AMPLIFIER BIASING MADE EASY

Jacob Trevithick | April 16, 2020
Amplifiers boost signal strength.

The Basics
• Active Device
• Amps Require DC bias voltages to operate
• Constructed with transistors
• External DC power converted to RF signal power
But they don’t have to be!

1. **Power Supply**
   - Linear and nonlinear metrics are sensitive to power supply and bias voltages.

2. **Bias Setting**
   - Controls bias point on the IV curve for your application

3. **Bypass circuitry**
   - Noise filtering, stability, and switching time are considerations

4. **Reliability**
   - Transistors can be damaged by over bias or improper sequencing
**FET Amplifiers**
- Gate current is negligible
- Gate can be biased with just a resistive network

**BJT Amplifiers**
- Base Current is always required
- Standard Current mirror typically used
Depletion Mode

Negative Bias, Requires Sequencing

- Negative threshold voltage
- Transistors conduct without negative gate bias
- Sequencing typically required to avoid damage

Enhancement Mode

Positive Bias, No Sequencing

- Positive threshold voltage
- Transistors are off without gate bias
- Eliminates the need for sequencing and negative voltages
BJT AMPLIFIER BIASING: TWO MAIN CONCERNS

Voltage Sensitivity
- Collector current is exponential with base voltage.
- Circuitry required to precise control $V_{BE}$

$IC \propto e^{V_{BE}}$

Thermal Runaway
- Self heating can cause thermal runaway
- Ballasting resistor used to dampen this feedback loop

$V_{BEon}$
- Decreases
- Junction Temp.
- Increases
- Power Dissipation
- Increases
- Supply Current
- Increases

$IC$ increases
- Power
- Supply
- Increases
- Dissipation
- Increases
- Junction Temp.
- Increases

BJT Amplifiers Typically Require Current Mirrors
- Makes biasing as easy as setting a voltage

Markki Microwave Inc.
**ELECTRICAL PERFORMANCE**

**Major Effects**
- Saturated Power Gain
- Harmonic Intercepts
- 1 dB Compression
- Phase Noise
- Current Consumption

**Minor Effects**
- Return Losses
- Isolation
- Max safe operating conditions

---

Marki Microwave Inc.
On Chip vs. Off Chip Biasing

Bypass Capacitors
- On chip bypass capacitors are limited because of size and dielectric.

Current Handling
- Thin printed metal lines are limited to couple hundred mA of current handling.

Inductance
- With thin wires and no magnetic material, on chip inductors are limited to >1 GHz.

Bypass vs. Blocking Caps
- Blocking capacitors block DC voltages and pass RF signals
- Bypass capacitors bypass stray RF signals to ground
Biasing affects the amplifier’s reliability

**Biasing Effects**

- **Heating**
  - During operation, power is dissipated as heat in transistor junctions

- **Max Power**
  - Exceeding max input power specs will cause damage to transistors

- **Quiescent vs. Saturation**
  - Higher input power typically draws more current

**Cooler amps perform better and last longer**

---

**Heating**

- During operation, power is dissipated as heat in transistor junctions

**Max Power**

- Exceeding max input power specs will cause damage to transistors

---

**Quiescent vs. Saturation**

- Higher input power typically draws more current

---

**Cooler amps perform better and last longer**

---

**Marki Microwave Inc.**

---

**Courtesy of David Wang, Global Communication Semiconductor**
Please take a moment to answer a three short questions

1. What amplifier specifications are majorly affected by bias condition?
   - Output Power
   - Return Losses
   - Harmonic generation
   - Gain
   - Lack of magnetic material
   - Current handling
   - Size restraints
   - All of the Above

2. What are some limitations of on-chip bias components?
   - Bypass circuitry
   - Input and output DC blocks
   - Sequencing
   - Current Mirrors

3. What is the best way to filter out power supply noise?
   - Bypass circuitry
   - Input and output DC blocks
   - Sequencing
   - Current Mirrors

**Bias Generation: Bypassing**

**Switching Time**
- Additional bypass capacitors will increase noise filtering
- Increases charge constant on input/output, increases switching times

**Immunity to Oscillation**
- Pay careful attention to LC resonant frequencies
- Use 5ohm -20ohm resistors to de-Q large bypass capacitors
- Off-chip shunt caps and series inductors limit feedback oscillations for multistage amplifiers
Multi-Stage Amplifiers

- Modifying interstage biases for gain/Psat/efficiency?

