Project 2:
5.8 GHz High-Power RF Amplifier

ECE 6361: Microwave Design Lab

Objective

The outcome of this project is to design, assemble and test a one-stage power amplifier based on a GaN HEMT transistor. The amplifier must be capable of providing 11 dB of gain across the 4.5-6.0 GHz band as well as a maximum 1dB compression point output power of 43 dBm.

Design Specifications

For this design project, the student teams will be provided the basic biasing circuit board (see resources online). You may modify the bias circuit as you see fit, but stability must be assured. You must use the brass block as is (with base plate and heat sink). It is recommended that you use the following design procedure, though it is not mandatory if you have a superior alternative plan:

1) Use device model to predict $Z_{l,opt}$ and compare to measured data for known I_{DSQ} (see datasheet in online resources).
2) Design matching networks using for input and output using device model and/or measured source/load pull data.
3) Simulate, gain, *k*-factor, P_{1dB}, P_{sat}, *IMD, etc.*, over the specified operating range (see datasheet in online resources). Iterate as necessary to achieve best compromise in performance. I_{DSQ} may need adjustment as well.
4) Assemble and test the PA.
5) Modify the design as necessary to achieve the best performance possible.

Please note that **PCBs and GaN HEMTs** are in very limited supply. Take the following precautions when assembling and testing your PAs:

1) Do not bias up the device without proper terminations on input and output.
2) Follow **ALL** guidelines stated in the "Biasing GaN HEMT" ap note.
3) Be sure to use appropriate **attenuators** to insure that the signal level applied to any test equipment is below the rated maximums.
4) Do not modify circuit **in any way** while it is operating at or near P_{sat}.
5) Use appropriate current limits on DC power supplies (PA should not draw more than 300 mA) to avoid trace burns.

6) Do not touch traces with fingers, tweezers, or other metal objects during RF operation.

Use the following power-up sequence for testing your PAs:

1) Use multi strain thick wires.
2) Disconnect all power pins.
3) Connect RF IN and RF OUT to signal source. (do not turn on the RF at this step)
4) Connect -5 V to V_{GG} referenced to GND.
5) Connect +28 V to V_{DD} referenced to GND.
6) Turn ON the RF signal source.
7) Decrease the V_{GG} to roughly -3V or until the drain current reaches 250 mA. (Do not exceed 250 mA).

Use the following power-down sequence for your PAs:

1) Turn OFF RF signals.
2) Turn OFF VGG.
3) Turn OFF VDD.

Below are the compliance specifications for this project:

Test Conditions:				
Parameter	**Symbol**	**Spec**	**Method of Compliance**	**Comments**
Input/Output Impedance	Z_0	50 Ω	Test Condition	
Drain DC Supply Voltage	V_{DD}	28 V	Test Condition	
Gate DC Supply Voltage	V_{GG}	-6 to -3 V	Test Condition	(adjusted to set I_{DSQ})
Frequency Range	f_0	4.5 – 6.5 GHz	Test Condition	
Test Parameters and Specifications:				
Small Signal Gain	G	11 dB	Test	Minimum at 32 dBm input
Power Output at 1 dB Gain Compression	P_{1dB}	43 dBm	Test	Typical
Power Added Efficiency at P_{sat}	η_{added}	50%	Test	Minimum, P_{sat} defined as P_{out} @ 3 dB gain compression
Drain DC Supply Current	I_D	300 mA	Test	Maximum At $P_{out} = P_{sat}$

Input Return Loss	$\|S_{11}\|$	-10 dB	Test	Maximum
Stability	K	>1	Simulate using measured S-parameters	Unconditional for any $\|\Gamma\| \leq 1$ from 0.5 GHz to 6 GHz
Junction Temp at P_{1dB}, T_{amb}=25°C	T_j	200°C	Calculate	At $P_{out} = P_{sat}$
Mean-time-to-failure	$MTTF$	$5{\cdot}10^8$ hrs	Calculate	At $P_{out} = P_{sat}$

Grading

Grading for the student teams is based on three parts:

1. **Written Report –** The base score of this project will be based on the written documentation of the group's project design and implementation. Key grading points for good design documentation:
    a. Technical Correctness
    b. Thorough Design Methodology
    c. Clear, *Concise* Writing
    d. Professional Content
    e. References

    Design documentation should strive for succinct repeatability. All design documentation must include a bill of materials.
2. **Compliance Test –** Each team must demonstrate to the course instructor that their final device complies with the project specifications. Various project score deductions will be assessed to a team depending on how far "out-of-spec" a final device performs. Compliance may only occur immediately after a scheduled lecture.
3. **Peer Evaluation Forms –** Download the peer evaluation forms from the course site and fill them out for each team member. Various project score adjustments may be assessed to a team depending on peer-assessment of individual team member effort. Form feedback is kept confidential.