parameter device model with the S Parameter mode of ADS to evaluate the basic

[1] H. Swain, "Series-Shunt Feedback Amplifier Design," EE344 High Frequency Laboratory, Stanford Univ., 1995. Can be found at ERES website.

design. Compare simulation with analysis in your report. Explain why there are significant differences. Can you improve the calculated results? How?



2. Design a suitable bias circuit to produce: I_C = 7 mA, V_{CE} = 10V, and assume βo = 80. Use the nonlinear model to verify the bias conditions with a DC simulation. Then use the S parameter mode with the nonlinear model to predict gain and input/output match with bias circuits present. The bias circuit should not degrade the gain of the amplifier significantly. You have a 15 V power supply voltage available. The RF choke is a Minicircuits ADCH-80-A. Data sheet is on the course Lab 2 web page.



RP is the effective parallel equivalent resistance of this choke.

3. Once the amplifier simulation meets the gain and S11, S22 specifications, then simulate the P1dB and third-order intercept using the ADS Harmonic Balance simulation mode. See the Harmonic Balance Tutorial on the course web page.

Construction:

An evaluation board will be provided. Assemble the surface mount components carefully. This requires very little solder. Attach the Male SMA board connector to the input and the Female SMA connector to the output. This will make the transmission measurement more accurate since no adapters will be necessary. Place the 4 spacers on each corner of the board.

The test fixture on the bottom of the board is a bonus fixture for you to use with the capacitance and inductance meter. Clip the leads to the two metal posts and place the chip C or L on the respective footprint. Since these components are not marked, it is easy to lose track of their values.

Evaluation:

Note: Be careful not to twist the board while attaching the SMA connectors to the measurement equipment. The chip caps are easily fractured with very little bending. Check them out with the microscope after soldering and before testing to make sure they are intact.

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1. S parameters. Use a network analyzer to evaluate the frequency response of the amplifier well beyond its upper 3 dB frequency. Measure all S parameters. Make sure that the output power level from the network analyzer is not driving the amplifier into compression during this measurement. Set the NA source power to around - 20 dBm. To do this:

Menu --> Power --> use buttons/knob to set to - 20 dBm.

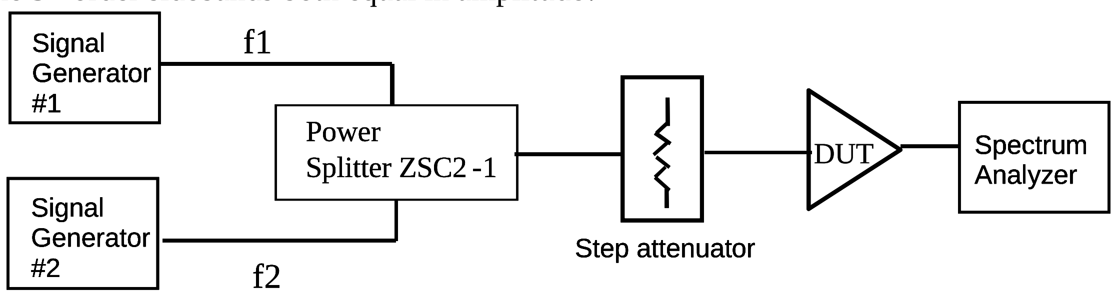
Compare your measurements against simulation, and explain differences. In order to explain why your prototype is not behaving as you would expect, you may need to evaluate the effects of nonideal components and layout parasitics on the amplifier with ADS. Measure components with the network analyzer if necessary to create equivalent circuit models and then re-simulate your amplifier. Use simple models to estimate layout parasitics.

2. Gain compression. Plot the Pout vs. Pin characteristic of the amplifier at 400 MHz, and determine the input available power level at which the amplifier gain compresses by 1 dB. This is called the P_{1dB} input power and is a standard index for gain compression. You may use the network analyzer power sweep to do this, or use a frequency synthesizer (generator) as the signal source and a spectrum analyzer or power meter as the detector. If you use the generator and spectrum analyzer, first calibrate your measurement setup by evaluating the loss in the cables without the amplifier in the signal path. Then, you can correct your measured amplifier data for cable losses.

3. Intermodulation distortion. The compressive gain characteristic that you plotted will generate intermodulation products due to the nonlinear transfer function. Perform a two-tone evaluation of your amplifier at 400 MHz with 1 MHz frequency spacing. The power splitter is in your tool kit. Read the Minicircuits Application Note on Power Splitters on the Lab 2 web page. Note that the loss of the splitter must also be accounted for.

Use the spectrum analyzer for this measurement and plot the fundamental and third-order IMD output power (IM3) as a function of Pin. Reduce the frequency span and use a narrow enough resolution bandwidth of the spectrum analyzer so that the intermodulation sidebands are clearly seen and that the noise floor is close to the bottom of the screen. Also make sure the fundamental signals do not exceed the spectrum analyzer reference level when measuring C-IMD behavior. The maximum input power per frequency should not be more than 13dB below your measured P1dB.

Also plot this as a carrier to IMD ratio. Calculate the slopes of the fundamental and IM3 and compare with theory. Calculate an input third-order intercept if possible (IIP3). Are the 3rd order sidebands both equal in amplitude?



Test setup for measurement of third order IMD with two signal sources.

4. Keep this amplifier. You will use it again in the next lab.

Report

This is a design lab. Follow the instructions on reports that can be found on the course introduction handout (on the course web page). Your report should be written to clearly present your design and interpret the measurement results. Make sure you describe how your measurement was performed and indicate important instrument setup conditions such as Resolution Bandwidth, Reference Level, Span, and Center Frequency unless they are clear from the plots. The grading will heavily weight the presentation of your results and the accuracy of your measurements. Don't make us try to guess what you did.

ECE218A	Parts List:
1ea	NEC NE85639 bipolar transistor
1ea	Minicircuits ADCH-80A wideband RF choke
1ea	evaluation board
2ea	board mounted SMA connectors (1 Male, 1 Female)
18"	insulated wire, #24 (red, black)
4	small metal standoffs with 4-40 or similar screw