Temperature Compensation of a JFET-Based Amplifier With a Simple Resistance Temperature Detector

By Alain Stas

With the trend toward miniaturization, temperature effects in power electronics are more pronounced than ever.

If you are dealing with temperature fluctuations in your circuit, you may need a stabilization system to keep the temperature constant and minimize noise in the circuit response. One approach is to use an optoelectronic circuit with a negative temperature coefficient sensing element and a thermoelectric cooling component. However, a more cost-effective and equally effective solution is to replace certain fixed resistors with temperature-dependent resistors that automatically compensate for temperature variations.

The circuit shown in Fig. 1 is a wideband gain amplifier stage built around a JFET transistor. This type of circuit is commonly used to convert a photodiode current into a voltage signal [3]. This configuration enables linear gain control over a range spanning up to three decades, thanks to the JFET placed in the feedback path of a non-inverting amplifier. onsemi describes this circuit in detail in application note AN-6603 [2].

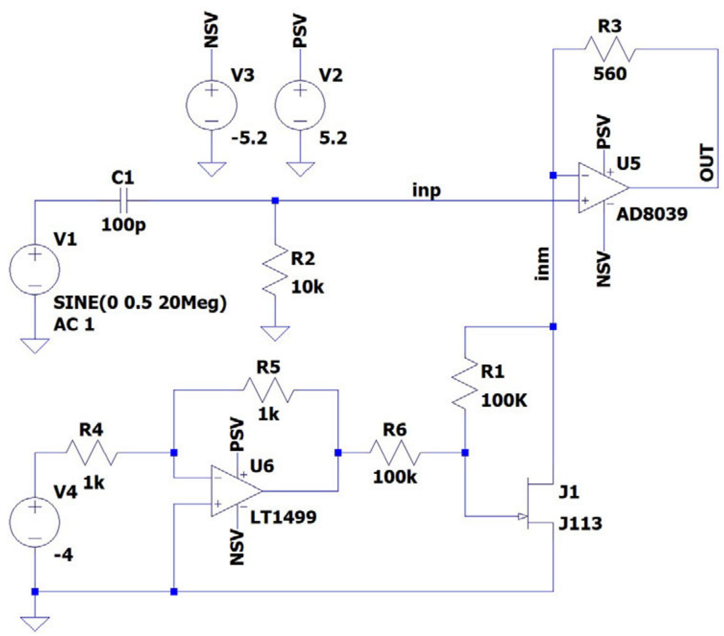

Fig. 1 - The examined circuit (used commonly, for example, to convert a photodiode current into voltage) is a large band gain amplifier stage based on a JFET transistor (J111). This linear control function over up to three decades of gain is achieved with this JFET in the feedback path of a non-inverting amplifier. This circuit is described by onsemi in AN-6603 A Linear Gain Controlled Amplifier [2]

But what about temperature fluctuations? Thanks to the very powerful SPICE simulator LTspice® (from Analog Devices) [4], the AC small signal gain frequency (1 Hz up to 1 GHz) analysis of the circuit of Fig. 1 is straightforward, and the parasitic temperature effect (from -50 °C up to +125 °C) can be directly represented in Fig. 2.

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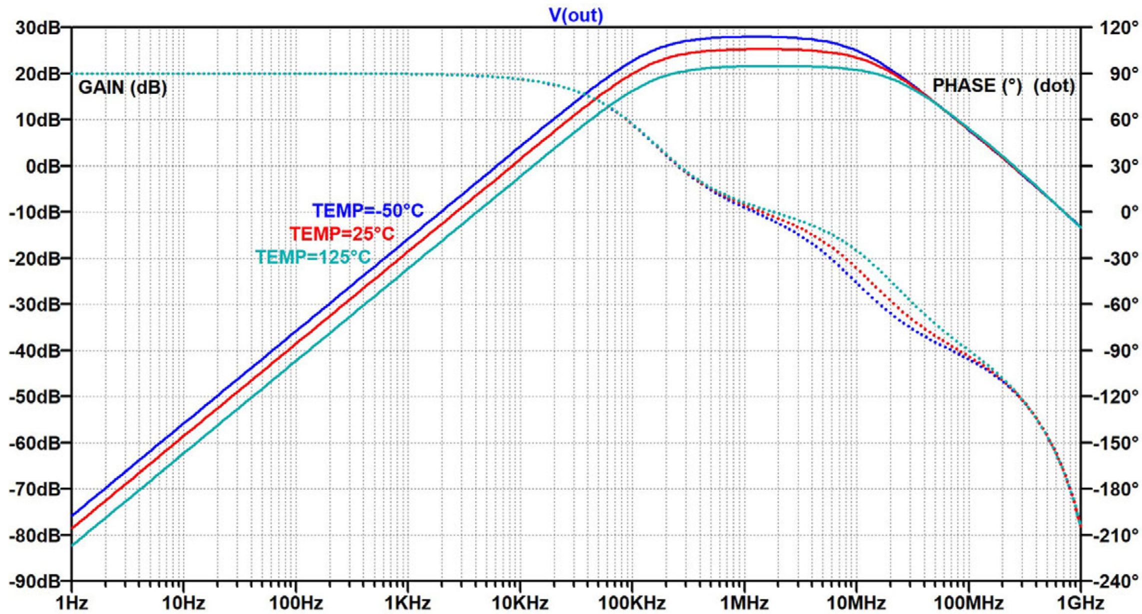

