APPLICATION NOTE

GaN Power Amplifier Pulsed Operation – Best Practices

Introduction

This document provides application information for pulse operation of Qorvo GaN MMIC-based power amplifier products.

Drain Pulsing - Summary

For decades, pulsing of RF/microwave amplifiers has been used in radar systems and other applications where pulsed RF signal are required. Drain pulsing has some advantages over gate pulsing for high power microwave amplifiers, primarily for switching speed and stability concerns. Although the need had developed over the years to switch higher voltages and currents, especially using GaN power amplifiers, the implementation of switching the drain voltage has been adopted in the majority of pulsed applications.

Additional circuitry can be included to reduce overshoot, provide current limiting, fault shutdown capability, etc., at the cost of additional components and complexity. These functions are not covered in this application note.

The next section presents a description and discussion of a simple drain voltage pulsing circuit (Figure 1).

Drain Pulsing – Circuit Schematic

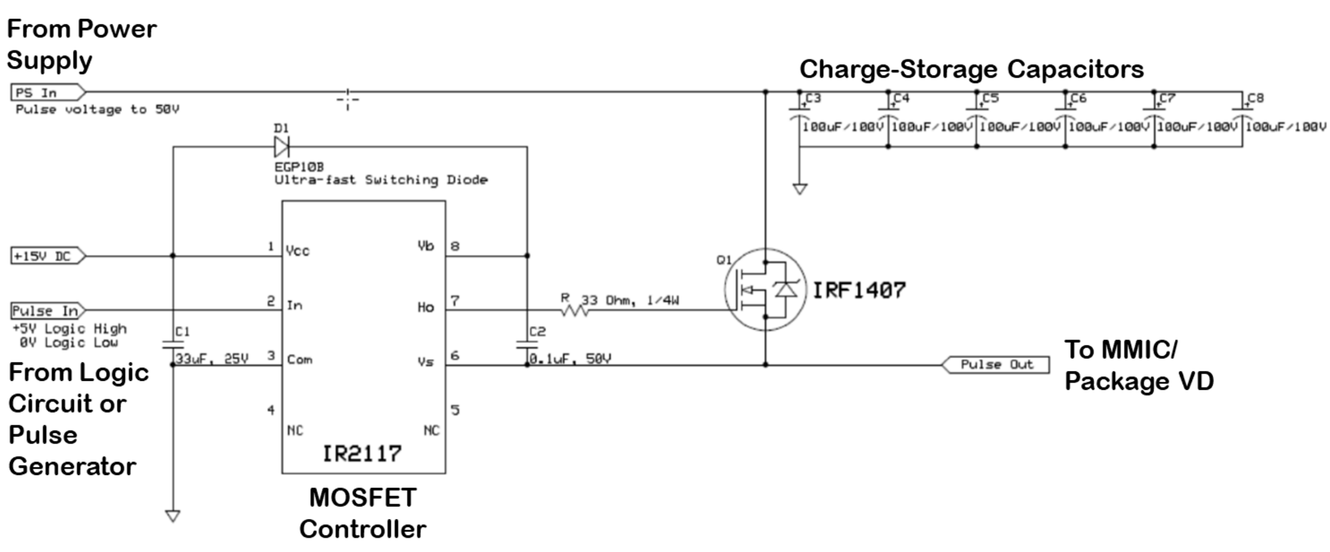

Figure 1. Schematic of a simple pulse drain voltage circuit

Drain Pulsing - Components

The primary component of a drain voltage pulsing circuit is the power switching MOSFET/HEXFET. It is required to have low Ron channel resistance (in the mΩ range) to provide a low voltage drop when switching high drain currents, fast switching speed, and sufficient voltage and current handling to maintain reliability.

The MOSFET controller drives the gate control signal to switch the power MOSFET. It accepts simple +5V/0V pulse switching logic (TTL/CMOS compatible) from other circuitry, or from a laboratory signal or function generator. This can be implements as an IC (simple) or built from discrete components (more complex, but can potentially achieve higher switching speed).

The charge storage capacitors (C3-C8) provide sufficient charge storage to allow for fast switching times. These capacitors must be of suitable voltage rating to avoid damage, and of sufficient capacitance value to store and supply sufficient charge during amplifier pulsing.

The layout of the drain pulse circuit PCB should seek to reduce any stray capacitance or inductance around the various components, especially between the MOSFET controller and the power MOSFET, so as to provide for good pulse fidelity to the amplifier. The use of short leads to minimize inductance between the pulse circuit and the amplifier to maintain good pulse fidelity at the amplifier, and reduce possibility of oscillation, is recommended. Shielded wires may also be required to avoid distortion of the pulse.

Any additional bypassing capacitance of the microwave amplifier needs to be considered when determining the amount of charge storage capacitance on the drain voltage pulse circuit. Pulsing an amplifier with approximately 1000-2000 pF of additional bypassing should be possible with minimal impact to the rise and fall times, but additional bypass capacitance will likely impact the achievable switching speeds.

For a system application, the power supply circuitry should have sufficient output capability to maintain its voltage in both the on and off states of the pulse circuit (lab supplies should have no problem with this); additional capacitance may be required to provide sufficient charge storage over environmental conditions.

Pusle widths of about 1 us and longer can be obtained with a circuit similar to the above.

