APPLICATION NOTE

Application Note 107

A Bias Sequencing Circuit for Amplifiers Requiring a Negative Gate Voltage

Introduction

When using depletion mode devices in amplifiers, both a positive and a negative voltage supply are required for operation, which doesn't normally present a problem so long as the negative voltage (gate control) is applied first. However, if the positive voltage (drain side) is applied first, the results can be catastrophic—device destruction being the most common outcome. Such destruction can also happen if the negative voltage is turned off first. To solve this problem, Custom MMIC has developed a sequencer circuit to ensure that the voltages are turned both on and off in the correct order, so that the device is not damaged.

Circuit Operation

A simplified block diagram of Custom MMIC's sequence circuit is shown in Figure 1. Here, U1 and U4 are voltage regulators, U2 is a negative voltage generator, and U3 is a comparator to control the timing of the circuit. The input voltage, V_1, powers both U1 and U4. The regulated drain voltage, V_4, is provided directly from U4 to the drain of the amplifier, but only when it receives an enable signal from U3. U1 produces a regulated voltage, V_2, which can provide a positive Vgg_2 gate voltage to the DUT (if needed). Voltage V_2 also powers the negative voltage generator U2 and the comparator U3. The output of U2 is applied to the DUT as Vgg_1. As for timing, the comparator is designed such that once V_2 is within 5% of Ref (a preset value), it will send the enable signal to U4. Then, and only then, is V_4 applied to the DUT. Since V4 will not be enabled until it has received the signal from U3, we are guaranteed that Vgg_1, the negative gate voltage, is applied before the positive drain voltage.

A functional schematic of the sequencer circuit is shown in Figure 2, while a PCB layout is provided in Figure 3. Here, we note the output voltages Vgg_1, Vgg_2, and V_4 can be set through external resistors. For example, Vgg_1 is controlled by resistors R_5 and R_6, whereas Vgg_2 is controlled by R_1 and R_2, and V_4 is set by R_9 and R_{10}. A table of resistor values for different Custom MMIC parts is provided at the end of this note in Table 1.

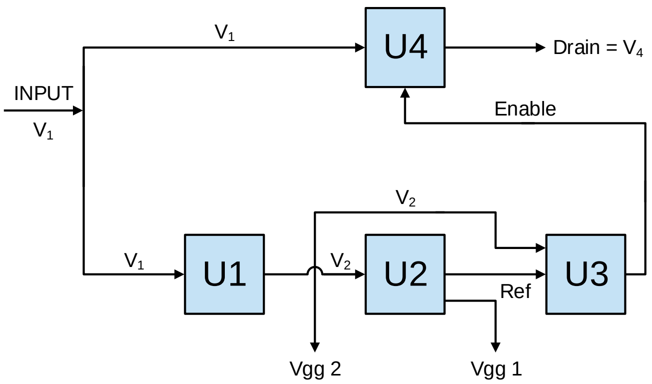

Figure 1. Block Diagram Of The Sequencer Circuit.

