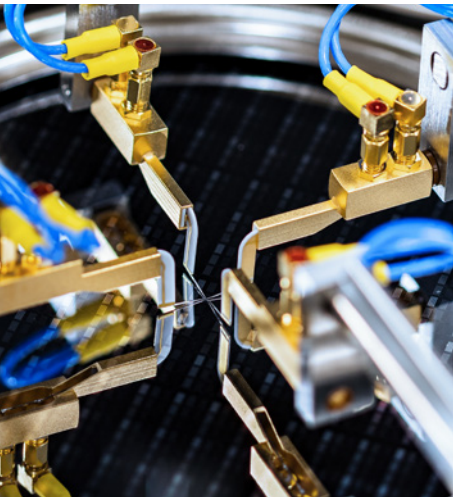


Cascade

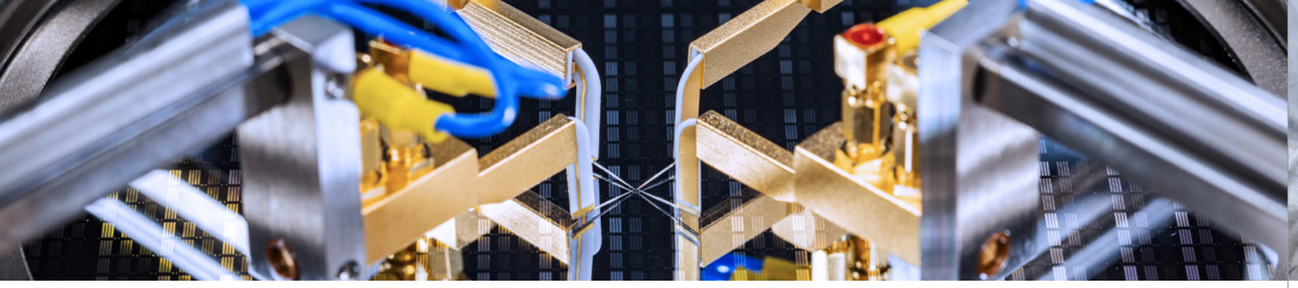
Ultra Low Noise Measurements

Contact Intelligence™

PureLine™ 3 Technology

Verified, 4x Faster, Accurate Measurements – Without the Noise

FormFactor™



Verified, 4x Faster, Accurate Measurements – Without the Noise

FormFactor's new CM300xi-ULN (Ultra Low Noise) is a revolutionary 300 mm wafer probing system designed for highly accurate flicker noise (1/f), random telegraph signal noise (RTN or RTS), and phase noise measurements of ultra-sensitive devices.

With the newly patented PureLine™ 3 technology, the ULN probing system enables up to 32x lower noise (1 kHz), eliminating 97% of the environmental noise experienced in previous probe systems, improving device characterization and modelling at the 7/5/2 nm technology nodes targeted for 5G and beyond applications.

When integrated with noise test equipment (flicker noise, RTN, phase noise), the CM300xi-ULN offers the industry's highest test throughput, using Contact Intelligence™ with motorized probe positioners, enabling fully Autonomous DC and low frequency noise probing with multi-DUT layouts for complete hands-free 24/7 operation.

Finally, the CM300xi-ULN takes the complexity out of low noise TestCell optimization. Just plug it in and go. Low-noise Site Survey and System Verifications significantly reduce setup costs and tool deployment time. This allows lab engineers to focus on getting good device data, that can be used to reduce the number of costly re-designs and accelerate time to market with lower development costs.

"The CM300xi-ULN enables up to 32x lower noise, for improved device characterization and modelling at the 7/5/2 nm technology nodes targeted for 5G and beyond applications."

FormFactor's CM300xi-ULN Probe Station with wafer loader and TestCell Power Management for ultra low frequency and noise measurements.

Industry-Firsts in Low Noise Probing

FormFactor has pioneered new precision electrical measurement innovations for the past 30+ years. Patented technologies such as MicroChamber®, FemtoGuard™ and PureLine™ revolutionized on-wafer testing and set the industry standard for DC, flicker noise and RF measurements. As next generation device technologies such as 5G and 7/5/2 nm emerge, new testing capabilities are needed. We have enhanced the industry-leading CM300xi with revolutionary technologies to meet these emerging test needs. The new CM300xi-ULN now enables unprecedented measurement performance and achieves four significant industry firsts in the arena of on-wafer, ultra-low flicker and phase noise testing.

PureLine 3 Technology
First automated probe station to achieve -190dB spectral noise*

Autonomous 24/7 Operation
Up to 4x faster flicker noise thermal testing on 30 µm pads

Plug In and Go
Integrated TestCell Power Management

Reduce Setup Time and Costs
Exclusive low noise site survey, and system verification services

* Typical noise (dBVrms/√Hz @1K,10KHz), with prober and thermal system enabled.

The Need for Low Noise Probing

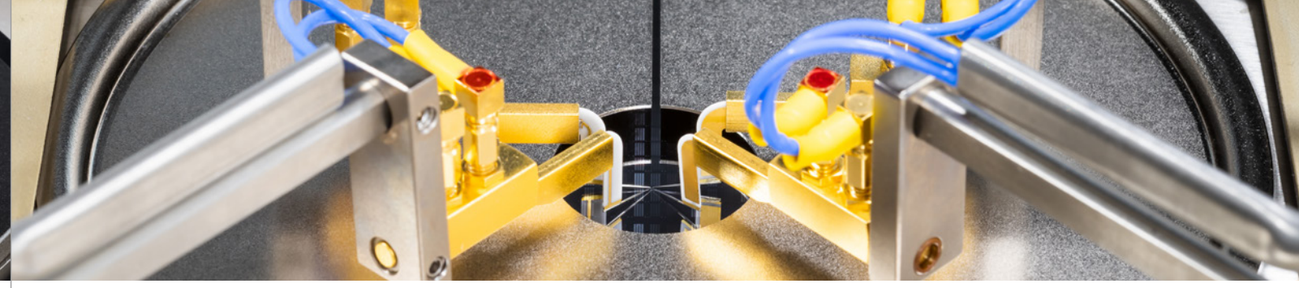
More Accuracy, Lower Costs

Increasingly, the semiconductor industry needs new equipment with advanced capabilities for higher accuracy testing, and faster data collection. However, test requirements also continue to expand requiring additional time consuming thermal data.

