RAIL-TO-RAIL BULK-DRIVEN AMPLIFIER

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The bulk-driven technique has many advantages mainly the large common mode input voltage range and voltage swing that could not otherwise be achieved at low power supply voltages, it has also better linearity and smaller power supply requirements, and It can be used the conventional gate to modulate the bulk-driven MOS transistor.

In this paper an alternative new technique of bulk-driven CMOS, will be used to remove the threshold voltage requirement of MOSTs from the signal path, and a device which is similar to the JFET transistor with depletion characteristics is obtained.

Keywords: Bulk-driven CMOS, Bulk-driven op-amp.

1. BULK DRIVEN PRINCIPLE

An important factor concerning analog circuits is that the threshold voltages of future standard CMOS technologies are not expected to decrease much below what is available today. To overcome the threshold voltage a bulk-driven MOST has been used, it is well known that a reverse bias on the well-source junction will cause the threshold voltage to increase. Similarly, a forward bias on this junction will cause the threshold voltage to decrease.

The bulk-driven transistor is a good solution to overcome the threshold voltage limitation. Because the bulk-driven transistor is a depletion type device, it can work under negative, zero, or even slightly positive biasing condition as depicted on Fig. 1.

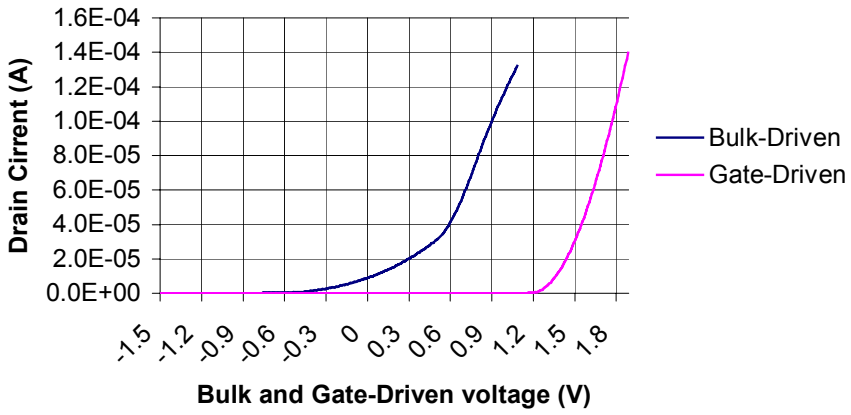

Fig. 1 Drain current versus Bulk and Gate-Driven voltage

The operation of the bulk-driven MOST is much like a JFET. To enable bulk driving, one must first bias the gate to form a conduction channel inversion layer by connecting the gate terminal to a fixed voltage that is sufficient to form an inversion layer (e.g., $V_{GS} > V_T$ for the NMOS). By applying a potential difference between the drain and source, this inversion layer will act very much like a conduction channel of JFET (see Fig. 2). Since the bulk voltage affects the thickness of the depletion region associated with the inversion layer (conduction channel), the drain current can be modulated by varying the bulk voltage through the body effect of the MOST.

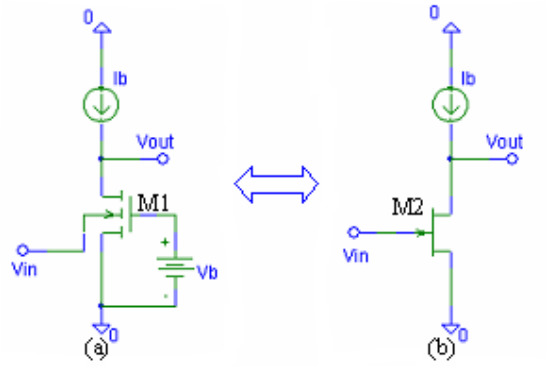

Fig. 2 Bulk-driven MOS transistor (a), and its equivalent JFET (b).

2. RAIL-TO-RAIL BULK-DRIVEN AMPLIFIER

Fig. 3 shows a fully differential input stage with a rail-to-rail input common-mode range. This circuit is capable of -1 V, +1 V operation.

The input stage of the op-amp use two differential bulk-driven input stages in parallel M_1-M_2 and M_3-M_4. The first pairs operate at high common mode input voltage V_{CM} since the second pairs at low common mode input voltage. With this topology, the device operates with V_{CM} in range between -500 mV up to 500 mV.

The gates of both M_1-M_2 and M_3-M_4 are tied to V_{bias2} and V_{bias1} respectively to form the inversion channel beneath each transistor's gate. Vbias3 is used to set M_7-M_8 and M_9-M_{10} which provide a level shift function.

The input offset voltage is measured at $V_{CM} = V_{SS}$+500 mV and V_{DD}-500 mV to ensure proper operation.

