Technical Article

Protecting Your RF Amplifier Stage with Analog Switches

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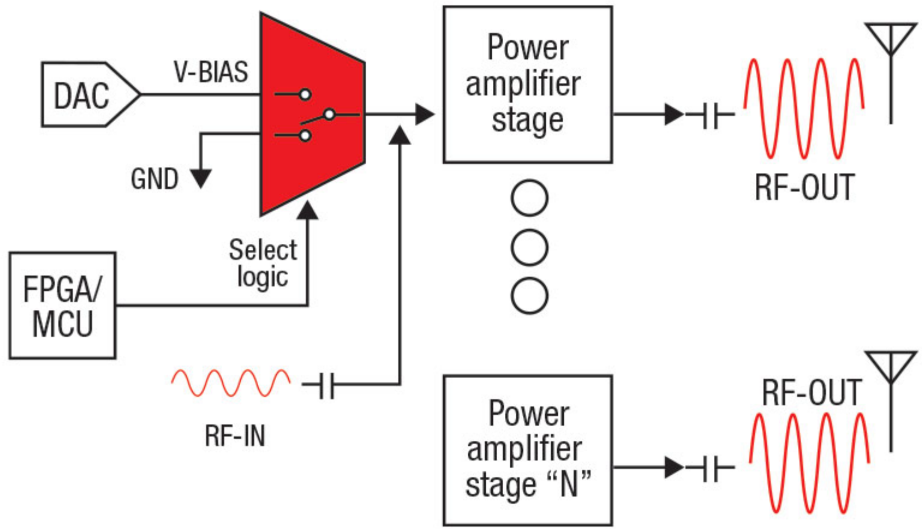
As the story of "The Hare and the Tortoise" taught us, sometimes it pays to be steady and calculated. With growing demand from consumers for higher bandwidth and speeds for their wireless data, the pressure is on semiconductor manufacturers to design systems that meet these requirements – much like how the hare focuses on being the fastest to reach the finish line. However, as the tortoise shows, it is just as important to be steady in this pursuit by ensuring that systems are rugged and reliable.

Because communications equipment, such as radio units and active antennas, is primarily based outdoors, it's critical that internal components operate reliably regardless of environmental factors. Analogous to Aesop's fable, systems must be high performing (like the hare), while being rugged (like the shell of the tortoise) to protect internal circuitry from external fault conditions. One way to ensure protection is to use an analog multiplexer, also known as a "mux," to protect the internal power amplifier (PA) stage.

Why the PA stage?

Amplifier integrated circuits (ICs) use electric power from a power supply to increase the power of an input signal. By using an amplifier, you can produce a strong output signal from a weak input signal. For example, PAs are used to drive the loads of output devices, such as headphones, speakers, servos and radio frequency (RF) transmitters.

In the case of RF transmitters, RF PAs amplify low-level RF signals in massive multiple-input multiple-output (MIMO) antenna systems. Traditional massive MIMOs contain eight transmitter and eight receiver (8T8R) RF channels to amplify their antenna signal. In contrast, modern 5G systems will have up to 64T64R channels that increase download/upload data rates and throughput. Having this many channels in one remote radio unit requires protecting each channel from external fault conditions. A simple and cost-effective way to protect a system from these fault conditions is to use a 2-to-1 analog switch per channel, as shown in Figure 1.



As you can see from Figure 1, there are multiple PA stages based on the number of transmit and receive channels in the radio unit. Getting these PAs to function correctly requires applying a bias voltage (V-BIAS) to the gate of each FET. Unfortunately, V-BIAS is susceptible to external fault conditions such as overcurrent, overvoltage or overtemperature events that can exceed nominal safe values. In such cases, a field-programmable gate array or microcontroller detects the fault condition and immediately sends a select logic signal to the mux, disconnecting the V-BIAS signal path. Without the V-BIAS signal, the PA stage turns off, protecting the channel from the fault condition. Ultimately, the 2-to-1 analog switch turns the PA stage off in the event of a fault while providing a safe path to ground for the low-level RF signal (RF-IN). Also, as each transmit path as 2-4 gain stages depending on the RF application, as shown in figure 2, the number of power amplifier that may require gate-side protection can grow significantly.

Protecting LDMOS Power Amplifiers

Analog switches, such as one-channel, 2:1 general-purpose analog multiplexer with 1.8-V logic control like the TMUX1247, can safely perform this function while operating at temperatures up to 125°C. Additionally, they can be directly controlled by 1.8-V field-programmable gate arrays or microcontrollers (MCUs) without the need for a level shifter due to their 1.8-V logic support. Read the application note, "Simplifying Design with 1.8 V logic Muxes and Switches" to learn more about the 1.8-V logic of these devices.

Protecting GaN Power Amplifiers

For GaN RF Power Amplifiers, the gate voltage is needed to pinch off the device so that there is no current rush through the device when the drain voltage is applied. Applying any drain voltage before the gate bias would destroy the device. Because GaN PA's are inherently depletion devices, the required gate bias is negative. The TMUX4157N, 2:1, 1-channel switch with negative voltage support of -4V to -12V, can be a cost-effective way of adding protection to your power amplifier from fault events while passing through negative voltages. Also, the TMUX4157N fast transition times and high continuous current through the switch make the switch well suited for Massive MIMO, radio communications, or radar applications, where the system needs to quickly switch between two different voltage inputs.

Adding Design Flexibility

Deciding between LDMOS and GaN power amplifiers or modules for the final stage solutions can be challenging with all the trade-offs between drain efficiency, linearity, video-bandwidth, and etc. The TMUX6219 (2:1 SPDT, 1-channel switch) can allow for faster design cycle time as it can support both pitch-off voltages that gate of GaN and LDMOS require, thus simplifying the BOM and adding more time in the decision between LDMOS or GaN power amplifiers. The TMUX6219 can operate with single voltage supply (4.5-V to 36-V), dual voltage supplies (±4.5-V to ±18-V), or asymmetric voltage supplies (e.g. VDD = 8-V and VSS = -12-V).

There are many solutions in protecting your RF power amplifier while adding flexibility to your BOM and development cycle. Protecting RF channels is critical because a fault event in one of these channels can cause significant damage to the RF-system line-up. With up to 64 channels per unit or ~1000 transmission lines in a radar system, this level of protection is critical to designing a high-bandwidth, high-speed system that has reliable performance. So, if you keep the tortoise's mindset when considering reliability and protection, you will remain in the race to meet the needs of next-generation networks.

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