Low-Noise Amplifier Design

ECE 6416
Georgia Institute of Technology

October 29, 2003

Abstract

Design and verification of a low-noise amplifier with electrical isolation between the sensor and load.

1 Objective

The objective of this experiment is to design, simulate, evaluate, and document a low-noise amplifier circuit.

2 Specifications

A basic circuit diagram of the amplifier is shown in Fig. 1. The low-noise amplifier is to have one input and one output. The amplifier is to employ a unipolar + 9 V or +15 V dc power supply. A 4N25 electro-optical isolator is to be used to isolate the source from the load. The source resistance of the sensor is to be $R_s = 6.8\,\mathrm{k\Omega}$. A preamplifier is to be used between the sensor and the isolator and a post amplifier between the isolator and load. The active devices used in these two amplifier will be discrete transistors. The load resistor is to be $R_L = 12\,\mathrm{k\Omega}$.

The maximum value of the amplitude of the open circuit voltage produced by the sensor is to be 10 mV.

The sensor drives a preamplifier which is ac coupled to the electro-optical isolator. The output of the isolator is amplified by the post amp to supply the output signal to the load resistor. The post amp should contain a coupling capacitor to keep dc off the load.

3 Design Goals

- The maximum output $SNR \geq 50\,\mathrm{dB}$ (V_{so}/V_{no}) with an input signal of 10 mV peak sine wave at a frequency of 3.2 kHz.

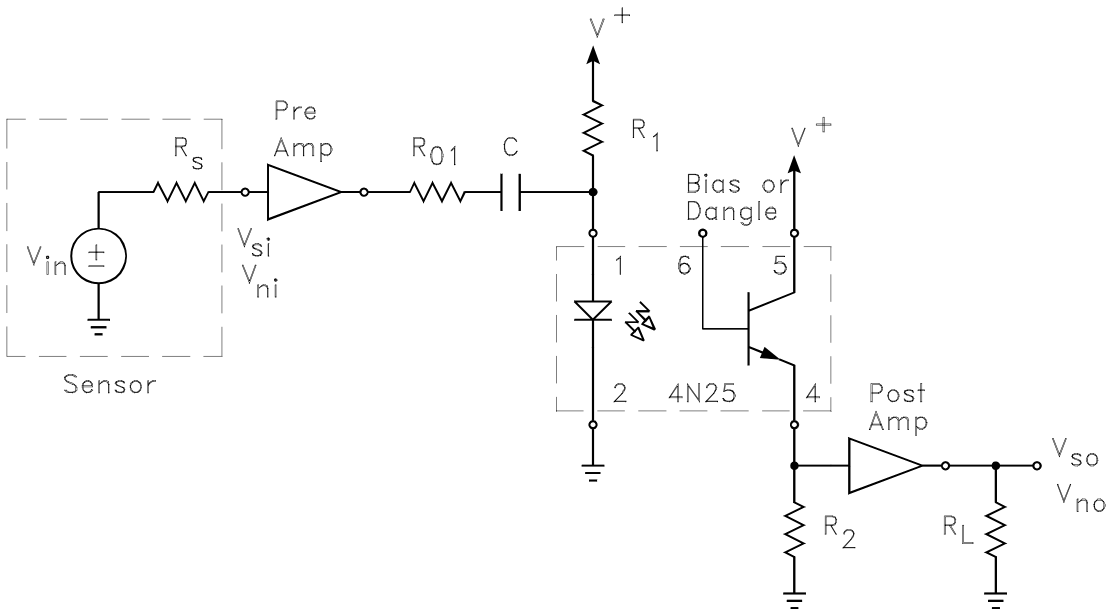

Figure 1: Simplified schematic of the amplifier.

- Midband voltage gain of 40 dB ±1 dB.
- No visible distortion on sine wave output
- Upper and lower −3 dB frequencies of 500 Hz and 20 kHz.
- Minimum noise.

4 Devices

Discrete transistors are to be used to implement both the pre and post amps. The choices should be restricted to those normally stocked (2N4401 and 2N3904 NPN BJTs, 2N4403 and 2N3906 PNPs, 2N5457 N Channel JFET, and 4007 MOSFETs).

The electro-optical isolator is to be a 4N25. This is a Dual In-Line package with pinouts shown in the circuit diagram. It contains a GaAs LED which produces light as a function of the current passing through it. A photo transistor is placed in the same package which has a base current that is a function of the light striking it and the dc bias current. Thus the base may be either biased or left dangling (unconnected).

Data sheets for all of these devices are readily available on the internet.

5 Simulation

The initial design should be verified with a SPICE simulation. This simulation must precede the circuit assembly.

Assuming BJTs are used, the default values for `IS`, `BF`, `RB`, `VA`, `CJC`, `CJE`, and `TF` for the transistors are not to be used for the simulation. Instead, use the values obtained from curve tracer measurements or manufacturers' data sheets.

A noise simulation of the circuit should be made which predicts the signal-to-noise ratio and noise figure of the amplifier.

The SPICE analyses should include `.OP` (to verify the biasing), `.AC` (to verify the frequency response specifications), `.TRAN` (to verify the clipping and slew rate specifications), `.FOUR` (to verify the distortion specification), and `.NOISE` (to verify the noise specifications).

For the electro-optical isolator a SPICE model should be developed based on measurements made in lab.

6 Experimental Measurements

Assemble the designed circuit on a solderless breadboard. Use a power supply decoulping network.

Use the laboratory equipment to measure and record the circuit:

- mid-band voltage gain @ $f = 3.2\,\text{kHz}$
- $-3\,\text{dB}$ bandwidth
- positive and negative slew rates
- distortion @ $f = 3.2\,\text{kHz}$
- quiescent operating point
- output dc offset with input grounded
- output signal-to-noise ratio
- noise figure

The noise measurements are made with the source grounded. The other measurements are made with the function generator or signal analyzer as the source.

7 Laboratory Report

The laboratory report should simply succinctly summarize the design philosophy, present the appropriate calculations, and compare the theoretical, simulation, and experimental results.

The design project will weighted as three lab reports and will graded somewhat more critically than the previous reports. Although the design project grade will in part depend on the write-up, the major criterion will be whether or not the circuit meets the design criteria.

8 Useful References

http://literature.agilent.com/litweb/pdf/5988-4082EN.pdf
http://encon.fke.utm.my/nikd/Internet/opto-couplers.pdf

9 Due Date

Friday December 5, 2003, @ 6 pm.