

Achieving Optimum CMRR with Differential Input A/D Converters

Introduction

Unbalanced source impedances are a widely recognized source of degraded common mode rejection performance, and the Crystal input buffer (CIB), shown in Figure 1, is occasionally touted as a solution to this problem. Unlike the InGenius® input stage, the CIB does not reduce the effects of unbalanced source impedances, and in fact, is inferior to even a standard differential amplifier in this regard.

This is not particularly surprising since the CIB was never supposed to be used for this purpose. It's intended function is simply to remove common mode voltages while leaving the differential signal in balanced form, which it does quite well. To address the issue of unbalanced common mode source impedance, we've developed a circuit (shown in Figure 3) which implements the function of the CIB using a THAT 1203. The InGenius topology of the THAT1203 integrated line receiver provides a cost effective solution with superior CMR performance relative to Crystal Semiconductor's recommended solution.

The Conventional Solution

The CIB can accept balanced or unbalanced inputs and produces a balanced output intended primarily to condition signals going into an ADC with a

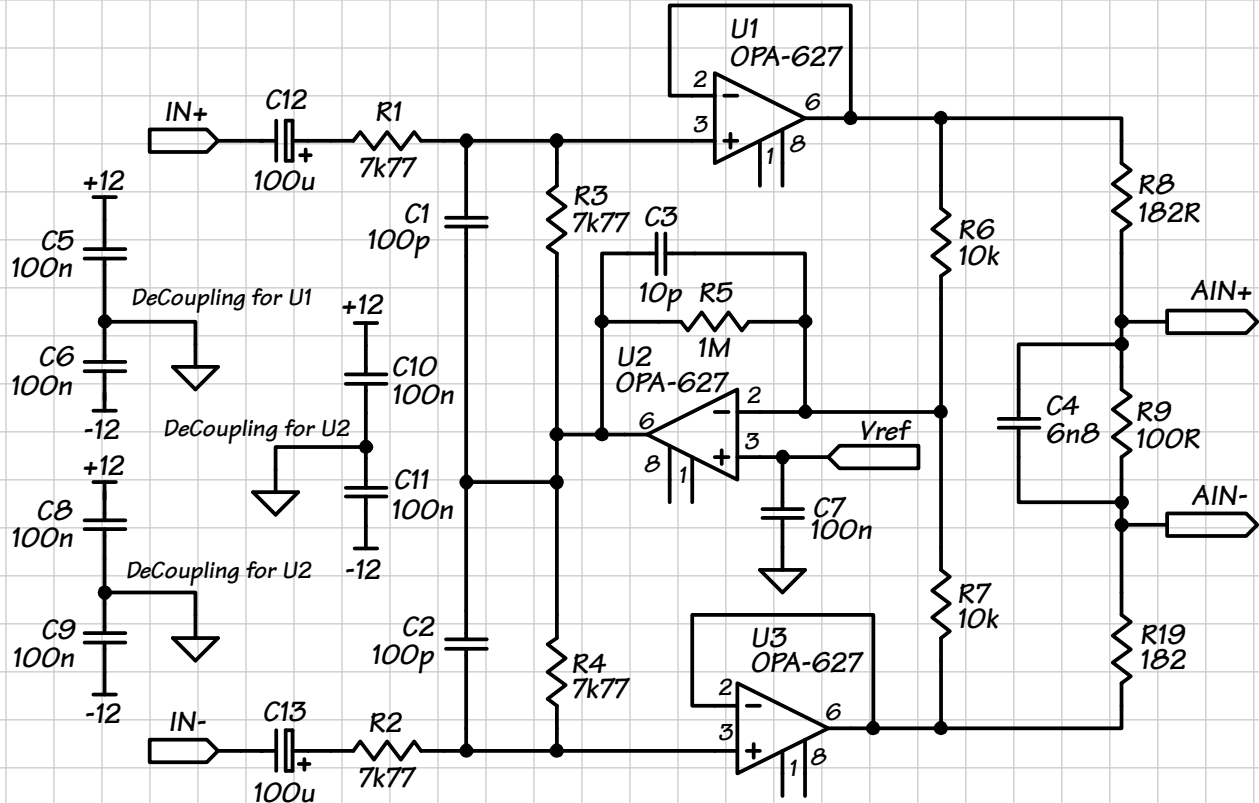


Figure 1. Crystal Semiconductor's recommended circuit for input conditioning

differential input. It reduces the common mode swing of these signals, and keeps the ADC input in the linear range where the ADC's own common mode rejection will perform properly.

