Designing More Efficient Power Amplifiers for LTE, LTE-Advanced, and Beyond

5 Test and Measurement Items for Your Lab

Optimal+ Delivers Big Data to Semiconductor Analytics

Interview with Dan Glotter, Founder and CEO of Optimal+
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Keysight InfiniVision oscilloscopes

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EEWeb | Modern Test & Measure

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PRODUCT WATCH
Product Insights
Analog Devices’ HMC1081/1105/1144

Inside the Lab
Analog Devices’ Dual Chamber Colorimeter

TECH REPORT
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EEWeb FEATURE
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INDUSTRY INTERVIEW
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For this Arrow Product Insights, we focus on gallium arsenide monolithic microwave ICs, or GaAs MMICs, from Analog Devices. These are MMICs that can be used in applications for V-band frequencies, WiGig, aerospace and defense, and high speed test and measurement.

The HMC1081 is an ideal mixer for military and test and measurement applications, offering a very wide IF of up to 26 GHz. A passive 50 to 75 GHz mixer based on GaAs schottky diode technology, the HMC1081 requires no DC bias, and operates at a nominal LO drive of 12 dBm. The HMC1081 is a double-balanced mixer, eliminating the need to filter the input signals from the output for easier integration into the final product. All bond pads and the die backside use a titanium/gold metallization, with the die measuring 1.23 × 1.21 × 0.1 mm.

When designs require a lower LO frequency, Analog Devices offers the HMC1105 passive frequency multiplier as an ideal companion. The HMC1105 provides frequency doubling of inputs from 20 to 40 GHz in a 1.79 × 1.19 × 0.1 mm die based on the same schottky diode technology as the HMC1081. The HMC1105 provides suppression for both fundamental and higher order harmonics and adds no measurable additive noise to the output. The die accepts an input drive power level of +15 dBm with conversion loss depending on the input frequency, but typical loss is 11 to 12 dB. The combination of HMC1081 mixer and HMC1105 multiplier offers a unique frequency conversion from 50–75 GHz wide frequency range, requires nominal LO drive and provides good performance across the frequency band.

The HMC1144 provides a gain of 19 dB across its entire 40 to 70 GHz frequency range, offering performance unmatched by any other medium power amplifier available today. Inputs and outputs are internally matched to 50 Ω to facilitate integration of the die into multichip modules, with the die measuring 2.3 × 1.8 × 0.102 mm and operating from a 4 V, 320 mA supply. The HMC1144 utilizes two cascaded, four stage amplifiers in quadrature between two 90° hybrids, providing at least 15 dB return loss on inputs and outputs and a saturated power of 22 dBm.

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Inside the LAB

Analog Devices’ Dual-Channel Colorimeter

For this installment of Inside the Lab, EEWeb engineer Josh Bishop examines ADI’s Dual-Channel Colorimeter, the CN0363. A colorimeter is used to measure light absorption by a solution to determine concentration of a solute. The CN0363 is not a typical evaluation board, and is full of components from ADI, but in this video, we’ll focus on the op-amps and ADC that are at the core of this colorimeter.

This colorimeter uses an FPGA to perform digital synchronous demodulation, which provides a number of advantages over the analog equivalent. One is that the analog demodulation hardware is removed, lowering the noise floor. Second, the light source is modulated using a sine wave rather than a square wave, eliminating the harmonic noise of the square wave. This leaves us with phase mismatch and drift as the two big remaining challenges. Phase mismatch can be addressed much easier in the FPGA than in hardware with things like variable caps. Drift, is addressed through calibration, but by using the right hardware you’re able to reduce the calibration effort.

Back to the light sources, the modulated light travels through a beam splitter, sending half of the light through the sample solution and the other through a known reference solution. Photodiodes are used to detect the light level and the output current is converted to a voltage by a transimpedance amplifier.

A transimpedance amplifier is an op-amp configuration that converts current into a voltage and is one part of the design where drift is a concern. ADI used the ADA4528 because it is a zero-drift, rail-to-rail amplifier with a maximum offset voltage of 2.5 µV, no 1/f noise, and very low broadband noise. So, not only does it eliminate drift at this point, but it also keeps the noise floor low for greater sensitivity. The output of the ADA4528 is connected to the input of the ADC, another possible source of drift. For the CN0363, ADI uses the AD7175-2, a 24-bit, 250 kSPS sigma delta ADC with an integrated 2.5 V low drift reference. This is the only source of drift, and it is well specified making it easier to account for in calibration. This combination of software with the right hardware reduces BOM cost, design time, and calibration frequency and complexity.

