Not Just for Logic: Programmable Analog ICs Bring FPGA-like Versatility, Virtues to Mixed-Signal World

By Sean Long, Director, Marketing and Applications, and
Tim Sheehan, Executive Business Manager, Maxim Integrated

Executive Summary

It's always been a challenge for engineers to design, evaluate, and debug a mixed-signal circuit with analog input/output (I/O) interfaces. The subtleties and harsh realities of the real world and the analog signal chain often combine to make what may seem like a straightforward design objective into a frustrating, time-consuming project. The final design is a carefully balanced collection of analog and mixed-signal ICs—including op amps, A/D and D/A converters, comparators, high-voltage drivers, analog switches—which are hardwired to build the mostly analog channel.

The project is even more difficult for the engineer whose background is primarily digital, and so is unfamiliar with analog design where issues of component selection, physical layout, and cost affect the basic circuit schematic and time to market. For these engineers, especially those used to working with programmable logic and FPGAs, the hardwired nature of the analog circuit is at odds with the mindset that they are used to employing in a new design.

As if this isn't enough, today's designers and teams face another challenge: the need to often develop similar, but somewhat different variations of the basic circuit to support multiple versions of the end product. For example, a core motor controller may need to have I/Os tailored to a family of motors, each with a slightly different range, drive requirements, and performance specifications.

To do this, the project team has two options, neither of which is attractive. They can build a single, all-encompassing circuit with all versions built in and just "turn on" the needed configuration, **Figure 1a**. This approach results in needing more of everything: design time, debug effort, components, power, and cost. As an alternative, they can develop individual tailored designs and PC boards (PCBs), one for each required end-product "version." But now they have to deal with separate debug and test procedures, multiple manufacturing issues, and different BOMs, **Figure 1b**. Either way, it's a long climb, made even longer when someone in marketing says, "Hey, maybe just add a few more digital outputs and another analog input. That can't be such a big deal, right?"

The obvious, and perhaps attractive, solution to this design dilemma is to use a microcontroller with embedded analog I/O and do as much in software as possible. However. this approach often does not work well. There are too many design shortcomings and compromises, resulting in performance shortcomings on the hardware side, and too much burden and uncertainty (e.g., indeterminate performance) on the software side.

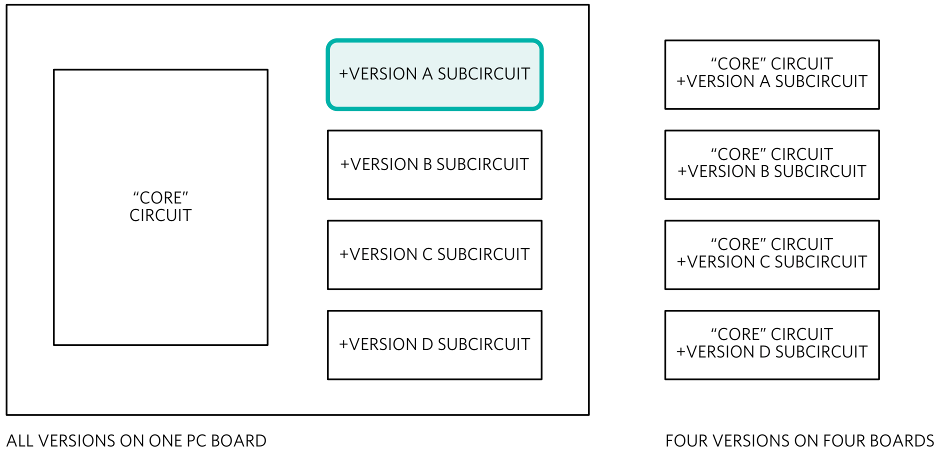

Figure 1. An all-encompassing circuit (1a, left) integrates all anticipated version needs into a single circuit; a tailored design (1b, right) breaks out functions designed for each required end application.

Programmable analog allows designers to set up an analog configuration and topology within the IC to meet a specific application need.

Programmable analog as an alternative

There is an another way of approaching analog/mixed-signal circuits which, in principle, overcomes these issues of design, debug, multiple versions, lack of flexibility, inadequate I/O, and software indeterminism.

Of course, the phrase "programmable analog" can mean different things, just as the words "programmable" or even "buffer" or "driver" do. It can mean a one-time, up-front wiring of internal interconnections which cannot be changed once set (done with fusible links).

