National Semiconductor

The Sight & Sound of Information

Application of Precision Amplifiers

Defining a Precision Amplifier

- **How accurately is a signal scaled?**
  - ***High open loop gain***
  - ***Low offset voltage***
  - ***Low offset voltage drift***
  - ***High CMRR***
  - ***High PSRR***
  - ***Low input bias current***
  - ***High GBW for wide-band signals***

National Semiconductor

The Art of Analog 22

Precision amplifiers accurately process a signal while buffering, scaling or filtering it. In general, Precision has been interpreted as "good" DC specifications, such as low offset voltage, low offset drift, etc. Some applications will also require precision AC characteristics.

OP Amp Error Sources

$$e_{id} = \frac{e_o}{A_{VOL}} + V_{OS} + (I_{B+})(R_{S+}) + (I_{B-})(R_{S-}) + \frac{e_{CM}}{CMRR}$$

- **Major input referred error sources of an Op Amp**
  e_{id} = 0 for ideal Op Amp
- **Precision requires Error terms to be small relative to the signal being processed.**
- **Do not forget about frequency.**

National Semiconductor

This equation considers the major contributors to errors in op amps. The value "e_{id}" is the voltage between the two inputs of the op amp and is equal to zero if the op amp is ideal.
The first term, e_o/A_{VOL} , results from the finite gain of the amplifier. There must be a small differential voltage across the input to produce an output voltage. For example, if the output of an amplifier is 1.0 volts DC and the open loop gain is 100dB the error voltage across the inputs is $1/10^5 = 10\ \mu V$
The second term, input offset voltage or V_{OS} , is a result of small imbalances on the differential input stage of the amplifier. The input offset voltage is also multiplied by the noise gain of the amplifier with its feedback. At high gains the V_{OS} can become a large offset error.
The third and fourth terms result from the input bias currents in conjunction with any source resistance. Any current flowing into the amplifier's input will cause a voltage drop across the source resistance of (I_B x R_S) This has two effects. The first is to generate an apparent offset voltage at the input to the op amp if the equivalent source impedances on each input are not equal. The second is to add an error voltage to the signal that changes its apparent magnitude.
The last term brings in the effect of the common-mode voltage seen by the amplifier's input. The common mode voltage, e_{CM} , is defined as the average voltage on the amplifier's inputs, $(e_+ + e_-)/2$. For example, if the common mode voltage is 1 volt and the CMRR is 80db, the error on the amplifier's input due to the common mode voltage is $1/10^4 = 100\ \mu V$
Each of the above error sources needs to evaluated with respect to the specifications of the amplifier being considered.
As the frequency of the signal increases the Open loop gain AVOL and the CMRR will roll off with increasing frequency.

Precision Op Amps

- LMV2011
  - *Chopper stabilized*
- LMV771
  - *Low offset, Low noise, High drive*
- LMH6624/26
  - *Low offset, 1.5 GHz GBW*

National Semiconductor

The Art of Analog 24

Three recent additions to National's precision amplifiers are the LMV2011, LMV771, and the LMH6624 and LMH6626.

Precision Amplifiers

	LMV2011	LMV771	LMH6624/26
Vos	3μV	*250μV*	250μV
TCVos	0.015μV/°C	0.35μV/°C	0.25μV/°C
Long-Term TCVos Drift	0.015μV/Month	NA	NA
CMRR	130dB	90dB	90dB
I_{BIAS}	3pA	0.23pA	13μA
A_{VOL}	130dB	100dB	79dB
GBW	4MHz	3.5MHz	1.5 GHz

National Semiconductor

The Art of Analog 25

The LMV2011 is a MOS input chopper-stabilized amplifier offering near zero offset voltage and offset voltage drift. The LMV2011 is available in singles, dual (LMV2012) and quads (LMV2014).
The LMV771 is a MOS input op amp which is designed to provide low offset voltage and low offset voltage drift and good output drive capability.
The LM6624 and LMH6626 are bipolar-input, laser-trimmed, low-noise, wide-bandwidth amplifiers that are available in singles and duals.