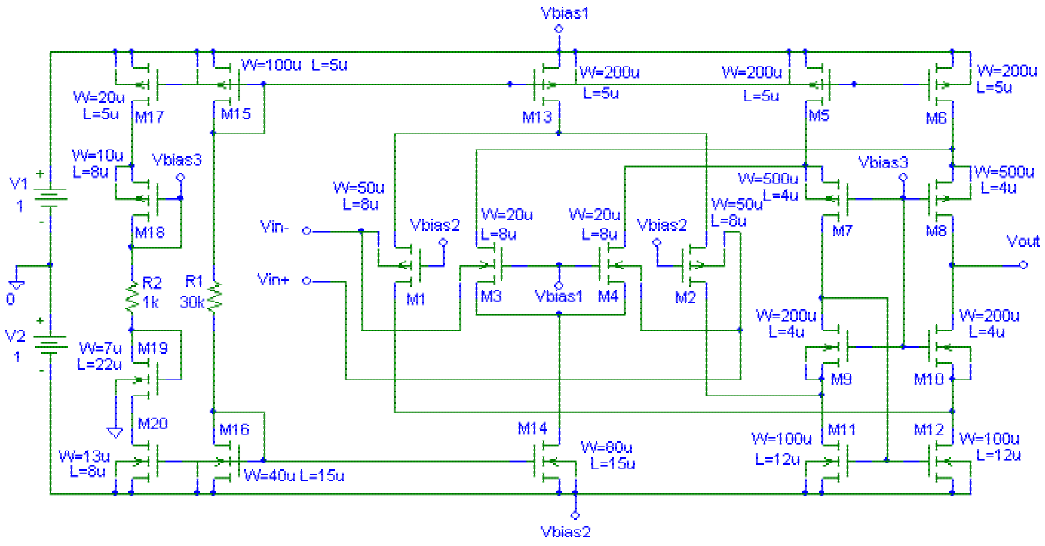

Fig. 3 Rail-to-rail bulk-driven amplifier.

The simulation results of the Rail-to-rail bulk-driven amplifier were carried out by the program OrCAD Pspice using two spice model files 1.2 μm and 0.7 μm CMOS technology from AMI SEMICONDUCTOR.

Table 1 The simulation results of the rail-to-rail open loop bulk-driven op-amp

Feature	Value	Unit
A0	71.6	dB
Gain-bandwidth product	1.63	MHz
Offset	0.1	mV
Supply voltage	±1	V
Input CMR	±0.5	V
Slew-rate	1	V/μs
Settling time	900	nsec
Load capacitance CL	2	pF
Phase margin	74	Degree
Input referred noise (white)	100	nV/√Hz
Output dynamic range	1.4	Vpp
Power consumption	33	μW

