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Return to March 9th Issue Table of Contents
Site Map Email Us Subscribe Home

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**Tech Insights**
Exploring advances in analog and mixed-signal ICs

# Tiny Op Amp Targets Miniature Portable Electronics

## An Advanced Submicron Silicon-Gate biCMOS Process Houses This General-Purpose Op Amp In A Flea-Size SC70 Package.

**Ashok Bindra**

**L**ike other electronic components, op amps also continue to get better in performance, smaller in size, and lower in price. This is all dictated by compact cellular handsets, pocket-size pagers, digital cameras, and other portable consumer electronics, which are constantly evolving to offer higher performance without cost penalties. Consequently, semiconductor vendors are constantly enhancing processes, refining architectures, and improving manufacturing.

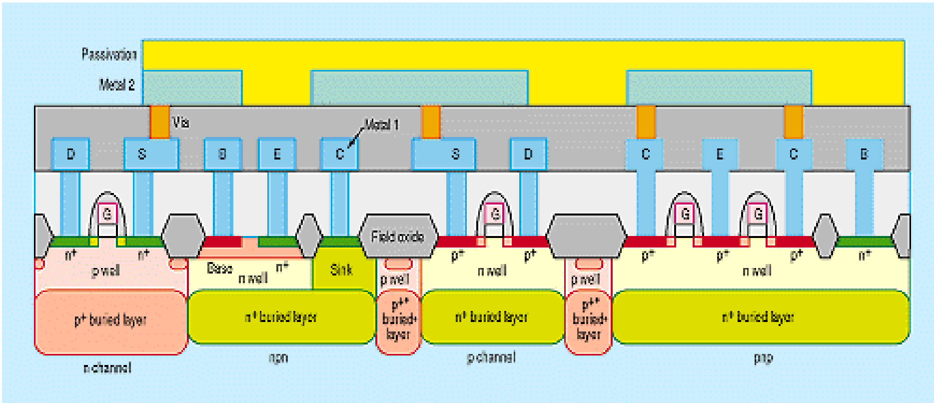
To meet the stringent needs of these applications, National Semiconductor has redesigned the ubiquitous work horse of the industry, the LM324, which has served the requirements of analog designers for the last twenty five years. The result is a low-voltage, single-supply op amp, the LMV321, in a micro-miniature five-lead SC70-5 package.

**Silicon Dust**

The company calls it the "flea size" package and likens the tiny op amp's development to giving designers microminiature "silicon dust" components to work with. National Semiconductor claims that it is the smallest available package for a standard op amp ***(see "Wait and See,")***. The LMV family is being aimed at compact portable electronics, where space and power consumption are key drivers, says Erroll Dietz, design manager for amplifiers at National Semiconductor's Analog Product Group based in Santa Clara, Calif.

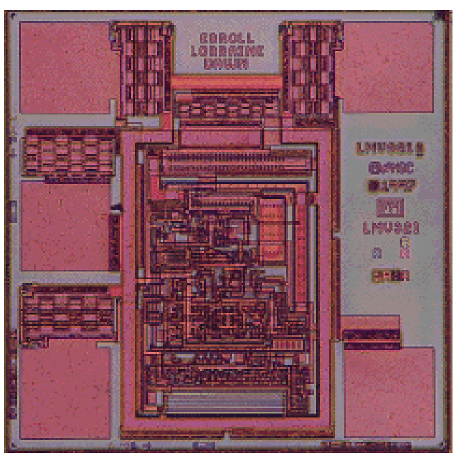
To be sure, the SC70 is not a brand new package. Several logic devices are being offered in this package today. At dimensions of 2.0 by 2.1 by 1.0 mm, the SC70-5 is approximately half the foot-print of the conventional SOT23-5 package. In fact, with these dimensions, the LMV321 approaches the size of the chip resistors and capacitors, as well as discrete transistors. As a result, this tiny package allows designers to insert the new op amp closer to the signal source in tight portable designs, thereby minimizing noise pick-up and improving signal integrity.

This miniaturization of the LMV family is made possible by National Semiconductor's advanced 0.8-µm silicon-gate biCMOS process that combines the speed of bipolar transistors with the low-power attributes of CMOS circuits ***(Fig.1)***. And, all this is achieved without incurring higher cost. In fact, the reduction in the size of the op amp's die has enabled National Semiconductor to lower the cost of the LMV321 op amp by about 50% over comparable CMOS parts.




**1. The biCMOS process cross section shows nMOS, pMOS, npn, and pnp transistors. The pnp transistors are basic lateral structures formed from pMOS source/drain diffusions. The parasitic gate, which forms the base on the lateral pnp transistors, is tied back to their source.**

The sub-micron biCMOS process the op amp is made on has shrunk the LMV321’s die size to 17 by 17 mils, allowing the company to place the chip in the micro-miniature SC70 package **(*Fig.2*)**. In order to fit the die in this package,the bond pads have also been reduced to 2.8 mils$^2$. The need for smaller bond pads has also pushed the wire-bonding technology employed, as well as stretched the wafer dicing process to new widths.