Satisfying these core needs enables the development of high-performance devices and IC's that fuel smaller and faster mobile phones, computers, consumer electronics, automotive, 5G and Internet-of-Things (IoT) devices. But at what cost? Companies are under constant pressure to reduce cost of test and get to market faster.

FormFactors's new CM300xi-ULN probing system directly addresses these needs. By enabling new high accuracy flicker and phase noise testing, high test throughput, and fast guaranteed tool deployment, the ULN system reduces the number of costly re-designs and speeds time to market with lower development costs.

"The CM300xi-ULN speeds time to market with lower development costs."



PureLine™ 3 Technology

New Capabilities for New DUT's

The most significant new feature in the CM300xi-ULN is PureLine™ generation 3 technology. This technology comprises of an extensive collection of FormFactor patents, electrical design knowledge, and measurement system IP, that together provide an effectively noise-free environment around the device under test (DUT).

Compared with previous PureLine™ versions in FormFactor's Elite300 and CM300 probe stations, the new PureLine 3 eliminates 97% of the environmental noise, enabling 32x improvement in spectral noise performance. With this technology, highly accurate device performance can be measured on-wafer and used to generate device models for IC designers.

Using the new CM300xi-ULN probing system with PureLine 3 technology, device test engineers, reliability engineers and IC design engineers can all benefit from this latest technology. Accurate flicker, RTN, and phase noise measurements for advanced materials, package interconnects, transistors, and IC's can now be done simply and automatically for faster time to data.

Eliminating Unwanted Noise

PureLine™ 3 technology provides a guaranteed solution that eliminates unwanted noise that can mask and corrupt high-performance device data. Unwanted noise can penetrate every part of the measurement test cell, coming from three main areas.

Noise from outside the probe station

Lab high-volume air-conditioning systems (HVAC's), high voltage floor AC power lines, and nearby WiFi access points. These produce floor vibrations, magnetic fields, and radio waves that all cause electrical noise.

Noise from inside the probe station

Electronics (switches, sensors, video cameras), electrical-mechanical automation (motors, stages), and computer and thermal control systems in and around the probe station.

Noise from measurement Test Cell interconnects

High resistance inter-connects (cables, control lines), instrument AC power distribution, and signal measurement leads from test equipment. All can cause significant low frequency noise in the 1Hz to 1KHz band – a key frequency range for flicker noise test data.

Performance Results – Chamber Noise

To demonstrate the significant improvements of PureLine 3 technology, the following data provides a comparison of chamber noise between two 300 mm probe stations. The chamber noise test setup is a common way to configure a flicker noise system to show the amount of noise seen by a DC probe inside the probe station at the DUT level. Figure 1 shows the physical test setup using Keysight A-LNFA flicker noise system (E4727A), and FormFactor's DCP-HTR probes. In Figure 2, data is shown using the new CM300xi-ULN probing system, and in Figure 3, a standard CM300xi-F model. With the same identical test setup on the two probe stations, the significantly improved clean noise floor of the new ULN system can clearly be observed.

Figure 1: Test setup for chamber noise data using Keysight E4727A (A-LFNA). Three DCP-HTR probes connected to drain, source, gate terminals. All probes inside the probe station MicroChamber shielding environment.

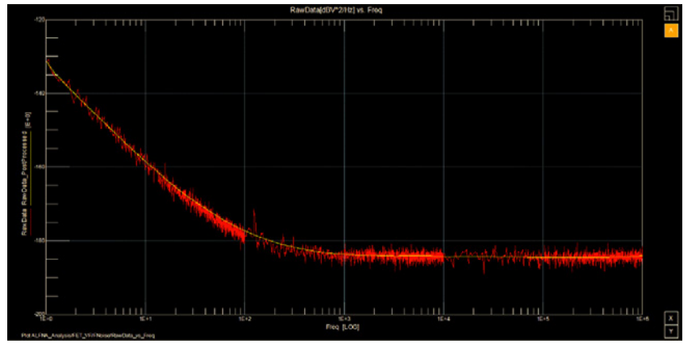


Figure 2: CM300xi-ULN chamber noise graph, 1Hz to 1MHz (VAMP LF), 32 ave, 1600points/dec, Rload and Rsource = 0 ohm, using Keysight E4727A (A-LFNA). Y-axis scale for Power -140 to -200.

