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Letter to the Editor

A self-buffered DC baseline restorer with quasi-ideal behavior

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Abstract

We present a DC baseline restorer featuring quasi-ideal behavior, capable of showing an undershoot of less than 0.023%. Its circuit structure allows using a single operational amplifier to realize both the buffering of the output signal, with line driving capability, and to discharge the decoupling capacitance. The operational amplifier in each working condition always remains in a closed-loop state, exploiting its full dynamic performance. The presented circuit allows the avoidance of an additional amplifying buffer stage, necessary, up to now, to drive a 50 Ω coaxial cable terminated at both ends. © 1999 Elsevier Science B.V. All rights reserved.

Keywords: DC baseline restorer; Circuit

1. Introduction

Applications with large number of acquisition channel need front-end systems having low-cost and reduced space occupation. To this aim we have studied and realized a DC Baseline Restorer (BLR) which, despite the minimum number of electronic components, shows outstanding performance. The BLR subject of this letter is a circuit solution for the classical configurations described in Refs. [1,2] and analyzed in Ref. [3]; our circuit is a feedback structure always operating in closed-loop condition, and incorporates line driving capability. In this way, a complete spectroscopy amplifier composed of an adjustable two-gain stage, a RC-CR shaper and a BLR can be easily implemented with a single quad operational amplifier chip.

The following section describes in detail the complete BLR circuit and the experimental results.

2. Principle of operation of the DC baseline restorer

The front-end of a nuclear detector includes at the end of the chain a shaping filter and a post-amplifier. AC coupling is usually adopted to avoid the presence of undesirable DC offset, which may impair the actual final resolution, when a high rate of events is present. The drawback of such a coupling is the undershoot given by the decoupling capacitance, which cannot transmit a net amount of energy. This problem is solved using the BLR, which, in essence, is a high pass single pole filter whose time constant varies depending on the signal state. Assuming positive signals, when the output is

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in its negative state the BLR must be able to discharge the decoupling capacitance with a negligible time constant. This is usually obtained by connecting an active impedance of negligible value at the output terminal of the capacitance, implemented with diodes which switch ON or OFF, when necessary.

3. The self-buffered DC baseline restorer

The BLR is a classical circuit that has been implemented in many different ways, [4–9], even with the current conveyor technique [10]. Nevertheless, up to now the circuit solutions are all active only when in the discharging state, while they behave as passive networks in the signal transmission state. The consequence is that a buffering of the signals is always necessary for driving the output, especially when a terminated line has to be fed. In addition, since the circuit must translate from the transmission to the discharging condition, distortions may be present if the system gain is large.

In the presented solution a circuit has been implemented which uses a single Operational Amplifier, OA, that is operative in both states, discharging and transmission. This way a number of advantages have been obtained. In the discharging state the large open-loop gain of the OA allows the implementation of an ideal short-circuit for the capacitance discharge. No effects are seen at the output when the network translates from the discharging to the transmission state, thanks to the fact that the OA is operating always in linear regime. Since the OA behaves as a buffer in all conditions, the output is able to drive directly a 50 Ω coaxial cable terminated at both ends: the circuit is self buffered. The self-buffered BLR circuit is of very simple implementation and has a very low cost, since it needs only a few components.

The circuit solution is shown in Fig. 1. When in the transmission state, the new BLR behaves as a unity gain inverting amplifier. The input signal is connected at the decoupling capacitance C_C. If the signal is falling fast enough, in comparison to the time constant $C_C R$, inducing the output to become positive, Q_1 is able to feed the load impedance present at its emitter, while the Schottky diode D_1 remains in the OFF state. The network behaves simply as a unity gain buffer amplifier (gain -1) since resistors R's are equal (resistor $R/2$ only compensates the OA's input bias current). We can take advantage of this condition for buffering the signal on a transmission line. If now the input signal becomes rising or slows down, such that the output should become negative, Q_1 is no longer able to feed the load, going in its OFF state. But since the OA has a large gain, as soon as its inverting input tends to lower the OA output, D_1 enters its conducting condition, maintaining the OA in the closed-loop state and promptly discharging capacitance C_C. While in this working condition, the output voltage V_{OUT} is zero, since the inverting input remains at zero volts and Q_1 is OFF: signal current flow into resistors R is zero. As a consequence, the potential at the anode of D_1 is the same as that present at the inverting input: C_C is then discharged to ground. This way we have achieved the simultaneous conditions that the output never becomes negative and the capacitance C_C is connected to an active load that has an ideally negligible impedance when in the discharging state.

