Analog Design
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The Current Feedback Myth

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Abstract

This paper addresses a very common misunderstanding regarding current feedback amplifiers.

It is claimed by many authors that the use of current feed back is superior to conventional voltage feedback, specifically, with regards to small signal bandwidth and large signal slew rates. This claim is not supported, and is generally a result of not accounting for the basic architectural differences in typical voltage feedback amplifiers and typical current feedback amplifiers.

This paper illustrates the reason why typical current feedback amps *appear* to be superior to voltage feedback amps, and in consequence, how suitable designed voltage feedback amplifiers can be constructed that are essentially as fast as current feedback amplifiers.

In fact, what may be said to be quite surprising is, that despite manufactures application notes that indicate that current feedback is superior, the manufactures themselves often manufacture equivalent speed voltage feedback amplifies, using the techniques described here!

The overall principle here is "I cannee change the laws of physics captain, I still need my 30 minutes".

Background

It is often claimed that switching currents is faster then switching voltages. Assuming that the output node does not swing a large voltage, this is indeed correct. Certainly swinging small voltages will take less time then swinging large voltages. However, in a typical operational amplifier, independent of whether an amplifier uses current feedback or voltage feedback, the output must still swing the full supply voltage. Therefore in a real operational amplifier application, current feedback, by itself, cannot make much use of such low voltage swings to gain a speed advantage.

Conventional Descriptions

A typical conventional overview of current feedback operation is described in the "Analog Devices" "Applications Reference Manual"[1.] The author makes many claims, some of which, are shown here to be misleading at best.

Slew Rate

In reference (1) it is claimed:

"An additional problem with voltage feedback amplifiers is that their slew rate is usually limited by the transconductance stage which has a finite maximum output current, normally equal to the tail current of the differential input pair, available to charge the compensation capacitor".

The author then goes on to explain that the current feedback amplifier is superior due to the lack of this limitation.

The basic flaw in this argument is that one is comparing a typical current feedback amplifier input stage with a typical voltage feedback amplifier input stage, which makes for an unfair comparison indeed. The former uses a class AB stage, i.e. it has a small bias current but can supply many times this on large signals, where as the later, typically only uses a class A stage. There is of course no reason as to why the input stage of a voltage feedback amplifier can not *also* be a class AB stage, as is shown in appendix 1. The technique is to simple mirror the input stage of the current feedback amplifier to construct a second high impedance input. A class AB input voltage amplifier is thus able to achieve slew rates equivalent to current feedback amplifiers.

In reference (2) it is claimed:

"The other major advantage of CF (current feedback) amps is the inherent absence of slew-rate limiting."

As described above, this claim is also flawed. It is indeed quite possible to design current feedback amplifies that uses a class A input stage, which would consequently have limited slew rates. Therefore there is nothing inherent at all in the use of CF and obtaining high slew rates.

<u>Bandwidth</u>

In reference (1) it is claimed:

"Constant gain bandwidth characteristics, resulting from the application of voltage feedback, presents a problem if one requires reasonable high gain whilst simultaneously achieving wide closed loop bandwidth".

In fact there is no such bandwidth limitation in voltage feedback amplifiers. This misconception arises from an inability to distinguish between the closed loop gain-bandwidth properties of a voltage feedback amplifier, with a constant compensation capacitor, and the closed loop gain-bandwidth properties of a current feedback amplifier with a constant compensation capacitor.

It can be shown (appendix 2) that for a given compensation capacitor, and for the same degree of loop stability, the closed loop bandwidth of a current feedback amplifier is essentially independent of it's closed loop gain setting feedback resistor. In contrast, in the case of a voltage feedback amplifier, the closed loop bandwidth will be inversely proportional to the gain set by the feedback resistor. This leads to the cursory and erroneous conclusion that current feedback amplifiers are *inherently* faster at high gains because it would appear that they do not suffer the bandwidth trade off at higher gains.

