IEEE SW Test Workshop

Semiconductor Wafer Test Workshop

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Probe Cards with Modular Integrated Switching Matrices

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Agenda

- Review of Traditional Scribeline Parametric IV and CV Probe Card Requirements
- Shift Toward Fast Pulsed Characterization Of 100nS Memory, Power Transistor, and ESD Clamping Devices
- Scalable Solution Automates All DC and PIV Tests Within A Scribeline Test Structure
- Conclusions

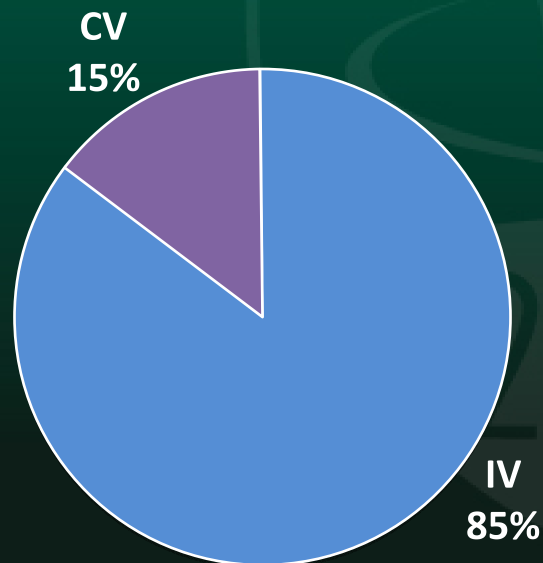
Traditional Scribeline Probing

- **12 to 32 Pin Complexity**
  - Trend toward fine-pitch in-line structures
- **IV and CV Using a 10 MHz Bandwidth Matrix**
  - External matrix works well for bench top characterization
- **PIV Is Very Limited**
  - Pulse widths to 1uS
  - Pulse amplitude to 40V (high impedance DUT)
  - Pulse power limited to a few Watts