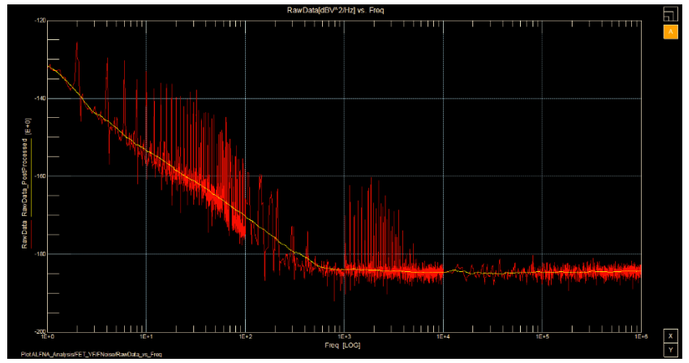
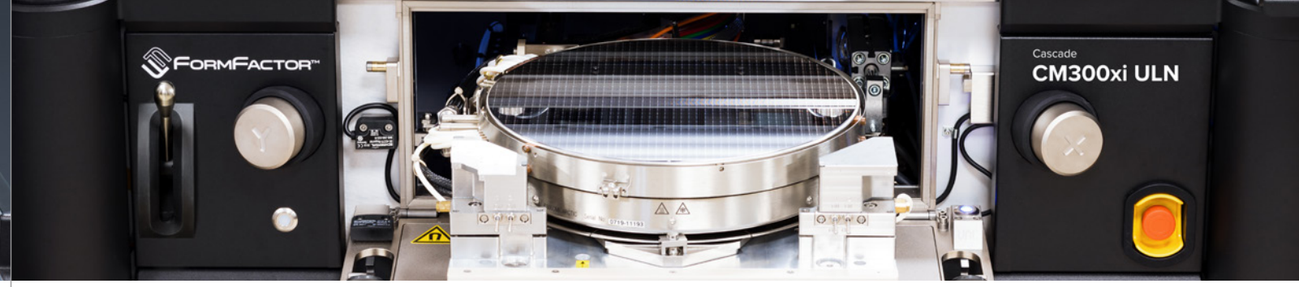


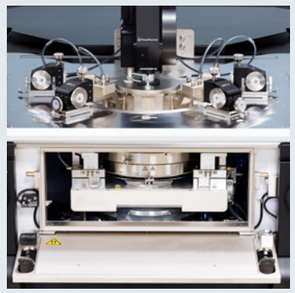
Figure 3: CM300xi-F chamber noise graph, same test conditions and display scales as both figures 2 and 3.



System Components Using PureLine 3 Technology

PureLine 3 technology is integrated into many components of the CM300xi-ULN probing system. Following is a list of the ULN components and a brief description of their key features and benefits. More detailed information can be found later in this document.

PATENTED TECHNOLOGY



ULN MicroChamber™

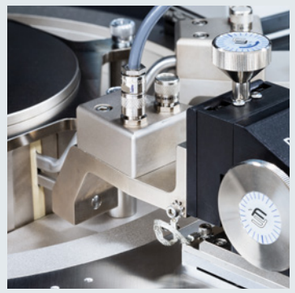
This provides the critical probing environment built into the prober and directly surrounding the DUT and wafer chuck area for low noise testing. The newly enhanced ULN MicroChamber ensures a complete EMI / RFI shielded area, like a small localized version of a large lab-sized Faraday cage. In addition, the ULN MicroChamber provides the required dark and dry environment critical for measuring light sensitive transistors, and devices at negative temperatures (<= -60°C) with frost free operation. The integrated dry (low humidity) environment control system also supports FormFactor's industry leading DC low noise/ low leakage device measurements.

ULN Power Conditioning Unit (PCU)

This integral ULN system component provides fully managed and filtered AC power to the entire system – prober and instruments. The patented PureLine 3 technology in the rackmount ULN Power Conditioning Unit (PCU) enables small footprint, low field emissions, and forms the foundation for the TestCell Power Management (TCPM), eliminating ground-loops between probe station and instruments that cause significant low frequency noise. The ULN PCU supplies clean, filtered AC power to the probe station, thermal chiller and controller, wafer loader, powered accessories, and all test instruments. In addition, the PCU provides a unified Emergency Off / Emergency Power control system for safe operation of the whole system and all instruments.

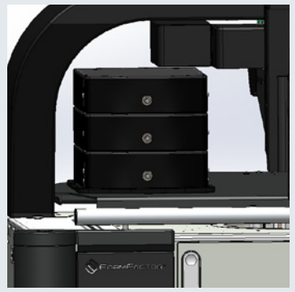
ULN Thermal Filtering Module

The ULN Thermal Filtering Module is included with all ULN systems with thermally controlled wafer chucks. It is vital for enabling ultra-low noise probing at temperature. Harmful noise generated by external thermal control systems is filtered from entering the critical low-noise measurement environment. The active module significantly reduces high frequency noise, by up to 30dB above 1Mhz.



ULN Single Point Grounding and Cabling System

Each ULN system also includes a single point grounding system for all the prober accessories, with low resistance grounding connections. PureLine 3 design practices enforce low resistance materials and hard connection schemes for mechanical assemblies – that results in reduced antenna effect injection of unwanted RF noise into the measurement path.



ULN SMU Filtering Modules for Accurate PLL Phase Noise

For highly accurate phase noise measurements of devices such as Phase Lock Loop circuits (PLL) and Voltage Controlled Oscillators (VCO), newly developed DC filter modules for Source Measure Units (SMU) can be used with the CM300xi-ULN probing system, to provide ultra-quiet / clean DC supply voltage. The high-performance DC SMU filtering modules provide up to 100 dB attenuation (50 Hz to 80 Mhz) with 100 mA max. DC current handling. Each SMU filter module supports one channel, and multiple modules can be configured together to provide multi-channel clean power.

Contact Intelligence™

ULN Contact Intelligence Modules

New ULN Contact Intelligence™ modules (1, 2, and 4 positioner systems) with PureLine 3 noise reduction, make the CM300xi-ULN the world's first probe station to achieve autonomous flicker noise thermal testing on 30 µm pads. With the Autonomous DC Measurement Assistant, the CM300xi-ULN can be configured to use ULN-optimized Contact Intelligence™ with motorized DC probe positioners, enabling fully autonomous DC and flicker noise probing, over multiple temperatures for complete hands-free 24/7 operation.

