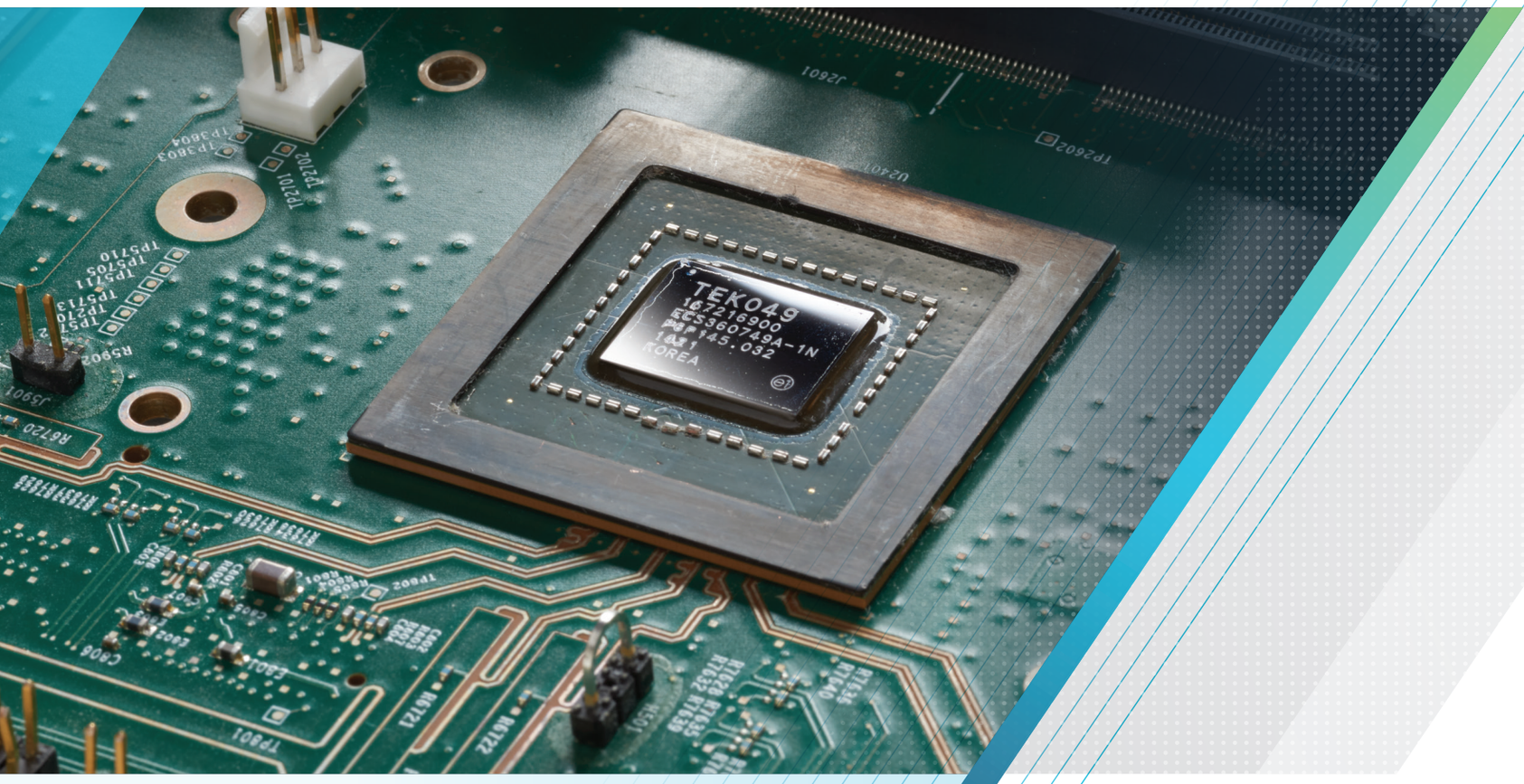
TEK049 ASIC POWERS NEXT-GENERATION OSCILLOSCOPES

WHITE PAPER



Tektronix®

Introduction

As electrical, optical, and wireless system technology grows ever more advanced, engineers require increasingly powerful tools to aid them in system design and debugging. To set the foundation for the next generation of oscilloscopes capable enough for the modern world, Tektronix has developed a completely new oscilloscope chip, the Tek049.

