

Getting Started with ADS & MMIC Designs

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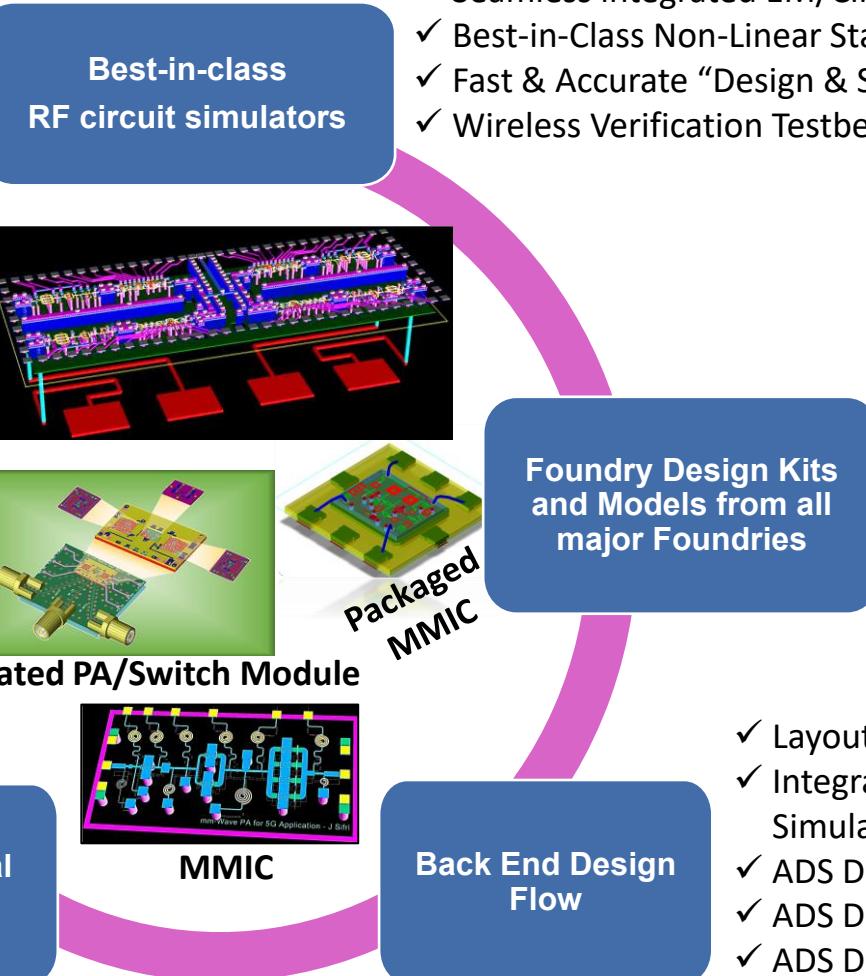
Keysight MMIC Solution

From Transistors to MMIC's to Modules

- ✓ Create Robust MMIC Designs with best-in-class tools
- ✓ Statistical Design Tools (including DOE)
- ✓ Non-Linear X-parameters modeling
- ✓ Cloud HPC
- ✓ New RF Circuit Simulation Professional (Nexus)

- ✓ Integrated Planar and 3D EM/Circuit Co-Simulation with RFPro
- ✓ Momentum Faster Gen2
- ✓ Near and Far Field Plots
- ✓ EM with Circuit Excitation
- ✓ Cloud HPC
- ✓ New Gen2 Mesher with speed and accuracy
- ✓ New High Freq Feed Types & Calibrated Ports