The sampled data is passed via the SPI interface to the FPGA, where the demodulation is applied to measure the light absorbed by the sample solution compared to the reference and displays the results on the screen.

Analog Devices’ AD7175 ADCs and ADA4528 amplifiers provide the performance and capabilities necessary for demanding applications like this dual-channel colorimeter, and they also lead to a lower cost, simpler design with improved dynamic range and sensitivity. To view the demo, click here. For more information, visit Arrow.com.
Your Circuit Starts Here. Sign up to design, share, and collaborate on your next project—big or small. Click Here to Sign Up
A typical phone must work with different technologies and transmit GSM, EDGE, CDMA, WCDMA, and LTE signals. Each of these technologies has different bandwidth, and power requirements. This means bandpass filters, power amplifiers and switches are needed before the antenna, which significantly increases the complexity of transceiver circuits including component design like power amplifiers (PAs). LTE and LTE-Advanced networks delivers higher peak data rates required from today’s smart phones. However, LTE, LTE-Advanced comes at a cost, significant power drain and heat generation. The need to make RF front ends more power efficient is vital for 4G LTE. Enter envelope tracking (ET).
Simply put, ET increases power amplifier efficiency by modulating the PA supply voltage with the envelope of the baseband input signal. Because the power supply voltage applied to the power amplifier is constantly adjusted, the amplifier operates at peak performance for the given instantaneous input power requirements. Power normally wasted as heat is saved. Using shaping functions, the amplifier can be further optimized and tailor the performance of the PA to meet the specific design requirements.

The concept behind envelope tracking has been around for many years, but has not been easy to achieve in a workable form until recently. This is due to the complexity of implementation. The circuit must be time aligned so that the envelope signal is synchronized with the incoming RF signal. With the additional signal and power supply complexity, many in the industry have even challenged the true efficiency and battery saving value envelope tracking provides.

However, with advanced testing procedures and equipment, implementation of envelope tracking can be simplified and validated.

**LTE Power Requirements**

SC-FDMA modulation used in the LTE uplink has a higher peak-to-average ratio (PAR) when compared to W-CDMA. This means less time is spent in the most efficient portion of the PA power curve. LTE requires specific power control of RF signals to provide high quality of service (QoS) and maximum battery life. The goal is to transmit with just enough RF power to maintain a high quality link without draining the battery. However, since the amplitude of the typical RF signal can vary quite significantly (high crest factor), the challenge is to design the output transmitter stage of the mobile device to work efficiently over a wide range input amplitude levels.

A primary challenge is maximizing efficiency with the large swing in RF power.

**Power Amplification**

The efficiency of amplifiers plays a major role in the design and operation of an overall system. Besides the display and processor, the main contributor to power consumption of a modern smartphone is the TX power amplifier. Power consumption, system functionality and heat generation/dissipation are just a few design elements dependent upon the efficiency of the amplifier, particularly when it is a significant user of power within the system.

PAs are most efficient when operating at peak output power, where the PA enters compression. When the input RF signal is lower in amplitude, the PA is less efficient. When the PA is operating in a linear Class-A mode, the traditional approach supplies the PA with a fixed supply voltage, which, at, or close to, its maximum level. For a typical LTE power amplifier, it is possible to attain up to 50 percent efficiency when the device is operating at peak output power. Unfortunately, much of the efficiency is reduced because LTE uses modulated signals with increasingly higher peak-to-average power ratios (PAPR). Modern modulation techniques drastically degrade PA performance.

Driving the amplifier into compression increases efficiency. At compression, the amplifier’s magnitude response is non-linear. One additional dB at the input does not mean one additional dB at the output. LTE OFDM waveforms are of course QAM modulated. They have both an amplitude and phase component. This requires a linear amplifier. In addition, PAPR values for LTE waveforms can be as high as 11 dB, resulting in a PA that is operating below its optimum output efficiency. An amplifier used in LTE and LTE-Advanced applications must accommodate the peaks, while still running at a low efficiency range.

As the use of RF signals with high crest factors is likely to continue, a different approach is required to improve the efficiency of the PA.
Signal Challenges

Envelope tracking inherently introduces intricacy because RF and ET signals must be time aligned. These new signals alter the behavior of the RF front end. Implementing ET can be an obstacle for PA manufacturers and OEMs.