Or it can mean a fixed, internal wiring configuration, but with functional parameters such as bandwidth or gain established digitally with setup software. However, programmable ICs with these characteristics still lack the features, flexibility, and predictable performance that designers have come to except on the digital side through the widespread use of PLDs and FPGAs.

Fortunately, there now is a better approach—a programmable, high-voltage, mixed-signal IC optimized for I/O needs, **Figure 2**. This IC integrates a 12-bit, multichannel, analog-to-digital converter (ADC) and 12-bit, multichannel, buffered digital-to-analog converter (DAC). Connected to these converters are 20 mixed-signal, high-voltage, bipolar ports, each of which is configurable (or "programmable") as an ADC analog input, DAC analog output, general-purpose input port (GPI), general-purpose output port (GPO), or analog switch terminal. In addition, it has one internal and two external temperature sensors to track junction and environmental temperatures, respectively. This MAX11300 PIXI™ device is well suited for applications that demand a mixture of analog and digital functions, as each port is individually configurable for one of four selectable voltage ranges from -10 V to +10 V.

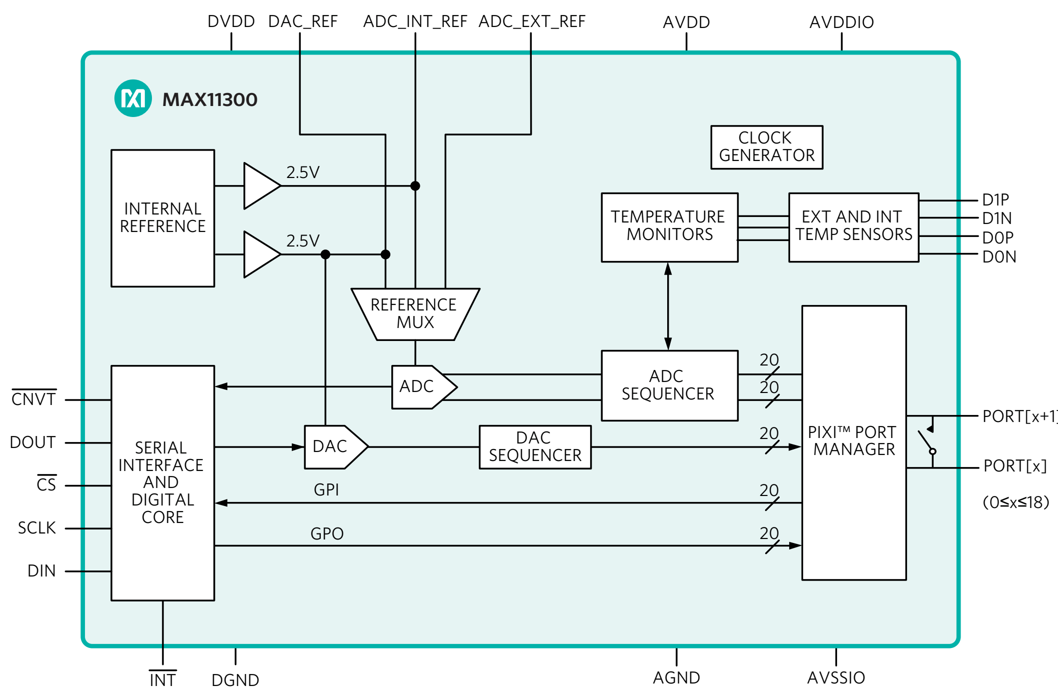

Figure 2. The PIXI programmable, mixed-signal IO allows 20 used-defined, programmable ADC, DAC, or GPIO functionality.

In operation, the MAX11300 is configured by its host microcontroller on power-up, and then runs independently. Not only does this offload the processor and its software, but it guarantees deterministic I/O performance which is not at the "mercy" of other processor priorities or interrupts.

Application example shows the power of programmable analog

The MAX11300 is a good fit for mixed-signal applications requiring moderate resolution and speed such as RF power-device bias controllers in base stations, controllers for optical components, power-supply monitoring and sequencing, and industrial control and automation. Temperature control of a PWM fan-motor controller is a good example, **Figure 3**, of this device's flexibility and versatility. The core of the control function is the closed-loop path formed by the temperature sensor and motor-control DAC, with high-level supervision by the microcontroller. If an advanced fan-motor controller version needs monitoring of additional analog points such as coolant flow, or other control points such as actuators and valves, the same MAX11300 can be configured for those extra channels. Or perhaps some larger motor is supplying more air ducts, and so needs to monitor two temperature points instead of just one. Again, the same MAX11300 can be configured to handle that variation as well.