Full Schematic

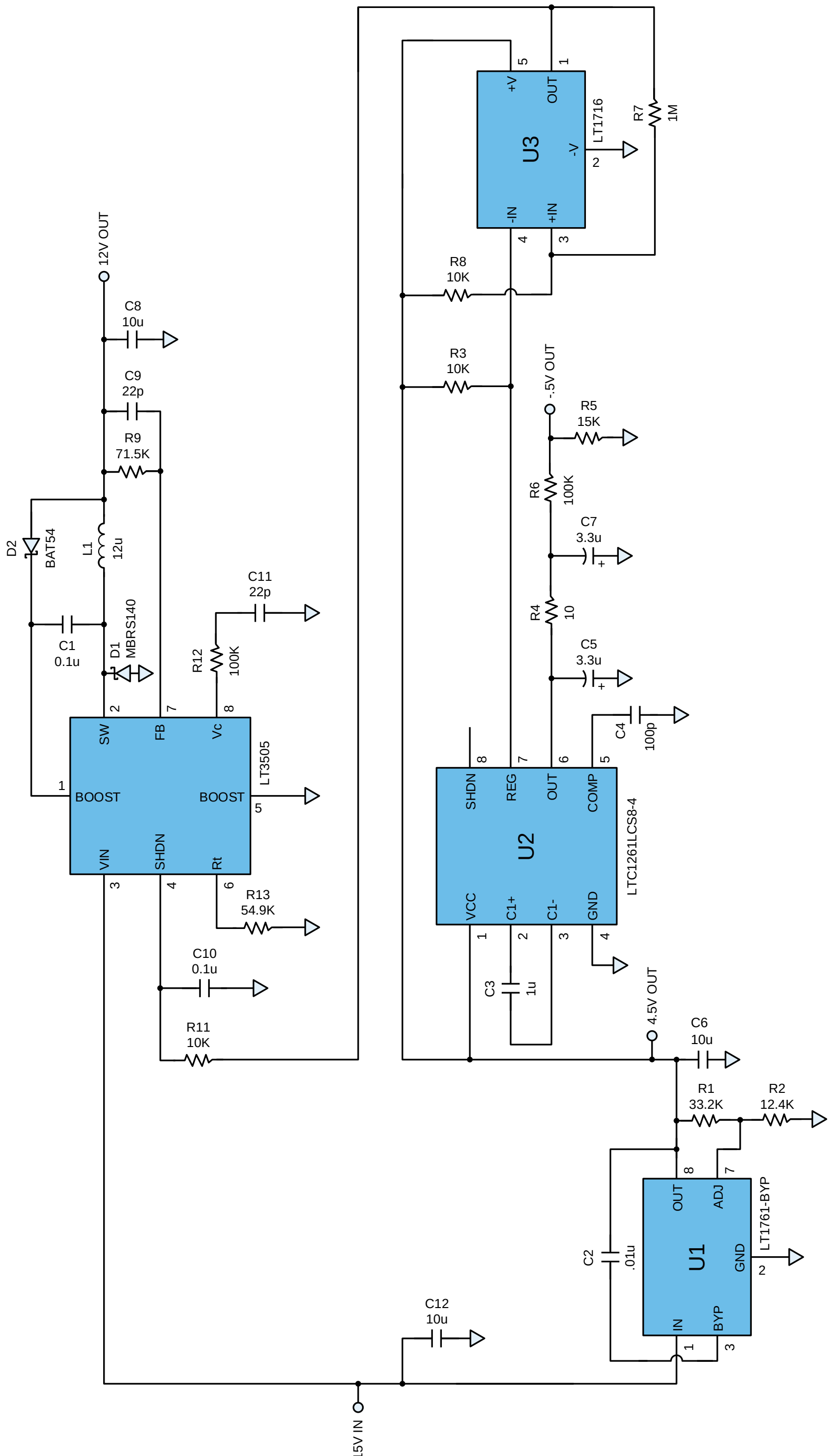

Figure 2. Schematic Of The Sequencer Circuit.

