GaAsFET LNA Bias – Simple, Cheap, and Fool-resistant

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Last year, I read an article[1] about negative bias for GaAsFETs and newer low-noise devices , using an optoisolator to generate the negative voltage. Recently I've been playing with an LNA for 10 GHz. I remembered the article and thought I'd give it a try.

How does it work? Many of us know that all diodes are light-emitting, at least for a very short time. All semiconductor junctions are light sensitive, so most devices are in light-proof packages. An LED is fabricated to emit light efficiently; it also produces a voltage if illuminated with a bright light – try it. An optoisolator contains an LED and a light-sensitive transistor; current through the LED normally causes the transistor to switch, but if we can get to all three terminals of the transistor, we can use the voltage generated instead.

The article suggested that connecting the LED in the optoisolator in series with the FET current could ensure that the FET would never operate without bias. I took it a bit further and came up with a bias circuit that is pretty fool-resistant (nothing is foolproof – there is always a bigger fool). The schematic diagram is shown in Figure 1.

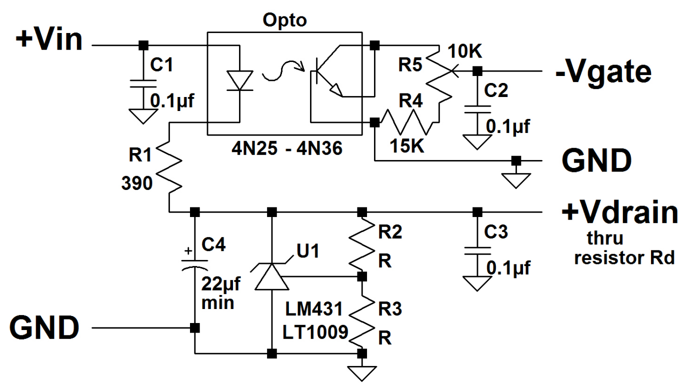

Figure 1 – Simple, Cheap, and Fool-resistant GaAsFET bias circuit

The total parts cost from Mouser should be about $2. I made a simple printed circuit board shown in Figure 2 and tested it with a couple of different optoisolators that I had on hand. They work as expected with my LNA prototypes.

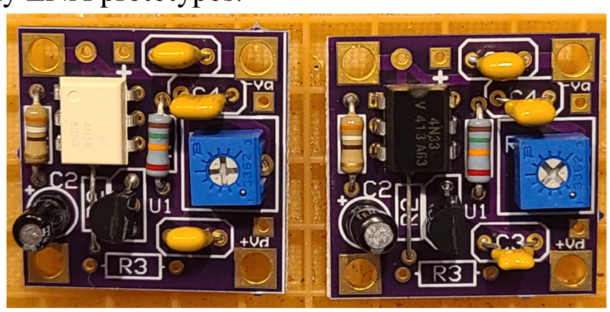

Figure 2 – PC Boards

How does it work?

The FET (or other fancy name low-noise device) drain current passes through the optoisolator, through R1 which limits total current, to an LM431 shunt voltage regulator, which limits maximum voltage. The optoisolator generates about 0.5 volts with a maximum current of around 50 microamps – plenty, since the gate should draw zero current. A typical LNA has a 51 ohm resistor in series with the drain, dropping the drain voltage, so the shunt regulator should be set to provide the desired operating voltage at the drain.

The device I am using, the CEL CE3512 Super Low Noise FET, is specified to operate at 2 volts and 10 milliamps. A current of 10 mA through the 51 ohm drain resistor is about 0.5 volts drop, so the shunt regulator voltage should be 2.5 volts. The LM431 (or TL431 equivalent) operates at 2.5 volts when R2 is zero and R3 is left open. The LM431 needs at least 5 mA for good regulation, so R1 is chosen to set the total current to at least 15 mA. For stability, C4 must be at least 22 uF. The gate voltage for 10 ma is about −0.4 volts. With R4 and R5 values shown, the gate voltage is adjustable from −0.3 to −0.5 volts. Bias adjustment is simple: turn the pot until the drain voltage is 2.0 volts – current must then be 10 mA.

For higher FET voltage, the LM431 is set to a higher voltage by R2 and R3:

$$Vreg \approx 2.5 * (1 + R2/R3)$$

Failsafe: maximum FET voltage is the shunt regulator voltage, and maximum FET current is limited by R1 to design current plus 5 mA or so.

Design Procedure

For a desired drain voltage Vd and current Id:

$Vreg = Vd + (Id * 51)$ [assuming a 51 ohm series resistor in LNA]

$R1 \leq (Vsupply - Vreg - 1.2) / (Id + .005)$ [1.2 volts for optoisolator, 5 mA for LM431]

Example

Tommy, WD5AGO, wants to use a higher IP3 device that operates at Vd=3.5V and Id = 40 mA.

$Vreg = 3.5 + (.04 * 51) = 5.5$ volts

R2 = 12K and R3 = 10K will produce 5.5 volts

$R1 \leq (12 - 5.5 - 1.2) /(.04 + .005) = 228$ ohms [220 ohms is standard value]

Higher bias voltage

The optoisolator only generates about –0.5 volts. If a higher negative voltage is needed, simply add another one in series:

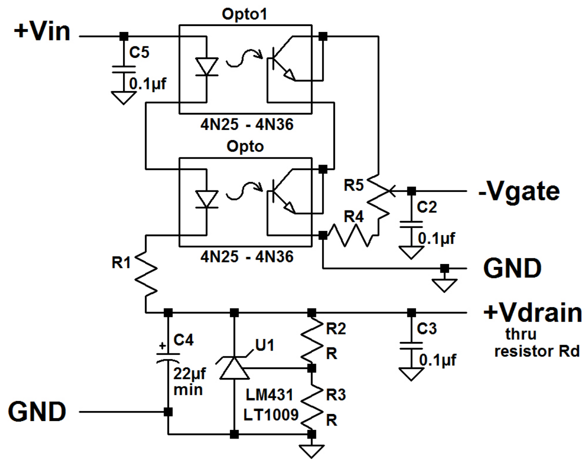

Figure 3 – Bias circuit with higher negative output voltage

The second optoisolator increases the voltage, but not the maximum current, so R4 + R5 should total at least 50K ohms.

Summary

This simple circuit provides negative bias voltage for an LNA without the need for voltage inverters and noisy switching power supplies. It is cheap and easy to build and fool-resistant.

Note

1. Aljaž Blatnik and Matjaž Vidmar , "Photovoltaic Bias for Depletion-Mode Devices in Low-Noise Amplifier Applications," *IEEE Microwave Magazine,* March 2023, pp. 44-51.