Amplifiers for Synthesizer and Local Oscillator Generation: The Unsung Application

Rob Maurer | May 14, 2020
Overview

What is a driver amplifier?

What are primary and secondary performance benchmarks of Driver Amps?

What is phase noise and when should you be worried about it?

Usability features

How can you optimize your amplifier selection for driver applications?
What is a Driver Amplifier?

Driver Amplifiers...

Amplify single-tone sine or square waves to sufficient power for other devices to operate

Are essential for proper operation of mixers, multipliers, and other frequency converters

Are essential for clock distribution from a single source

Have different modes of operation and performance metrics than signal amplifiers, which amplify information as well as carrier tones

Simplified receiver block diagram with LO driver

Typical passive doubler application circuit with input driver and output amp
Why Can’t Amplifiers Just be Good At Everything?

Nearly all performance benchmarks come with tradeoffs

Noise Figure

Gain

Tradeoff

Stability

Odd order harmonic suppression

Power output/linearity

Bandwidth

Rise Time

Efficiency

Bandwidth

You can’t have it all, so it’s important to know what you need
Primary Performance Benchmarks for Drivers

Sufficient Output Power
The amplifier won’t work at all if it cannot provide the necessary power for your application!

Sharp Rise Time
Mixer LO drivers, NLTL drivers, and tripler drivers operate most efficiently with sharp rise times. “Square waves” are the ideal.

5 GHz, +5 dBM In, 5V/5V bias
APM-6848PA 5 GHz Waveform with 20 picosecond rise time

Marki Microwave Inc.

Flat Output Power vs. Frequency
Compensates for frequency dependent system gain/loss when amplifier is saturated

Gain, Bandwidth, Return Loss
Gain reduces the input power requirement to run into compression, reducing sensitivity to input power, and bandwidth increases frequency plan flexibility

Phase Noise?
A major concern for some, not at all a concern for others, more on this later...

High gain & high bandwidth
Secondary Concerns

**Even/Odd Harmonic Generation**
Odd harmonic generation in many cases is **beneficial** in driver amps because it increases rise time.

**Noise Figure**
Amplitude noise suppressed in driver applications for passive/digital components

**Power Efficiency**
Depends heavily on application/power budget

**Gain Flatness**
Drivers operate in continuous wave (CW) compression, so gain flatness is only relevant to maintaining consistent compression levels

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Some critical performance benchmarks for signal path applications take a back seat for driver amplifiers
Can you have too much drive power?

Most driver applications require a minimum “threshold” power level for proper function.

More power above threshold can improve performance, but often with diminishing returns.

More output power comes with more DC power consumption and often reduced gain/bandwidth!

As a rule of thumb, 3 dB above “threshold” power level is a good driver output power to aim for, but it depends on the device. When it comes to Marki mixers, NLTLs, and multipliers, the easiest solution is to let us handle it.

Higher power can improve device performance, but eventually sees diminishing returns.
Rise time and harmonic generation

A perfect square wave carries odd harmonic content:

\[ f(x) = \sin(t) + \frac{1}{3}\sin(3t) + \frac{1}{5}\sin(5t) + \frac{1}{7}\sin(7t) + \ldots + \frac{1}{199}\sin(199t) \]

Even ordered harmonic distortion is bad, but some odd ordered harmonic distortion is often beneficial for driver applications. This is a major reason we encourage customers to drive driver amps beyond 1 dB compression.
Most efficient performance (highest PAE) is typically around 3-5 dB of gain compression

Phase noise contribution minimized around 2-4 dB of gain compression

Mixer/NLTL performance degrades with no compression

Many engineers are hesitant to push driver amplifiers beyond 1dB compression due to worries about distortion, efficiency, or reliability. To the contrary, Marki encourages customers to drive driver amplifiers with 3-5 dB of gain compression to benefit from odd harmonics, increased PAE, and improved phase noise performance.
Poll

Please take a moment to answer a three short questions

1. What are some of the primary performance benchmarks for driver amplifiers?
   - Rise time
   - Noise Figure
   - Gain Flatness
   - $P_{sat}$

2. What is usually the dominant source of phase noise in an LO chain?
   - Driver Amplifier
   - Filters
   - Oscillator
   - Multipliers

3. What is the optimum operating condition for driver amplifier for most applications?
   - Small signal operation
   - 3 dB gain compression
   - 5 dBm input power
   - As hard as possible
When Should You Care about Phase Noise?

**What is Phase noise?**
It’s the transient uncertainty in the period of the signal *presented in frequency domain*.
“Jitter” is quantifying the same thing, except presented in time domain.

**How does phase noise propagate through a driver?**
Phase noise is not noise figure!
Phase noise of each component adds together when cascaded

**Oscillators are usually dominant source of phase noise**
Unless you have an extremely clean LO source, your oscillator phase noise will dominate your amplifier phase noise

Phase noise is NOT suppressed in most driver applications
Phase noise projects directly onto your RF/IF signal through the LO of your mixer, causes high jitter in clock generation, and is increased by frequency multiplication!
How Does Implementation Impact Phase Noise?

**Cascaded/parallel amps**
2 amps in series add together (~3dB extra)
2 amps in parallel cut phase noise in half (~3dB less)
Attenuators & loss have no impact on phase noise of a chain

**Sensitive to gain compression**
Optimum Phase noise performance is with some gain compression

**Independent to frequency**
To our knowledge, amplifier additive phase noise doesn’t get worse at higher frequency
Variations with frequency are more related to compression levels
BJT/HBT amplifiers contribute an order of magnitude less phase noise than pHEMT amplifiers.

Marki Microwave has developed proprietary design techniques to minimize additive phase noise and increase output power in GaAs HBT distributed amplifiers.

Coming soon to the Marki catalog: The APM-7098!

The newest addition to the APM line has 500MHz – 35 GHz bandwidth and 24+ dBm power output, making it the most powerful wideband GaAs HBT amp in its class, and an ideal NLTL driver amp.
Positive Supply Only/Sequenced

Some process technologies (D-mode GaAs pHEMT) require a negative bias voltage applied prior to positive supply being applied.

Chips or circuits which eliminate this issue make your life easier.

Marki’s ADM and APM amplifiers require no sequencing, and our APM amplifiers require positive-only bias voltages.

Marki’s new UC5 sequencer board allows for single-supply voltage operation of our AMM-6702 and future AMM-series amplifiers.

Positive Gain/Psat slope

A positive gain/Psat slope can offset some of the higher interconnect/component losses at higher frequencies.

Ultimately, positive gain slope either comes at the expense of low frequency performance or stability.

Keeping equalizers and amplifiers discrete offers more flexibility.

Our APM amplifiers are positive supply only.
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 APM Amps
Medium Power HBT amplifiers
High gain
Surface mount, bare die, and connectorized module

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

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

Marki Mission Statement
Empower our customers to **design faster**, **simplify production**, **eliminate complexity**, and **shatter performance barriers**

For More Information
Tech Notes
Videos
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Residual phase noise measurement

Additive Phase Noise Measurement Setup.
1 GHz Crystek Crystal Oscillator Source, DPXN2 Diplexers (operated as 1.4 GHz LPF), 2GHz LPF1, 970 MHz LPF2 filters. 100µF Bypass Capacitors on Driver/DUT Amplifiers.

Grounding cables are connected to outside of Coaxial cables to ensure sufficient grounding.
Additive Phase Noise Setup

100 uF bypass capacitors placed on Driver Amplifier and DUT Amplifier from the positive supply voltage to ground to reduce power supply noise.