IQ modulation is an important and efficient way to transfer information in both analog and digital formats. In-phase (I) and quadrature (Q) signals are generated separately and are applied to the modulator to create the singular signal. This is a complex process involving digital to analog converters, signal mixing via oscillators, low-pass filters for distortion, and finally the signal passes to the amplifier for amplification to the required level.

One key element when implementing envelope tracking is generating the envelope signal. Although the envelope tracking power supply (modulator) control signal is generated from the original IQ baseband signals, the creation of the envelope tracking control signal is multifaceted. This envelope is typically generated in the chipset. RF and ET signals must be time aligned.

The ET signal is generated by first obtaining the magnitude of I and Q. This tells us how much RF power is necessary. The larger the magnitude, the more RF Power, and thus more PA voltage is needed. Then shaping is applied to the ET signal. The most basic shaping, detriggering, is used to avoid applying 0V to the PA.

A designer may also choose to alter where an IQ pair lands on a PA efficiency/linearity curve. One may choose to be more linear or more efficient.

The challenge lies in that there is no standard envelope shaping technique. Because the IQ waveform is generated at the chipset using proprietary ET algorithms, software, and shaping tables designed for R&D, each method is different. The shaping function is defined by user defined value pairs in form of a lookup table (LUT). Applying, adjusting and recalculating the tables can be a long tedious process, but must be done to ensure the PA performance is optimized.

Simplifying ET Testing

Simulating, testing and verifying an envelope tracking power amplifier can present a number of challenges. Typical test setups to measure power amplifiers consist minimally of a signal generator and a spectrum analyzer. Envelope tracking requires an additional generator to provide the envelope signal to the DC modulator. This demands precisely adjusted time alignment between the RF signal and the envelope signal, to ensure that modulator and the power amplifier are time aligned. Additionally, this approach limits the ability to make real-time adjustments, as any change to the RF signal requires a new envelope waveform be loaded into the second generator. This can make the whole characterization of the ET-PA significantly more time consuming, as each time the RF signal is changed, a new envelope signal needs to be loaded.

To characterize the performance of the PA, the power added efficiency (PAE) needs to be analyzed, requiring time synchronous measurement of the PA’s input and output power and corresponding power consumption. Precision synchronization is the key, which can represent a significant challenge when several test instruments are used. If synchronization is not achieved, inaccurate tracking of the signal amplitude causes distortion of the RF signal. As you can see in the below figure, PA can be in saturation if the voltage (ET) and RF signals are not time aligned. This clipping leads to poor ACLR measurements.

Since the timing between the envelope signal and the RF signal is crucial for a power amplifier, it is beneficial to deliver both signals simultaneously, preferably with a single instrument. A high-end vector signal generator has recently been developed that can create both RF and envelope signals—effectively replacing complex test setups. Advanced vector signal generators, such as the Rohde & Schwarz R&S® SMW200A feature an envelope tracking option that offers fast and simple power amplifier testing, including generation of the envelope tracking signals from a single signal generator. Providing both signals with one instrument eliminates the concern of signal synchronization. DPD and ET settings are applied in real-time with no changes to the original baseband arb file. Using a signal and spectrum analyzer like the The R&S® FSW provides a single instrument analysis solution, which can simultaneously measure the

![Diagram showing misaligned timing](Figure 3)
RF and baseband signals, thus providing for instantaneous PAE measurements, as well as underlying modulation quality measurements such as EVM and ACLR. AM/AM AM/PM DPD files can also be calculated real-time.

Testing in real-time saves significant time and resources by streamlining ET simulation, testing and verification. It is vital to calculate and modulate waveforms in real-time and in the box — eliminating the need to use external software like Metlab to modify signals before retesting. Real time envelope shaping automatically tunes and shapes the power amplifier signal for the optimum efficiency or linearity.

The envelope signal is generated from the baseband signal in real-time, enabling any user-specific I/Q file or wireless communications standard, such as LTE or WCDMA, to be used. Generating the RF signal and the related envelope signal in a single instrument simplifies the test set up, reduces measurement error and speeds up testing by automatically generating the envelope signal in real-time. The vector signal generator adjusts the delay between the two signals in picosecond increments within a range of ±500 ns in real-time, meeting tight specifications – e.g., less than 1 ns for a 20 MHz LTE signal. The voltage parameters of the envelope signal are completely changeable as well.