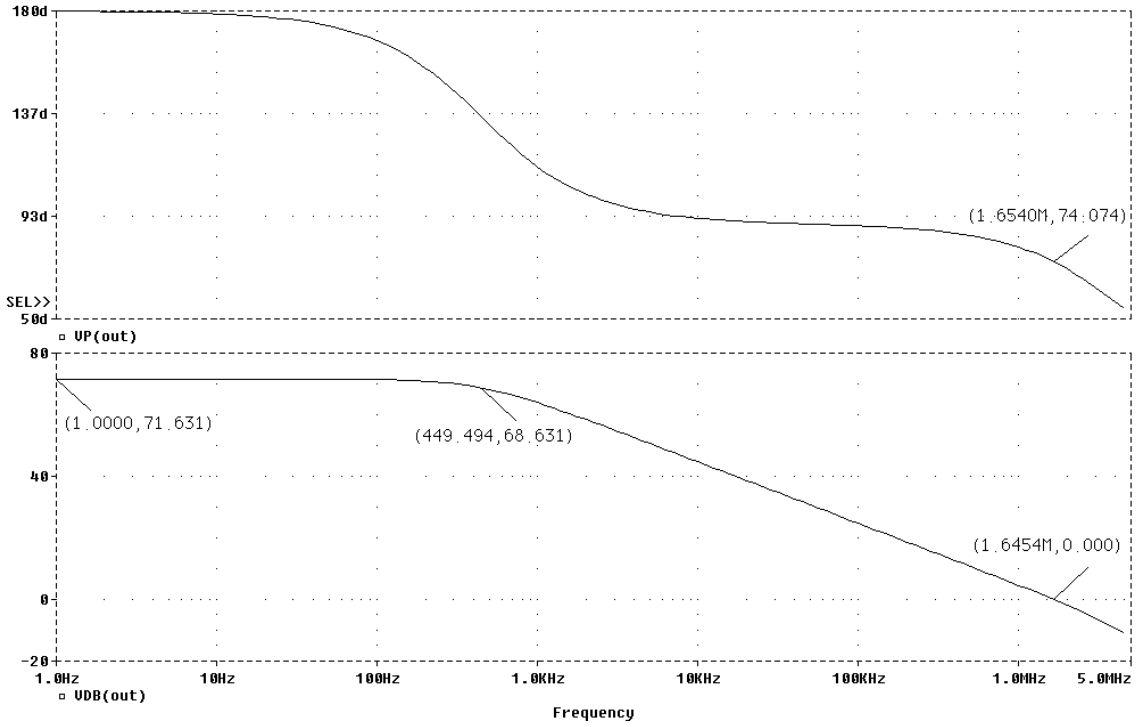

Fig. 4 Amplitude and phase frequency responses of the Rail-to-rail bulk-driven amplifier.

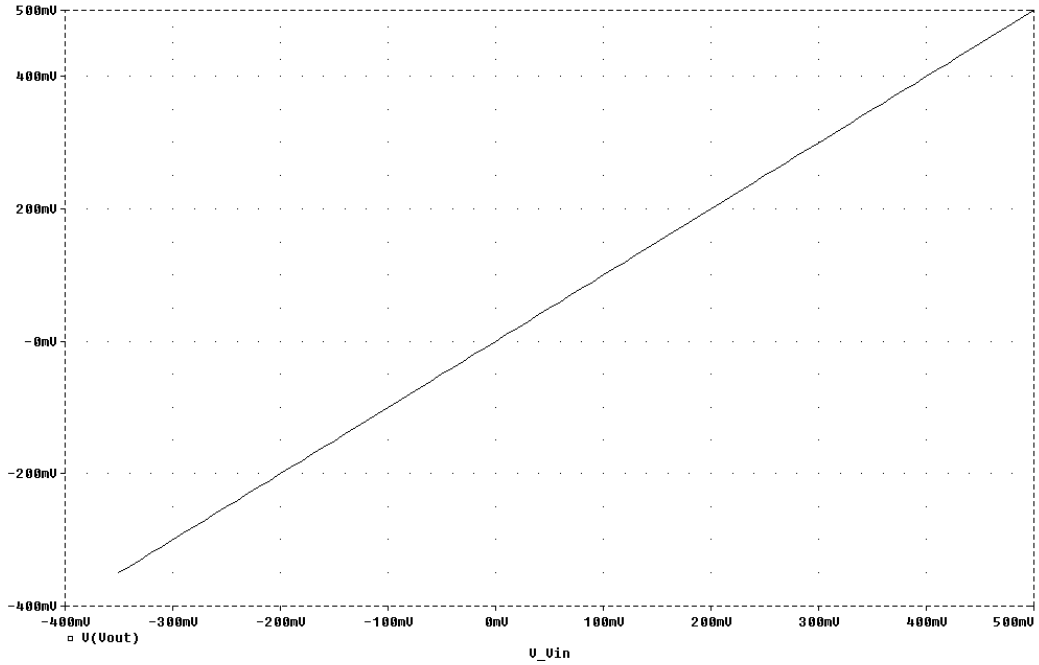

Fig. 5 DC characteristics of the Rail-to-rail bulk-driven amplifier in the unity gain configuration.