The basic flaw in this argument is that at high gains, in a voltage feedback amplifier, the amplifier is *excessively* frequency compensated, thereby reducing it's *inherent* potential bandwidth. The compensation capacitor in a typical voltage feedback amplifier is set such that at unity gain for example, the amplifier is stable. If it is known that the amplifier is going to be used at a higher minimum closed loop gain then, for the same stability as the current feedback amplifier, the compensation capacitor can be reduced in order to increase the closed loop bandwidth to that of the current feedback amplifier.

Thus, the only real advantage of the current feedback amplifier with regards to bandwidth is that it eliminates the relatively minor task of optimizing the amplifiers compensation capacitor for different closed loop gains.

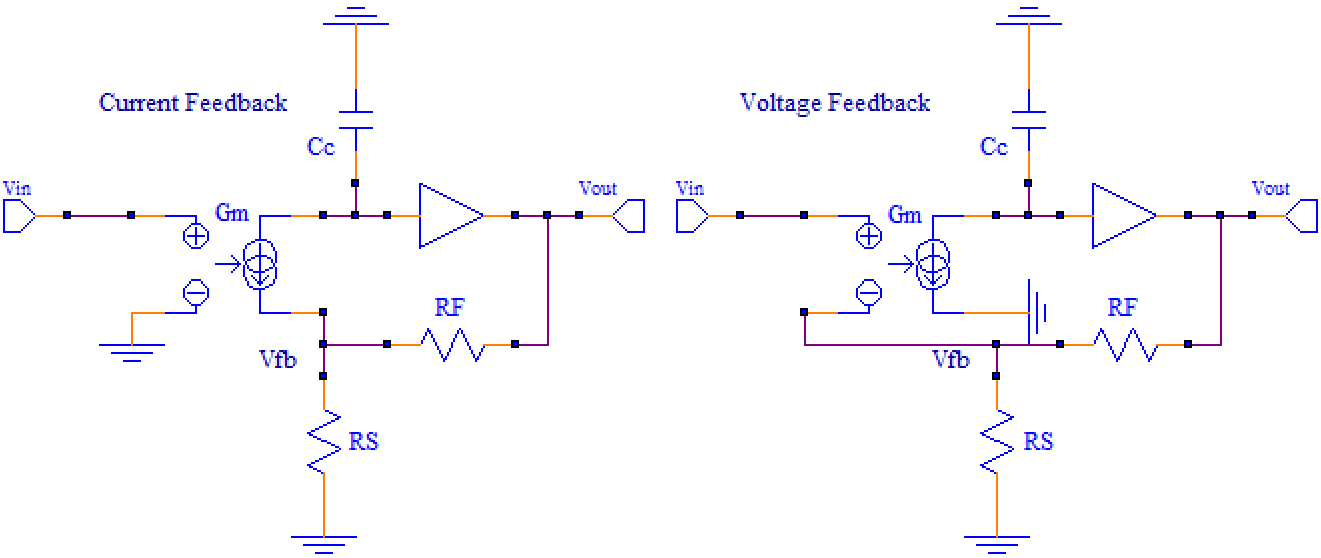
Summary

It was shown in this paper that current feedback amplifiers are essentially no faster, in principle, then voltage mode amplifiers. With suitable design of voltage feedback amplifiers, the advantages claimed for current feedback amplifiers are somewhat dubious. One only has to do two basic procedures.

1 - Use a class AB input stage
2 - Chose the compensation capacitor correctly.

Appendix 1 - Bandwidth

Fig. 1



Current Feedback – The input resistance at the feedback point V_{fb}, is $1/G_m$, and in the limit approaches zero for large Gm by design. The feedback current is therefore V_{out}/RF, and flows through the G_m source into the compensation capacitor C_c. The loop gain is therefore given by 1/s.RF.Cc. It is independent of RS, and hence closed loop gain.

Voltage feedback – From inspection, the loop gain is $G_m/s.C_c$ X the attenuation of the feedback divider, hence is $G_m/s.C_c(RS/(RS+RF))$. The loop gain depends on the feedback attenuation, hence to ensure stability for all attenuation ratios, the compensation capacitor C_c. is chosen such that it is too large for large closed loop gain settings.

