



GaN HEMT Pulsing Circuit

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1. INTRODUCTION

In many applications such as military, weather and marine radar, RF power amplifiers are used in pulsed mode. Typically, the RF signal is pulsed while the DC bias used to power the transistor to a set point is left constant. However, in other applications pulsing the DC bias allows for reduced interference to the receiving path, noise and power consumption.

For Wolfspeed GaN on SiC HEMT devices careful consideration needs to be taken when pulsing either the gate or drain of the device. Wolfspeed GaN on SiC HEMT are depletion mode devices, which means a negative voltage (such as -5 V) needs to be applied on the gate to turn off the transistor. Applying drain voltage with 0 V on the gate will result in catastrophic damage to the device.

The main challenge of drain pulsing is the high current on the drain side and switching time that can be achieved. This application note goes over a circuit that was used to achieve 1.9 μ s turn on time for a high-power (20 A peak) device using drain pulsing.

2. DRAIN PULSING CIRCUIT

A load switch configuration is used to apply the voltage needed to the drain of the device and is comprised of two main elements: the pass transistor and the on/off control block, as shown in Figure 1.

The pass transistor is most commonly a MOSFET (either N-Channel or P-Channel) that passes the voltage supply to a specified load when the transistor is on.

The selection of a P-Channel or N-Channel load switch depends on the specific needs of the application. When using a P-Channel MOSFET in a load switch circuit (as in Figure 1) the source is directly connected to the input voltage rail and the drain is connected to the load. For the P-Channel load switch to turn on, the source-to-gate voltage V_g must be greater than the threshold voltage.

Therefore:

$$V_{in} \geq V_g + V_{th} \quad \text{Eq.1}$$

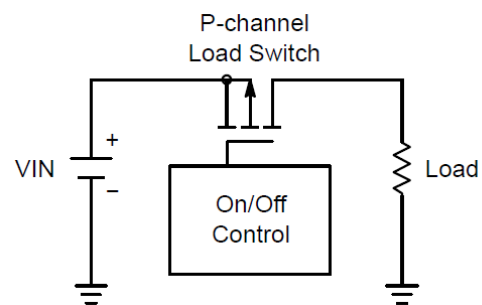


Figure 1. Commonly Used P-Channel Load Switch Circuit

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At a minimum, the input voltage rail must be greater than the threshold voltage of the selected pass transistor (assuming the gate voltage is 0 V when the load switch is turned on).

The N-Channel MOSFET has several advantages over the P-Channel MOSFET. First, the N-Channel transistor has lower turn on resistance ($R_{ds,on}$) and lower gate capacitance for the same die area. When using an N-Channel MOSFET in a load switch circuit, the drain is connected directly to the input voltage rail and the source is connected to the load. The output voltage is defined as the voltage across the load, and therefore:

$$V_s = V_{out} \quad \text{Eq. 2}$$

For the N-Channel MOSFET to turn on, the gate-to-source voltage must be greater than the threshold voltage of the device. This means:

$$V_g \geq V_{out} + V_{th} \quad \text{Eq. 3}$$

To meet Equation 3, a second voltage rail is needed to control the gate shown in Figure 2. Therefore, the input voltage rail can be considered independently of the pass transistor. Because of this, the N-Channel load switch can be used for very low input voltage rails or for higher voltage rails, as long as the gate-to-source voltage V_{gs} remains higher than the threshold voltage of the device.

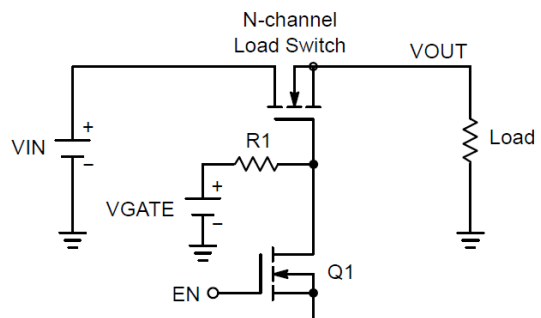


Figure 2. N-channel Control Circuit Block

For this reason, the P-Channel MOSFET has a distinct advantage over the N-Channel MOSFET, and that is the simplicity of the on/off control block. The N-Channel load switch requires an additional voltage rail for the gate; the P-Channel load switch does not.

When the switching time, especially the off time is not critical, P-Channel MOSFET is preferred because of the simplicity of the circuit. In the drain pulsing circuit described in the next section, a P-Channel MOSFET is used as the switching FET.

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3. CIRCUIT OPERATION

As shown in Figure 3, to meet high current requirements (up to 20 A) and to simplify the drain DC power switch control circuit needs, the 100 V P-Channel MOSFET SQM120P10 is selected.