Evolving Parametric Test

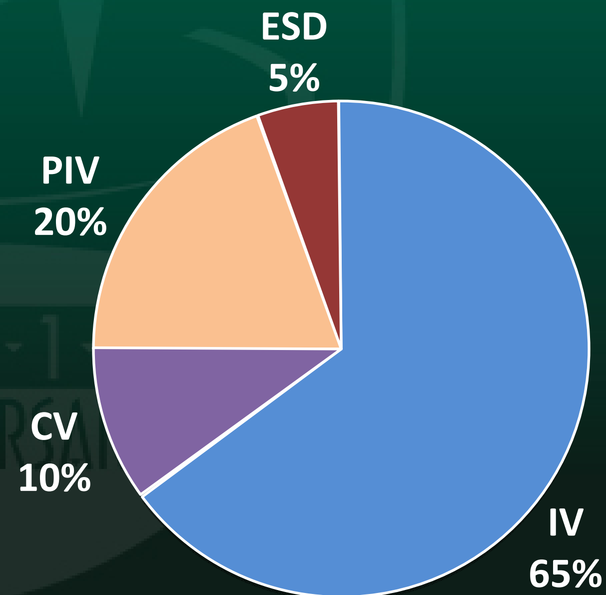
1990's Traditional DC Para

10 MHz Matrix Required



2010's Expanding to HF Para

1 GHz Matrix Required



Parametric Test Bandwidth

- **Matrix is 5x to 10x Bandwidth of Device Test Freq.**

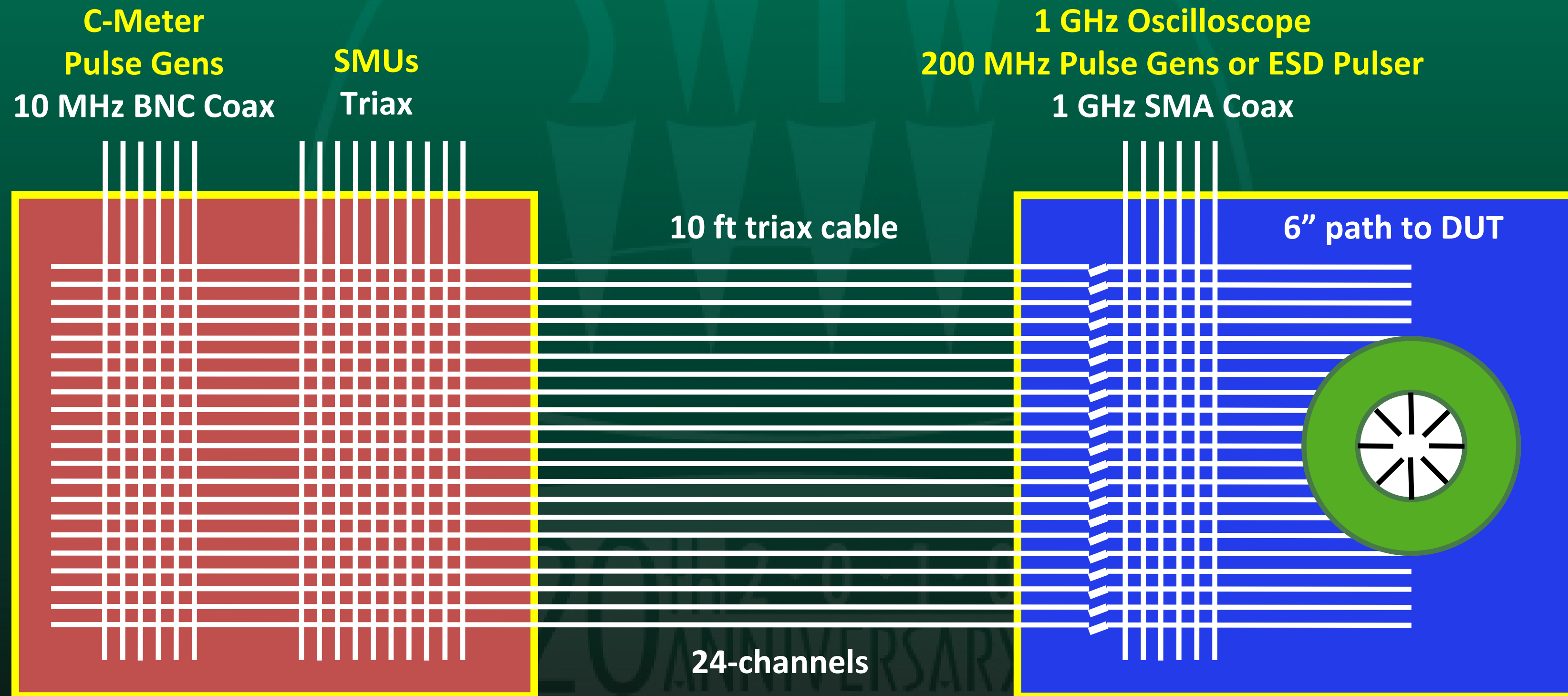
Type	Device	Freq	Matrix	Test Name
IV	Transistor	1 MHz	10 MHz	Vt, Gm, Vsat, BV, IDVD, IDVG, Gate & Drain Leakage, V-ramp, J-ramp, TDDB, HCI, Charge Pump, EM
CV	Transistor Oxide	1 MHz	10 MHz	Thick Gate Tox, Field Tox, Diffusion Profiles, Trapped Charge, Mobile Ion, C-gate, C-drain
HF-CV	Transistor Oxide	100 MHz	1 GHz	Thin Gate Tox, Carrier Life Time, Contamination
PIV	Transistor	200 MHz	1 GHz	Vt, Gm, Vsat, IDVD, IDVG, Gate Charge, Trapped Charge
ESD	ESD structure	200 MHz	1 GHz	TLP, HBM, MM, HMM (IEC 61000-4-2) waveforms, CDM stress pulse failure, PIV & leakage curves
Flash R-ram	Transistor Resistor	200 MHz	1 GHz	State 0-State 1 Programming Current/Time, Read Leakage Current

Wafer-Level 1 GHz Matrix Challenges

- I/O paths needs need to be very short (inches)
- Must easily fit onto standard analytical probers
- AC Kelvin required for high current PIV
- 100 pA-level DC leakage desirable
- All resources should MUX to all TEG pins
- Support of legacy DC Analyzers is important
- High uptime, quickly configurable
- Modular, adaptable, extendable, and reusable