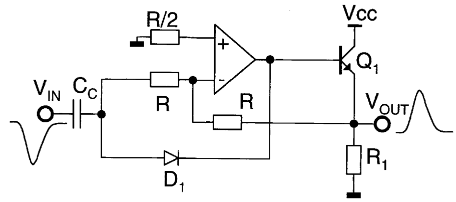

Fig. 1. Circuit diagram of the self buffered DC baseline restorer.

The circuit of Fig. 1 has been tested experimentally. The OA used was the monolithic EL2044, which features large bandwidth and high slew rate, to assure good linearity up to 10 V of output signal. The capacitance C_C is 10 nF. The oscilloscope plot of Fig. 2 shows the circuit response to a train of semi-Gaussian impulses of 1 μs time constant, read from an Ortec 450 spectroscopy amplifier. The output signal was sent to the two inputs of the oscilloscope, and terminated with 50 Ω at both ends of the connecting coaxial cable. On one scope input the signal is shown full scale, while it is zoomed on the other input, to document the

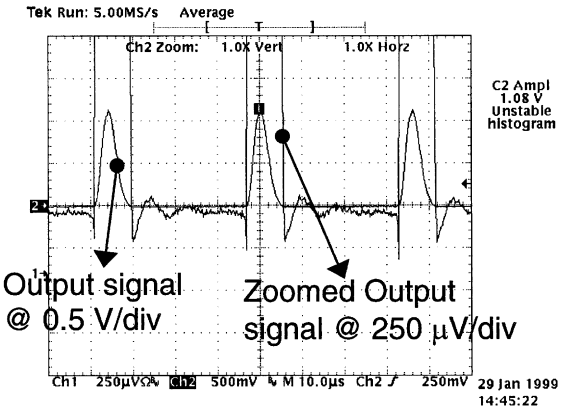

Fig. 2. Tektronix photograph of the response of the self-buffered BLR to a train of semi-gaussian pulses with 1 μs time constant, obtained from an Ortec 450. The signal is terminated with 50 Ω at both ends of a coaxial cable and it is connected to the two inputs of the oscilloscope. On the photograph a 1 V signal read at the receiving end of a cable is fully shown with 0.5 V/div vertical scale and zoomed to 250 μV/div vertical scale, to illustrate the quasi-absence of undershoot. The horizontal scale is 10 μs/div.

recovery. As can be seen, the undershoot is at a practically negligible level. If we conservatively estimate from the figure a value of 250 μV of undershoot on about 1 V signal (2 V at the sending BLR output), the error we get is only 0.023%, a figure never obtained up to now. It must also be remarked that, thanks to the OA always operating in linear regime, no distortion is present due to switching of a large gain system from one state (transmission) to another (recovery).

4. Conclusions

A new self-buffered DC baseline restorer has been implemented. Its main feature is based on the use of a single Operation Amplifier, OA, which always works in its linear region, with a double feedback loop, one for the buffering of the signal, the other for the discharging of the decoupling capacitance. Taking advantage of the large open loop gain of the OA, an ideal active impedance of negligible value is obtained for the discharging of the capacitance. On the other side, the buffering of the signal allows direct driving of terminated 50 Ω coaxial cables, saving the use of an additional circuit devoted to this purpose, as needed in previous solutions. The measured undershoot following the signal was practically negligible, being less than 0.023%, proving that a quasi-ideal behavior has been obtained.

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