TestCell Power Management

Noise from TestCell Interconnects

As semiconductor device performance increases, especially in the area of low power and small signal operation, improved signal-to-noise testing is needed. As discussed previously, finding and eliminating unwanted noise is required in multiple areas. Noise sources can be found inside a prober, outside a prober, and in a measurement TestCell. Historically TestCell-generated noise was a small concern, because device signal levels were high. This is not the case anymore.

A traditional measurement TestCell is defined as a connected set of equipment, including test software, a few instruments, probe station, thermal system, and related measurement accessories (cables, on-wafer probes) for the purpose of collecting specific types of test data.

Even when all the individual equipment parts are well-designed (low noise, high quality, good EMI/RFI shielding), when they are joined together, long AC power ground-loops are formed. And when any common nearby magnetic fields pass through these ground-loops, they are converted into very small electrical signals resulting in unwanted power line frequency noise, with multiple harmonics.

This is shown in the following TestCell example, with unwanted noise (red trace) versus ground isolated condition (green trace).

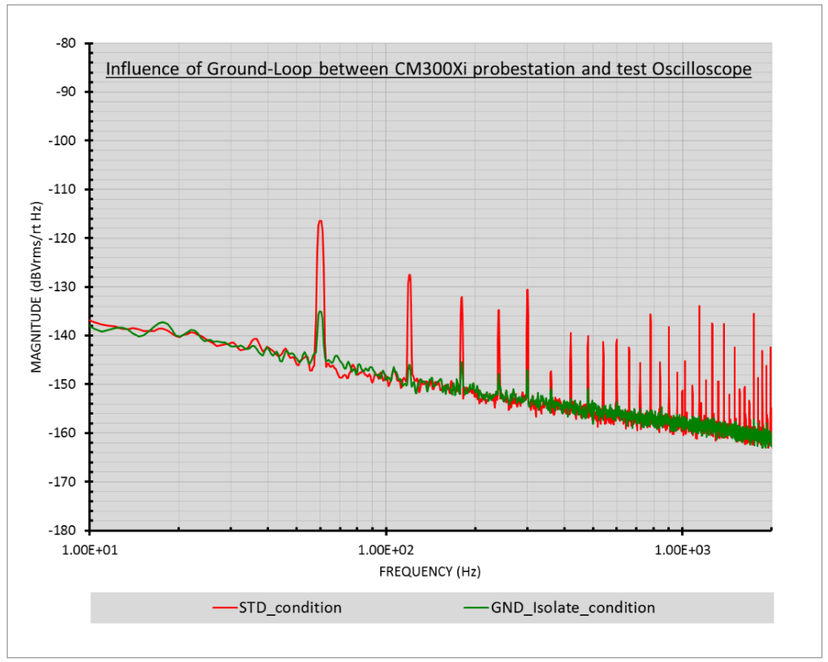


Figure 4: Measurement of chuck noise with Keysight Oscilloscope. The STD condition with ground-loop shows more than 30 power line fundamental and harmonics noise spectrums. With the improved GRD isolated condition, the power line fundamental and harmonics noise spectrums are dramatically reduced. (Note: 60 Hz power line spectrum is only -20dB (= 1/10) reduced.)

Beyond Traditional Probe Stations

Engineers and technicians have often needed to improve a test setup in their lab for low-noise applications. For small applications this is easy, using simple battery power to eliminate unwanted power line frequency noise. And for small applications where AC power is needed, an isolation transformer can be used.

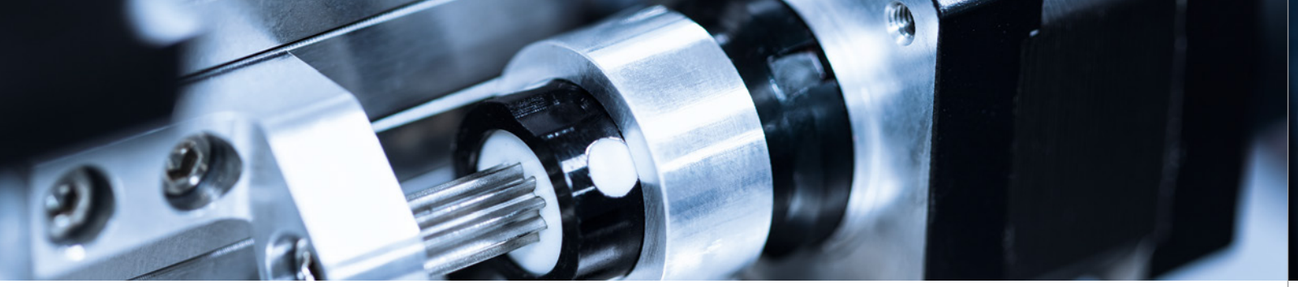
However, this technique has serious limitations when scaling up to support the size and power needs of a tradition TestCell with a thermal probe station – limitations such as high cost, large physical size, complex cabling, safety issues, and increased magnetic field generation.

To address and solve this problem, FormFactor has developed a new TestCell Power Management system using PureLine 3 patented technology. And the CM300xi-ULN probing system, is now the world's first probe station with integrated TestCell Power Management. It not only eliminates all ground-loop induced TestCell noise, but also has a small footprint, and low field emissions, providing fully managed and filtered AC power to the entire system, prober and instruments.

"The CM300xi-ULN is the world's first probe station with integrated TestCell Power Management."