Combined with a high bandwidth for the envelope signal and spectral purity with a typical noise of only -155 dBc/Hz, the vector signal generator is well suited for RF and envelope signal generation. Since the RF and baseband envelope waveforms are generated within the same instrument, no extra cabling is needed to synchronize the two waveforms and no added jitter occurs, yielding 100% repeatability.

Shaping of the envelope signal is used to optimize the amplifier for efficiency or linearity. A large selection of flexible shaping functions, including table based approach for proprietary shaping techniques, and more generic capabilities like polynomial based shaping and detroughing. Together these enable users to optimize the shaping of the envelope in real time by automatically generating a new envelope signal each time a parameter is changed.

Matching the characteristics of the envelope signal to the DUT is simplified by enabling key parameters to be entered directly into the signal generator. Automatic envelope voltage adaptation automatically generates an envelope signal to match the limits of these key parameters (VCC voltage range, PA in range, DC modulator gain, DC offset and power offset). This makes it possible to perform power sweeps over the amplifier’s entire input range as the signal generator will automatically calculate the appropriate envelope signal for each individual input power level.

A voltage or current probe can be used to measure the envelope tracking. By adding a small current sense resistor in the circuit between the PA and the DC modulator, current can be calculated. Since the input and output powers of the amplifier are known from the signal generator and the spectrum analyzer, real time PAE can be calculated.

$$\text{PAE} = \frac{\text{RF Output Power} - \text{RF Input Power}}{\text{DC Power}}$$

**Digital Predistortion**

With envelope tracking, the amplifier is operated close to or even in saturation, which leads to distortion at the amplifier output. In some cases, the ET table is designed to keep the PA in compression at all times, for maximum efficiency. Therefore ET is often used together with digital predistortion (DPD) to compensate for this effect. DPD improve the linearity of RF amplifiers, ensuring accurate, linear output signals. An amplifier that compresses the input signal or has a non-linear input/output relationship causes the output signal to interfere with adjacent radio frequencies and channels. The advanced vector signal generator pre-distorts current waveform in real-time with AM/AM and/or AM/PM, across all standards-based or user-defined waveforms. Envelope tracking can be created before or after digital pre-distortion is applied, and the digital pre-distortion can be used as a standalone option in systems that do not utilize envelope tracking.

Multiple ET shaping tables can easily be edited, imported, and switched to apply DPD. By applying real-time amplitude and phase corrections to each complex I/Q sample in line with the received DPD table, testing is further simplified. This also enables quicker verification of the effect of predistortion, even for different power levels, without having to manually recalculate the original waveform file.
Conclusion
Most major smart phones already utilize envelope tracking technology as a method to improve power amplifier efficiency, resulting in longer battery life and improved heat dissipation in mobile devices. Envelope tracking enables the amplifier supply voltage to be controlled in such a way that it tracks the envelope of the RF signal. As a result, the amplifier always operates in a range close to its instantaneous maximum output power, considerably boosting amplifier efficiency.

Advancements to test and measurement instrumentation have simplified envelope tracking and digital pre-distortion simulation, testing and verification. Vector signal generators combined with the signal and spectrum analyzers in a single instrument deliver real-time envelope shaping that automatically tunes and shapes the power amplifier signal for more accurate data in less time, reducing a customer’s time-to-market. Advancements in test and measurement equipment prove that envelope tracking delivers a more reliable amplified signal with up to 20% improvement in power amplifier efficiency, providing longer battery life and higher QoS.

http://niviuk.free.fr/lte_ca_spectrum.php
If you’re an up-and-coming professional electrical engineer looking to outfit your new lab at work or if you identify yourself as an electronics hobbyist who’s excited to fill your basement/garage/shop with the basic electrical engineering test and measurement equipment, then the items called out below should be helpful to you. This list includes some of the most basic tools every electrical engineer should have. Now, if you’re a seasoned or a specialty engineer or even a jack-of-all-trades engineer, then you’ll definitely want (and need) more than what’s listed here—but this list should serve as an excellent starting point.