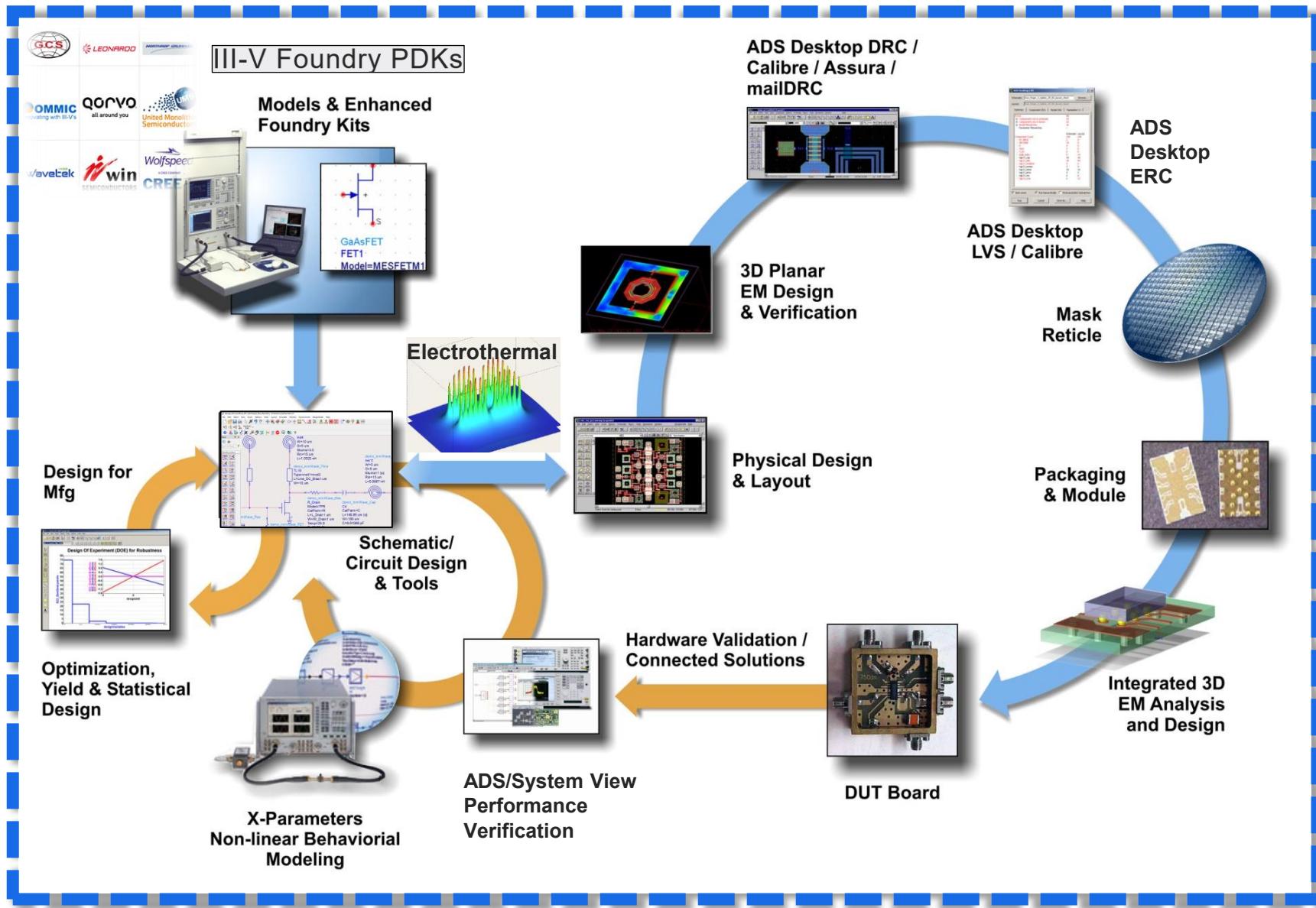
- ✓ Electrothermal effect at chip and package/module levels
- ✓ Layout Thermal Floor-Planning
- ✓ Improved Dynamic Model Generation & Reuse
- ✓ Many foundry PDK's are Electrothermally enabled



- ✓ Seamless integrated EM/Circuit Co-Simulation
- ✓ Best-in-Class Non-Linear Stability Analysis / Winslow Probes
- ✓ Fast & Accurate "Design & Simulation with Modulation/EVM"
- ✓ Wireless Verification Testbenches (VTB) and Modulated Sources
- ✓ Design Kits from all major Foundries
 - ✓ Full Front-to-Back ADS PDKs
 - ✓ DRC / LVS with MMIC toolbar support
 - ✓ GaAs, GaN, InP, HEMT, PHEMT, etc.
- ✓ New Front-to-Back mm-Wave DemoKit with Electrothermal capability
- ✓ Layout / Electrothermal Simulation
- ✓ Integrated Planar and 3D EM/Circuit Co-Simulation with RFPro
- ✓ ADS Desktop and Third-Party DRC & LVS
- ✓ ADS Desktop LVS on Multi-Technology Modules
- ✓ ADS Desktop LVL
- ✓ ADS ERC Current Density
- ✓ 3DHI Smart Mount/Multi-technology for 3DHI Package/Module Assembly and Simulation