Genus 1GHz Matrix/Probe Card

- Supports legacy DC; adds short HF paths



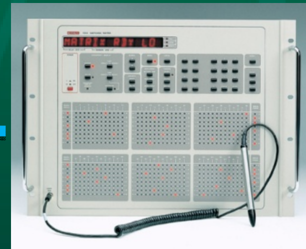
DC Equipment Matrix
Keithley K707A
or
Agilent B2201A

GTS Genus Wafer-Level Matrix
Integrated Probe Card
200 MHz using wire needles
1 GHz using 50Ω ceramic blades

24 Pin DC + ESD Automation

- Leverage Legacy DC Software Platform

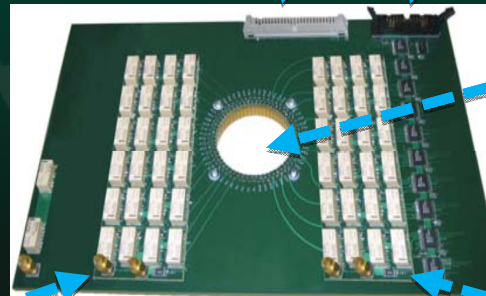
Agilent 4156 Semiconductor Parameter Analyzer



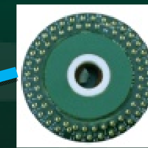
Keithley 707 Low Leakage Matrix

USB Relay Control + Power

ESD Test System

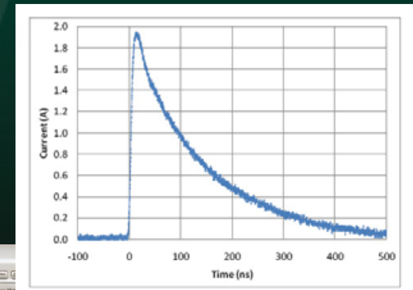


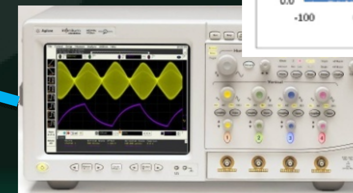
Genus 1 GHz Pin Expander



Low Cost Probe Card

2 Amp 500nS HBM Waveform at DUT





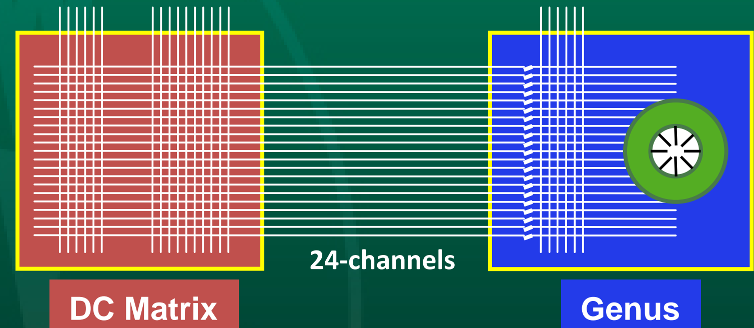
Agilgent Oscilloscope

24 Pin DC + PIV + HF-CV Automation

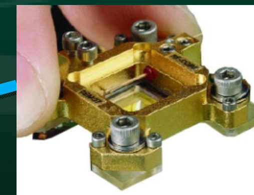
- Leverage Legacy DC Software Platform

Agilent Semiconductor Device Analyzer

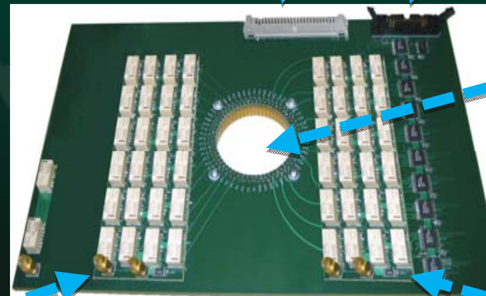
Agilent Low Leakage Matrix



USB Relay Control + Power



HF Probe Card



Genus 1 GHz Pin Expander

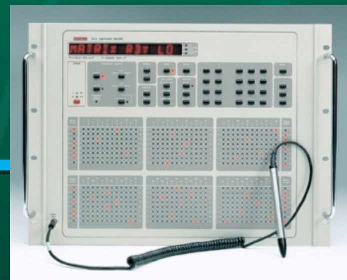
HF CV-Meter

Pulse Generator

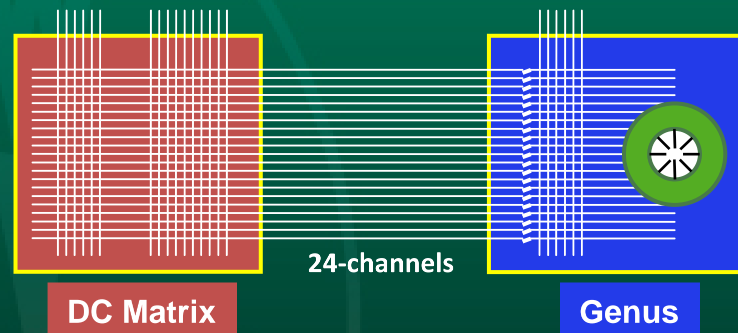
24 Pin DC + Power PIV Automation

- Pulsing down to 200nS Widths at 10 Amps

Keithley Semiconductor Characterization System

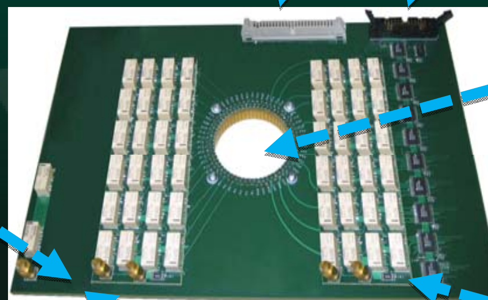


Keithley Low Leakage Matrix

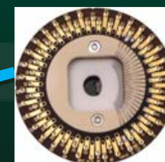


USB Relay Control + Power