Application circuit

- Drain supply need to be individually broken out
- Gate bias pads resistively connected on-chip
Bias Generation: Incorrect Supply/Bias Voltage?

Bias current is low and constant.
Size resistors based on gate/base current draw.

Step Diodes for Power Supplies
- Diode voltage drop is relatively constant with current change.
- Size step diodes for max current handling.

Resistive Dividers for Bias Voltages
- Bias current is low and constant.
- Size resistors based on gate/base current draw.
Bias Generation: Negative Bias

Voltage Inversion and Sequencing

- Apply +5V and produces sequenced supply and negative bias voltages
- Negative Voltage can be produced by Charge inverter chip
- Sequencing is available with COTS parts
- Minimal cost, larger board size

Introducing Marki Microwave’s New UC5 Single-Supply Voltage Sequencer Package for AMM Amplifiers
Marki Amplifier Catalog

Positive Only Low Phase Noise Amps
High power for high linearity
High gain
Surface mount, bare die, and connectorized module

No Sequencing/Grounded Gate Optional Amps
Medium power square wave LO driver amplifiers for general purpose mixer driving

mm-wave LO driver Amplifiers
Medium Power for mm-wave LO
Sequencing/Negative bias circuitry available
High gain
Surface mount, bare die, and connectorized module

For More Information
Tech Notes
Videos
support@markimicrowave.com

Marki MISSION STATEMENT
Empower our customers to design faster, simplify production, eliminate complexity, and shatter performance barriers
PLEASE REGISTER FOR OUR FUTURE WEBINARS COMING UP SOON!

April 30th: A Brief Guide to Mixer Spurs
Presented by: Harley Berman & Christopher Marki

May 14th: High Frequency Packaging from the Experts
Presented by: Christopher Marki

Registration links and a recording of this webinar will be provided through email.
Thank you for joining us today!
Amplifiers Degraded with Temperature

Increasing bias voltage with increasing temperature can counteract gain/power degradation.

Compensation can be digital or analog.

Must be careful about reliability.

<table>
<thead>
<tr>
<th>Temp.</th>
<th>$-40^\circ$</th>
<th>$-30^\circ$</th>
<th>$-$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gain</td>
<td>$+10$ dB</td>
<td>3V/3V</td>
<td>3V/4V</td>
</tr>
<tr>
<td></td>
<td>$+11$ dB</td>
<td>3V/4V</td>
<td>$-$</td>
</tr>
<tr>
<td></td>
<td>$-$</td>
<td>$-$</td>
<td>$-$</td>
</tr>
</tbody>
</table>
Current mirror used to control the Base voltage of the RF transistor
FET vs. BJT CLASS A OPERATION

FET/HEMT

Bias
Supply
RF input
DC Block
G
D

RF output

FET

Saturation

Quiescent operating point

Load-Line

Cut-off

Ohmic

I_d

V_ds

V_{gs}

BJT/HBT

Bias
Supply
RF input
DC Block
B

RF output

Circuitry

Bias

Linear

Active

Quiescent operating point

Load-Line

Cut-off

I_c

V_{CE}

I_B
AMM-6702UC5 SEQUENCER PLOTS

AMM-6702-U5 Amplifier-level Vd vs. Applied Voltage

AMM-6702-U5 Amplifier-level Vg vs. Applied Voltage

AMM-6702-U5 Total Current vs. Applied Voltage