You Thought You Knew Analog-----------------------------------

New Common Wisdom Regarding Opamps

The more you know about something, the more interesting it often becomes. In this edition ROHM will provide new information about some of the latest the trends in analog along with new common wisdom on operational amplifiers.

What's Changing, What's Not

When one thinks about a representative player in the analog IC field the operational amplifier (opamp) quickly comes to mind. However, the increased proliferation of digital worldwide results in fewer opportunities to learn about analog, despite the fact that the demand for opamps continues to enjoy steady growth. Among the many varieties of opamps, the standard (conventional) type has seen long-standing and continued use. But what may come as somewhat of a surprise to learn is that it remains the flagship product of many component suppliers.

On the other hand, the evolution and differentiation of opamps with respect to low power consumption, low noise, low offset, and high speed are progressing steadily. Furthermore, their operating ranges are expanding to I/O full swing (rail-to-rail), along with a shift to lower voltages. CMOS opamps are also trending towards lower noise and other desirable factors.

And in addition to the move to lower voltages in industrial equipment, the need for high-voltage CMOS products is quickly gaining traction as well. Plus, packages are becoming more compact – up to 2 x 3 x 0.6mm (VSON008) – representing a substantial change in accordance with evolving mounting technologies.

A recent topic is the development of high-reliability components for vehicles and other applications. These automotive-grade components feature an expanded operating temperature range and guaranteed rated values for all temperatures within the entire range, incorporating improvements in wafer processing to withstand vehicle reliability testing. Furthermore, the workmanship of the products in the assembly process is controlled

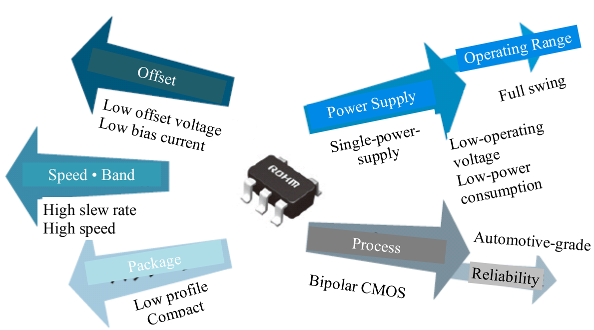


Fig. 1: Evolution and Differentiation of Opamps

Expanding Product Variety (Tips on Product Selection)

based on automotive standards (i.e. 100% inspection). <Fig. 1>

They say that the fastest way to mastering opamp design is to become familiarized with the standard types and how they are used. Sufficient operation with standard products can actually be attained in many of the circuits that use opamps. Moreover, if the sizes of the signals that are handled are extremely small or very fast, or if only a low-voltage power supply can be used, there is a way to search for different varieties of opamps and sort them based on application.

In recent years the 358 and 2904 opamps are considered industry standard. Both are general-purpose products that integrate two circuits (and were originally named the LM358 and LM2904). However, due to their widespread adoption many companies soon began incorporating their part numbers in equivalent models, such as the BA10358 and BA2904 from ROHM. <Fig. 2>

Incidentally, the BA2904 features nearly the same electrical characteristics as the BA10358, but with higher withstand voltage resistance and expanded operating temperature range.

It is extremely useful to learn typical varieties as well as standard types of each variation for practical use. It also helps to remember the numerical order of the digits in the part number, since they often indicate certain important specifications (i.e. offset voltage). <Fig. 3>

While remembering circuit component constants used in the standard opamp, one should also get into the habit of thinking about why those values are appropriate. This is because the circuits used are 'ripe' circuits and component constants, which have been narrowed down after considering the general performance requirements, likelihood of failure, as well as costs and availability.