Gate Pulse Generator Avtech 10W-100V

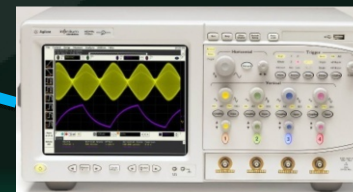


Genus 1 GHz Pin Expander



Celadon High Temp Probe Card

Drain Pulse Generator Avtech 10W-600V



Agilgent 1 GHz 4 –Chan Oscilloscope

24 Pin DC + Memory PIV Automation

- nA level currents using 14-bit AC digitizers

24-channels

DC Matrix

Genus

24 – SMU channels

Agilent Low Leakage Matrix

Donut Probe Card

4 – SMUs

Genus 1 GHz Pin Expander

Agilent Analyzer with Waveform Generator/ Fast Measurement Unit

2 – WG/FMU channels

Feature of Modular Probe Card Switching Matrices

- Motherboard – daughter board concept
- Reconfigurable & expandable daughter boards
- Designed to adapt to future test needs
- Small foot print for existing probe card holders

Motherboard Components

- **Holds the needle assembly and two stacks of daughter boards**
- **Microcontroller for overall control**
- **Interconnects**
  - Standard replaceable probe needle assembly
  - 50-ohm connectors to daughter boards provide high frequency signal paths
  - 12 V DC power routing for relays
  - USB control cable to controlling computer

Daughter Board Components

- **Approximately 25 relays and their drivers**
- **Local Microcontroller**
- **SMA connectors for input/output pulses**
- **Parallel cable connectors for DC signals**
- **Special Connectors**
  - Mechanical support for daughter boards
  - 2 sets of 25 signals
    (allows grouping of daughter boards)
  - Power for relays and electronics

