

A Family of Instruments for Testing Mixed-Signal Circuits and Systems

This entirely new product category combines elements of oscilloscopes and logic analyzers, but unlike previous combination products, these are “oscilloscope first” and logic analysis is the add-on.

by Robert A. Witte

Electronic circuits have been a part of modern life for so long that most people take them for granted. Some devices are inherently electronic in nature such as telephones, radio receivers, calculators, and personal computers. Other devices started out as mostly mechanical and have gradually had more electronics incorporated into them over time. Electronics has made its way into automobiles, cameras, water heaters, home appliances, elevators, thermometers and weighing scales. This “electronics everywhere” trend has gradually filled modern life so that it is difficult to imagine what life would be like without all those electrons running around doing their jobs.

Most early electronic systems were analog, especially if they interfaced to real-world physical phenomena. The emergence of digital technology resulted in the gradual diffusion of digital gates into applications that were once exclusively analog. Thus, an “analog moving to digital” trend emerged as the number of digital gates per acre of silicon continued to grow at a fast rate. Analog circuits will never be totally replaced, since for the most part the real world stubbornly retains its analog behavior and circuits that interface to this world must retain at least some analog circuitry. The result is that many electronic systems are mixtures of analog and digital circuitry that have come to be known as “mixed analog and digital” or simply “mixed-signal.”

The single-chip microcontroller has emerged as an important component in these mixed-signal designs. Of course, microcontrollers have been around for decades, doing the lowly control tasks in cost-sensitive applications while their more powerful siblings (“real” microprocessors such as an Intel80486 or a Pentium®) got all of the attention, usually because of their critical role in personal computers. Meanwhile, the single-chip microcontroller improved in performance, moving from 4 bits to 8 bits and 16 bits while also improving in cost-effectiveness. Without much fanfare, these single-chip devices found their way into a wide range of designs, causing one author to refer to them as “The Ultimate ASIC.”¹ These devices are often used to control or measure a physical system (e.g., antilock braking, camera control, appliance controls, industrial control systems). A generic block diagram for such a system is shown in Fig. 1, and an example of a mixed-signal single-chip microcontroller is presented *Subarticle 1a*.

This increased use of mixed-signal electronics is showing up in a wide variety of industries and applications. Consumer electronics is an obvious area, with mixed-signal designs being used in CD players, stereo receivers, tape decks, and camera electronics. Similarly, communications devices such as modems, telephone answering machines, and multimedia boards for PCs all use mixed-signal electronics. There are many applications in industrial electronics, including process control, industrial water heater controls and other sensor-based systems. The growing area of mechatronics (the merger of mechanical and electronic technology) is primarily mixed-signal in nature. A large and growing mixed-signal area is automotive electronics, including subsystems such as the previously mentioned antilock braking systems and ignition control. Biomedical applications are another emerging area, with mixed-signal electronics being applied in pacemakers, hearing aids, and other medical devices.

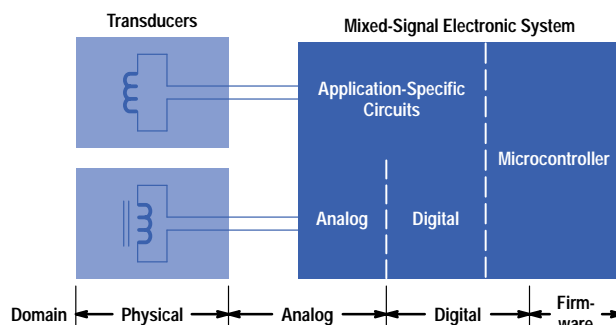


Fig. 1. Block diagram of a generic mixed-signal system.

Systems can be totally digital if only on-off control is required. More likely, there is some physical quantity being measured or controlled that requires a portion of the electronic system to be analog. The increased use of sensors allows engineers to create smarter control systems that monitor physical events and do a better job of controlling the system. A good example of this is antilock braking systems in automobiles. In this case, electronics (including sensor technology) is being used to make the braking effectiveness of the automobile far better than would be possible in a purely mechanical system.

Oscilloscopes

For designers of mixed-signal systems, the troubleshooting tool of choice is the oscilloscope. The versatility of the oscilloscope for viewing a wide variety of waveforms allows the design engineer to see what's happening in the device under test. Other test instruments may also be used but the oscilloscope remains the first tool that most users turn to for debugging circuits.