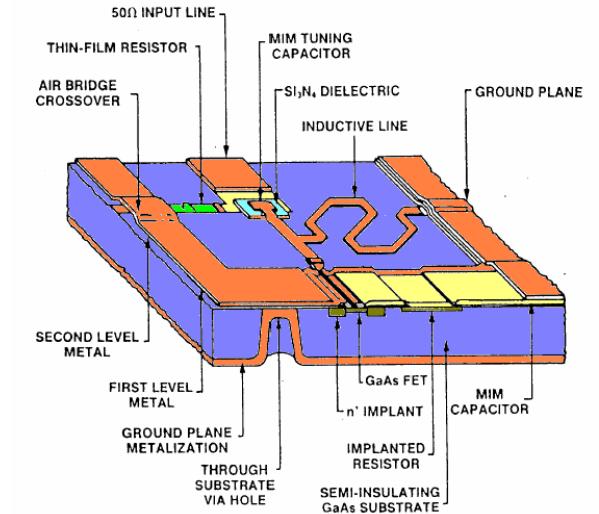
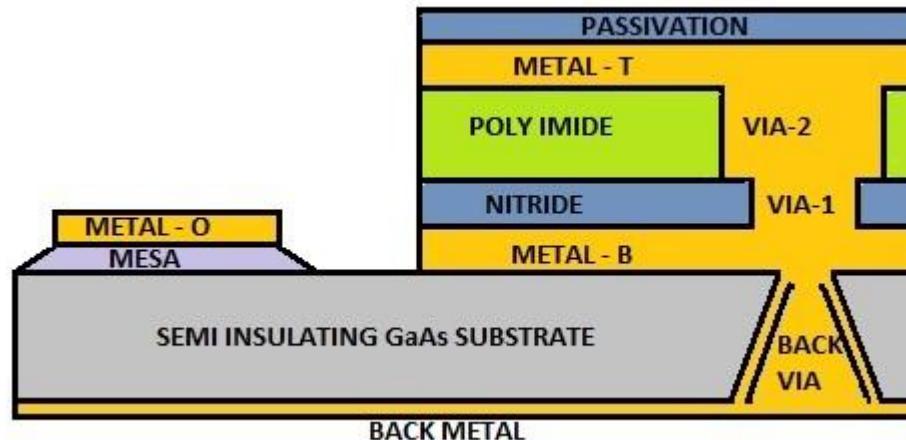
Keysight MMIC Solution

Front-to-Back MMIC Design Flow



What are MMICs?

- MMIC stands for Monolithic Microwave Integrated Circuits
- All the Microwave circuit elements are realized on a common substrate (ex: Si, SiGe, GaAs, GaAlAs..)
- Active devices are realized only on Mesa
- Metal O is deposited only on Mesa
- All the other layers are on Mesa & outside Mesa
- **Gate orientation is fixed by axis of Wafer** (for compound semiconductors)



