Simplifying Signal Chain Design for High Performance in Small Systems

Texas Instruments

William Cooper
Marketing and Applications Manager
Temperature & Humidity Sensing
Texas Instruments

Peter Semig
Applications Manager
General-Purpose Amplifiers
Texas Instruments

Ravi Singh
Marketing Manager
Transceiver Interface
Texas Instruments

The focus on smaller, faster and cheaper products has increased the demands for more compact solutions and form factors.

Engineers are pushing the boundaries of environmental sensing, data management, energy harvesting, data communication, transportation and many other facets of electronics and software.

For example, in the automotive industry, each new vehicle design includes more electronics and expanding feature sets than the previous model. Companies that provide automotive-specific electronic components must adapt their portfolio to keep up with these trends.

To accommodate the demands for smaller systems, engineers might incur higher production costs due to complex manufacturing methods, board assembly tolerances and machine requirements for component placement and inspection. Due to higher printed circuit board (PCB) density within smaller systems, designers may expect an increase in board routing/layout difficulty.

To address these concerns, this white paper will explore how to use analog signal-chain products developed specifically to help engineers optimize board space without sacrificing features, cost, simplicity or reliability in their systems. In some cases, these products can even help boost performance.

At a glance

This paper examines how small-package analog products can help designers overcome several challenges and provides examples to overcome these barriers.

1 Addressing vibration, temperature and performance requirements

Consolidating functionality with small-package devices may achieve significant performance and cost benefits.

2 Overcoming prototyping challenges

Second-sourcing footprints can help designers future-proof their designs in the event that a package type becomes unavailable.

3 How package options lead to greater design flexibility

Having more package options enables designers to take advantage of equal or increased reliability in a smaller package.

4 Finding the right balance

Smaller packages don't always translate to more difficult or costly designs.

Addressing vibration, temperature and performance requirements

Many factors go into the selection of components during schematic and PCB design: semiconductor-device-related parameters typically include noise, data rate or response, and function. Components meeting these parameters are usually available in multiple packages to provide options in terms of environmental use, such as temperature, vibration and overall size.

How do these options affect device cost? It depends on the chip, but many smaller components don't vary significantly in cost when compared to similar package alternatives. The real cost difference may be found in board fabrication or assembly, but minimizing the number of components in a signal chain by consolidating functionality may achieve a cost savings and performance increase that's far greater than using larger components. This section will discuss a few device-specific examples.

The TLV9061 operational amplifier (op amp) from Texas Instruments (TI), shown in **Figure 1**, has an extra-small outline no-lead (X2SON) package that is one-tenth the size of small outline transistor (SOT) packages. Using a device of this size can free up so much board space that it becomes possible to reduce the overall solution size, enabling significant cost savings on PCB fabrication. Depending on how many layers are used, this savings can be exponential. Additional board space also enables the inclusion of more functionality, such as sensors or processing components.

***Figure 1**. The TLV9061 operational amplifier is offered in a 0.80-mm × 0.80-mm X2SON footprint.*

One of the most significant advantages to having smaller package options is in minimizing overall PCB and device packaging for a better and more convenient end-user experience with the application. An example use of the TLV9061's X2SON package in an electret microphone amplifier circuit is detailed in the technical article, Designing tiny microphone circuits with the industry's smallest op amp. Typically, microphone amplifier circuitry can be very compact, and the op amp is the bulkiest, costliest component on the board. In the TLV9061 example, shrinking the size of the op amp down to 0.64 mm^2 can enable designers to push the boundaries of wearable microphones and, ultimately, provide a better user experience with a smaller form factor.

Interface components such as the TCAN1044-Q1 Controller Area Network Flexible Data Rate (CAN FD) transceiver also provide opportunities to save space. It is offered in a 2.9-mm × 2.8-mm eight-pin small-outline transistor (SOT) package that is 72% smaller than the standard SOIC package. In addition to shrinking the footprint and costs for CAN interface designs, the leaded packaging of the TCAN1044-Q1 enables easier automated optical inspection during assembly – helping simplify manufacturing processes.

