Current-mode Based Low-voltage to High-voltage Range Analog Signal Converters

Mariusz Jankowski, Andrzej Napieralski

Abstract - **In this paper introduction to current-based conversion of voltage-mode analog signals is presented. Circuit operation idea and possible fields of application are proposed.**

Keywords – **high-voltage circuits, current-mode signal processing, voltage-range extension.**

I. INTRODUCTION

Analog integrated circuits can be designed and manufactured both as low-voltage (LV) and high-voltage (HV) structures. Though, even high-voltage integrated systems usually comprise low-voltage modules. Such modules can be both analog and digital function units. Low-voltage structures are better suited for many signal-processing tasks.

Digital processing modules produce their output, which in turn can by various means be input into high-voltage parts to drive them with resolution of two logic values. Analog signals need to save their quality and properties, while stretched into high-voltage range. Conversion of low-voltage analog signals into HV range is a more complex transformation.

II. CURRENT-BASED VOLTAGE AMPLIFICATION

Common way for precise and linear amplification of voltage signals is application of operational amplifiers. Design of HV OPAMPs can be a challenging task [3], also due to limitations of maximum voltage between gate and source terminals of many types of HV transistors - special solutions must be implemented. Luckily, low-to-high voltage-range signal conversion demands only HV output stage of the OPAMP.

Luckily, it is possible to design a kind of a hybrid amplifier equipped with a precise low-voltage differential-pair first stage and a robust HV output stage. The connection between LV input and HV output is kept through feedback resistors. These can be either single HV devices or serial chains of LV devices. Application of LV resistors makes it possible to obtain high quality of signal amplification. Exemplary structure of such an OPAMP, along with installed feedback loop, is presented in Fig. 1.

Though, there is also another possibility of low-to-high voltage transformation. This interesting, this way is based on current-mode of signal transmission. The idea is to use an OPAMP-based voltage-current converter, next a current-path to send the signal-coding current into HV part of a circuitry, and finally a resistor as a current-voltage converter, to recreate a voltage signal. It is possible to use here a fully LV OPAMP. In practice, also a V/I converting transistor can be applied as a LV one. In such solution, auxiliary HV shielding MOS transistor must be applied in the structure. A current-mode low-to-high voltage-range extending circuitry with a HV MOS transistor at the output of an OPAMP is presented in Fig. 2.

Mariusz Jankowski, Andrzej Napieralski
Department of Microelectronics and Computer Science,
Technical University of Lodz,
ul. Wolczanska 221/223, budynek B18, 90-924 Lodz, POLAND
E-mail: jankowsk@dmcs.p.lodz.pl

It could be stated here, that this solution has a drawback. A HV buffer offering very high input impedance is required to isolate the fragile HV I/V converter from the following stage. In fact, also mixed LV/HV OPAMP-based and fully HV OPAMP-based circuits require additional voltage buffer at the structure output, to provide low output impedance [1].

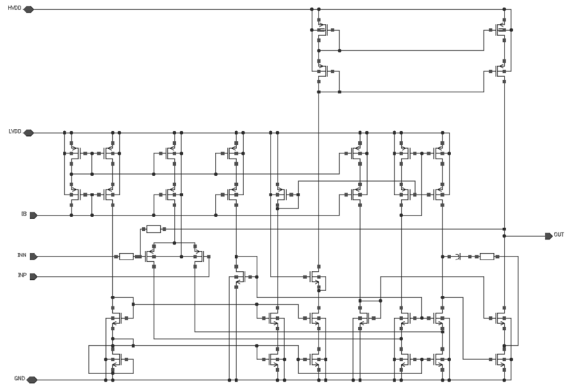

Fig. 1 Low-voltage input high-voltage output OPAMP

The true part is that circuit stage, which precision strictly depend on current value preservation, needs very high quality isolation from following stages, better than in case of typical voltage-processing stages. It is typical issue all current-processing stages connected to following voltage-processing stages [2]. Though the main problem of efficient protection is related to HV range of circuit operation, there are known solutions to this problem. One of such buffers is based on HV source-follower structure (Fig. 3), additionally equipped with a high-impedance input stage with no DC current-path in it.

III. DISTINCTIVE SET OF PROPERTIES

The current-based circuit can be considered as a bit strange approach, but it offers a set of properties missing in its more conventional OPAMP-based counterparts. First, though both approaches offer possibility of tuning amplification of the input signal, only the current-based concept provides easy way of multiplication of the input signal. The only part to be multiplied in this structure is output of output current mirror and I/V converting resistors.

Moreover, the current-based solution offers easy way of providing a phase-inverted HV signal. This is impossible with mixed LV/HV OPAMP circuits.

