Introduction to Current-mode Converters of Voltage Logic Levels

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Abstract - **In this paper introduction to current-based converters of voltage logic levels is presented. Selected circuit solutions and possible fields of application are discussed.**

Keywords – **Logic level conversion, current-mode signal processing, high-voltage logic.**

I. INTRODUCTION

Digital logic circuits are usually regarded as high-complexity low-voltage pure digital systems. Though, digital logic is very often used for driving and control of analog circuitry placed in same semiconductor bulk. This way analog-digital mixed-signal systems are formed. Typical solutions of voltage-mode digital logic systems are based on low-voltage circuits. On other hand, mixed-signal circuits often comprise a high-voltage analog circuitry, which also requires some digital control.

Low-voltage digital logic signals need to be converted into a modified voltage-range. In case of high-voltage mixed-signal circuits it is usually possible to provide source of high-voltage virtual ground related to high-voltage supply voltage. Owing to this, it is sometimes possible to provide a kind of a pseudo- high-voltage logic, consisting of structures powered by high-voltage supply and virtual ground. These structure work with low- voltage range between power lines and are placed into separate wells in a semiconductor bulk. Thus, it is possible to construct and use logic structures that closely follow their truly low-voltage counterparts.

Only problem that remains is the very logic signal transmission into a high-voltage range circuitry.

II. CURRENT-MODE APPROACH

There are various solutions of digital logic signal conversion problem [1]. Current-mode based approach is now of possible approaches. It is interesting, as it provides a flexibility of converter applications. This flexibility is directly related to the operation-mode. Many high-voltage systems are expected to work with different high supply voltages. By its nature, transistor-based current-mode of signal transmission has good immunity against change of voltage-drop over current transmission path [2]. Though, analog circuits require special treatment in case of high-voltage circuitry, transmission of digital logic level can be easily achieved this way.

Simplicity of such approach can be observed in circuit of Fig. 1, which shows low-to-high voltage-range logic level converter with application of resistors. Input logic signal simply drives a high-voltage transistor. It is important, that such a transistor is driven which typical low-voltage signal (Fig. 2). Many HV devices can only work with LV signals applied between gate and source terminals.

In case of logic one value, the HV transistor opens and current flows through an upper resistor, the HV transistor and a lower resistor. The lower resistor is used to limit current value produced by driving a gate of the HV transistor with full logic one voltage value.

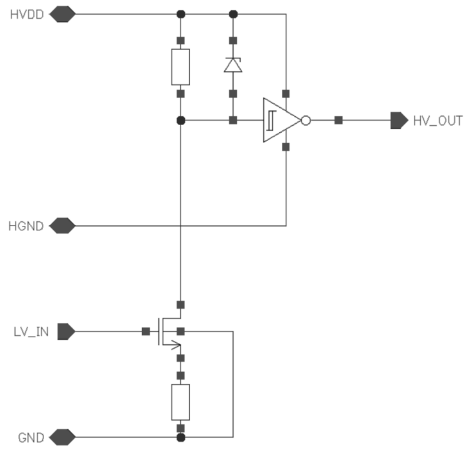

Fig. 1 Structure of current-mode voltage logic level converter

A Zener diode is used to limit voltage-drop on the upper resistor in case of excessive current flow produced by the HV transistor. It is a problems related to process variations. More precise voltage-definition approach uses just the same components arranged in different way. Paper [3] presents such circuitry. The upper resistor of Fig. 1 is divided into two parts, and output signal is provided by means of resistive voltage divider.

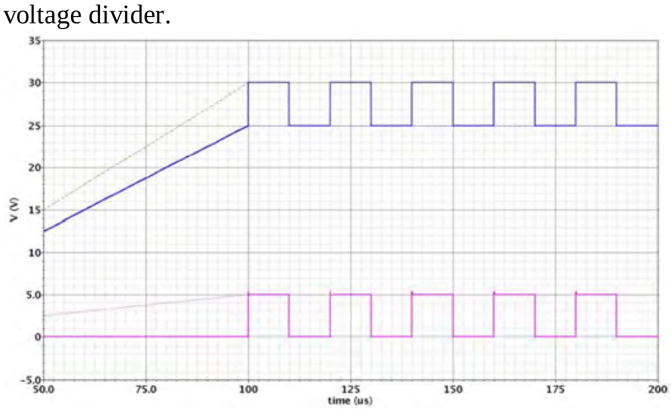

Fig. 2 Low-voltage logic signal and its high-voltage copy

It is a handy trick, which help overcome this typical problem of non-precise control of generated current flow [2]. The operation rule is that current value is chosen so as to

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keep the Zener Diode constantly open, while the current flows. Similar structures can of course be implemented for high-to-low voltage-range logic level conversion.