Similarly, the HDC2010 humidity and temperature sensor, shown in **Figure 2**, is available in a 1.5-mm × 1.5-mm wafer-level chip-scale package (WCSP) that offers full functionality in a fraction of the size of other sensors. These footprints, which are smaller than industry average, allow for significant PCB

***Figure 2**. The HDC2010 humidity and temperature sensor is offered in a 1.5-mm × 1.5-mm WCSP footprint.*

space savings and provide additional options for the designer.

In addition, sensors with improved accuracy and sensitivity are now being packaged in smaller footprints. An example of this can be seen in the TMP61 linear thermistor's 0402- and 0602-compatible package options, shown in **Figure 3**. These package options have a ±1% resistance tolerance that provides better sensitivity and accuracy than a traditional negative temperature coefficient thermistor at high and low temperatures. In addition to its small size, the TMP61's package type enables quicker thermal transfer and response times because of the smaller thermal mass and minimized pad-to-pin copper area.

Figure 3*. The TMP61 linear thermistor is offered in through-hole and surface-mount 0402 and 0603 footprint options.*

Saving space without sacrificing performance and reliability

Isolators can consume the entire perimeter of a PCB to facilitate offboard connections. Some devices have an integrated reinforced isolation technology using a silicon-dioxide barrier with other functions such as RS-485 transceivers, CAN transceivers, low-voltage differential signaling buffers, analog-to-digital converters, amplifiers and drivers, saving board space without compromising performance.

As discussed in the application brief, How to isolate RS-485 for smallest size and highest reliability, designers use optocouplers to enable communication between nodes with large ground potential differences. These circuits generally consist of a transceiver, two optocouplers for receiving/transmitting, a low-speed optocoupler for direction control with an additional Schmitt trigger to clean up slow edges, two buffers for the optocoupler LEDs, a few resistors for biasing and some bypass capacitors. Not only do all of these components consume a large amount of board area, but they also expose edge-sensitive contact points and create a risk for potential reliability issues, such as inductive coupling and interference. Integrating a capacitive-based isolation technology inside the ISO1500 transceiver, shown in **Figure 4**, results in performance, reliability and space savings.

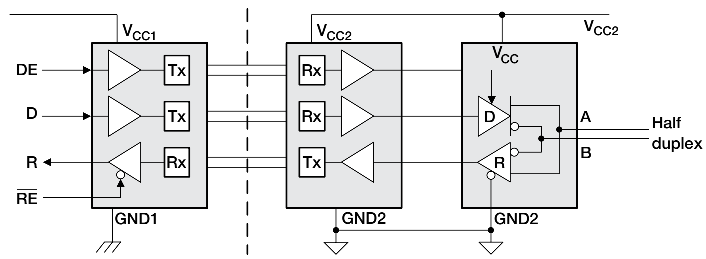

Figure 4*. A functional diagram of the ISO1500 isolated RS-485 transceiver containing an integrated galvanic isolation barrier in a 4.90-mm × 3.9-mm 16-pin shrink small-outline package (SSO16).*

Overcoming prototyping challenges

Innovation in new device generations sometimes drives the obsolescence of the older generations, making it imperative for design engineers to incorporate future-proofing during initial product design. Additionally, designers are trying to reduce system costs as much as possible by optimizing footprints and packages that utilize cheaper alternatives. Thus, some designers strategically select components with common footprints to allow for drop-in replacements when needed.

For example, a second-sourcing footprint (shown in **Figure 5** on the following page) can help designers source pin-to-pin-compatible components as a second source in case one package type becomes unavailable or if there is a cheaper alternative. In the

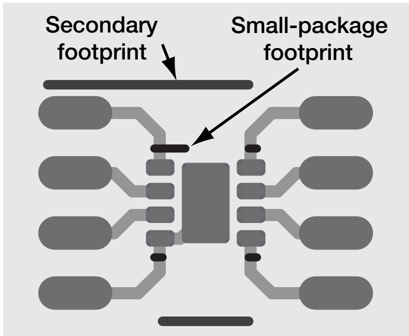

Figure 5. Second-source solution example for PCB layout.

event that a package becomes obsolete or is more costly, the only change necessary is an update to the bill of materials.