Appendix 2 - Slew Rate

Fig. 2

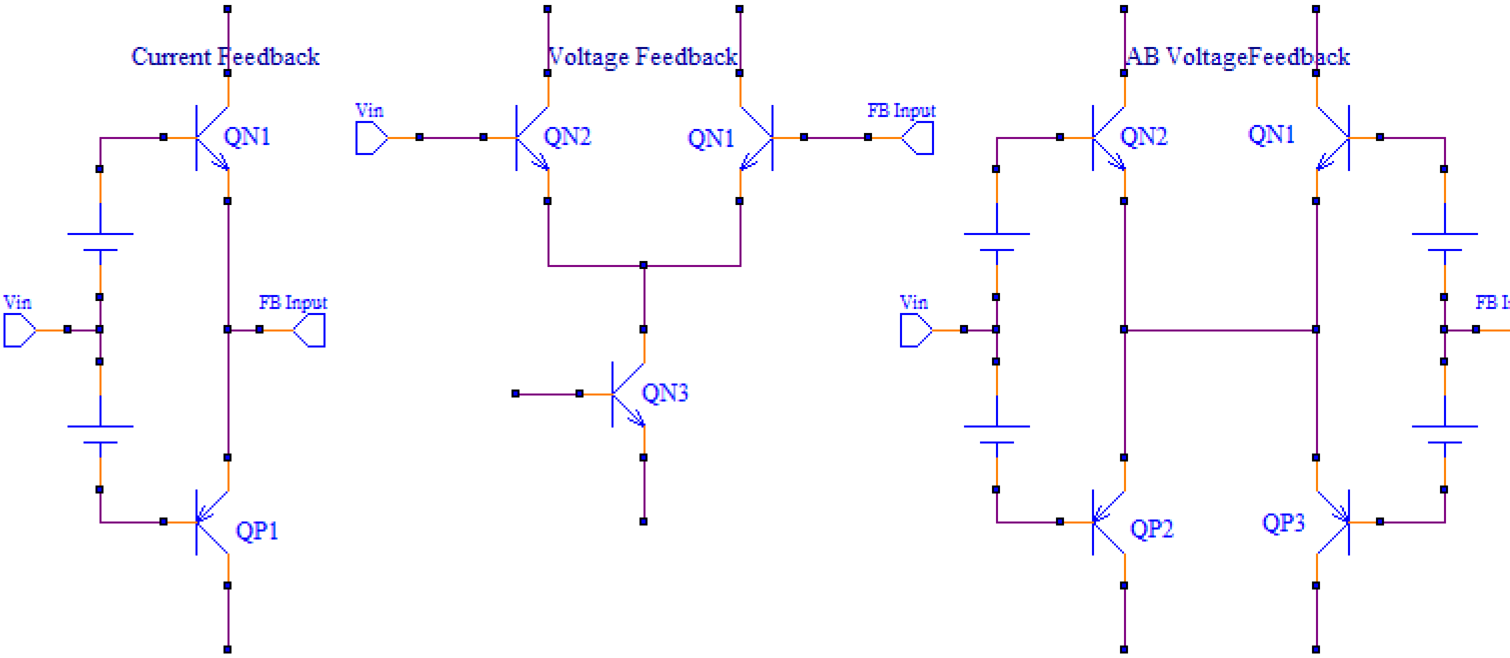


Fig. 2 is representative of the input stages of typical operational amplifiers. It is noted that typical voltage feedback amplifiers have a fixed biased current, which limits the current available to charge the compensation capacitor. However there is no inherent reason for this to be the case. An example of the AB, voltage feedback, input stage is the THS4509 from Texas Instruments which has a slew rate of 6,600V/µs and 1.5 GHz BW.

References:

1 - "Analog Devices" "Applications Reference Manual"- ISBN:0-916550-12-5. Applications note number AN-211, page 4-57 to 4-76, author, Mark Alexander.
2 - "Analog Circuit Design" - Edited by Jim Williams of Linear Technology. ISBN 0-7506-9640-0. Sergio Franco Chapter, page 269.
3 http://www.ti.com/product/THS4509 THS4509 operational amplifier data

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