Mixed-signal engineers expect many things from their oscilloscopes. The oscilloscope must have sufficient fundamental performance in terms of bandwidth and sample rate to capture and display signals accurately and reliably. At the same time, the oscilloscope must be easy to use so that the engineer can focus on the operation of the circuit and not on the operation of the oscilloscope. In the heat of the troubleshooting battle, it is very distracting for the user to have to interrupt the debug process to deal with an uncooperative test instrument.

With the increasing digital content in these mixed-signal systems, a two-channel or even a four-channel oscilloscope quickly runs out of inputs. It is just not possible to view the complete operation of even a simple digital circuit with a conventional oscilloscope. Take the trivial example of a 4-bit up/down counter. With four output lines, a clock input, a load input, and an up/down count control, the counter will have at least seven digital signals associated with it (and perhaps more). Since an engineer cannot view all of these signals at once with an oscilloscope, the usual remedy is to apply "mental storage." The engineer applies the oscilloscope probe to a particular signal, views it, and stores the image into mental memory, then moves to other signals of interest and repeats the process. Eventually, a picture of the entire circuit's operation is formed in the mind of the debug artist. Sometimes this picture is precise and meaningful but sometimes it is cloudy and full of uncertainty.

Logic Analyzers

The idea behind a logic analyzer is that many digital signals can be viewed simultaneously so that an engineer can obtain a complete and accurate picture of what is really going on in a circuit. One of the trade-offs made in a logic analyzer is that only digital signals can be viewed and only an idealized reconstruction of the waveform is possible. That is, the waveform is treated as a purely binary signal and is displayed as either a logic high or a logic low, with no detail of the actual waveform shape. This is a reasonable compromise since the major problem in a digital system is determining whether the circuit operation is correct. It is a functional check that does not require the waveform detail. In fact, it can be argued that complete waveform detail is mostly visual noise when checking the functionality of a digital circuit.

As logic analyzers evolved, they tended to be optimized for solving the really tough problems that come with complex, bus-based microprocessor systems. Most modern logic analyzers have a minimum of 32 channels and may have 128 channels or more. They also provide extensive trigger and selective storage features that make them unmatched in debugging and troubleshooting power. This power inherently leads to a certain level of complexity in the analyzer; complexity that can be a barrier to the oscilloscope-oriented engineer. Many designers of mixed-signal systems, even when limited by the number of channels on their oscilloscopes, remain reluctant to adopt logic analyzers.

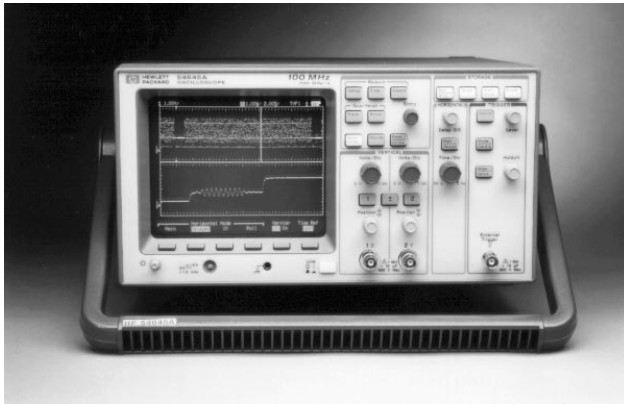
Mixed-Signal Oscilloscopes

Further investigation into this avoidance of logic analyzers revealed the opportunity for a new kind of test instrument that would expand the channel count of the oscilloscope without losing its inherent appeal. A series of market research activities were launched to determine how to fill this gap between oscilloscope and logic analyzer. Clearly, engineers were limited by the number of channels on their oscilloscopes but they were not always adopting a logic analyzer as the solution. What eventually emerged is an entirely new product category that combines elements of oscilloscopes and logic analyzers.