Safety Certified and Expandable

A key part of the TCPM systems design, is the ULN Power Conditioning Unit (PCU) with expandable power modules, enabling unlimited instrument support with full power filtering and EMO management. The PCU provides a unified Emergency Off / Emergency Power control system for safe operation of the whole system and all instruments. It also supports instruments that do not have any special EMO capability, through a dedicated module with EMO controlled AC outputs. Safety is guaranteed through industry exhaustive compliance testing and full safety certifications supplied by TUV worldwide.



Achieving High Throughput Flicker Noise Measurements

Flicker noise testing can take a long time, especially when measuring down to frequencies of 1 Hz or below. Sweep times up to 30 min at a single temperature are common. And standard data collection for device models requires DUT data at multiple temperatures on small pads.

To lower Cost of Test (CoT), and significantly increase on-wafer test throughput, automation can be added to a test setup using four different methods:

Motorized positioners with patented FlexShield.

1. Automatic wafer loading

2. Motorized probe positioners for small pad touchdown optimization

Lower Cost of Test

Increased On-Wafer Test Throughput

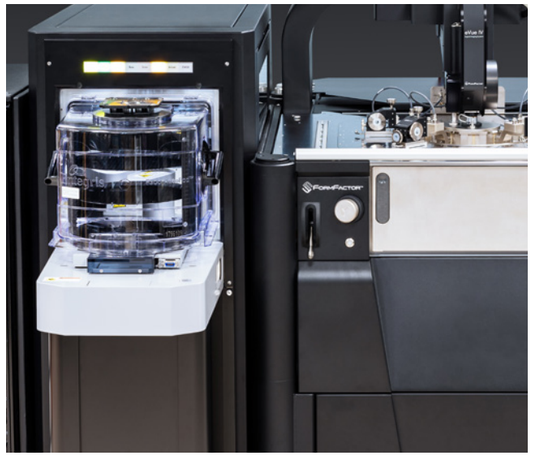
3. Automatic thermal transitions with probe-to-pad-alignment

4. Multi-DUT layout automation

For addressing method 1, a standard production prober can be used to increase data collection throughput, but these probers are designed for high-speed production test, not high accuracy flicker noise measurements. The resulting data accuracy is severely compromised by prober noise.

For solving methods 2, 3 and 4, significant technology development – optical, mechanical and software – is required to switch away from slow, manual probe positioning.

In all cases, it is important to note that the automation methods must not compromise TestCell low-noise performance by adding or transmitting unwanted noise into the probing environment. This has been a common problem with traditional approaches that add non-optimized thermal control, hardware and electronics modules.



The MHU301 enables fully automated SEMI-compliant loading of up to 25 different wafers.

Contact Intelligence™

Paradigm Shift in Test Methodology

Adding FormFactor's Autonomous DC Measurement Assistant to the CM300xi-ULN creates a paradigm shift for engineers and lab managers setting up flicker noise testing. It is now possible to setup a high throughput TestCell, for both semi- or fully-automatic CM300xi-ULN systems, offering complete hands-free 24/7 operation.

The Autonomous DC Measurement Assistant combines motorized probe positioners with state-of-the-art image processing to achieve highly-reliable measurement data at any time. It enables small pad touchdown optimization, automatic testing over multiple different temperatures, and automatic probe layout spacing for testing sub die. All capabilities are optimized to ensure ultra-low noise performance is not compromised.

Both single-DUT probe layouts and multi-DUT layouts can be easily called by measurement software for complete automation. The Autonomous DC Measurement Assistant takes care of all the complex management of thermal transitions, and thermal soak time optimization of probe-to-pad-alignment (PTPA). The result is ultra-low noise probing, with low contact resistance on small pads down to 30 µm, for any flicker noise modelling and extended temperatures (-55 to 200°C), over all dies on a wafer, and all wafers.

"The Autonomous DC Measurement Assistant combines motorized positioners with state-of-the-art image processing to achieve hands-free 24/7 operation."

Figure 4 shows data using the Autonomous DC Measurement Assistant to probe on 30 µm pads at multiple temperatures.

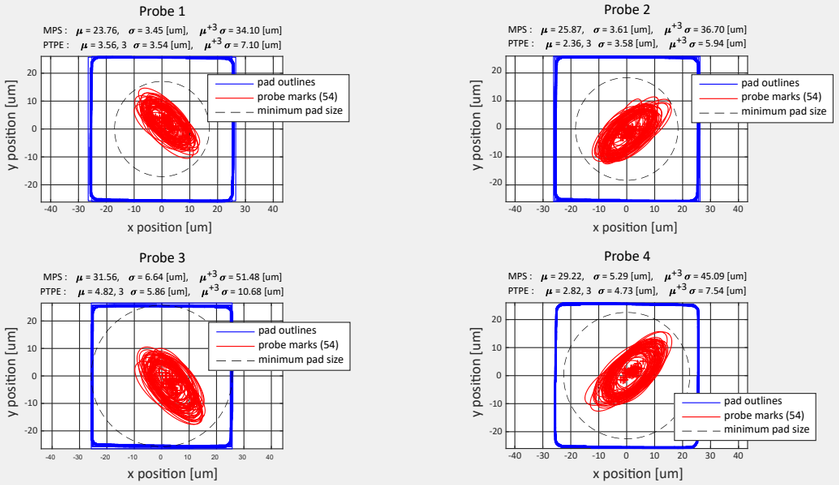
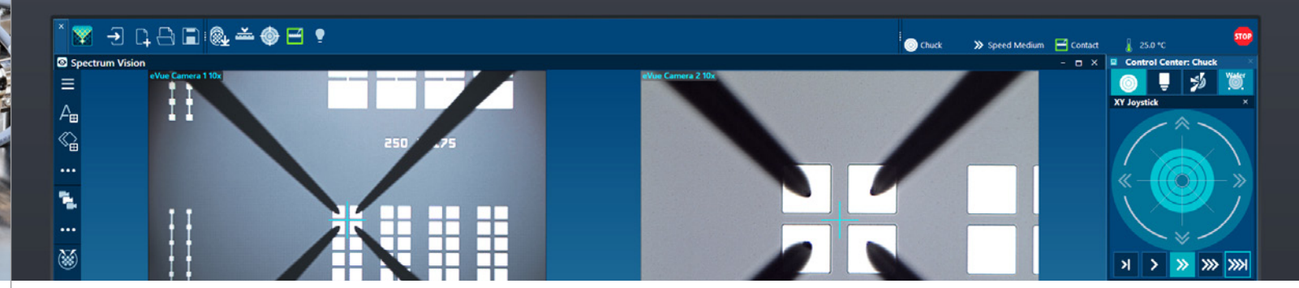