BA10358 BA2904

	BA10358	BA2904
Input Offset Voltage	7mV (Max)	
Input Bias Current	45nA (Typ)	20nA (Typ)
Gain Bandwidth Product	0.5MHz(Typ)	
Slew Rate	0.2V/µs(Typ)	
Power Supply Voltage	+3.0V ～ +32.0V	+3.0V ～ +36.0V
Operating Temperature Range	-40℃ ～ +85℃	-40℃ ～ +125℃

Fig. 2: Main Specifications of BA10358/BA2904

Features	Applications	Part No.	Specifications
Low noise	Audio circuits	BA4580R	Input conversion noise: 5nV/√Hz@1kHz
High speed/high voltage resistance	High-speed current detection, etc.	BA3472	Slew rate: 10V/µs; Supply voltage: +3 to +36V
Low offset	High power amplification circuits	BA8522R	Supply voltage: + 4 to + 30V; Offset voltage: 1.5mV
I/O full swing	Battery-driven devices	BU7262	Supply voltage: 1.8 to 5.5V; Circuit current: 250µA/ch
Low power consumption	Battery-driven devices	BU7265	Supply voltage: 1.8 to 5.5V; Circuit current: 0.35µA
High accuracy	High resolution sensors	BD5291	Supply voltage: + 1.7 to + 5.5V; CMRR: 70dB (Min)
High speed	High-speed current detection, etc.	BU7485	Slew rate: 10V/µs; Supply voltage: +3 to +5.5V

Fig. 3: Opamp Variations and Representative Models

Understanding Product Variety

Before long, as circuits that use standard opamps become more and more familiar, it should be noted that standard general-purpose types are not necessarily better simply because they are superior in terms of design and ease-of-use. A variety of other factors must be taken into account, and explains the wide variety of opamps available on the market.

For example, there have been questions regarding a higher output voltage than anticipated from the popular BA10358. Upon careful investigation, it was discovered that problems occurred due to an increase in the lower limit of the output voltage when a current sink is applied in single power supplies. This phenomenon is caused by the particular output voltage vs output current characteristics of the BA10358, and does not occur with other CMOS opamps. <Fig. 4>

Therefore, it is necessary to possess a deep understanding of the features and characteristics of individual analog ICs, including opamps. And it is important to refer to the datasheet, which contain a wealth of information such as specifications and characteristics.

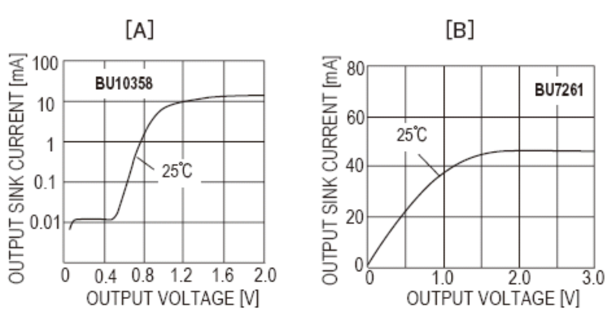


Fig. 4 [FAQ] The output voltage is higher than the design value despite using a standard component.

The BA10358 shown in [A] can output a voltage near the ground level when the output sink current is 10µA or lower. However, output sink currents above this threshold prevent low-level voltage output near GND.

[A]: BA10358 Output Sink Current – Output Voltage Characteristics [B]: BU2761 Characteristics

Deciphering the Data <Important Aspects of Design>

Nevertheless, being told to obtain a deeper understanding of the characteristics in the datasheet may seem daunting at first. As a concrete example, we have chosen the relationships between offset, bias current, and CMRR in CMOS opamps.

Compared to bipolar opamps, the temperature variations of the input bias current (Ib) for low-voltage CMOS opamps are larger, making it a necessary consideration when joining high impedance circuits. Incidentally, Ib is affected by CMV (Common Mode: Phase Signal Voltage), albeit only slightly. <Fig. 5>

Normally, this is not much of a problem, but depending on the CMV, care must be taken for opamps in which Ib is large and fluctuates discontinuously. In such cases, CMV that exists externally as noise is observed as unnatural fluctuations in the output voltage.