ESD Pulse Delivery With Full DC Parametric Analysis

ESD Pulser

SMU / Test

1

MUX

25

SW

25

Keithley 707A Matrix

Custom Cable

25

Gnd SW and/or Pass Thru SW

25

Agilent 4156 Analyzer

Identifying major matrix modules – MUX, Ground SW and Pass Thru, Pin SW

Kelvin Sensing

- 2 Daughter Boards Allow AC Kelvin Sensing

Pulse Sense

Test 1

1

MUX

25

SW

Two sets of probe pads required on TEG structure

25

25

Ground Sense

Test 2

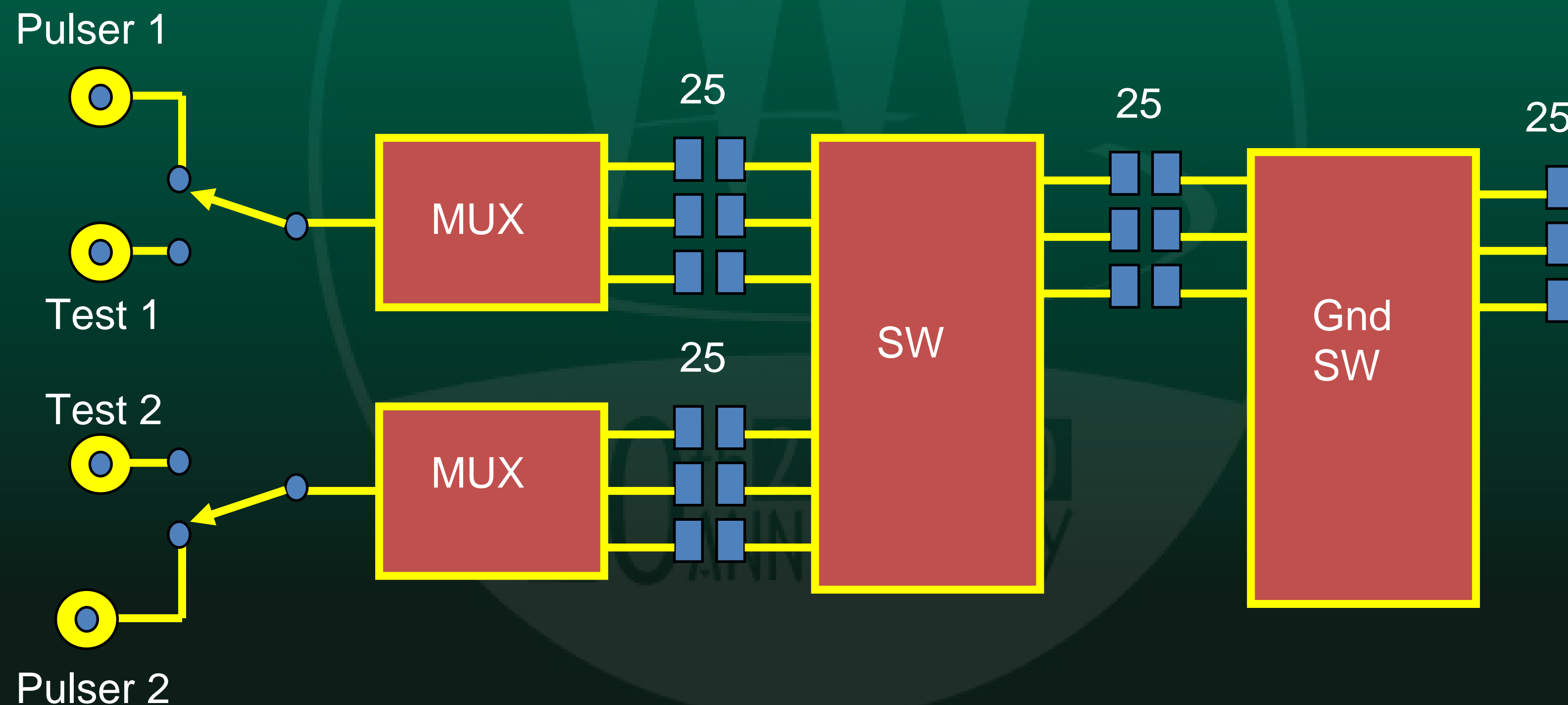
1

MUX

25

Expanding Auxiliary Pulsers

- **Additional pairs of SW and MUX boards allow expanding the number of pulsers**



Genus Modular Matrix Boards

- Transistor PIV example with synchronized gate/drain pulsing
- Add an additional matrix board for AC Kelvin sensing on drain