Figure 4: Measured data: 54 sets of die touchdowns / probe scrub marks, at multiple locations across 300 mm wafer, with accurate touchdown of 4 motorized probes on 30 µm pads, at 6 different temperatures (25, 150, -45, 175, -55, 200°C). Conditions include wafer soak 3 hr, die soak: 10 min, and 30 min contact test time.



High Throughput – Lower Cost of Test

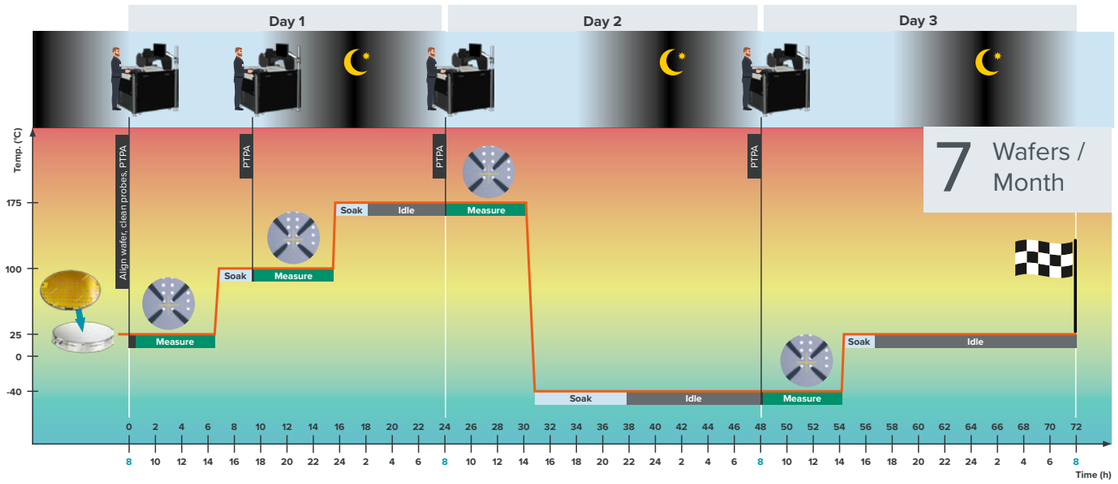


*Figure 5: CM300xi-ULN with manual probe-to-pad alignment. The system is idle at night and the weekends.**

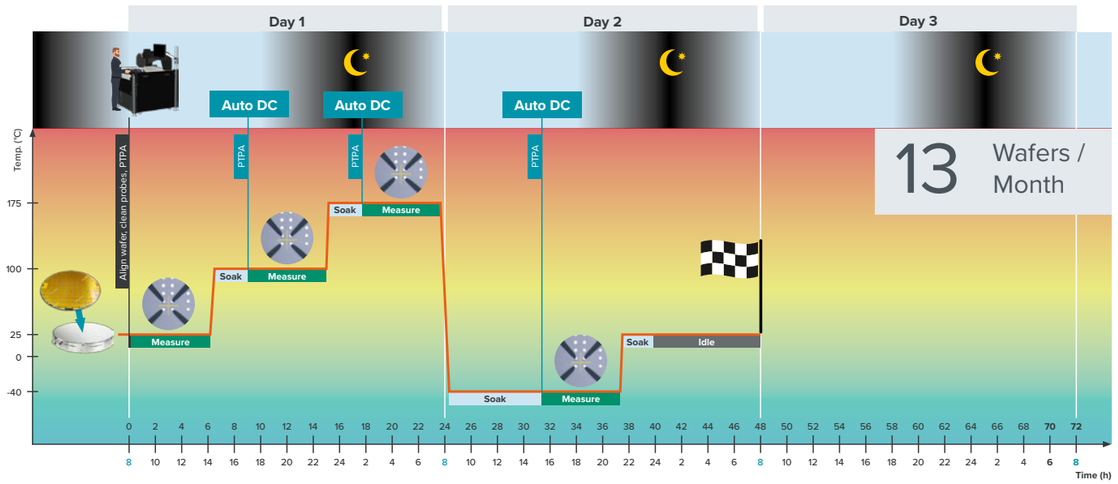


*Figure 6: The CM300xi-ULN with Autonomous DC Measurement Assistant achieves a 1.8X increased wafer throughput and requires 75% less test engineers time than Figure 5.**

Contact Intelligence™

Improved flicker noise data accuracy and increased test throughput add up to significant time and cost savings for semiconductor companies needing to improve Cost of Test (CoT). Figures 6 and 7 show an example of the real-world savings potential with the Autonomous DC Measurement Assistant and wafer loader.