Assembly Drawing

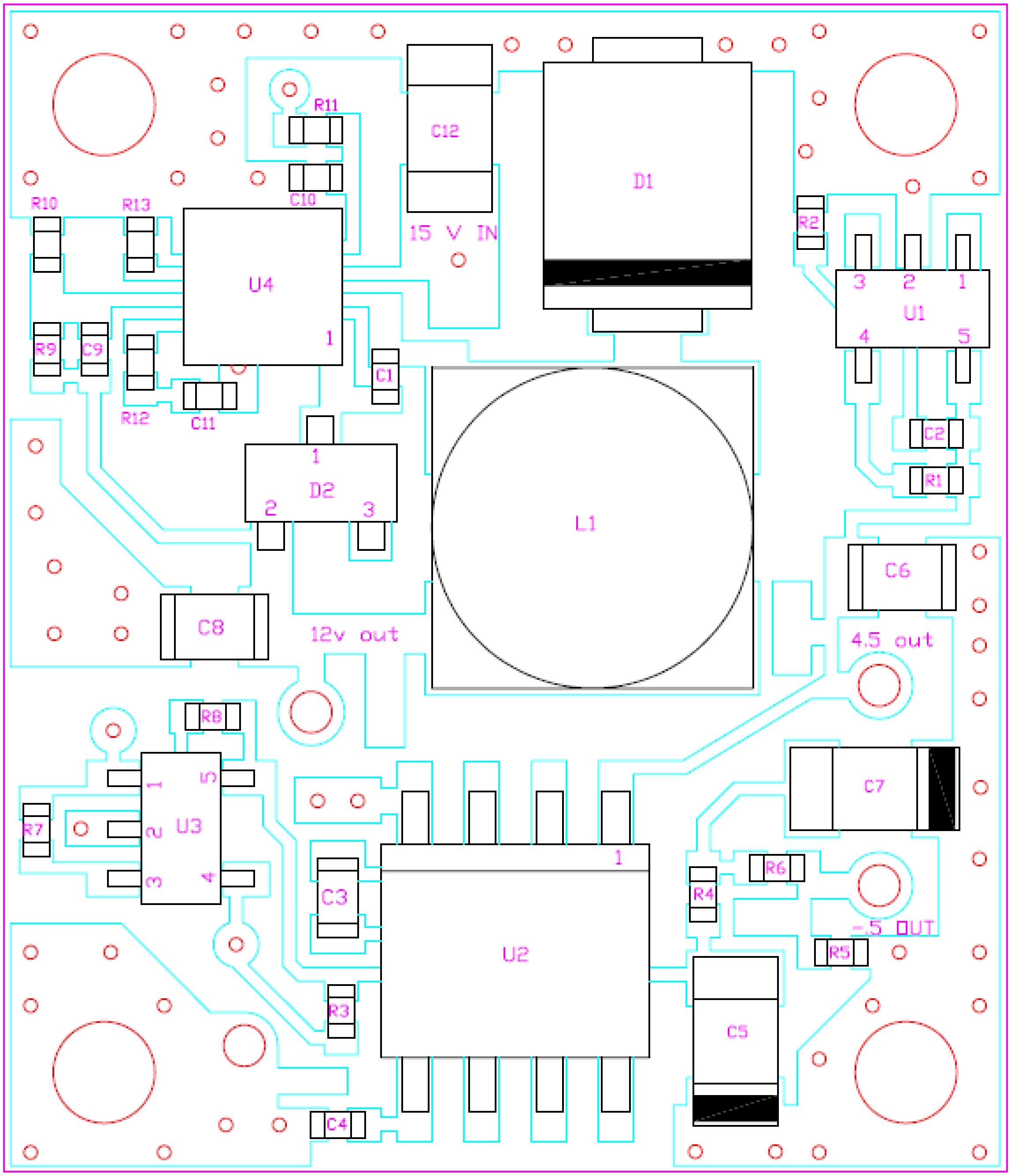

Figure 3. PCB Layout Of The Sequencer Circuit.

Sequencer Testing

To demonstrate performance of the circuit, we assembled the sequencer circuit described in Figures 2 and 3, and chose resistor values using the equations provided in Table 1 such that output (drain) voltage V_4 was 12 V and the gate voltage Vgg_1 was –0.58 V. In Figure 4, we present a timing diagram the drain voltage and Vgg_1 as the external supply voltage, V_1, is cycled on and then off. We note that on the rising edge (near 0.3 s), Vgg_1 reaches its negative value before the drain voltage V_4 is turned on, as intended. At the falling edge near 1.2 seconds, the external supply voltage V_1 is turned off, and it is clear that the drain voltage V_4 turns off before Vgg_1 turns off. We experimented with different levels of drain (V_4) and gate (Vgg_1) levels, and in all cases the results were identical in terms of sequencing.