The Tek049 is a newly developed ASIC (Application-Specific Integrated Circuit) from Tektronix. It's a highly-integrated System-on-Chip (SOC) mixed-signal ASIC containing 400 million transistors and 2 billion connections which form 4 internal ADCs (Analog to Digital Converters) and integrated DSP (Digital Signal Processing). Fabricated on a 40 nm RF CMOS process and packaged in a 1927-pin fine-pitch ball grid array, the Tek049 is a one-of-a-kind oscilloscope on a chip.

The Tek049 has made its debut as the powerhouse behind Tek's new 5 Series MSO (Mixed Signal Oscilloscope). Thanks in part to the Tek049, the Tektronix 5 Series MSO is capable of supporting a 15.6-inch HD touchscreen display, up to 8 FlexChannel® inputs, 16 bits of vertical resolution, and much more.

This new ASIC will be the heart of Tektronix oscilloscopes going forward, powering a new generation of oscilloscopes designed for the modern engineer. This paper will examine some of the technology and innovations in the Tek049.

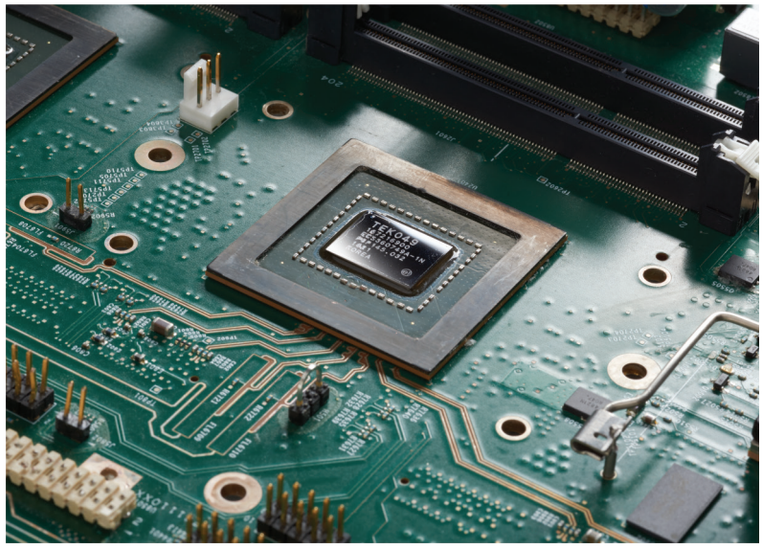


Figure 1 – The new Tek049 ASIC.

Design Goals

To realize the performance necessary for their vision of modern oscilloscopes, the Tektronix team couldn't rely on off-the-shelf ASICs. By designing custom ICs, Tek can achieve a more holistic oscilloscope design with the levels of performance and integration needed by modern engineers.

In designing the Tek049, the Tektronix team had a number of overarching goals:

- **Integration**

  To consolidate into one package a number of disparate parts, to allow for both unprecedented integration of DSP functionality as well as a smaller form factor

- **Flexibility**

  To create a design that would be flexible enough to be the heart of all future Tektronix oscilloscopes, as well as one that could provide enhanced user flexibility

- **Performance**

  To achieve the best possible oscilloscope performance in its class in oarder to equip engineers with oscilloscopes that can keep pace with future technological advances

The Technology Behind Tek049

The Tek049 team spent years designing and developing the Tek049, and were able to consolidate a wide range of previously separate chips into a single, highly-integrated package. The chip includes 4 advanced ADCs, a high-speed memory interface, high-speed communication bus, trigger circuitry, logic analysis, display formatting, rasterization, and other DSP components.

