# 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 MIMIX GaAs HEMT transistor. The amplifier must be capable of providing 15 dB of gain across the 5.725-5.850 GHz band as well as a maximum 1dB compression point output power of 30 dBm.

## Design Specifications

For this design project, the student teams will design and fabricate their own circuit board to provide the basic biasing for the amplifier (see last year's board in the laboratory for examples). You must use the brass block as is with no other heatsinking. There are two alternative biasing approaches for fulfilling the design compliance: a manual approach and an automatic approach.

**Manual Approach:** In this approach, the students use the DC power supply to bias the device. Successful demonstration of amplifier compliance with this approach will yield a project ceiling score of 90 (the last 10 points will only be available to those teams who bias with the automatic approach). It is recommended that you use the following design procedure, though it is not mandatory if you have a superior alternative plan:

1) Use a device model to predict $Z_{l,opt}$ and compare to measured data for known $I_{DSQ}$.
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. 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.

**Automatic Approach:** In this approach, a digital Maxim chip is provided, which sequences voltages on the gate, drain, and source that properly and safely biases the device. Students will receive the full 100 points for successful demonstration of this technique.

Please note that the **GaAs HMETs** 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) Be sure to use appropriate **attenuators** to insure that the signal level applied to any test equipment is below the rated maximums.
3) Do not modify circuit **in any way** while it is operating at or near $P_{sat}$.
4) Use appropriate current limits on DC power supplies (PA should not draw more than 1A) to avoid trace burns.
5) Do not touch traces with fingers, tweezers, or other metal objects during RF operation.

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 | |
| Max Drain DC Supply Voltage | $V_{DD}$ | 24 V | Test Condition | |
| Gate DC Supply Voltage | $V_{GG}$ | 0 to -5 V | Test Condition | (adjusted to set $I_{DSQ}$) |
| Frequency Range | $f_0$ | 5.725 -5.850 MHz | Test Condition | |
| **Test Parameters and Specifications:** | | | | |
| Small Signal Gain | $G$ | 15 dB | Test | Minimum at 10 dBm input |
| Power Output at 1 dB Gain Compression | $P_{1dB}$ | 30 dBm | Test | Minimum |
| Input Return Loss | $\|S_{11}\|$ | -10 dB | Test | Maximum |
| Stability | $K$ | >1 | Simulate using measured S-parameters | Unconditional for any $\|\Gamma\| \leq 1$ from 0.1 GHz to 6 GHz |
| Junction Temp at $P_{1dB}$, $T_{amb}$=25°C | $T_j$ | 125°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.