Fig. 2 - The cause of gain variation in temperature shown here can be attributed to the BETATCE transconductance temperature coefficients (in %/°C) of the J113 JFET. This is seen in the SPICE model description text

onsemi's application note [2] acknowledges that the gain of this circuit is temperature-dependent, a result of the JFET's inherent sensitivity to temperature. The note also briefly mentions that this effect may be mitigated by using a silicon resistor for the feedback resistor R3 - but offers no further guidance. This lack of detail left the author looking for a clearer solution.

Unfortunately, the widely used KTY81 silicon resistor series (a positive temperature coefficient component) has been discontinued as of 2023 [6], and no clear equivalent is currently available - at least, not to the author's knowledge. So, what can be used instead?

Fortunately, Vishay offers a compelling alternative: the surface-mount RTD TFPT0603L5600, an alumina substrate component with a nickel-based PTC thin film element having a well-characterized positive temperature coefficient. This component is also RoHS-compliant without exemption [1].

The root cause of the gain variation shown in Fig. 2 lies in the transconductance temperature coefficient (BETATCE, in %/°C) of the J113 JFET [5], as documented in its SPICE model. Replacing resistor R3 with the Vishay TFPT0603L5600, which has a temperature coefficient of 4110 ppm/K ± 400 ppm/K, provides a partial correction. A SPICE model for this TFPT component is available at www.vishay.com/doc?29171.

Both versions of the circuit - the original and the one modified with the TFPT - are shown in Fig. 3. For simulation accuracy, all relevant tolerances are included: those on the ambient resistance values, on the temperature coefficient of the fixed resistor, and on the TFPT itself. The simulations randomly vary these parameters. To ensure a fair comparison, the ambient resistance tolerance for both the fixed resistor and the TFPT is set to ± 0.5 %.

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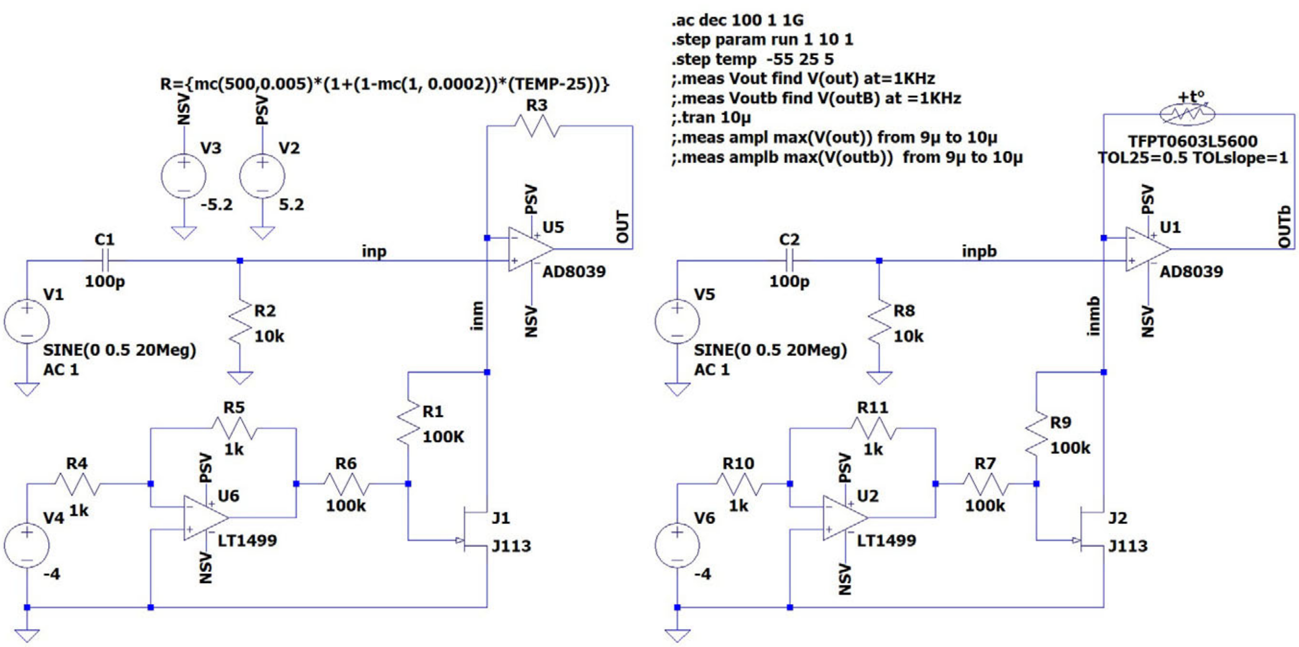