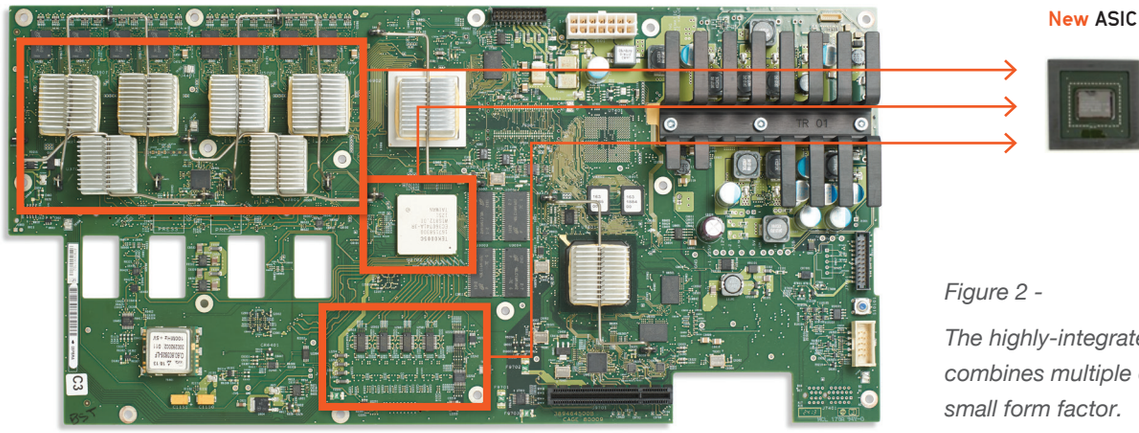


Figure 2 -

The highly-integrated Tek049 combines multiple chips into a small form factor.

The new 12-bit ADC is the fastest in the world, running internally at 25 GS/s to give it a 25% higher sample rate per channel than previous oscilloscopes in its class. The 12 bits allow for 4096 vertical digitizing levels, providing 16x more resolution than other oscilloscopes utilizing 8-bit ADCs. Each ADC channel is based on an interleaved Successive Approximation Register (SAR) architecture, and each Tek049 chip includes four ADCs for a total throughput of 100 GS/s.

Typical oscilloscope signal paths are quite complicated, as signals must pass through a variety of components including amplifiers, relays, filters, ADCs, and more before being processed for display. For MSOs, logic analysis for digital signals is typically done in the same chip used for analog trigger functionality.

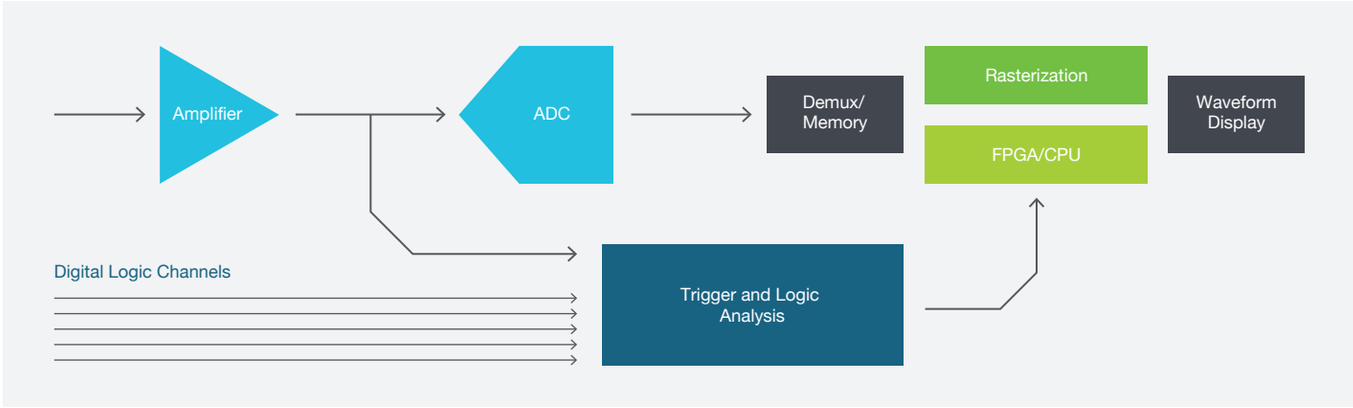


Figure 3 - Traditional oscilloscope acquisition path.

The Tek049 team rethought this signal path to more tightly integrate analog and digital channels, allowing for both real-time signal processing as well as the ability to implement an industry-first: FlexChannel inputs. These inputs, currently available only on the 5 Series MSO, can operate either as a single analog channel or eight digital channels. Whether the FlexChannel operates as an analog or digital input is determined simply by the choice of probe plugged into that channel.