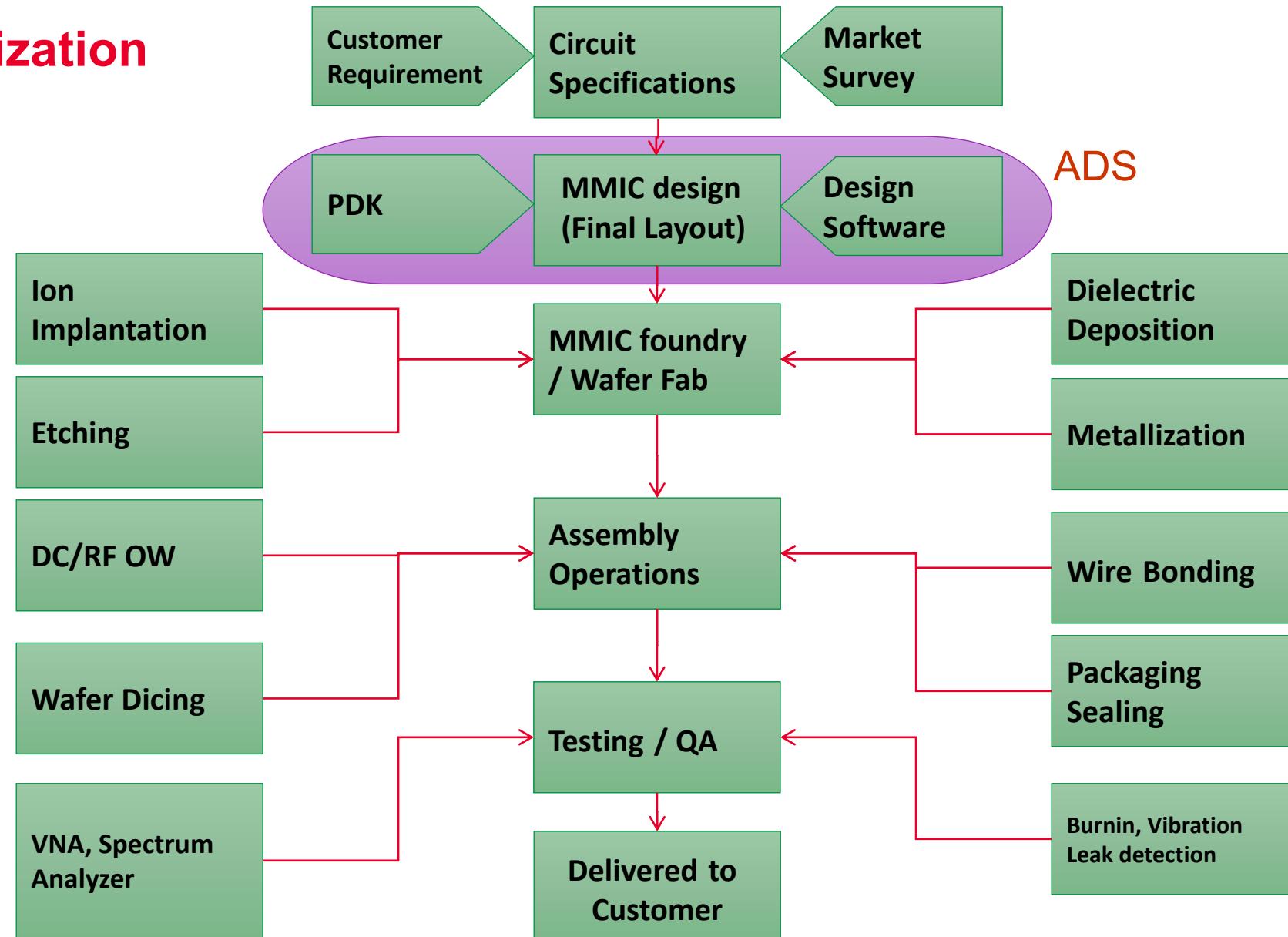
RF Board

- These are bulky, as the devices like- FETs, inductors, resistors, capacitors are externally bonded onto a substrate like Alumina/PTFE.
- Fabrication is cheap, as it does not call for sophisticated clean rooms and equipment.
- These can be tweaked. If a device does not work, it can always be replaced.
- Can be used for high power applications, as heat dissipation can be taken care by properly designing a heat sink.
- Large volume production is difficult, as each circuit needs to be assembled. Hence these are generally more expensive.

MMICs

- MMICs are very compact since they are realized on a single substrate. Typical size = 3 x 3 mm.
- Fabrication process needs high class clean rooms, expensive process equipment, sophisticated monitoring. Hence, first time success is a must. This calls for extensive design methodology, reliable element models, proven software package etc.
- Once fabricated, MMICs cannot be “tweaked”. A mistake in the design causes rejection of the entire batch.
- Used in Low power applications due to their compact size and poor heat dissipation.
- Very large volume production is possible. All the components resulting from a single process batch will track. Due to the large volumes, they are cheap.

MMIC Realization



Building blocks for MMIC Design

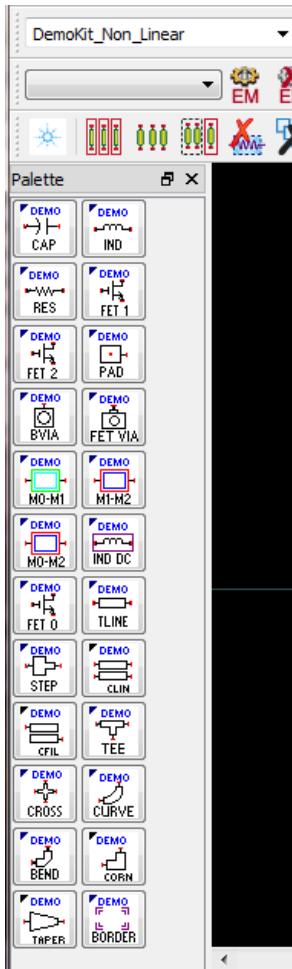
Active Elements	Passive Elements
<ul style="list-style-type: none">➤ Metal Semiconductor FET (MESFET)➤ High Electron Mobility Transistors (pHEMT, mHEMT)➤ Hetero Junction Bipolar Transistor (HBT)	<ul style="list-style-type: none">➤ Planar Spiral Inductors➤ Metal-Insulator-Metal (MIM) capacitors➤ NiCr and Mesa resistors➤ Metal and Dielectric vias➤ Transmission Lines, bends, tees etc.➤ Bond Pads➤ Ground vias

Models for every MMIC element should be available for accurate simulation of circuits.