The benefits of a programmable analog IC go beyond flexibility and configurability. The hardware-based implementation means that once established, the analog functions are fixed, deterministic in execution, and

The combination of configurability and autonomy make it a much better solution than microcontroller-based analog I/O devices.

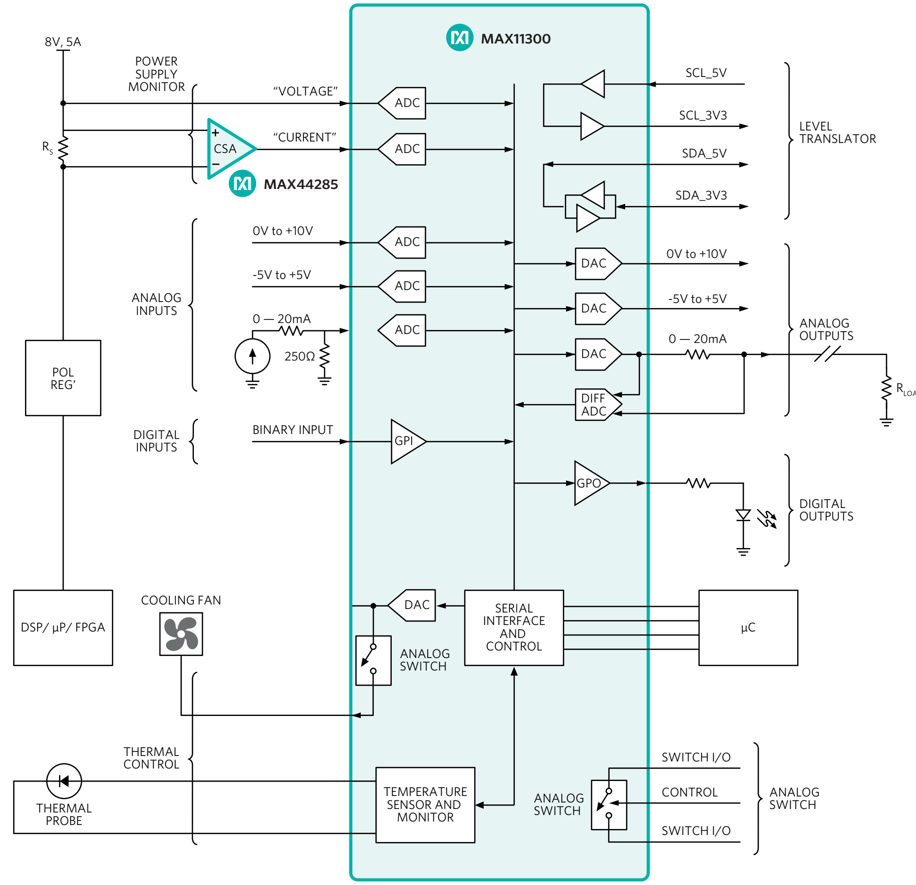

Figure 3. Control and monitoring with the MAX11300.

Why not a microcontroller for mixed-signal I/O?

At first glance, one viable alternative to the MAX11300 and PIXI technology is a microcontroller with on-chip analog I/O. But there are significant limitations to the microcontroller solution. Consider these attributes of the MAX11300 as compared to a microcontroller approach:

- Flexibility of resources: any of its 20 ports can be programmed as a resource whenever needed; port function is not fixed as they are in a microcontroller.
- High-voltage, true-bipolar capability: each I/O port is selectable for 0 to 2.5V, ±5V, 0 to +10V, and -10V to 0V ranges; microcontrollers do not offer this.
- Deterministic performance: once initialized, the performance will not vary or be dependent on a specific configuration or the microcontroller's operating code, regardless of how MAX11300 is configured internally.
- Ease of use: programming/coding skills are not required with the drag-and-drop configuration software available for the MAX11300.
- Slave device operation: as a complementary device for digital-logic products, it boosts system performance rather than impeding it.
- High-power I/Os: each pin can sink/source up to ±25mA current, often needed for direct connection to many real-world interfaces such as MOSFET drivers, electromechanical relays, and even LEDs. Each pin is also current limited at ±50mA for safety.

function in parallel with the system microcontroller. Therefore, that processor can be modest in its own features (e.g., speed, memory, I/O, power, and cost) since it doesn't need to try to become a software-based analog front end (AFE) itself. The overall result is minimal compromise, and faster time to market.