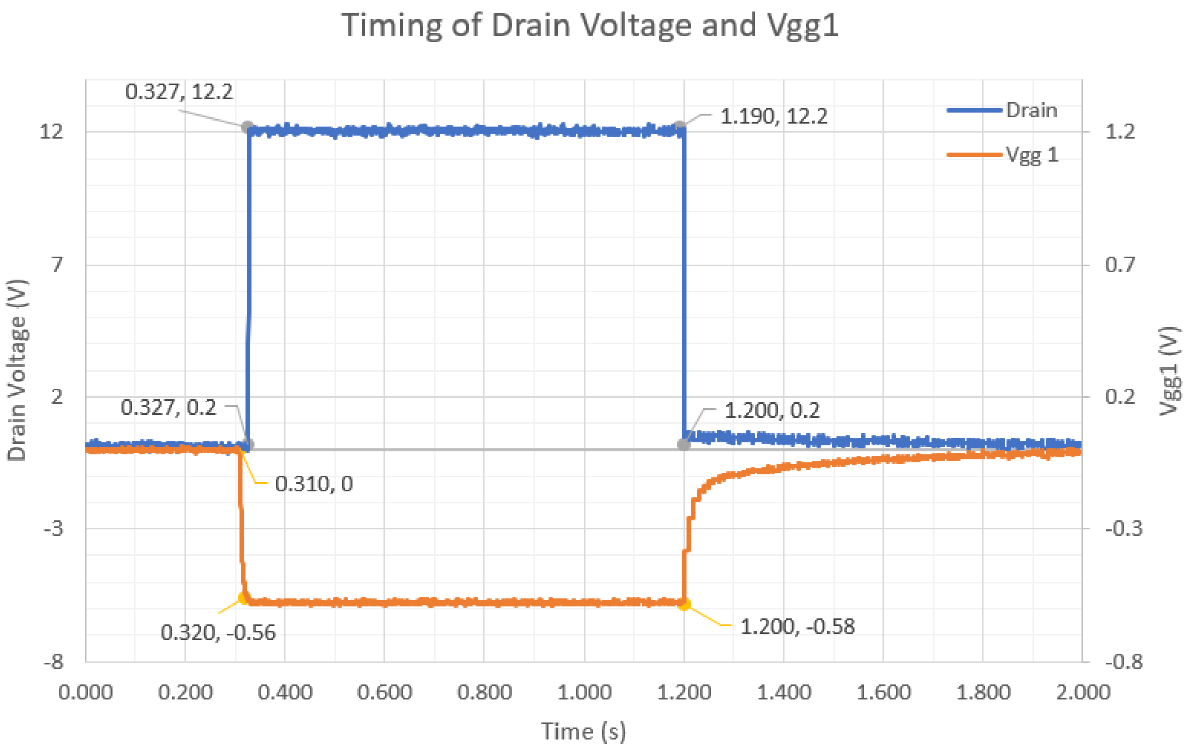

Figure 4. Timing Diagram For Drain Voltage V_4 And Gate Voltage Vgg_1.

Sequencer Applied to CMD201P5

Our next step was to use the sequencer to power a Custom MMIC amplifier. For this demonstration we chose the CMD201P5, which requires the following voltages for operation: V_4 = 10 V, V_{gg1} = -0.5 V, and V_{gg2} = +5 V. Using the equations shown at the end of Table 1, we determined the necessary resistor values for R1, R2, R5, R6, R9, and R10 to generate these voltages. We then tested the sequencer without the CMD201P5 applied to make sure the timing and levels were correct. We next used the sequencer board to power up a CMD201P5 and then we measured the amplifier's S-parameters on a network analyzer. In Figure 5, we present the results of this measurement, which shows normal operation for the CMD201P5. Indeed, there is no significant difference between these results and those obtained from manually biasing the CMD201P5 with separate dedicated supplies that were turned on in the proper sequence. Therefore, these results illustrate that the bias sequencing circuit both assures that all of the voltages are applied in the proper sequence and that it does not negatively impact the RF performance of the amplifier.