Evaluation modules (EVMs) and tool sets from TI give designers a way to experience the benefits of layout, size and performance. The TLV9001 evaluation board shown in **Figure 6**, for instance, is easily configurable as an inverting, noninverting and difference amplifier while demonstrating high performance in a small footprint. Other evaluation modules, such as TI's Universal Do-It-Yourself (DIY) Amplifier Circuit EVM, Dual-Channel Universal DIY Amplifier Circuit EVM or Small-Amp-DIP-EVM enable designers to evaluate operational amplifiers in a plethora of packages and configurations.

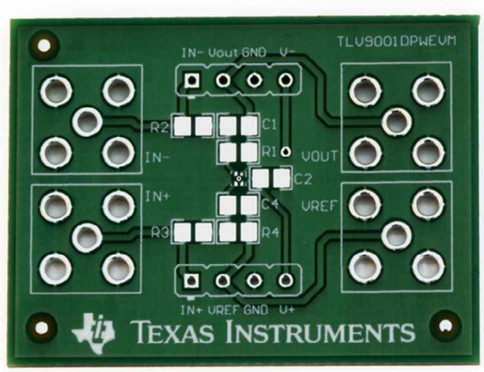

Figure 6. The TLV9001 EVM comes pre-populated with the TLV9001.

How package options lead to greater design flexibility

Having more package options enables designers to take advantage of equal or increased reliability in a smaller package. Automotive designers have traditionally been hesitant to use leadless components such as quad flat no-lead (QFN) packages because of concerns that vibration affects soldering reliability. They have typically opted for leaded components, which are larger but pass optical inspection more easily.

There is an ongoing effort amongst integrated circuit (IC) manufacturers to provide compact packages for several automotive-specific components while maintaining leaded features. SOT-based packaging, for example, provides a reliable pin-to-pad solder junction while also making inspection easier during manufacturing. The TMP709-Q1 automotive temperature switch is offered in an SOT-23 package, whereas before, it was offered only mostly in leadless or other proprietary packages without leads. In addition, the leadless packages that were offered consisted of larger, higher-pin-count packages.

A voltage reference is another type of common IC used in signal chain applications that provides a highly accurate and stable reference voltage, enabling engineers to optimize signal chain performance. Since the voltage references often only need three to five pins (input, output, ground and an occasional noise trimming or enable pin), many of these devices are offered in industry standard SOT-23-3 and TO-92 packages, which makes them very easy to use. For really small designs, some of TI's series voltage references products, such as REF2025, REF3325 or REF3425, commonly found with data converters, are offered in even smaller SC70-3, SOT-23 or QFN packages. Similarly, shunt voltage references, such as LM4040 or LM4050-N-Q1, commonly found with comparators, come in small SC70-3 and SC70-5 packages, with the ATL431 being the industry's smallest shunt voltage reference, allowing engineers to optimize signal chain performance without compromising solution size.

Finding the right balance

Many PCB designers wince at the thought of transitioning to smaller packages and denser PCBs because the associated layout strategies may drive complexity and cost. Having the option to choose smaller packages doesn't necessarily translate to more difficult or costly designs. However, smaller components with a similar board complexity still mean an overall decrease in PCB cost. Furthermore, if a designer works with a PCB vendor to optimize panel/sheet size, layer count options, pad-pitch capabilities and via/trace size cost points, they may find that incorporating smaller packages translates to easier-to-manufacture boards at a lower price point due to relaxed constraints in some areas of the manufacturing process.

Conclusion

Smaller packages can be space- and cost-effective without sacrificing performance or PCB layout simplicity. They can also help designers meet environmental and application-specific needs. TI provides evaluation tools and online support forums to help customers migrate to smaller package types, enabling designers to reap the benefits of small signal-chain component footprints without sacrificing performance, cost or reliability.

Additional resources

Amplifiers

- Second-sourcing options for small-package amplifiers
- Taking the family-first approach to op amp selection
- Designing tiny microphone circuits with the industry's smallest op amp

Sensing

- Driving industrial innovation with small-size sensors

Isolation/interface

- How to isolate RS-485 for smallest size and highest reliability
- Isolate your CAN systems without compromising on performance or space

Isolation/digital isolators

- Small doesn't mean you compromise performance when implementing signal isolation

Packaging

- Designing and manufacturing with TI's X2SON packages

Other

- 5 ways TI's tiny devices deliver huge innovations to engineers

IMPORTANT NOTICE AND DISCLAIMER

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265