*Test conditions	
Test Time / Die (min)	30
# Dies to Test on Wafer	12
Test Time / Wafer (min)	360
# Temperatures (°C)	+25 / +100 / +175 / -40

Using a CM300xi-ULN semi-auto prober with manual probe positioning as the baseline condition (Figure 5), a 1.8X increased wafer throughput is achieved with FormFactor's exclusive Autonomous DC Measurement Assistant (Figure 6). And using the CM300xi-ULN with wafer loader and the Autonomous DC Measurement Assistant, a huge 4.1X increase wafer throughput is gained (Figure 7).

Implementing these new CM300xi-ULN automation solutions allows reduced capital equipment costs, and reduced operator/staffing costs resulting in cost savings of up to US$815,000 per year for 3 years.

In the same typical testing seen in figure 5, three additional full thermal ULN semi-auto probers (~US$1.35 M) would be needed to reach the test capability of the single full-auto prober with the Autonomous DC Measurement Assistant. And three additional test engineers (~US$30k / month) would be needed (1 per shift x3 for 24/7 operation) to operate all 4 probers continuously.

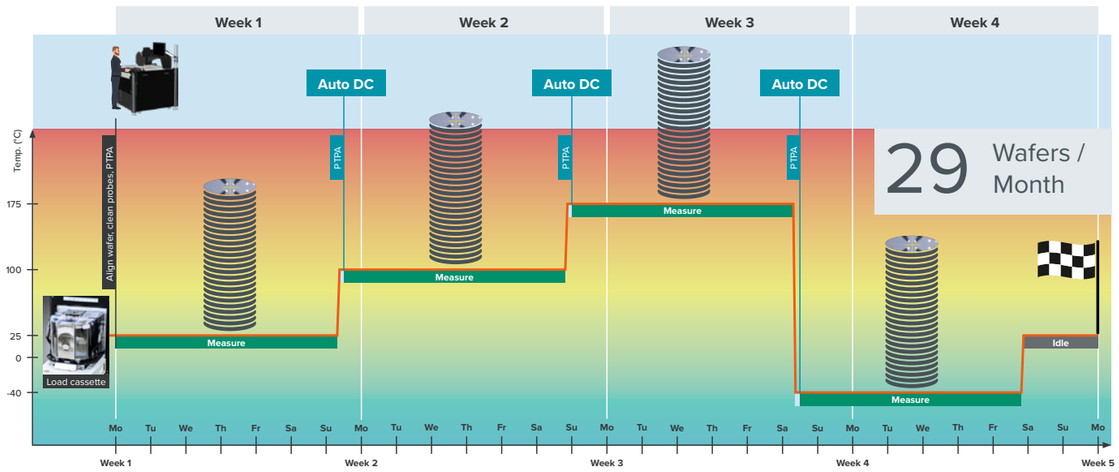
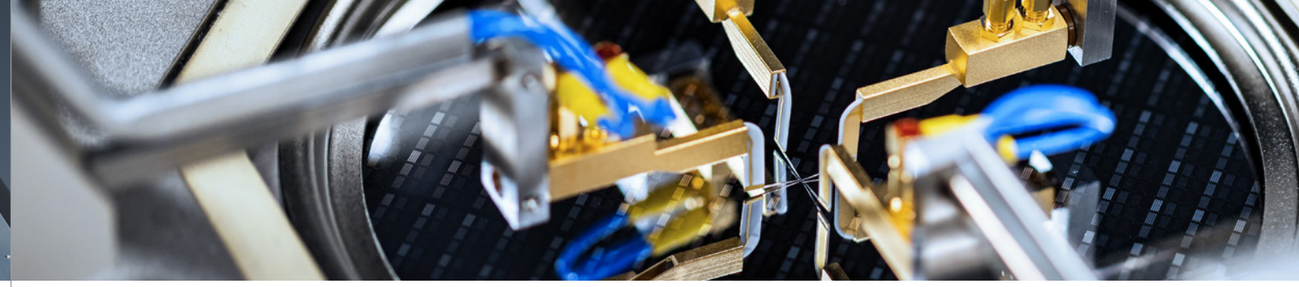


*Figure 7: CM300xi-ULN with Wafer Loader MHU301 and Autonomous DC Measurement Assistant achieves 4.1X increased wafer throughput and requires 92% less test engineers time than Figure 5.**



Eliminating Costly Tool Deployment Issues

Cost Savings in the Lab

The CM300xi-ULN takes the mystery and complexity out of low noise TestCell optimization. **Just plug it in and go.** The ULN system significantly reduces setup time and allows lab engineers to focus on getting good device data, instead of having to troubleshoot grounding problems that cause bad data.

Cost savings can be significant, saving up six to ten weeks of wasted engineering time and two to three months of delayed product testing. And with high throughput testing automation capabilities, test labs and companies can focus on getting accurate data faster, making technology business data decisions more efficiently, and ensure the right products are delivered faster to market.

Picking the Best Location

High performance flicker noise or phase noise TestCells can be degraded by installing them in a bad location. And just like developing a high-performance system, finding a good location can be a time consuming and difficult task for the typical lab technician that is tasked with setting up the new prober. To do it right requires specialized measurement equipment and tools such as accelerometers, oscilloscopes, high performance low noise amplifiers (LNA's), test software, magnetic flux probes, and more. Often, it requires specific applications knowledge on how to identify noise signatures and troubleshoot installation location issues.

"The CM300xi-ULN takes the mystery and complexity out of low noise TestCell optimization. Just plug it in and go."

Only Available VERIFIED From FormFactor

New Services that Reduce Deployment Costs

Customers working with FormFactor have expressed the desire for a range of services addressing this need, and this has led to another world's first for the CM300xi-ULN probing system: the first probe station with customer low-noise site surveys and low-noise installation verification.