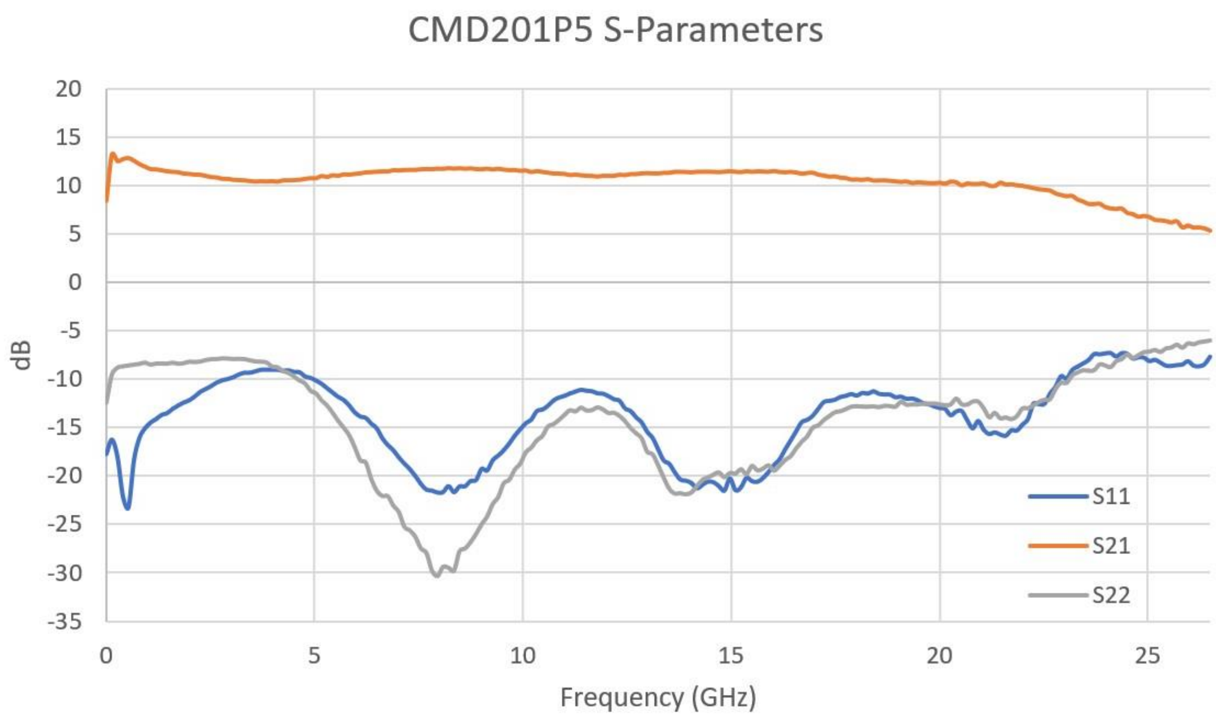

Figure 5. Measured S-Parameters Of CMD201P5 Using Sequencer Bias Circuit.

Table of Resistor Values

In Table 1 below, we present the resistor values (1% tolerance required) needed to produce the voltages listed for each Custom MMIC depletion mode amplifier. The equations to calculate these values are also stated below. Please note that all voltages listed are typical values for each part and may vary in practice.

PART CMD	R1 (Ω)	R2 (Ω)	R5 (Ω)	R6 (Ω)	R9 (Ω)	R10 (Ω)	DRAIN V_4	Vgg1 (V)	Vgg2 (V)
192/C5	100k	33.2k	Open*	1.74k	93.1k	10k	8	-1	N/A
201/P5	100k	32.4k	15.8k	100k	59k	4.99k	10	-0.55	5
218/C4	100k	33.2k	57.6k	42.2k	59k	4.99k	10	-2.3	N/A
219/C4	100k	33.2k	57.6k	42.2k	59k	4.99k	10	-2.3	N/A
240/P4	100k	33.2k	10k	56.2k	53.6k	10k	5	-0.6	N/A
241/P4	100k	33.2k	10k	51.1k	53.6k	10k	5	-0.65	N/A
242	100k	33.2k	10k	115k	93.1k	10k	8	-0.32	N/A
244	100k	33.2k	Open*	1.87k	93.1k	10k	8	-1	N/A
249	100k	33.2k	10k	31k	59k	4.99k	10	-0.95	N/A
276C4	100k	33.2k	57.6k	42.2k	59k	4.99k	10	-1.5	N/A
277C4	100k	33.2k	10k	10k	59k	4.99k	10	-2	N/A
278/C4	100k	33.2k	11.8k	13.7k	59k	4.99k	10	-1.85	N/A
291	100k	33.2k	10k	69.8k	53.6k	10k	5	-0.5	N/A
292	100k	53.6k	10k	71.5k	59k	4.99k	10	-0.5	3.5
293	100k	33.2k	10k	78.7k	53.6k	10k	5	-0.45	N/A
304	100k	33.2k	10k	88.7k	28.7k	10k	3	-0.4	N/A

Table 1. Summary of 1% resistor values required for the correct bias of each Custom MMIC part.

$$V_{drain} = 0.75\left(\frac{R9}{R10} + 1\right)$$

$$V_{gg1} = -4\left(\frac{R5}{R5 + R6}\right)$$

$$V_{gg2} = 1.22\left(1 + \frac{R1}{R2}\right) + (30.\ \ 10^{-9}(R1)$$

* The CMD192/C5 and CMD244 both include shunt resistors which need to be accounted for when calculating the value of R6. For the CMD192/C5 the effective resistance of R5 is 588 Ω and for the CMD244 it is 633 Ω.

Acknowledgements

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Additional Information

For information on ESD, Soldering Profiles, Packaging Standards, Handling and Assembly, please contact Qorvo for general guidelines.

Contact Information

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