This circuit could be replaced by a standard differential amplifier followed by an inverting amplifier, with the +Ain being driven by the output of the differential amplifier and the -Ain being driven by the output of the inverting amplifier, much like the THAT1203 circuit that will be discussed later. One would also need to buffer the ADC's voltage reference, and the differential amplifier and inverting amplifier would both need to source the 40 mA needed to develop 4 Vpp across the 100 Ω resistor that shunts the ADC input. The CIB, for a given degree of resistor mis-match, actually allows for 6 dB more CMRR than the differential amplifier, but this apparent advantage is, to a degree, negated by the fact that differential amplifiers and instrumentation amplifiers can be built, for minimal cost, with on-chip resistors that can guarantee 70 dB of CMRR. To make the CIB perform this well requires a resistor network with resistor matching better than 0.02 %. Such networks are neither inexpensive nor easy to acquire. These precision networks make a high performance version of the CIB an unattractive option.

Up to this point, we have assumed that the nature of the source impedance driving the CIB has no impact on CMRR. In many, if not most applications, this is not the case, and in this regard, the differential amplifier is substantially better than the CIB. The common mode input impedance of the CIB is equal to the parallel combination of R1 and R2, which is 3.9 kΩ as shown below. In a standard differential amplifier, using the same resistor values, the common input impedance is 11.6 kΩ. Therefore, the CIB will be nearly three times more

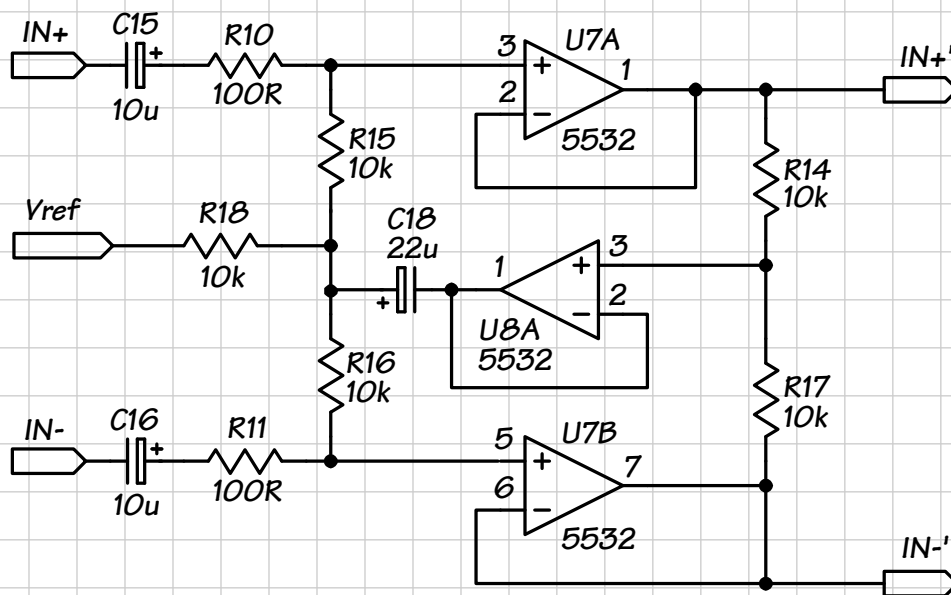


Figure 2. An example of an InGenius® input stage

Note that the InGenius® topology is patented, and requires a license from THAT Corporation unless purchased in the form of the THAT 1200, 1203, or 1206.

susceptible to source impedance mismatch relative to a standard differential amplifier.

The InGenius® Input Stage

Fortunately, the performance of both topologies can be improved by the addition of an InGenius input buffer, shown in Figure 2. The fundamental difference between the InGenius stage and the CIB is the polarity of the feedback.

In the CIB, the feedback signal is in the opposite polarity of the common mode signal at the input and, as a result, tends to subtract out the common mode portion of the signal, though this effect is limited by the maximum amount of gain that can be used in U2 (the feedback op-amp). This approach essentially makes the positive inputs of U1 and U3 (in Figure 1) virtual grounds for common mode signals, and thus lowers the overall common mode input impedance of the CIB.