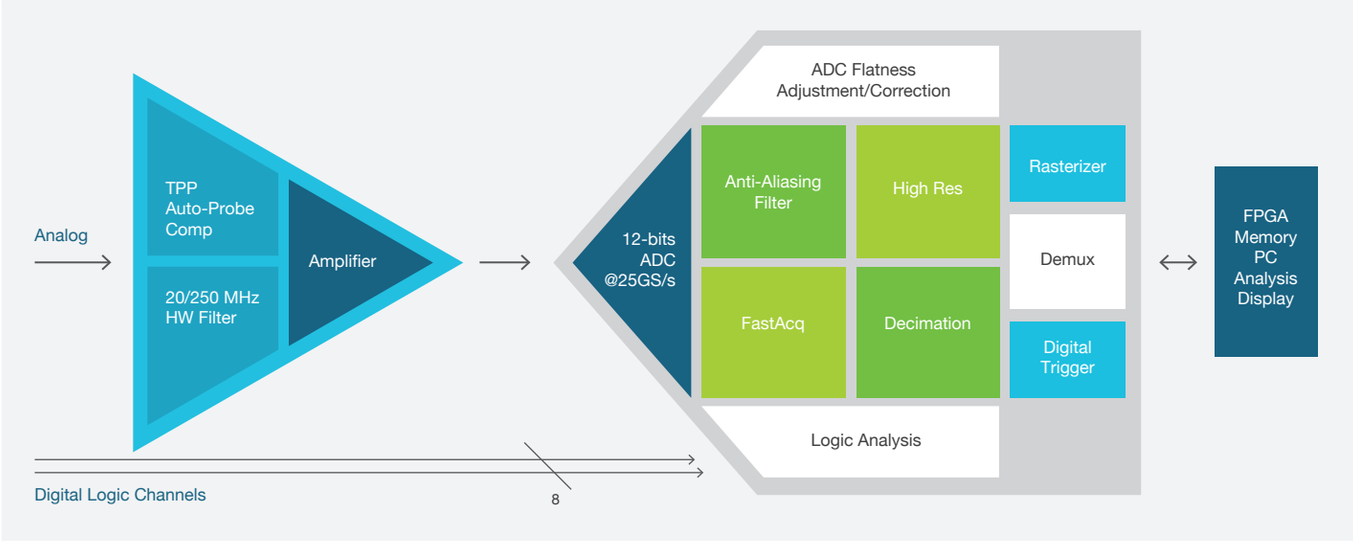


Figure 4: The 5 Series MSO acquisition path for one channel.

Lastly, the Tek049 was designed with a scalable architecture to support a wide range of system configurations and oscilloscope platforms, starting with the new 5 Series MSO. Its architecture is flexible enough that the Tek049 will be the heart of Tektronix's oscilloscope portfolio going forward. Some instruments may use subsets of the chip, while others will use the full functionality available. The 5 Series MSO is nearer to the latter case, utilizing over 80% of the Tek049's functionality.

The Development Story

It took a lot of dedicated people and a lot of hard work to make the Tek049 a reality. The multi-year design and development process was a massive effort involving partners around the globe and around-the-clock engineering. “We were going 24 hours a day, sometimes 7 days a week, and everyone had to contribute at all levels to make this happen,” explains Bart Mooyman-Beck, the director of technology at Tektronix.

The team that Tektronix put together to develop the Tek049 was world-class, according to Mooyman-Beck. “When we sent out to the world that we were developing this, people came from all over the world to say that we want to be part of this solution,” he explains. “There’s a motto that says best team wins. Well, we were able to build that best team, and with that group of people we were able to deliver the highest fidelity chip that exists on this planet.”

And even though developing the Tek049 was a monumental effort, according to Bart, the experience was one-of-a-kind. “In my career, I’ve been able to work with developing and delivering many different types of chips. The Tek049 was special… it’s an experience that I’ll probably never get to do again, because of all of the wonderful people that we pulled together.”

5 Series MSO: The First Application of the Tek049

While the Tek049 will drive Tektronix's entire oscilloscope portfolio going forward, this section will highlight what the Tek049 brings to Tek's 5 Series MSO, the first oscilloscope to use the new ASIC. The 5 Series MSO utilizes over 80% of the Tek049, taking full advantage of the new chip in its goal to be the best oscilloscope available for today's engineers.

Here are some of the new features and capabilities that engineers will find with Tek049 and the 5 Series MSO:

HIGH RESOLUTION DISPLAY AND CONVERSION

With smartphones and tablets now ubiquitous, touchscreens are becoming an increasingly popular way of interacting with electronic devices. Oscilloscopes have been largely left in the dust of this new trend, but the 5 Series MSO aims to shift the outdated oscilloscope UI paradigm. The 5 Series MSO offers the first oscilloscope interface built from the ground up with touch in mind, modelled after phone and tablet screens so that touch gestures will be extremely familiar. Users can swipe, drag, pinch-to-zoom, and find key functions easily without digging through layers of menus.