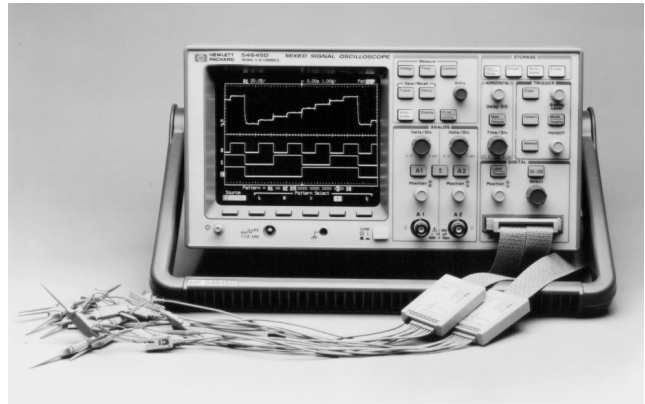
As a world leader in logic analyzer products, HP had already pioneered the creation of hybrid instruments that combine oscilloscope and logic analyzer technology (HP 1660 Series and HP 16500 Series logic analyzers, for example).² However, these products were designed with full-featured logic analysis as their top priority and the oscilloscope capability is an adjunct to the analyzer. The new product line starts with the oscilloscope user in mind. These products are "oscilloscope first" and logic analysis is the add-on.

A family of HP products aimed at mixed-signal testing has been created. The HP 54600 product line now offers the following set of test instruments appropriate for mixed-signal work:

- The HP 54645D mixed-signal oscilloscope (Fig. 2) combines two 100-MHz oscilloscope channels with 16 logic timing channels. This is the ultimate mixed-signal testing tool because it seamlessly integrates oscilloscope channels and logic timing channels. This product includes HP's MegaZoom technology, which delivers the benefits of a million-sample memory for each channel without the agonizingly slow responsiveness normally associated with deep memory.



(a)



(b)

Fig. 2. The HP 54645A two-channel oscilloscope (a) and the HP 54645D mixed-signal oscilloscope (b), both with MegaZoom, are examples of the new product category of mixed-signal oscilloscopes.

- The HP 54645A two-channel oscilloscope with MegaZoom (Fig. 2), a general-purpose oscilloscope, is the first affordable 100-MHz digital oscilloscope with sufficient sample rate and memory depth to capture a wide range of analog and digital signals. The HP 54645A has the same basic MegaZoom technology as the D version but does not have the logic channels.
- The HP 54620A/C 16-channel logic timing analyzer is an easy-to-use logic analyzer designed to be the perfect companion product to an oscilloscope, perhaps the one that the user already owns. This logic analyzer has an oscilloscope user interface metaphor so that it is familiar and easy-to-use for the typical oscilloscope user.
- The HP 54615B and 54616B/C 500-MHz two-channel oscilloscopes are general-purpose oscilloscopes that provide the bandwidth and sample rate (1 GSa/s and 2 GSa/s, respectively) needed for high-speed digital work while maintaining the responsiveness and trustworthiness required for mixed-signal debugging and troubleshooting. The HP 54616C has a flat-panel color display.

While each of these products represents a particular mix of features and performance, they all share the core values of the HP 54600 product line:

- **Direct Access Controls on Main Functions.** The volts/division, time/division, position, and trigger level controls are all dedicated knobs for easy access.
- **Responsive User Interface.** Instant response to front-panel changes is critical to making an oscilloscope easy to use. All of these products provide sufficient processing power to maintain a responsive front panel.
- **Fast Update Rate and Low Dead Time.** These products use multiprocessor architectures to make sure the display is updated quickly.
- **Digital Peak Detection.** These products have true digital peak detection, which is available on all sweep speeds. Digital peak detection keeps the sample rate operating at its maximum specification even on very slow time base settings, guaranteeing that short-duration events (such as glitches) are not missed (see [Article 4](#)). Peak detection also prevents aliasing. On the HP 54620A/C logic analyzers, the equivalent feature is glitch detection.
- **HP Proprietary Alias-Reduction Techniques.** All of the HP 54600 Series oscilloscopes employ HP's proprietary alias-reduction techniques to reduce the possibility of an erroneous displayed waveform (see [Article 5](#)).
- **Compact and Portable.** These products pack a lot of measurement power into a compact size and the small footprint helps save precious bench space.
- **Optional HP-IB, RS-232, and Parallel Interfaces.** These products offer a choice of computer and printer interfaces.
- **Optional Measurement/Storage Module.** This option provides FFT, advanced math, and pass/fail mask testing (oscilloscope products only).

The accompanying articles in this issue describe some of the key design contributions incorporated in these products.

References

1. "Single-Chip Microcontrollers: The Ultimate ASIC," *Electronic Engineering Times*, March 20, 1995.
2. *1996 HP Test and Measurement Catalog*, Hewlett-Packard Company.

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