This list includes some of the most basic tools every electrical engineer should have.
Current Probe

2

Dual Power Supply

3

4

The item that tops the list (because it’s arguably the most valuable test equipment around for electrical engineers) is the tried-and-true DMM, or digital multimeter. Many non-electrical engineers may not know what a “DMM” is, and some may not even know what a multimeter is, but every sparky knows that a DMM is a voltmeter (AC and DC), an ammeter (i.e., current meter), an ohmmeter, a capacitance meter, a frequency meter, a diode tester, and, some higher-end units include many more features. Having so many meters integrated in to a single piece of equipment is what makes this items so valuable. DMMs are available in handheld units, ideal for field/mobile applications, and benchtop units, which typically fancy themselves with extreme accuracy—and a higher price tag. DMM’s are available from many manufactures and cost from 10’s to 1000’s of greenbacks. As a product design and test engineer with 15 years of experience, I would suggest paying a few hundred dollars for high quality DMM from a reputable manufacturer. My personal favorite DMMs are the handheld units made by Fluke. And, you don’t need to buy new as there are many acceptable used units available for discounted prices. Check out www.testequity.com for new, used and rental units.

Almost as important as the DMM, but not nearly as versatile, is the scope or o-scope, and more formally known as the oscilloscope. If you’re designing and/or troubleshooting analog designs you’ll definitely appreciate using a high-quality oscilloscope. Yes, DMMs can measure DC and AC voltage signals just fine but they are excellent at hiding high-frequency noises and spikes (both negative- and positive-going). A good oscilloscope with the proper time-base setting and trigger set point will immediately identify elusive noises and trouble-causing blips. $500 should get you an excellent 2-channel oscilloscope from a respectable OEM such as Tektronix. If you want a 4-channel scope plan on spending $1000. Again, go to www.testequity.com for new, used and rental units. There are other on-line vendors but I’ve been real happy with TestEquity’s products and service.

Number 3 on the list is the current probe. Current probes attach to o-scopes and may or may not require an associated current probe amplifier. DMMs are capable of measuring current, but again they conceal noises and don’t scrutinize high-speed signals too accurately such as inrush currents. In contrast, current probes are designed specifically for measuring high-speed signals on the order of 10’s of microseconds or even faster if you’re willing to pay more. Additionally, current probes perform admirably at displaying waveforms on your o-scope where the waveforms can be analyzed for minimum values, maximum values, average values and many, many other measurements. For cost you should expect to pay between $1000 and $2000 for a quality current probe. Although some brands of current probes will work with different brands of o-scopes, it is recommended that you purchase the same brand of current probe as is your o-scope.

The DC power supply is number 4 on the list. You’ll want a minimum of two power supplies (or at least a dual-channel power supply). In fact, depending on your PCB’s power timing requirements you may find a dual-channel power supply is more important than two independent power supplies because a dual-channel power supply usually synchronizes its outputs. And, depending on how many independent power supplies your PCB has and how much testing/troubleshooting you plan to tackle, you may find that three or more power supplies are needed. It’s recommended that you consider purchasing a low-noise, high current and high voltage (i.e., high power) power supply unit. The old HP power supplies (the term “old” is used because HP doesn’t make power supplies any more) are perfectly acceptable units if you’re looking for older used power supplies. Agilent (now Keysight) also offers good power supplies; remember that Agilent was a spin off of HP. Most recently, I’ve been using Sorenson’s benchtop power supplies due to their higher power and smaller form factors. You should expect to pay between $500 and $1000 depending on your needs.

A good oscilloscope with the proper time-base setting and trigger set point will immediately identify elusive noises and trouble-causing blips.

It’s recommended that you consider purchasing a low-noise, high current and high voltage (i.e., high power) power supply unit.
5

The final item on the list is a microscope. Most novice EE may not even consider a microscope as a useful lab tool, but once you start cutting PCB traces or replacing small passive components such as 0201 resistors—recall that an 0201 resistor has physical dimensions of 0.6mm x 0.3mm—you’ll soon come to appreciate and depend on your microscope. I highly recommend you to consider paying a little more for a binocular stereo microscope (has two eyepieces for viewing your subjects) vs. the monocular (single eyepiece) microscope; binocular microscopes are more comfortable to look through for extended periods of time than a monocular microscope. Other features to get include 10x super-widefield eyepieces, an adjustable interpupillary distance, a fixed 30 or 45-degree vertical inclination to reduce eye and neck strain, a zoom objective lenses for providing continuous zoom magnification, an adjustable vertical post and horizontal boom for adjusting the microscope on the X- and Y-axes, and, most importantly excellent lighting—look for microscope “ring lights.” You should expect to pay between $200 and $500 for a complete setup.