Fig. 3 - Original (left) and modified (right) versions of the large band gain amplifier stage circuit

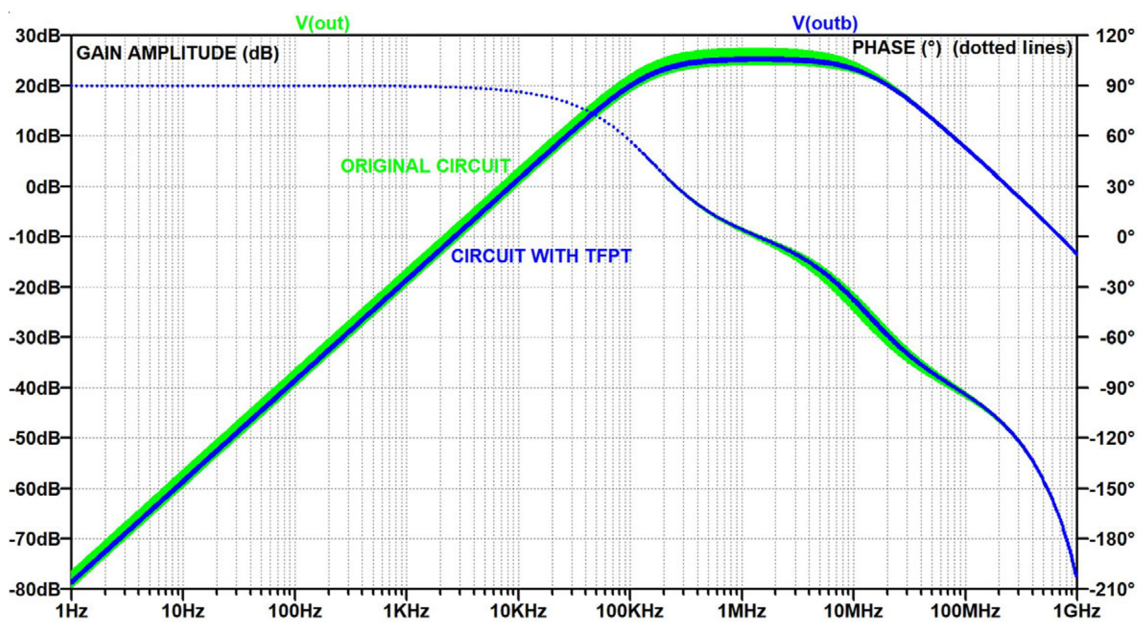

Fig. 4 - The blue curves (representing the circuit with the TFPT0603L5600) show a significant reduction in temperature-induced noise in both gain amplitude and phase compared to the green curves (representing the original circuit with a fixed resistor). This demonstrates a substantial improvement in temperature stability with the compensated TFPT0603L5600 version

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Thus a simple circuit modification can effectively reduce temperature-induced noise and enhance overall system stability at a reasonable cost. The simulations presented here are available for download on Hackster.io and can be adapted for different component values and circuit configurations as needed [3].

References:

[1] Vishay TFPT Datasheet: www.vishay.com/doc?33017

[2] AN-6603 A Linear Gain Controlled Amplifier

[3] Low Noise Amplifiers for Small and Large Area Photodiodes, Design Note 399 by Glen Brisebois

[4] LTspice Download LTspice | Analog Devices

[5] MMBFJ113 - N-Channel Switch

[6] LTspice: Temperature compensation of JFET amplifier gain - Hackster.io

[7] KTY81 Product Information | NXP

A similar version of this article appeared in Planet Analog magazine on August 6, 2025.