Perhaps more impressive is the screen itself, a 15.6" HD (1920 x 1080) capacitive multi-touch display. This generous screen gives users enough room to see several signals at once, with space left over for readouts and details. The Tek049 also enables a new stacked display mode that automatically adds or removes signal as slices. With previous generation oscilloscopes, users must sacrifice display resolution to see waveforms separated from one another. Users would need decrease the vertical scale of each signal and then offset them from one another. Decreasing the vertical scale decreases the vertical resolution by the same amount. Scaling then offsetting 4 signals in a traditional oscilloscope results in each signal using less than 25% of the resolution of the ADC. With the new 5 Series MSO, the waveforms can be displayed as slices. Each slice is offset from the others but still utilizes the full range of the ADC resulting in the highest resolution possible.

Stacked vs Overlay Display Mode

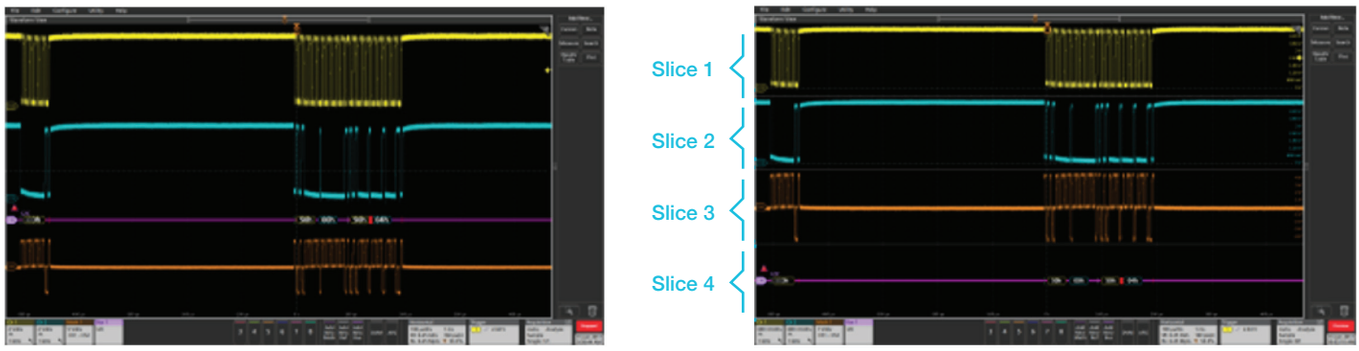


Figure 5: Each slice of the stacked display mode (right) can utilize the full range of the Tek049's ADCs, whereas each waveform in the overlay mode (left) uses only a fraction of ADC range.

Not only is the 5 Series display high resolution, so too are its waveforms. The Tek049's 12-bit ADCs give the oscilloscope 4096 vertical digitizing levels of resolution, so users will see 16 times more detail than was possible with previous 8-bit ADCs.

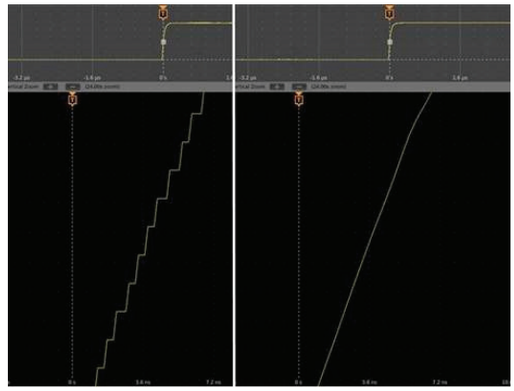


Figure 6: Zoomed in on a fast step, an 8-bit acquisition shows ADC quantization. At the same zoom factor, a 12-bit acquisition is smooth.

FLEXCHANNEL INPUTS

To align with their goal of better oscilloscope flexibility, the Tek049 team developed an industry first, the FlexChannel input. Rather than having to choose from a limited number of analog/digital channel combinations, engineers using the 5 Series MSO have access to 4, 6, or 8 FlexChannel inputs, each of which can be a single analog channel or eight digital channels. With FlexChannel inputs, users always have access to whatever combination of channels they need, with dual-purpose ports that accept all existing TekVPI probes. Whether a FlexChannel operates as an analog or digital input is automatically determined simply by what kind of probe is connected. The user is free to mix and match analog and digital probes across all channels.

In addition to this operational flexibility, there are several other benefits of FlexChannels over the separate digital inputs of a typical MSO architecture. The digital channels are now on the analog inputs, therefore the digital channels get the benefit of the full sample rate and record length of the analog channels. In traditional oscilloscope architectures the digital sample rate and record length are only a fraction of what the analog channel uses. Further, by using the same inputs, the digital signals can achieve much finer timing resolution with respect to the analog signals which results in more accurate measurements and analysis.