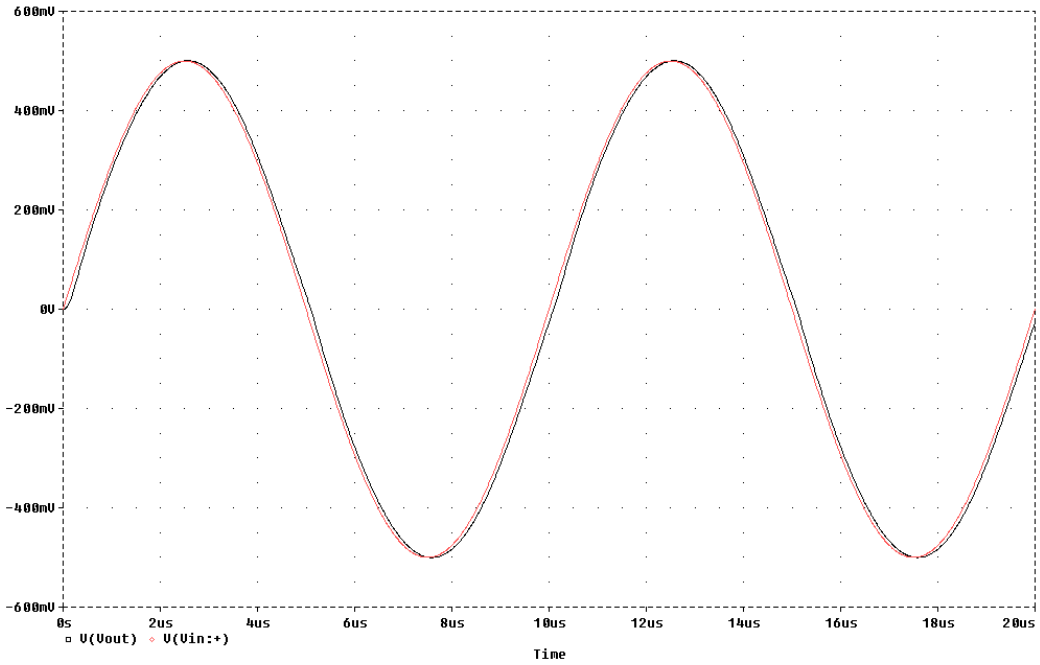

Fig. 6 The transient characteristic of the Rail-to-rail bulk-driven amplifier

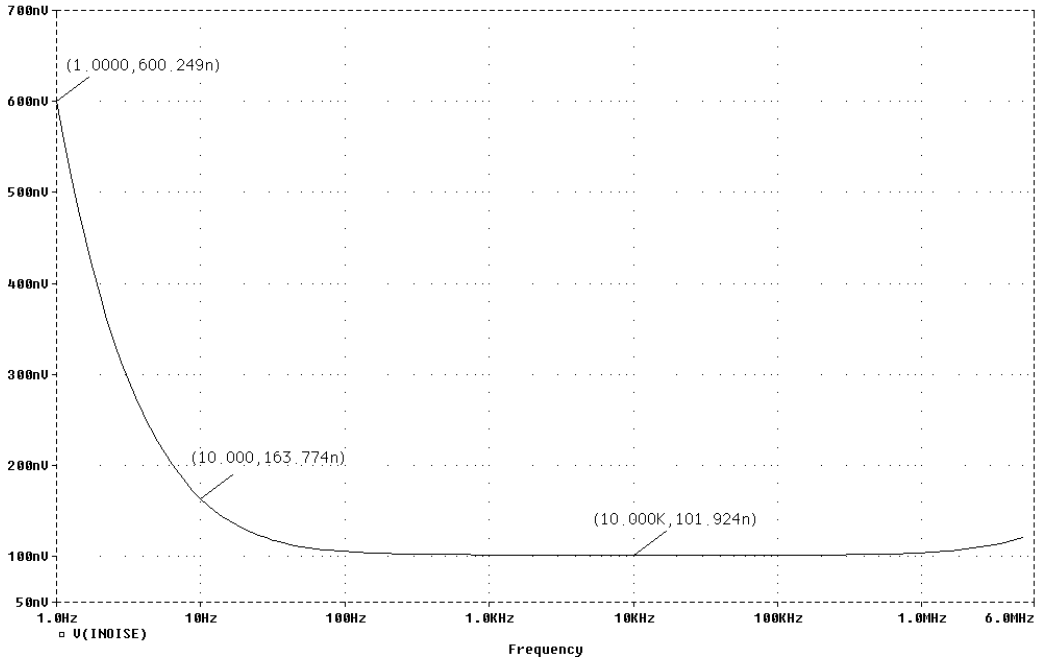

Fig. 7 Input noise voltage of the Rail-to-rail bulk-driven amplifier

3. CONCLUSION

Based on the results it was achieved, we could present the main advantages and disadvantages of bulk-driven technique.

Desirable characteristics of bulk-driven transistors are:

- Depletion characteristics avoid VT requirement in the signal path, voltage swing for low voltage supply is increased, and minimum operational supply voltage is pushed to its limit.
- We can use the conventional front gate to modulate the bulk-driven MOS transistor.

Undesirable characteristics of bulk-driven transistors are:

- The transconductance of a bulk-driven MOST is substantially smaller than that of a conventional gate-driven MOS transistor, which may result in lower GBW and worse frequency response.
- The polarity of the bulk-driven MOST is technology related. For a P (N) well CMOS process, only N (P) channel bulk-driven MOSTs are available. This may limit its applications. For example a rail-to-rail bulk-driven op-amp needs a dual well process to realize it.
- The equivalent input referred noise of a bulk-driven MOS amplifier is larger than a conventional gate-driven MOS amplifier because of its smaller transconductance.
- Prone to turn on the bulk-channel PN junction, which may result in a latch-up problem.
- Rail-to-rail op-amp need separate wells (dual well process), which is:
  - More expensive process
  - Bigger chip area needed
  - Worst matching comparing with one well process

The bulk-driven circuits could have a role to play in many applications, which needs low-voltage low-power current mirrors, current sources, and conventional op-amp applications ranging from unity-gain buffer, signal amplifiers, to filters and switched capacitor, and so on.

ACKNOWLEDGEMENT

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5. REFERENCES

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