Today's projects are also about development risk. Development flexibility means that changes to design requirements can be met more easily, without board respins or layout surprises. And as any analog circuit designer knows, there is no such thing as, "it should be no big deal to just add another analog input over there." Using this programmable IO device, design and development risks are reduced, so designers can be more confident about schedule and performance. A single IC and, thus, Bill of Materials (BOM) entry will support multiple end-product variations such as small, medium, or large, or basic, advanced, and full-featured. The PCB layout remains unchanged even as the analog-channel configuration changes. Meanwhile, the microcontroller's software can be reused to a greater extent.

Further, design risk is reduced with the MAX11300 because there is no need for analog-circuit expertise or component-selection headaches. The circuit is within the IC itself, and the designer's task is to configure the IC, which is fairly straightforward. Of course, no single IC can meet all needs.

Tools and support smooth the process

The virtues of a flexible and versatile mixed-signal component are lost if it cannot be configured easily. Fortunately, configuring the MAX11300 is comfortable even for digital designers who are familiar with FPGAs and programmable logic, but not analog circuits. There is no need to read through a 60-page data sheet to get started with the PIXI technology of the MAX11300. Just boot up the graphical user interface (GUI) and you'll be in an easy-to-use, familiar, drag-and-drop environment which makes programming the device easy and intuitive, **Figure 4.**

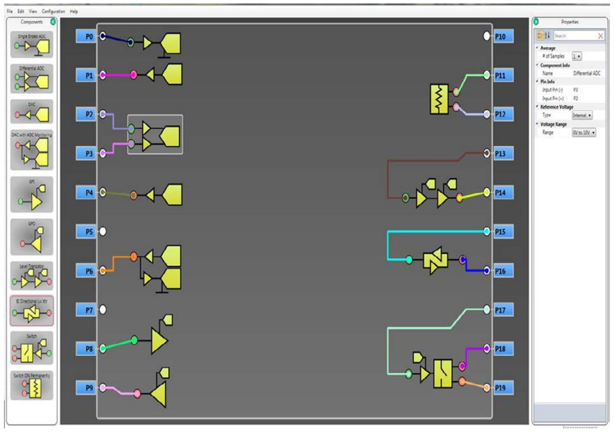

Figure 4. The GUI for PIXI is a familiar, drag-and-drop environment to make programming the device easy and intuitive.

To further speed the uptake, there are multiple hardware and support options for the device. These include the MAX11300 evaluation (EV) kit which provides a proven platform to evaluate the MAX11300 and includes Windows XP®-, Windows Vista®-, Windows® 7-, and Windows 8.0-/8.1-compatible GUI for exercising the features of the IC, **Figure 5.**

For simple prototyping of PIXI designs, the MAX11300PMB1 peripheral module makes it easy to interface the MAX11300 to any system that uses Pmod™-compatible expansion ports configurable for SPI communication, **Figure 6.**

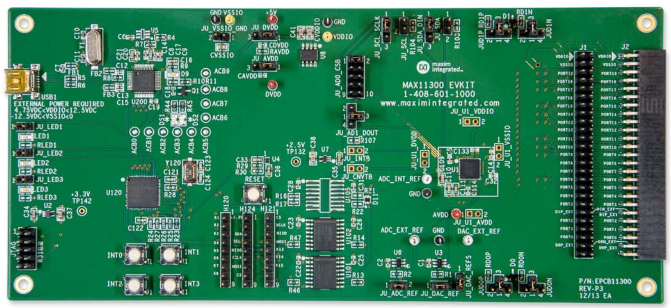

Figure 5. The MAX11300 EV kit board.

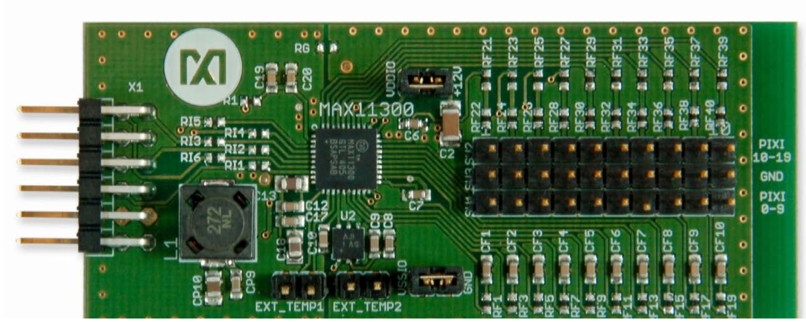

Figure 6. The MAX11300PMB.