Keysight TrueIR Thermal Imagers from Gap Wireless

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With an increasingly competitive marketplace, semiconductor and electronics manufacturers are seeking a way to receive the most accurate and up-to-date data regarding their supply chain. Optimal+, a leader in big data analytics, has found a way to deliver the data their customers need. Not only does Optimal+ deliver this data, they have fundamentally changed the relationship between the way data is collected and how it is used. With their big data solutions, they have enabled their customers to explore proactive solutions within the manufacturing world.

EEWeb recently spoke with Dan Glotter, CEO and founder at Optimal+, to discuss how his company’s cutting edge technology enables semiconductor and technology companies to flourish financially.
What is your core business?
Optimal+ is a big data analytics company providing software solutions for the semiconductor and electronics industries. Our solutions support both internal and external supply chains. So whether a customer is vertically integrated or has a globally distributed supply chain, our solution can easily support both types of organizational structures.

What types of information do you provide your clients?
Optimal+ delivers an end-to-end solution that collects all the manufacturing data generated by our customers’ supply chains, either internal or external. Using our big data analytics solutions, we transform their manufacturing data into actionable intelligence that is used to make timely, informed decisions that dramatically improve yield, quality and efficiency.

What have you found to be the most valuable data for your clients?
Our customers tell us that the visibility we deliver into their globally-dispersed manufacturing environments is the most valuable benefit we provide. Today, it is more important than ever for semiconductor and electronics manufacturers to have complete transparency into their internal or external supply chains to improve overall quality and reliability.

How do you measure your success?
Our customers are the world’s leading semiconductor and electronics companies including the top five fabless, and they measure us by the return on investment we collected and analyzed over 35 billion devices on their behalf, which is roughly 15 percent of global semiconductor production (according to IC Insights). Over our 10-year history, our customers have realized tremendous ROI from our big data solutions, resulting in 100 percent customer retention.

Can you give any examples of process changes that customers have implemented due to the insights your data has provided?
Optimal+ solutions fundamentally change how customers view their supply chain data. Our big data solutions enable our customers to be proactive with manufacturing data instead of being reactive. Historically, our customers would review key manufacturing data on a periodic basis to see if everything was operating smoothly. More often than not, an issue would be found that negatively impacted their manufacturing operations. They would then remedy the situation, but by the time the problem was found, there was nothing that could be done about the lost yield, or test excursions that had already happened, because that material was long gone. With Optimal+, they now are proactive, and can see manufacturing problems within minutes and take immediate action, preserving yield entitlement and catching test escapes before they enter the supply chain.

What sets your analysis apart from individual companies running their own numbers?
The analysis a company does is only as good as the quality of the data they are analyzing. We provide the most comprehensive manufacturing test data in the industry and deliver it to product teams within minutes of test completion. At that point our automated rules engine analyzes that data 24/7 to find the problems that need to be addressed. In addition, our data infrastructure is already installed in 90 percent of the major foundries and OSATs in the world, making adoption by new customers very easy.

How much time does it take to start collecting and analyzing data?
In our customer engagement process, we are typically streaming data from our customers’ supply chains within two weeks.

How quickly do you typically get actionable information?
Most of our customers get their data within 10 minutes of test completion, which is typically 1 to 2 orders-of-magnitude faster than they receive their data from prior solutions.

How will NI’s Semiconductor Test System augment Optimal+’s capabilities?
Optimal+ is tester-agnostic. We support the test platforms our customers demand. We support the NI STS platform because it was requested by our customers.

How long and how challenging will it be for customers to use the two systems in an integrated manner?
For new or existing customers, that addition of the NI STS platform will be completely seamless to the end user, as it is just another source of test data for our solutions.

Anything else you would like to add?
Optimal+ is transforming the way that semiconductor and electronics companies utilize the manufacturing data they generate. Our big data infrastructure dramatically improves the way that test data is collected and delivered to product teams, and combined with our big data analytics solutions, enable our customers to make more informed decisions that have a dramatic financial impact for their businesses.

DAN GLOTTER
Founder and CEO Dan Glotter brings over 20 years of experience in the semiconductor industry to Optimal+. Before founding the company (formerly named OptimalTest) in 2005, Dan held various senior positions in semiconductor management and test operations at Intel from 1994 to 2004. During his tenure at Intel, Dan was granted several patents and has received numerous awards, including the Intel Achievement Award and the Intel Quality Award for his leadership of Intel’s Fab 18 in Israel. Dan holds a BS in Engineering from the Technion and an MBA in Finance from Bar-Ilan University.