ADS MMIC Demo Kit: Non-Linear and mmW Demo Kits

- Keysight provides MESFET based MMIC demo kit for design practice which we can be used by new designers. This demo PDK is very similar to the PDKs which users will obtain from various foundries so steps performed while using the Demo Kit can be applied easily for the real design work.
- MMICs can be designed up to 18 GHz using Non-Linear demo kit and mmW kit can be used for higher mmW frequencies.
- Planar square spirals, MIM capacitors, NiCr and Mesa resistors, TLINEs & TLINE elements, vias, bond pads which can be fully synchronized between Schematic and Layout.
- EM simulations of these elements closely match with schematic models.

MMIC Demo Kit Elements



Inductors: Four Types. 5/5, 10/5, 10/10 & 15/10. Max inductance is 7.4nH

Capacitors: Two Types. M0-M1 (up to 59pF) & M0-M2 (up to 2.3pF)

Resistors: Two Types. Mesa (250ohm/sq) & NiCr (50ohm/sq). Max resistance 10Kohm.

MESFETs: Two Types. Low noise and medium power. No. of fingers 2 to 8, gate width can vary from 50 to 300 um.

Bond pad, Back via and FET ground: Fixed in size.

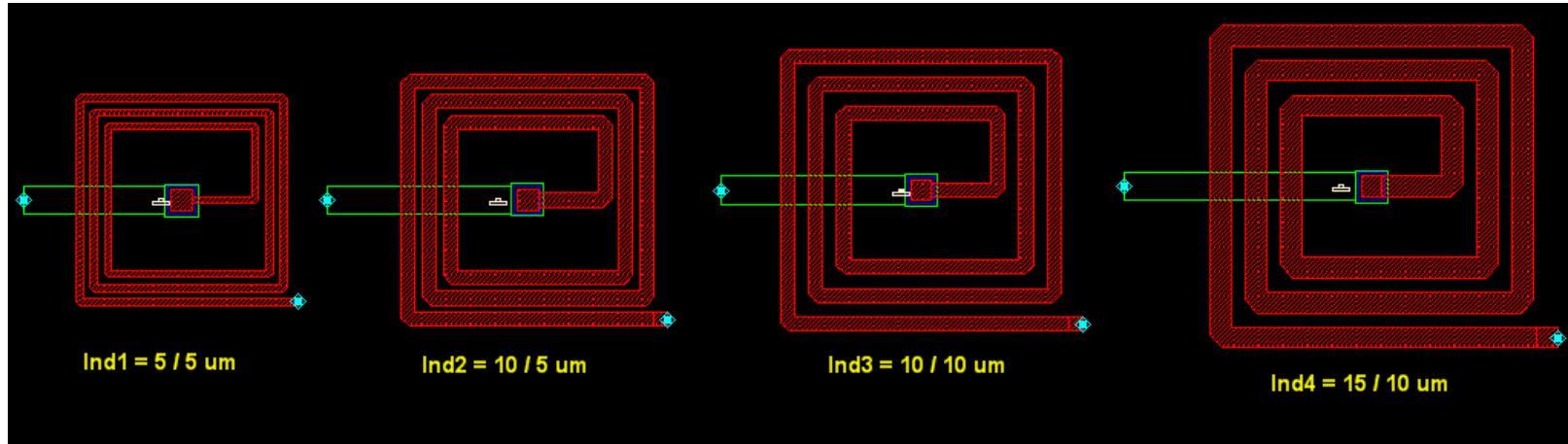
TLINs: Four Types. M0, M1, M2 and (M1+M2)

TLINE elements: Bends, Tee, Cross etc.

Demo Kit tool bar – for easy editing!

MMIC Demo Kit elements

Inductors: Four Types. 5/5, 10/5, 10/10 & 15/10. Number of turns are varied in steps of 0.25. Hence inductance varies in discrete steps.