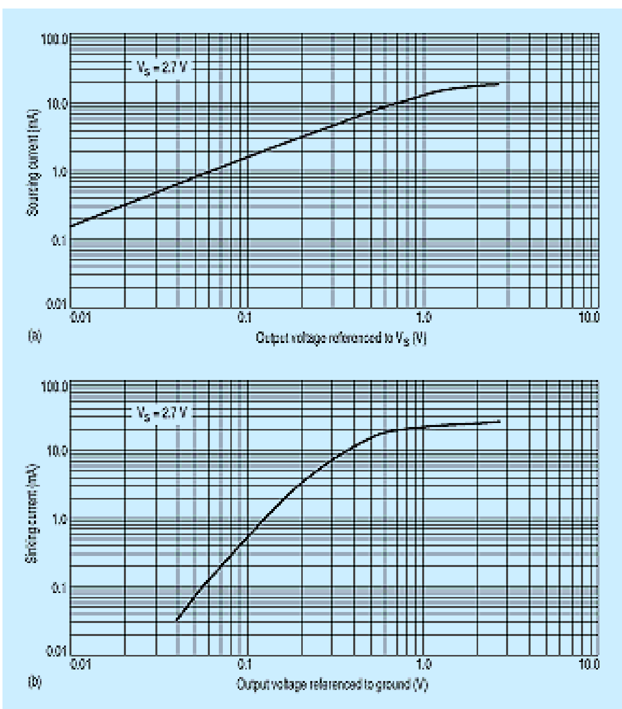


**2. The 0.8-µm biCMOS process has shrunk the die of the LMV321 to 17 by 17 mils. And the bond pad size has beeen redued to 2.8 mils$^2$.**

**ESD Protection**

Despite finer device geometry, the process incorporates a proprietary energy spreading technique that provides reasonable ESD protection for such a tiny op amp. An efficient energy dissipative transistor in this scheme clamps the electrostatic voltage to a safe level by spreading the heat energy efficiently over as large an area as possible. This approach also alleviates the problems due to localized heating, which can be damaging to aluminum interconnects. Consequently, under human body simulation, the LMV321 is rated to withstand 900 V, while the machine model indicates a tolerance of 100 V However, according to National Semiconductor, its designers have developed structures that pass over 2 kV of human body model discharges.

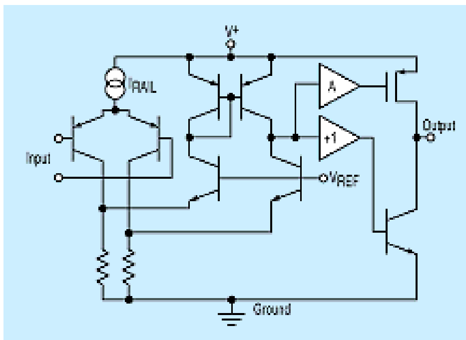
The finer process has also lowered the single-supply requirements of the LMV321 down to 2.7 V, thereby guaranteeing operation from 2.7 to 5.5 V. By comparison, the existing standard LM324 op amp operates over a supply voltage range of 5 to 32 V. In addition, the LMV321 provides rail-to-rail operation with no crossover distortion down to 2.7 V (***Fig.3***). The rail-to-rail output swing sets the dynamic range of the output, which is particularly important when the op amp is running on low supply voltages. Additionally, the amplifier offers a gain-bandwidth product of 1 MHz and a slew rate of 1 V/µs, while drawing typically only 130 µA of current under no-load conditions from a power-supply voltage of 5 V.




**3. The National Semiconductor tiny op amp offers high source (a) and sink (b) currents at low voltages to permit a rail-to-rail swing at the output.**

## Redesigned Architecture

Besides an improved speed-power ratio, the biCMOS process has also allowed the manufacturer to implement matched input bipolar transistors to minimize input offset levels and errors, while reducing the 1/f noise. In fact, to realize well-matched transistors, the LMV321 uses pnp transistors instead of pMOS transistors **(*Fig.4*)**. Furthermore to retain the ac and dc characteristics of the popular LM324 all the way down to 0 2.7 V, the LMV321 implements a differential folded cascode circuit at the input.This allows the designer to operate at lower voltages with a very wide input common-mode voltage range, notes Dietz. Typically, at a 2.7-V supply voltage, the input common-mode voltage range for the new part is -0.2 to +1.9 V. Consequently, the LMV321 allows direct sensing near ground in single-supply operation.




**4. To achieve well matched transistors at the input, the op amp uses PNPs instead of pMOS transistors. While the output is a combination of pMOS and npn to obtain higher output current.**

Other key features of LMV321 op amp at a 2.7-V supply include a maximum input offset voltage of 7 mV, average input offset voltage drift of 5 µV/°C, typical input offset current of 2 nA, a common-mode rejection ratio (CMRR) of 63 dB, and a power-supply rejection ratio of 60 dB.

