

Proceedings Article

A low-noise differential JFET amplifier for magnetic particle imaging

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Abstract

In MPI systems designed for large areas of the human body, drive fields are a significant source of interference for the receive electronics. Their influence, in addition to the direct feedthrough of the signal, can manifest itself in the form of common-mode noise, which can be effectively suppressed using filters and low-noise amplifiers with a differential architectures. In this work, we demonstrate a prototype of a low-noise amplifier based on a differential first stage, which works in combination with fourth-order notch receive filter. Our preliminary results show a gain of at least 40 dB over the frequency range of 50-700 kHz, effectively covering measurable harmonic signals for head-sized MPI scanner.

I. Introduction

The drive field coils required to generate sufficient alternating fields in the region of interest inevitably have stray fields that interfere with sensitive receiving electronics, even if the direct feedthrough is suppressed sufficiently. To reduce this influence, filters and low-noise amplifiers with symmetrical differential architecture are used [1],[2]. The latter can be implemented using operational amplifiers [3], or by using specialized symmetrical pairs of transistors [4]. In our work we employed low-noise junction field-effect transistors (JFETs) as the basis for the differential amplifier design. This type of transistor offers advantages that make it particularly suitable for MPI signal detection applications, including low voltage and low current noise, high gain, and high input impedance [5].

II. Methods

The amplifier circuit with a fourth-order notch filter, tuned to the frequency of the drive field (25.8 kHz) is shown in Figure 1. The filter and amplifier are coupled via a transformer, which prevent direct electric contact with the receive coil to suppress common-mode interference and allows impedance matching to different receive coils. The first stage of the amplifier is based on a JFE2140 (Texas Instruments, Dallas, USA) matched pair of transistors, followed by an NPN pair to form a classical cascode topology. For initial tests, we used the AD8253 (Analog Devices, Massachusetts, USA) instrumentation amplifier as a second stage, configured for 20 dB amplification and also serving as a differential-to-single converter. To reach the optimal operating point of the JFETs, we adjusted the base voltage of the NPN pair to maximize the gain in the first stage. Gain measurements were performed using a

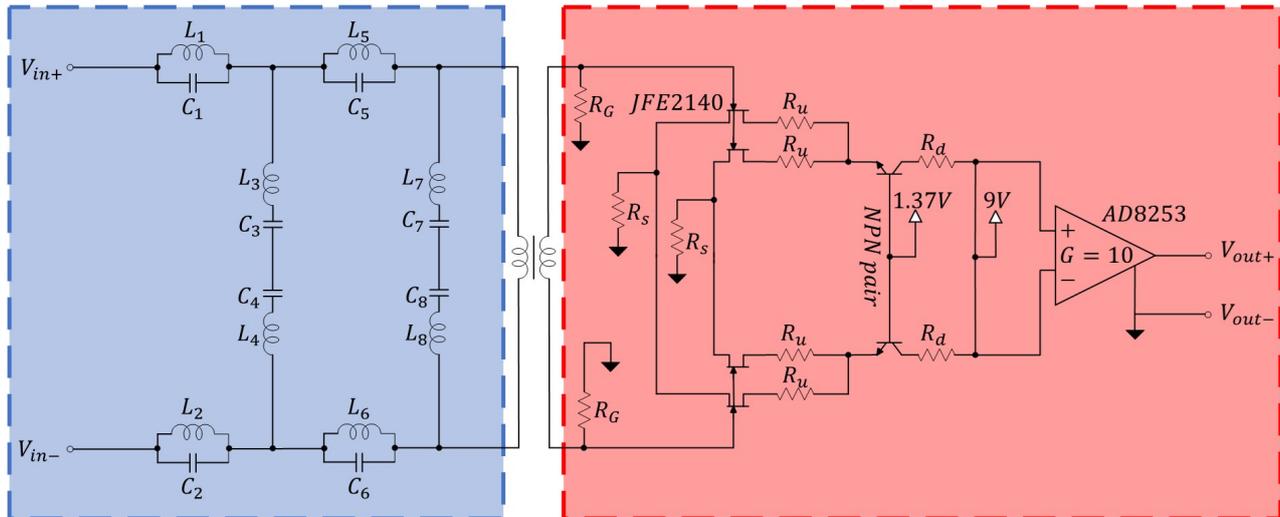


Figure 1: Schematic of the differential receive chain. The left section (blue) depicts fourth-order notch filter, where inductors are fine-tuned to achieve maximum suppression at the operating frequency of 25.8 kHz. The right section (red) illustrates the designed 2-stage low-noise amplifier, featuring a JFET input stage with NPN-pair cascode followed by an instrumentation amplifier. They are separated with a 1:1 transformer.

Siglent SSA3021X spectrum analyzer (Siglent Technologies, Shenzhen, China).

III. Results and Discussion

Gain measurements showed that the stability of the bias supply is crucial to ensure the transistors are biased at their operating point. By searching for the optimal bias current (produced by 1.37 V in our schematic), we managed to achieve a gain of ≥ 40 dB on the band of 50-700 kHz, which fits the harmonic signals detectable in the head-sized system.

As the next steps to improve the prototype, we plan to change the second stage of amplification to differential one, which will allow us to use the artificial cold resistor approach described in [4]. This potentially reduces the thermal noise introduced by the damping resistor which will be required to reduce the resonant effects caused by the combination of the inductance of the receive coil and the input capacitance of the amplifier input.

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Author's statement

Conflict of interest: Authors state no conflict of interest.

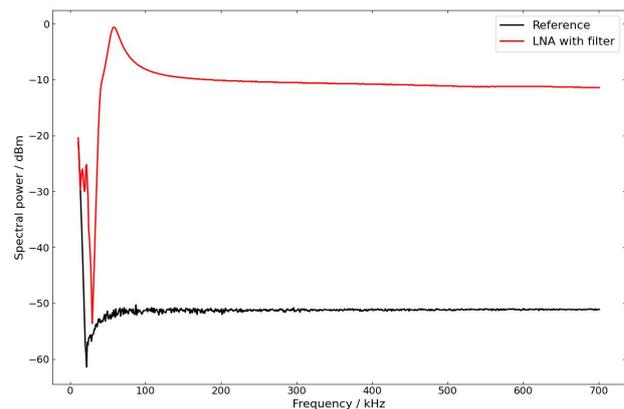


Figure 2: The gain of the designed low-noise amplifier with four-stage notch filter. The reference measurement corresponds to the SSA3021X with its input directly connected to its output

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