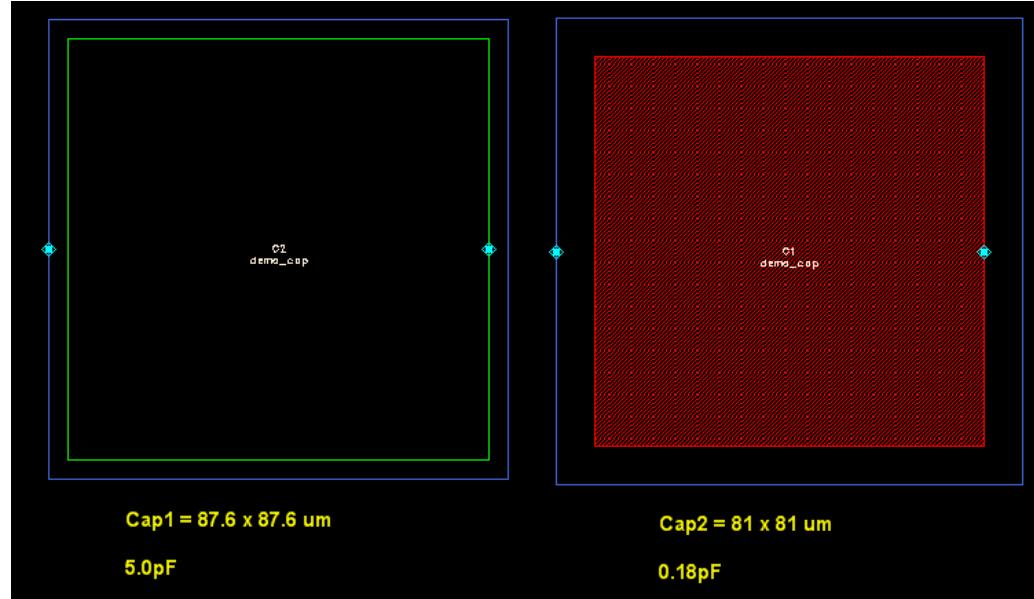


To get small or incremental inductance, a meander line can be used (and tuned later) after the discrete spiral inductors. The max. number of turns (& hence inductance) vary with each type. Use wide inductors for carrying high currents. **Refer to foundry manual for maximum current ratings.**

Some foundries offer other types of inductors - circular spiral and stacked inductors etc as well and those be used for design purposes in pretty similar manner.

MMIC Demo Kit elements

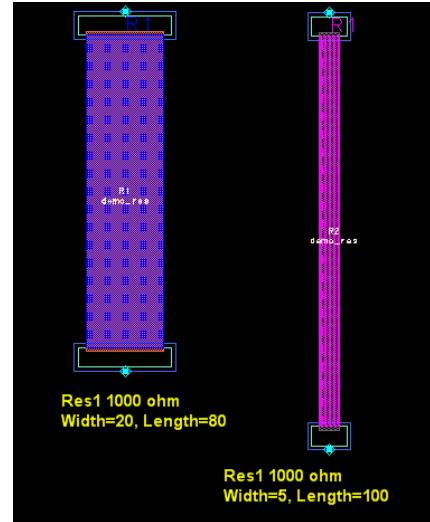
Capacitors: Two Types. M0-M1 (up to 59pF) & M0-M2 (up to 2.3pF).



Cap1 has one dielectric while Cap2 has two dielectrics between top and bottom plates.
Capacitors are chosen depending on the application (like DC bias, RF bypass, matching etc).

MMIC Demo Kit elements

Resistors: Two Types. Mesa (250ohm/sq) & NiCr (50ohm/sq).
Max resistance 10Kohm.



Calculation of resistance:

Mesa Resistor: if $w=20$ and $L=80$, no. of squares = $80/20 = 4$

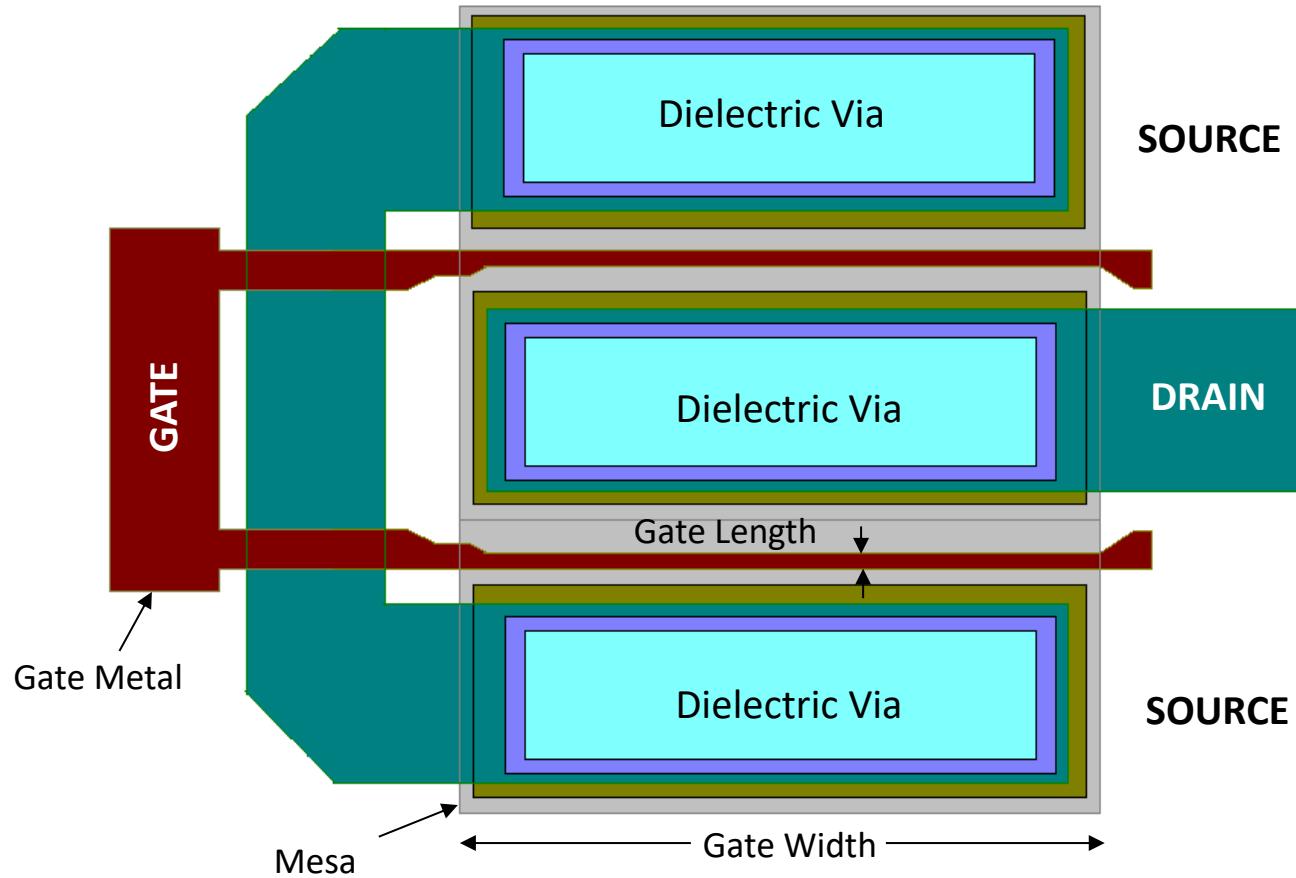
$$\text{Resistance} = 250 \text{ ohms/sq} \times \text{no. of squares} = 250 \times 4 = 1000 \text{ ohm}$$

NiCr Resistor: if $w=5$ and $L=100$, no. of squares = $100/5=20$

$$\text{Resistance} = 50 \text{ ohms/sq} \times \text{no. of squares} = 50 \times 20 = 1000 \text{ ohm}$$

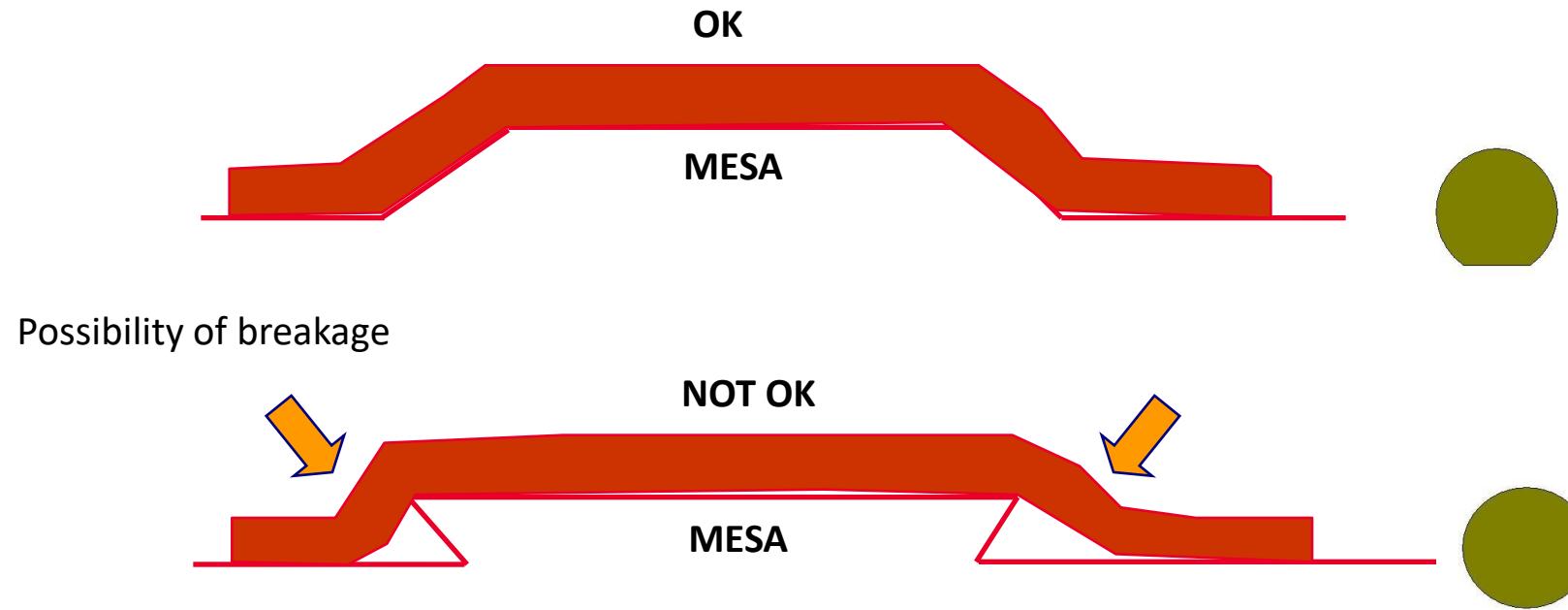
User needs to specify Resistance required and width. Length is automatically calculated. Width is chosen based on I_{max} .