Finally, FlexChannels provide the user much more flexible cost-of-ownership. With traditional MSOs, users must make the decision at the time of initial oscilloscope purchase whether or not they need, or can justify, the cost of digital inputs.

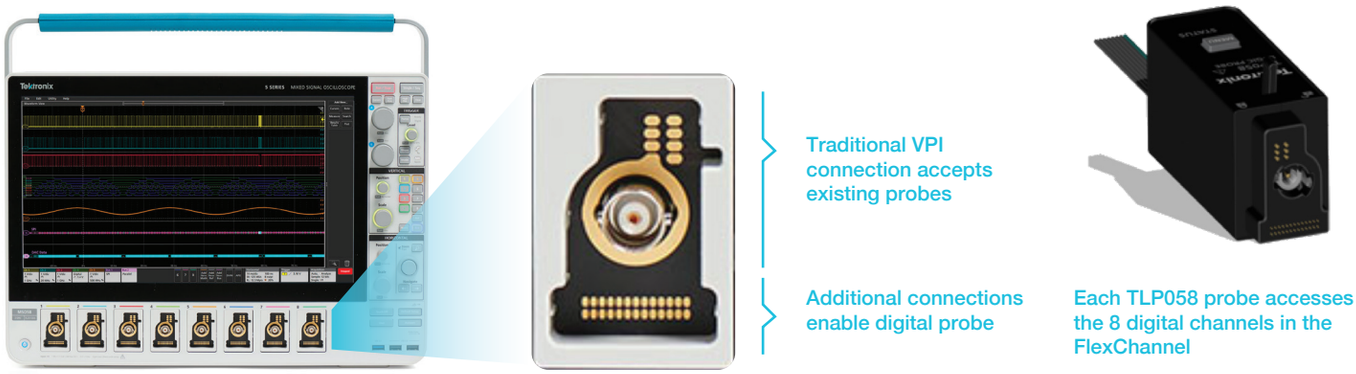


Figure 7: FlexChannel inputs can be a single analog channel or eight digital channels as needed.

As needs change, the number of digital channels on a traditional MSO is not able change with them and are typically locked at 16 channels. Because FlexChannel inputs are both analog and digital, the choice to add more digital channels, or any at all, is made simply by the purchase of one or more TLP058 Logic Probes each of which can measure 8 digital inputs. The user is able to purchase the 5 Series MSO with no digital probes then add up to 8 digital probes as their needs grow for a total of 64 digital inputs on a single oscilloscope.

REAL-TIME DIGITAL SIGNAL PROCESSING

The highly-integrated Tek049 ASIC contains powerful DSP functionality that, combined with the 5 Series' updated front-end amplifier with up to 40% lower noise at high gain settings, provides the lowest noise and highest signal fidelity in its class. Furthermore, the Tek049 architecture efficiently makes use of external DRAM memory bandwidth to enable real-time data processing before being stored in memory, so signal imperfections can be removed immediately with high fidelity. Here are some more powerful DSP features enabled by the Tek049:

- High-resolution acquisition mode that supports a 16-bit acquisition format with real-time DSP filtering
- Programmable real-time bandwidth limit filtering on each channel for frequencies down to 20 Hz, with no impact on acquisition capture throughput
- Advanced trigger capabilities with integrated digital trigger support
- High speed waveform display and analysis with hardware acceleration of fine equalization filtering, interpolation, math between channels, and waveform averaging modes
- Hardware acceleration for waveform search and decode of acquired data
- Gain and offset error compensation
- Non-linear distortion correction
- Time-interleave mismatch correction
- Support for fine resolution phase control of each channel
- Precise channel-to-channel alignment
- Breakthrough noise, jitter, and distortion performance

Future Applications of the ASIC

The scalable architecture of the Tek049 means it can support a variety oscilloscope platforms, and in addition to the 5 Series MSO, the Tek049 will be introduced into new additions to the Tektronix oscilloscope portfolio going forward. Communication between Tek049 chips is made possible by the Tek049's high-speed digital interfaces and a high-speed inter-component communications bus. Together, these allow for real-time coordination of acquisitions and triggering, enabling multi-channel triggering and math functions.

Because of this built-in flexibility, the Tek049 will allow Tektronix to design new oscilloscopes in the future that combine the ASIC in new ways. This capability means the Tek049 can continue to power Tek oscilloscopes even as external technology and requirements advance, while still offering the power and flexibility to continually refine and innovate the modern oscilloscope experience.

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