Programmable analog need not be a contradiction

Traditionally, "analog" and "programmable" were two realities that existed very far from each other. That's no longer the case, as they can now support each other instead. An innovative, programmable, analog IC like the MAX11300 provides flexibility in critical I/O and interface functions, while offering consistent, predictable, independent performance in parallel with a host microcontroller.

The MAX11300 resolves the two problems of the analog-integration conundrum, **Figure 7**. Usually, increased component integration is contrary to design flexibility, while software-based functionally makes it difficult to ensure robust, deterministic, mixed-signal hardware performance. The MAX11300 is the complement to: digital logic, which takes an array of gates and allows the user to configure them to meet specific functional needs; and software-based processors, which provide programmability and reprogrammability through execution of code.

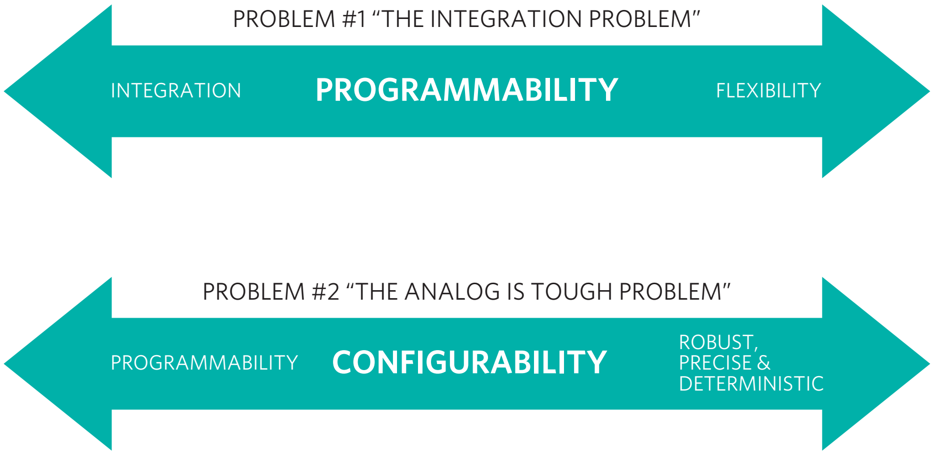

Figure 7. The MAX11300 solves the traditional problems of "analog" and "programmable."

Limitations of PIXI technology

All components have limitations as a result of unavoidable design trade-offs that must be made by its developers. Without meaningful limits, a device becomes unwieldy, power hungry, or costly (or all of those). That's why the MAX11300 PIXI technology was carefully tailored to fit a large group of applications, but not all.

For example, the A/D and D/A conversion has 12-bit resolution (1 part in 4096). This is more than adequate for many real-world measurement and control needs, but not suitable for high-end precision instrumentation. Similarly, the 400ksps conversion rate meets the needs of a large segment of data acquisition/control situations, but will not be a match for digitization of very-high-speed signals.

Also, the MAX11300 is not an autonomous component which is "live" when powered up. It needs a host microcontroller to load in the configuration specifics—although once loaded, it does function independently. This is really not a shortcoming, as it is fairly common in many systems to have many tasks on power-up: perform a self-test, check of I/O, implement calibration, and begin system initialization routines.

Finally, the analog signal range is limited to ±10V (maximum). Again, this encompasses a large majority of signals in the real world. For input signals beyond this range, designers can add a simple resistive-divider or buffer. For outputs, a basic voltage/power-gain stage/driver solves the problem; both are standard circuit add-ons.

By setting some well-defined limits on capabilities, the MAX11300 PIXI technology provides a price/performance/size balance. This results in a very attractive solution for digital (and other) designers who need a mixed-signal solution which offers the flexibility, configurability, and ease of use that they need and expect.

Learn more

For the MAX11300 data sheet, demo video, and free samples, visit:
maximintegrated.com/MAX11300

About the Authors

Sean Long is Director, Marketing & Applications for the Industrial and Medical Measurement business unit at Maxim Integrated. Sean joined Maxim May 2012. He has a BSc Electrical and Electronic Engineering from Aston University, Birmingham UK.

Tim Sheehan is Executive Business Manager for PIXI technology at Maxim Integrated. Tim joined Maxim in 1994. He has an MBA from Paul Merage School of Business, UC Irvine, California.