RF Pulse Within the Drain Pulse Envelope

Potential power and phase measurement improvement can be obtained by pulsing the RF input signal within the drain voltage pulse (Figure 2), and gating the measurement system to measure the RF power within the same pulse window.

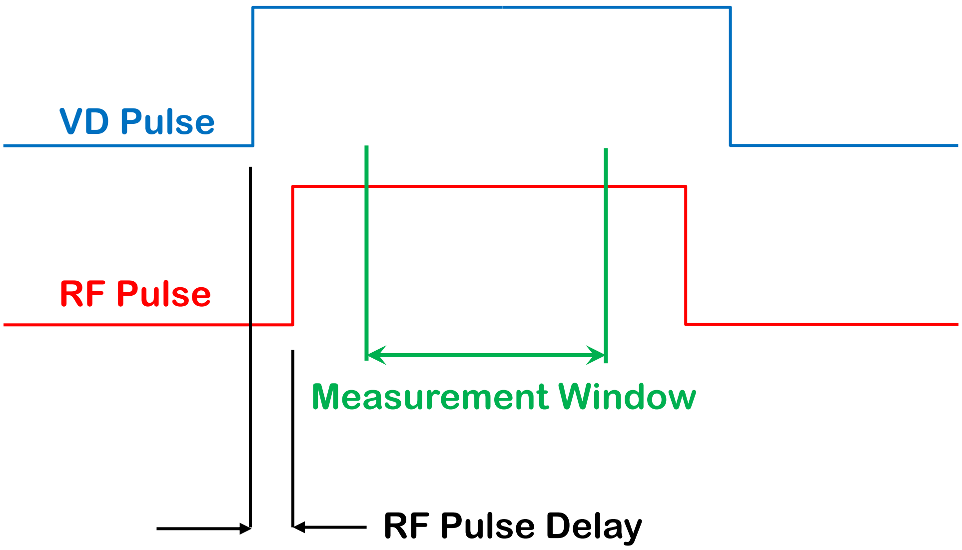

Figure 2. Gating of the RFpulse within the VD pulse

Delaying the start of the RF pulse after the start of the drain pulse (~ 100 ns to 10 us) allows for any potential transient instabilities to settle out prior to application of the RF signal, when moving through a momentary (potentially) unstable voltage condition on the leading edge of the pulse. It also reduces the variation when comparing amplifier performance due to the thermal variations during the on period. It also allows for obtaining consistent performance among several amplifiers in a given application (e.g., a phased-array antenna, or power-combined SSPA), since any amplifier voltage transients have dissipated prior to applying RF power to the amplifier(s). The amount of delay between the drain and RF pulses is system specific, and is dependent on the amount of transient disruption (if any) on the leading edge of the drain voltage pulse, and the settling time required of the voltage pulse.

Gating the pulse measurement (e.g., between 35% to 65 % of the RF pulse) allows for settling out of RF power variation due to transients on the VD pulse, or thermal variation during the RF pulse. Gating the RF measurement allows for a consistent measurement reference point for the output power, both within a specific device, and from device to device. This allows for uniform comparison of a group of amplifiers, or uniform comparison between different amplifier products.

Gate Voltage Pulsing

Pulsing the gate voltage has been of interest for a number of years. The elimination of the need to switch high drain voltages and large amounts of drain current, with the subsequent potential simplification of the circuitry involved, is the primary motivation.

While the potential exists for faster switching speeds, smaller pulse widths, plus the reduced voltage switching, when using a gate voltage pulsing circuit, there are some issues to be considered. The first is that many RF/microwave power amplifiers require large capacitive bypassing to insure stable operation over RF load and temperature conditions. This additional capacitance (usually > 10 uF) is difficult to drive with conventional small signal voltage components. Removal of the largest of these capacitors may be possible, but due diligence needs to be performed to ensure that the amplifier remains stable over its expected operating conditions.

Additionally, switching between the pinchoff voltage of the amplifier and the nominal gate voltage is a smaller voltage range, but is much more sensitive in voltage variation at the amplifier than drain switching (between 0 V and the operating drain voltage). The range of gate voltage for given value of quiescent drain current in a GaN power amplifier can be 0.3 V or more over process variations, with a subsequent variation of quiescent current at a fixed value of gate voltage. This requires the gate voltage pulse circuit to be more immune to voltage variations due to power supply variations and extraneous signal coupling that can be passed to the amplifier which can cause variation in performance.

Ability to meet fast switching times and narrow pulse widths means that the gate voltage pulse circuit is even more sensitive to circuit parasitics. Detailed modeling and electromagnetic analysis of the circuit and component layout is required to minimize these effects.

Note that the additional large value drain storage capacitors are required for gate pulsing operation as well as for drain pulsing, so as to reduce the loading of the drain power supply.

Qorvo engineers are actively investigating gate voltage pulse circuitry for our GaN-based power amplifier products; as more information becomes available, this applications note will be updated.

Additional Information

For information on pulsed power amplifiers, ESD, Soldering Profiles, Packaging Standards, and Handling and Assembly, please refer to the relevant product data sheets and application notes at **www.qorvo.com**, or contact Qorvo for general guidelines.

Contact Information

For the latest specifications, additional product information, worldwide sales and distribution locations:

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