Presented solutions have one drawback. The resistors used in these solutions may tend to be large devices, even in comparison with HV MOS transistors. Possible solution for this problem is presented in Fig. 3. This circuit only consists of transistors. Now, there are two HV transistors, but due to a connection-mode of the upper HV transistor, no Zener diode is required anymore. Backward polarized source-gate structure of this transistor works as a kind of diode structure.

It should be observed, that in case of no current-flow, the voltage provided to the first digital cell differs from virtual ground value. The first digital cell must be devised so as to assure proper operation of the circuitry. In general, operation of a pseudo current-comparator can be controlled with value of a biasing potential of the upper LV PMOS transistor, and by its proper sizing. The current-flow limiting lower resistor from circuits in Fig. 1 can be used, but it can also be replaced with e.g. an LV MOS transistor in diode connection, to save semiconductor bulk area.

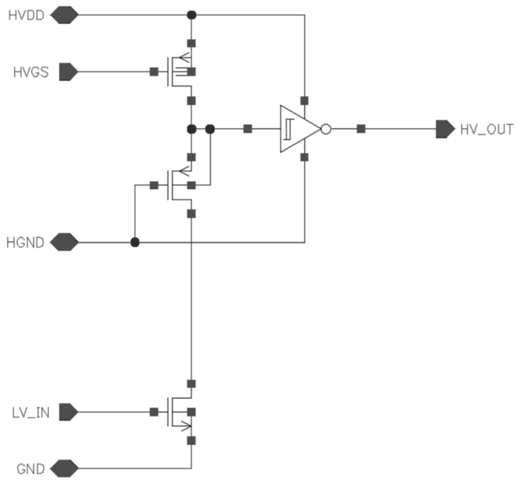

Fig. 3 Converter structure without resistors

III. VOLTAGE LEVEL OPTIMIZATION

If there is problem with current-flow level, but logic levels at the input of the first pseudo-HV digital cell need to be strictly defined, circuit presented in Fig. 4 can provide solution. This circuit is equipped with a modified HV part of the converter.

The current-flow drives a current mirror, the output of which is in turn connected to form a current comparator. The other half of the comparator is tuned to provide limited current-flow, so output signal from this current-comparator is properly defined both in case of flow of the converter current, as well as is case of its lack.

In order to control the current-flow level resistor or diode-connected MOS transistor between ground and source of the lower NMOS transistor. Because this comparator output is connected to the HV supply voltage and virtual ground, the output signal is well suited for digital cell control.

In case of the latest solution, the first digital logic block is also best secured against excessive input voltage surges, as it is connected only to LV MOS.

All presented circuit solutions are able to work for wide range of HV supply voltage, going down close to LV supply voltage level. In case of Fig. 4 circuit, the HV supply voltage can equal the LV logic supply voltage, even go below it, and still the converter functionality is sustained.

All presented circuit versions offer can offer conversion time equal to single nanoseconds.

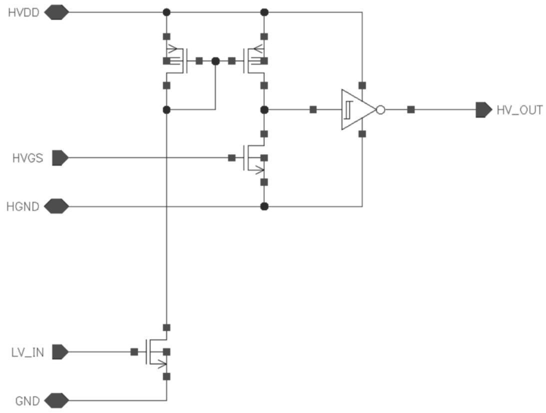

Fig.4 Level converter with a current-comparator

III. CONCLUSION

In this paper the current-mode approach to voltage-mode digital logic level conversion has been presented. Introduced circuit structures offer simple structure while offering flexibility of application and low susceptibility to wide variation of HV supply voltages. Such set of features makes such circuits good candidates for application into HV mixed-signal integrated systems.

HV analog circuitry designed to widely float in the voltage-range is particularly fitting destination of presented approach to logic level conversion. In fact, same operation rule can be used for transmission both digital and analog signals through voltage-space.

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