The ULN's facility planning guide has a list of the standard and unique system requirements for the probing system. For customers that do not have full on-site services, the new ULN Site Survey is available. And to ensure customer satisfaction after the system installation is complete, a new ULN System Verification is performed demonstrating key specifications and performance tied to the standard product datasheet.

ULN Site Survey

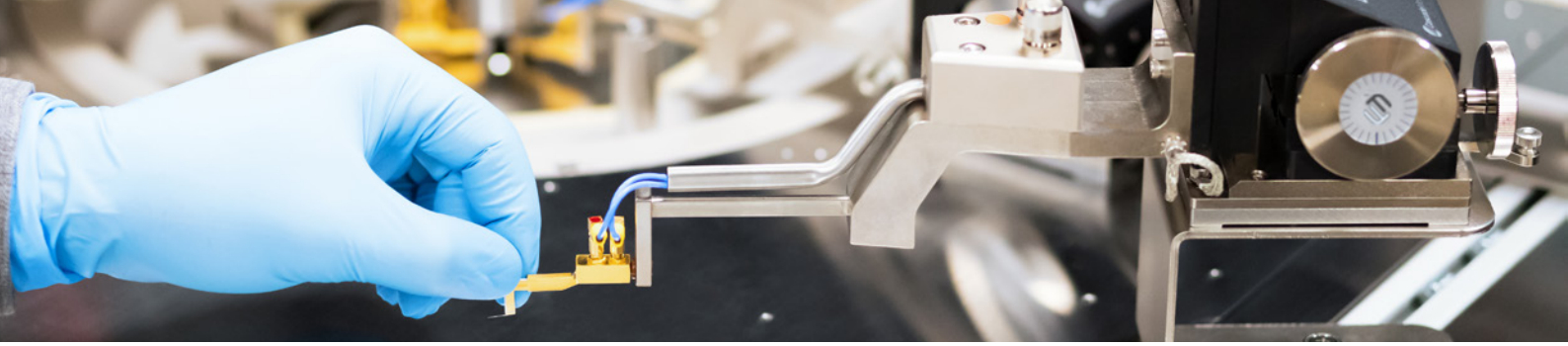
Pre-installation Site Surveys can be performed by FormFactor-trained engineers to determine the best location to install the ULN system. Customers will pick typically two or three locations, and a site survey will be done at each. The site survey includes precision measurements of four critical noise sources:

1. Floor vibrations (µg over 0.1Hz to 1KHz range)
2. Magnetic field strength (AC milligauss)
3. Power-Line Noise (10kHz to 10MHz), and
4. Power-Line THD (total harmonic distortion).

Comparing the survey results with the system requirements enables a good location to be selected that will limit unwanted environment noise from degrading the TestCell performance.

ULN System Verification

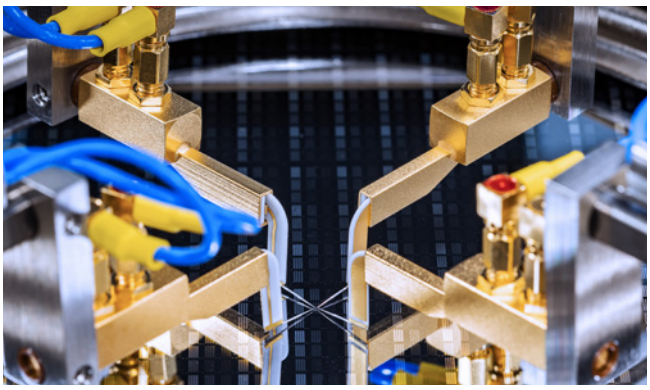
Included with every CM300xi-ULN probing system is a ULN System Verification that is performed after the ULN probe station is installed. This specialized service using FormFactor-supplied test equipment, is in addition to the standard probe station verification (50+ point check list) and is also performed by a FormFactor factory-certified engineer. Key product specification parameters are measured such as Spectral Noise Density (dBVrms/√Hz, 1Hz to 20MHz) and AC chuck noise (mV p-p, DC to 2.5GHz).



Industry-Leading High-Performance Probes

The DCP-HTR Probe

The DCP-HTR probe delivers fA-level measurement capability from -65 °C to 300 °C for advanced characterization and reliability testing. Its unique design offers superior guarding and shielding over-temperature, overcoming the high-temperature performance limitations of standard coaxial needles. The optional probe tips with small diameter are ideal for probing pads as small as 30 x 30 µm.

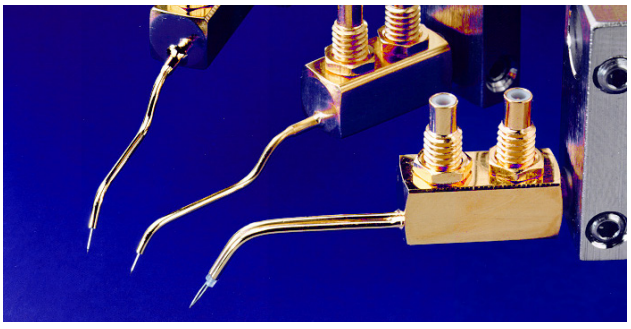


- / Ultra-low, fA-level current and fF-level capacitance measurements from -65 °C to + 300 °C
- / Guarantees fully-guarded measurements to fA and fF levels
- / Individual connectors provide force-sense connection for quasi-Kelvin and CV measurements

DCP 100 Series Probe

The DCP100 delivers the measurement accuracy needed for advanced on-wafer process, device characterization and reliability testing. With superior guarding and shielding, these probes overcome the performance limitations of non-coaxial needle probes. Probe tips are available in 1, 3 and 10 µm diameters.

- / Ultra-low, fA and fF measurements from -65°C to 150°C
- / Full electrical guard to the probe tip
- / Highly reliable, stable and repeatable



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