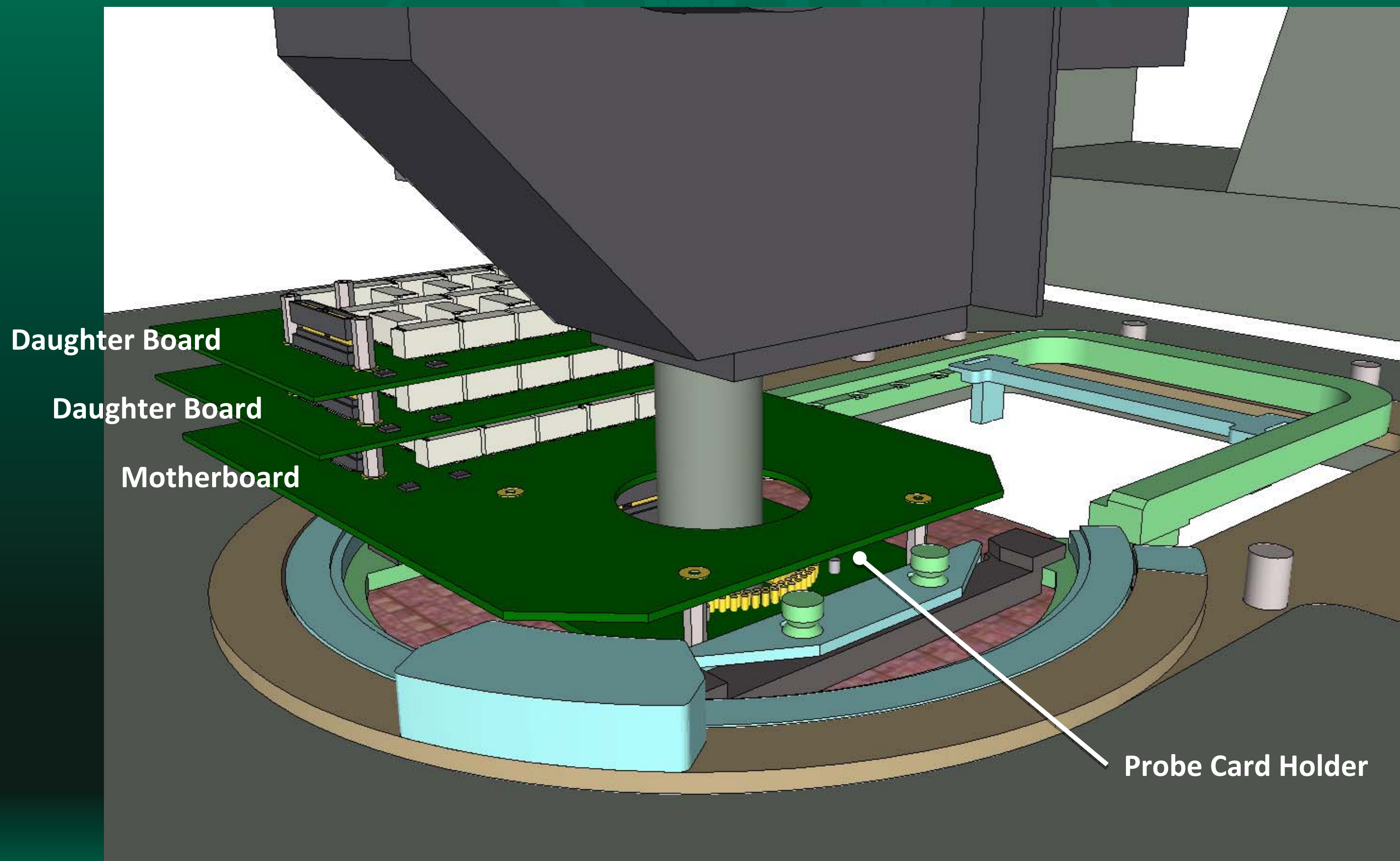
1 GHz SMA

Gate, Drain HF-PIV
Expanded to 20 probes

Gate Channel
Drain Channel
Control Board

Genus Modular Matrix Boards

- View showing how the boards stack on top of each other



Genus Modular Matrix Boards

- View showing donut probe card mounted in card holder

3D-CAD drawings by Google Sketchup

Standard C60
Donut Probe Card

Software

- **Genus application SW is developed in Microsoft C#**
- **Can be integrated with Microsoft Languages**
  - C++
  - Visual Basic
  - .NET Framework languages
- **GTS supports popular parametric test shells**
  - Prober control suites such as Cascade Nucleus and Suss Prober Bench
  - Parametric test productivity suites such as Metrics ICV, Keithley ACS, and Agilent Easy Expert
  - Customer’s legacy parametric test SW platforms

Conclusions

- **Scribeline parametric test is evolving toward HF PIV**
  – Many of these tests are not automated for full TEG testing
- **A probe card with integrated and modular switching matrices can address most of the HF PIV challenges**
  – GENUS is a very flexible "next generation" probing system
  – The modular design allows hundreds of configurations
  – Configure motherboards to meet current expected needs
  – Add daughter boards as applications grow