Conversely, the feedback for the InGenius stage is the same polarity as the common mode signal. Therefore, when a common mode signal appears at the inputs, it is extracted by the feedback amplifier, and a replica of the common mode signal is superimposed on the junction of R15 and R16. Since there is no net change in the voltages across these resistors, there is no net change in the currents through them. The changing current through these resistors in a

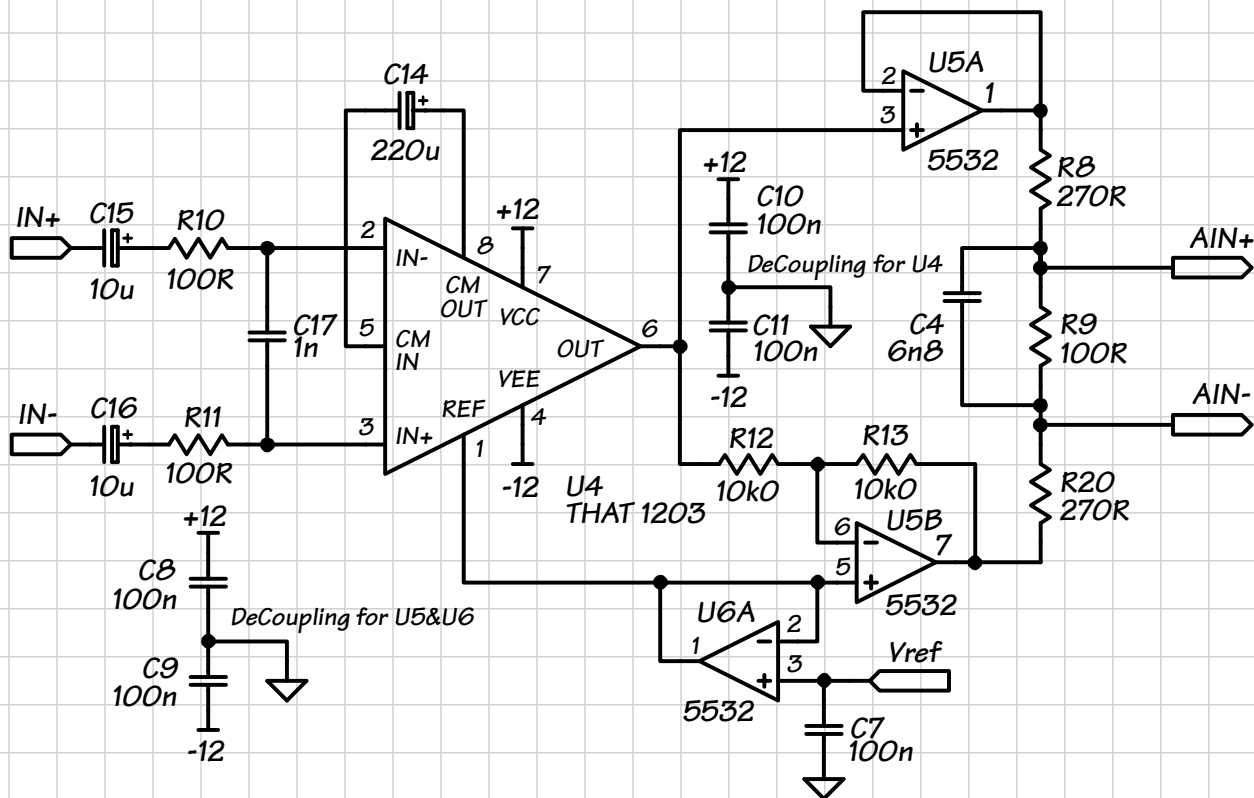


Figure 3. InGenius® circuit for input conditioning

conventional input stage is the source of common mode degradation due to unbalanced source impedances, since this variable current must come from the signal source and as a result produce errors across the mis-matched source impedances wherein a portion of the common mode signal is converted to normal mode signal, and cannot be rejected. An InGenius stage is not subject to these errors due to its high, bootstrapped common mode input impedance.

The InGenius® IC Solution

While adding an InGenius input stage to a CIB will directly improve its performance, the op-amp based circuit is expensive in cost and real estate. A better approach, show in Figure 3, uses a THAT1203 (essentially a differential amplifier with a net gain of -3 dB and an InGenius input buffer) along with three 5532s and a handful of passive components. One 5532 is configured as a buffer and another is configured as an inverting amplifier, An additional op-amp is required to buffer the ADC's reference voltage. The THAT1203 provides an InGenius input with unbalanced output. The inverting amplifier converts the signal back to balanced, and both amplifiers serve to provide the high current drive to the voltage across R9.

This approach can yield an appropriately conditioned signal with a minimum CMRR @ 60 Hz in excess of 70 dB irrespective of source impedance mismatch.

Conclusion

In spite of the novel characteristics of the CIB, a circuit using a THAT1203 integrated line receiver will provide better performance in terms of price, specifications, and board space, for most applications. These differences are the result of using a less demanding topology that eases the requirement for DC precision and associated component cost, the advantage of having on chip precision thin film resistors, and the InGenius front-end which eliminates common mode errors due to mismatched source impedances.