Still one more advantage is related to the current-based amplifier. It can be more easily used in HV systems that need to work with different HV supply levels. Keeping the output HV signal centered in the voltage-space is difficult for the OPAMP-based amplifiers. On the other hand, the current-based amplifier, or rather the LV/I/HV converter, can have its DC part of output voltage arbitrary decided outside the amplification unit.

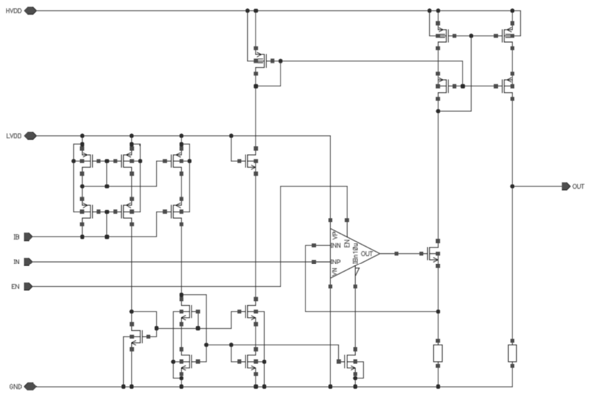

Fig. 2 Current-mode low-to-high analog signal converter

In general, control over a DC level of the processed signal can be achieved in more than one way. One of these ways is to connect I/V converting resistor to a floating voltage level. This can be achieved by connecting this resistor to a output of a robust HV buffer. If such HV buffer is driven with a resistive voltage divider, connected between HV supply and ground rails, the output HV signal becomes related to the specific DC level, related to HV supply voltage level. Other way is to define a DC voltage level with a DC value of an auxiliary current, added to the current that codes the voltage signal being processed.

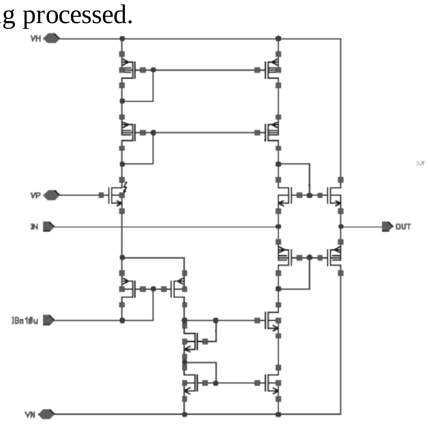

Fig. 3. Basic HV voltage buffer

One further interesting feature of current-mode voltage signal HV amplifiers can be pointed out. Through redesign of the V/I OPAMP stage and mirroring obtained current with ground-bound current mirror, like in Fig. 4, it is possible to use only low-voltage MOS transistors for proper signal processing. Only HV transistors utilized in circuit of Fig. 4 work as buffers against HV surges for low-voltage MOS transistors in the current-mirror. Side effect of their presence is that the current-mirror gets a kind of an additional cascade stage, which improves the mirror operation.

III. Conclusion

In this paper current-mode approach to voltage-mode analog signal amplification into high-voltage range has been introduced.

Presented structures have simple internal structures, no feedback is required for high-quality operation. Also, set of very handy assets is present for these circuits. DC voltage levels can be decided in an easy way. Generation of several differently amplified copies of the input signal is available without increasing complication of the circuits. This is not the case for more typical OPAMP-based solutions.

Such combination of properties enables application of presented amplifiers of LV signals into HV domain in many analog and mixed-design systems. Current mode of signal transmission inside these circuits makes them circuits of choice for HV systems prepared to work with changing HV supply level. Simple and efficient mechanisms of a DC level adaptation to a changing supply voltage can be applied.

Favorable properties of these circuits can lead to cascading a number of HV current-mode modules into complete current-mode signal processing paths.

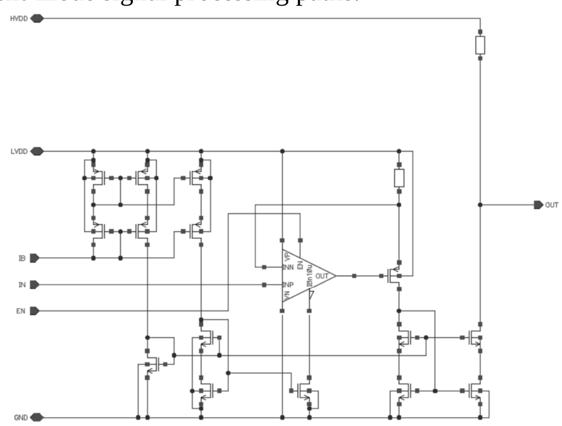

Fig. 4 Current-mode low-to-high analog signal converter with low-voltage only active devices

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