This P-Channel MOSFET has very low turn on resistance with the key specifications listed below:

- Vds (V) = -100 V
- Rds(on) (Ω) = 0.0101 @ Vgs = -10 V
- Rds(on) (Ω) = 0.0150 @ Vgs = -4.5 V
- Drain Current (Id) = -120 A

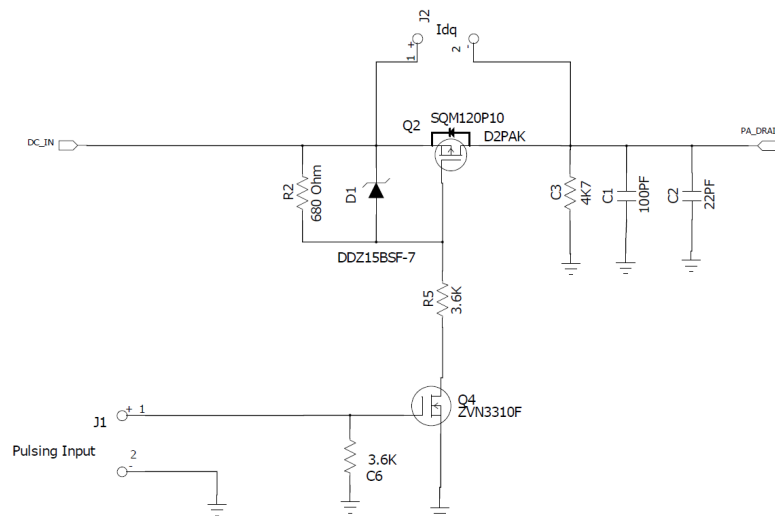


Figure 3 Circuit Schematic

The following are the inputs/outputs of the circuit:

- DC_IN: connected to the DC power supply
- PA_DRAIN: connected to the drain of the RF transistor
- J1: connected to the pulse control signal
- J2: setting the Idq of the transistor (short J2 to bypass Q2 for setting the desired Idq)

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During operation R2 and R5 form the voltage divider to provide the control voltage for gate of Q2. When the voltage on pin 1 of J1 is greater than 2 V, the N-Channel FET Q4 is on (drain and source are connected), Q2 gate to source voltage, V_{gs} , changes from 0 to -8 V (DC_IN=50 V), Q2 is turned on (drain and source are connected), and the output voltage is

$$PA_DRAIN = DC_IN - R_{ds}(ON) * I_d$$

In the application fixture tested at Wolfspeed, the drain current, I_d , is 18 A and $R_{ds} \approx 0.010 \text{ Ohm}$, resulting in the following:

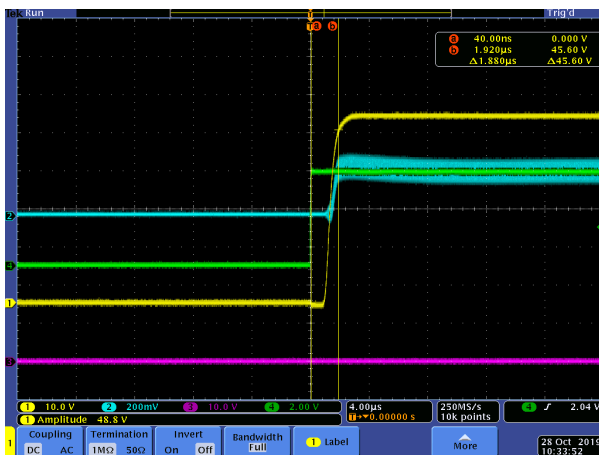
$$PA_DRAIN = 50 - 18 * 0.01 = 49.82 \text{ V} \approx DC_IN.$$

When pulsing input signal at pin 1 of J1 is low (less than 0.7 V), Q4 is off and Q2 $V_{gs} = 0$, Q2 is off, output voltage at PA_DRAIN is 0 V.

Selection of R2 and R5 values is based on the current through the divider and the MOSFET gate control voltage. The current can be set between 5 mA to 15 mA and under the on condition, the voltage at the MOSFET gate V_{gs} should meet the value on the MOSFET datasheet.

In high current applications, set the Q2 gate voltage V_{gs} at a value to reduce Q2 turn on resistance R_{ds} such as -10 V by changing the voltage divider resistor values. The downside of doing this is it may delay the turn off time. Under normal conditions, setting the Q2 V_{gs} to -4.5 V is preferred because the $R_{ds} = 0.015 \text{ } \Omega$ and turn off time will be shorter.

The zener diode is used to protect the MOSFET so the Q2 V_{gs} does not exceed 14 V.



Notes: Green: RF Pulsing Trig Input. Yellow: DC Output Voltage. Blue: RF Output

Setting $V_{gs} = -8 \text{ V}$ at turn on allows for 28 V to 50 V wide DC range. In this DC range, the V_{gs} ranges from -4.5 to -8 V.

Below is measured turn on delay plot under 50 V DC and 18 A peak current condition. The test signal used is 1 mS, 10% Pulse. The resulting turn on time is 1.88 us when the output DC voltage reaches 90% of the DC Input (45 V).