Mini-Circuits®

Application Note

AN-60-149 - Setting Up GaAs/GaN MMIC RF Power Amplifier Evaluation Boards for Bench Testing

Bias Sequencing of Depletion Mode Devices Such as GaAs and GaN MMIC RF Power Amplifiers

This application note provides a structured procedure to prepare and test depletion mode devices such as GaAs and GaN MMIC RF power amplifier (PA) evaluation boards on an RF test bench. It ensures safe handling, protects devices from damage, and supports accurate RF characterization.

1.0 APPLICABLE DEVICES AND SYSTEMS

- GaAs MMIC PAs
- GaN MMIC PAs
- Both evaluation and custom test fixtures

1.1 PRE-TEST PREPARATION STEPS

1. Safety First

- Use **ESD protection**: wrist strap, grounded mat, ESD-safe tools
- Confirm device and board are **free of physical defects**

1.2 TEST BENCH SETUP STEPS

2. Mount the MMIC Evaluation Board

- Always **mount the evaluation board on a proper heatsink**
    - Ensure flat thermal contact surface
    - Use thermal interface material (TIM) like thermal grease or pad
    - Bolt down evaluation board assembly on heatsink with fins to ensure proper heat dissipation
- For GaN MMICs, which generate high heat, forced-air cooling or water-cooled plates may be required

Several Mini-Circuits evaluation boards are supplied with a heatsink already attached; consult the product datasheet for details

3. Perform Resistance & Continuity Checks

- Prior to connecting the power supply, use a multimeter to verify:

Test Point	Expected Value
Gate to ground (VG)	High resistance (no short)

4. Connect RF Cables and Supply Lines

- Use high-quality **RF cables**
- **Minimize cable length** to reduce loss and reflections
- Confirm RF port labeling (e.g., RF_IN, RF_OUT) matches test setup

- Route **DC lines away from RF** to reduce coupling
- Perform another resistance check with a multimeter between all supply pins (e.g. VD and VG) to ensure there are no shorts

5. Check Power Supply Connections

- Identify all DC supply ports:
    - VD (drain voltage) — high-voltage supply (e.g., 28 V for GaN; refer to product datasheet for exact voltage)
    - VG (gate supply) — negative gate supply (typically –3 V to ~-0.5 V; refer to product datasheet for exact voltage)
    - Control lines if applicable (enable, etc…)
    - Fan voltage or other active-cooling power supplies, if applicable
- Double check:
    - Correct voltage range
    - Current limit settings (to protect device under test (DUT))
    - Polarity (reverse polarity may destroy the MMIC)

1.3 BIASING PROCEDURE (MANUAL OR SEQUENCED)

6. Bias Sequencing (Critical for MMIC PA Devices)

- **Manual Sequencing Steps:**
    1. Apply gate supply first (VG):
        - Set to a safe negative voltage (e.g., –4 V GaN, -2V GaAs)Confirm gate voltage is present on the Evaluation Board near the device by probing with a multi-meter
        - This pinches off the device, preventing current flow
    2. Apply drain voltage (VD):
        - Ramp drain voltage slowly from 0V to target voltage, taking care to monitor drain current.
            - Often it is helpful during first turn-on to set the current limit on VD much lower than that under nominal operation in order to verify proper pinch-off conditions are applied prior to fully biasing the device. Once pinch-off conditions (no drain current drawn) are verified, the current limit can be increased to a safe level for nominal operating conditions while the drain voltage is subsequently increased to the desired operating voltage.
    3. Slowly increase VG toward 0 V:
        - Monitor quiescent drain current (IDQ)
        - Stop when desired drain current is reached

Note: Reversing this sequence (applying VD before setting a safe VG) can **damage MMIC PAs** due to uncontrolled drain current.

7. Bias Sequencer Overview (Recommended for Automation or Reproducibility)

- **Functions of a Bias Sequencer:**
  - Controls **timing**: applies gate before drain (power-up), removes drain before gate off (power-down)
  - Monitors **voltages and potentially currents** for faults
  - Enables **soft-start ramp-up/down** of supplies
  - May interface with **bench power supplies or test software** (via GPIO, SCPI, USB, etc.)
- **Examples:**
  - **Custom-built sequencer** (microcontroller or DAQ-based)
  - **Commercial systems**:
    - Keysight B2912A + software control
    - PMK Bias-T or Tabor Electronics sequencers
- **Typical Sequencer Timing:**

Event	Time Offset (ms)
Apply VG	0 ms
Apply VD	+100 ms
Ramp VG to bias	+200 ms

Reverse for shutdown

8. Shutdown Sequence

- Reduce VG to pinch off the MMIC device. (e.g., –4 V GaN, -2V GaAs)
- Turn off VD (drain supply)
- Turn off VG (gate supply)
- Then remove VD (drain supply)

Then remove VG (gate supply)

Never turn off or remove VG before VD on depletion mode MMIC PAs

📌 Final Notes

- **Thermal management** is critical—monitor temperatures during test using a thermocouple or other means of temperature monitoring
- **Repeatable supply sequencing** improves reliability and consistency
- If automating, ensure proper **interlock and fault detection** in test scripts

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