Unnatural fluctuations in the offset are related to CMV and CMRR (Common Mode Rejection Ratio). In general, although CMRR is likely to focus on multiple frequency characteristics that can be captured based on noise countermeasures,

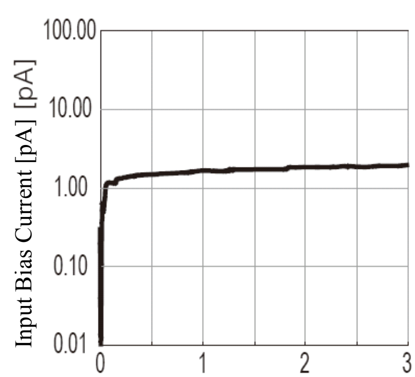
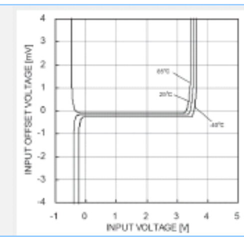


Fig. 5: Example of Common Mode Input Voltage vs. Input Bias Current Characteristics for a Full-Swing CMOS Opamp

Removing offset fluctuations caused by common mode voltage - BD5291 I/O full-swing low-input offset voltage operational amplifiers



Achieves full swing input/output operation at a supply voltage of 1.7V. Designed for applications used in conjunction with low-voltage digital devices such as DRAM. Also ideal for applications with a bias current of 1pA (typ.) and extremely small sensor amps.

Conventional full-swing CMOS opamps switch paths based on input voltage by vertically stacking two input circuits (PMOS/NMOS). However, the BD5291 eliminates switching using only a depletion-type input circuit. This allows for a high 70dB CMRR due to elimination of discontinuous offset fluctuations caused by CMV. Also, the number of vertically stacked transistors was reduced, simplifying circuit configuration. This makes operation possible at an industry low supply voltage of 1.7V, ensuring sufficient operating margin in 1.8V power supply systems.
(Explanation)

- Operating supply voltage range (single power supply): +1.7V to +5.5V
- Slew rate: 2.5 V/µm
- Operating temperature range: -40°C to +85°C
- Common mode input range: VSS to VDD
- Input offset voltage: ±2.5mV (Max)
- Common mode signal rejection ratio: 70dB (Min)
- Package: 2.90 x 2.80 x 1.25mm (SSOP5)

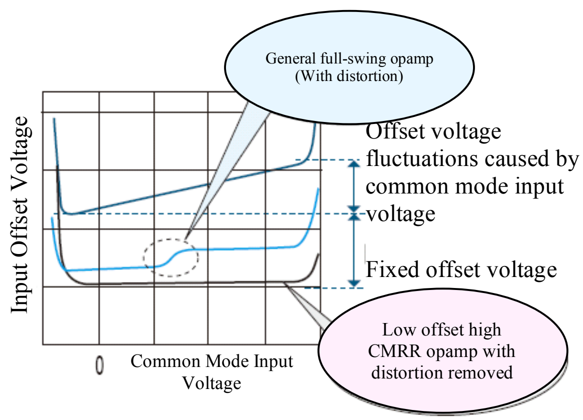


Fig. 6: Common mode voltage and offset fluctuations

CMV is DC as well (although attenuated by the CMRR component). It is added to the signal and appears at the output. <See Fig. 6> (Slope of blue line corresponds to CMRR) Therefore, to minimize error, CMRR should be as large as possible. Furthermore, the voltage offset fluctuations of full-swing type CMOS opamps are generally not uniform, and often involve distortion that changes in a step-like manner at a certain level. This is because the internal circuits (PMOS and NMOS input differential stages) are switched based on the input voltage in conventional full-swing CMOS opamps. As a result, opamps have been recently introduced that enable simultaneous high CMRR with full swing operation without switching. (Refer to the column)

Integrated Production Capability and Comprehensive Support are Deciding Factors

The fact that there are no limits or boundaries to the degree that it can be understood and mastered – together with the virtually limitless possibilities – are some of the reasons that make analog so attractive. However, this requires that designers consider the strengths and capabilities of the manufacturer/supplier when working with analog devices and applications. For example, since it is now customary to design and evaluate using circuit simulators, consideration must be given as to whether SPICE models are available or the datasheet contains sufficient information. And the existence of additional support tools such as study materials or seminars makes a surprisingly big difference as well to the inexperienced.
Ultimately, selecting a supplier that offers a total support system and broad product array developed using an integrated, in-house production system ensures stable, worry-free supply and superior reliability in the face of unexpected problems and situations that may arise regarding analog devices and/or other products used in combination, as well as when purchasing components for mass production.