The typical input bias current of the new op amp is 15 nA at a 5-V supply and 11 nA at 2.7 V. Thus a 100-kΩ resistor will cause 1.1 mV of error voltage at a 2.7-V supply. However, this error due to the amplifier's input bias current can be reduced by balancing the resistor values at both the inverting and non-inverting inputs, according to the op amp's manufacturer.

While the open-loop gain of the redesigned op amp is only 15,000 in the sinking mode and over 100,000 in the sourcing mode, National Semiconductor's Dietz believes it is more than sufficient for many applications. "As long as the gain error is less than 10% of the offset voltage, the gain of 15,000 is adequate" says Dietz. The output impedance of the amplifier in the open-loop mode is 500 ?

The shrinkage in die size has also permitted National Semiconductor to produce dual and quad versions of the single LMV321 in comparatively smaller packages. While the dual LMV358 comes in an 8-lead mini SOIC package, the quad LMV324 is housed in a 14-pin TSSOP. Both, the dual and quad versions provide true single-supply operation and retain the ac and dc characteristics of the LMV family.

**Challenging Issues**

Although, the SC70 package looks attractive, it also poses many challenges to the analog designer Key among them are thermal issues, mechanical reliability, and parasitic influences. The smaller package presents higher thermal resistance. Consequently, the thermal resistance ($*_{jA}$) of the SC70-5 package is 440°C/W. Such a high value warrants proper thermal design, ensuring that the part is not overheated and operates within the specified temperature range. The thermal resistance drops significantly as the package size increases. For example, the thermal resistance offered by the 8-pin miniSOIC package is 235°C/W, and the 14-pin TSSOP package presents 155°C/W.

While the part is compatible with existing pick-and-place machinery, its mechanical reliability requires assurance. Toward that end, National Semiconductor has subjected the LMV321 to thermal cycling and other life tests. According to National Semiconductor, the LMV321 in an SC70-5 package passed without any rejects when subjected to 1000 temperature cycles from -65 to +150°C. This test evaluates the device's ability to withstand both the extremes of rated temperatures, as well as rapid changes in temperature.

Additionally, the LMV321 also underwent humidity and parametric stability tests, and emerged without any failures,asserts the manufacturer. To determine the tolerance to humidity, the package is subjected to moisture resistance test of Method 1004. In this test, which is considered destructive, the package is subjected to 10 cycles, during which the temperature is varied from 25°C to 65 °C at a relative humidity of 90% when the temperature is stabilized. Each cycle is for a duration of 24 hours. During this test, the part is tested electrically for degradation, and examined visually for any damage. The parametric stability test indicates the op amp''s ability to perform consistently over time. This capability is analyzed via burn-in. Since parasitic effects are critical with such a small size, the signal traces must be routed in a manner that minimizes ac and dc parasitic effects on the input of the amplifier.

## Price And Availability

*The LMV321/358/324 op amps are in production and are available now.The single op amp LMV321 in an SC70-5 package is priced at 27 cents. Likewise, the dual version LMV358 in an 8-pin miniSOIC package is priced at 27 cents, and the quad LMV324 version in a 14-pin TSSOP* *package is priced at 30 cents. All prices are for 1000-piece quantities.*

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# Wait And See

**W**hile National Semiconductor has taken the pioneering step in further shrinking the package size for general-purpose op amps, other major competitors in the analog world are not sitting idle. They are keenly watching the introduction of the popular single op amp in the tiny SC70 package, which approaches the size of chip resistors and capacitors. However, before they commit to such a miniaturized form, these semiconductor vendors want to see the response of the analog designers to the SC70-5.

Meanwhile, major players like Maxim Integrated Products, Linear Technology Corp., Analog Devices, Texas Instruments and Burr-Brown have opted for the SOT23 as a proven miniature package for their respective op amps. For instance, Maxim has released its single micropower op amp, the MAX4240, in a 5-pin SOT23-5. With beyond the rails input and rail-to-rail output capabilities, the MAX4240 operates from a single +1.8 V to +5.5 V or dual ±0.9 V to ±2.75 V supplies. It has an input common-mode range that is guaranteed to exced either rail by 200 mV , while the output typically swings within 9 mV of the rails with a 100-kΩ. load. Plus, this amplifier provides a 90-kHz gain-bandwidth product, and uses only 10 µA of supply current. In fact, this ultra-low power device is designed to operate from two AA cells.

Linear Technology is also suporting the SOT23 for its precision high-speed op amps. And, Burr-Brown has unveiled a single-supply, CMOS-based dual op amp, the OPA2337, in a SOT23-8. Accordong to Burr-Brown, the SOT23-8 offers a 75% smaller foot-print than the industry standard SO-8. The manufacturer has also developed a single op amp version in a 5-pin SOT23-5 package. The trend is toward the SOT23-5 for single op amps, says Burr-Brown’s strategic marketing engineer Howard Skolnik. No matter how small it gets, it is going to get smaller with time, notes Skolnik.

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Return to Top