Keywords: bipolar, CMOS, input bias current, input offset voltage, op amps, operational amplifier

TUTORIAL 717

Operational Amplifier Inputs

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Abstract: When does input bias current become a concern? Which architecture offers the lowest offset voltage? This application note introduces common op-amp input structures with their associated design advantages and challenges.

Operational amplifier (op amp) inputs vary widely in structure and performance. This document presents common op-amp input structures. By using the Electrical Characteristics table, the op amps are identified by type and part number.

Each op amp structure type offers its own advantages and disadvantages. Therefore, Maxim will continue to introduce op amps with a variety of configurations to optimize each product for its intended application. **Table 1** below lists the various types used, some of which are very common while others are represented by only one or two examples in our product line.

Table 1. Op Amp Input: Types and Parameters

Type	V_{OS}	I_B	I_{OS}	TC_{IB}	Comments
Bipolar PNP	100µV to 2mV	100nA to 1µA	10% I_B	< 20%	• VCM includes the negative supply rail. • MAX4493, LMX321
Bipolar NPN	10µV to 1mV	100nA to 1µA	10% I_B	< 20%	• Usually used for dual-supply precision amplifiers.
Bipolar Rail to Rail	500µV to 5mV	±100nA to 1µA	50% I_B	< 40%	• Uses both NPN and PNP types. • Most common rail-to-rail input stage. • I_B changes polarity with different V_{CM}s. • MAX4091, MAX4321
CMOS p-Channel	350µV to 20mV	±10pA to 1nA	I_B	10x per 30°C	• Lowest I_B • Most common CMOS type due to its V_{CM}, which includes the negative supply rail. • MAX4475, MAX4036
CMOS n-Channel	350µV to 20mV	±10pA to 1nA	I_B	10x per 30°C	• Not very common; performs similar to p-channel without single-supply operation.
CMOS Rail-to-Rail	1mV to 20mV	±10pA to 1nA	I_B	10x per 30°C	• Uses both n- and p- channel devices. Lower I_B, but higher VOS, compared to bipolar rail to rail. • MAX9910, MAX9914, MAX4230
					• An internal current mirror is used to cancel the

Bipolar NPN with I_B Cancellation	100µV to 200µV	±10nA to 100nA	50% I_B	< 40%	input bias current. • MAX400, MAX427, MAX437, OP07, and MXL1028.
Bipolar Current-Mode Feedback	500µV to 5mV	±100nA to 10µA (IN+ only)	NA	< 40%	• IN+ is high impedance; IN- is low impedance. • Maxim has only a few CMFB types, generally high speed. • Limited range of useable feedback impedance. • MAX4223, MAX4112
JFET Op Amp	500µV to 2mV	±10pA to 1nA	I_B	10x per 50°C	
Active Input Offset Cancellation	1µV to 25µV	±10pA to 100pA	I_B	~ 0	• Chopper and autozero technique. • MAX4238, MAX4239, MAX420, ICL7650

The bipolar PNP has been Maxim's most common input because of its inherently low offset and single-supply operation. The bipolar rail-to-rail stage is, however, challenging the PNP version for customer use, and now constitutes more than 50% of our new op amp products. The remaining input stages shown in the table account for less than 20% of our op amp product line.

Generally if customers are looking for low offset voltage, they will have to use one of the bipolar input stages. If high impedance is needed, the application will require a CMOS input stage. If the application requires a JFET input stage, a CMOS-type op amp might satisfy the criteria. Maxim currently offers few op amps with JFET input stages, and those devices are very high priced.

Most of Maxim's op amps can be identified using the above table as a guide. Compare the offset voltage, the bias current, and the offset current to determine which of the above categories is the closest match for an application.

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