MMIC Demo Kit elements - MESFET



2x100 MESFET = 2 gate fingers, 100um Gate width (Note: gate length is fixed by the foundry and cannot be varied by the designer)

Why Gate Orientation is important?

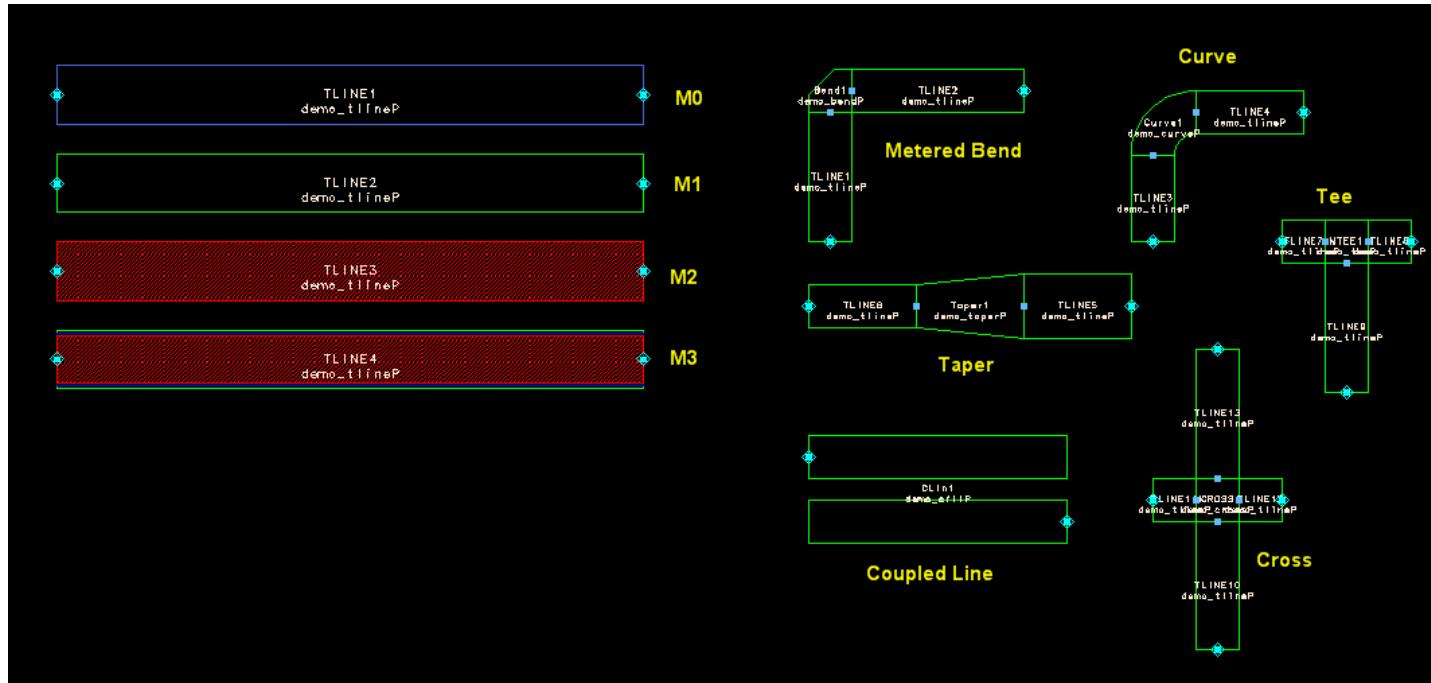


GaAs is Anisotropic medium; hence etching is different in X & Y directions.
Observe a 'cut' on the wafer to denote Gate orientation

MMIC Demo Kit Elements

TLINs: Four Types. M0, M1, M2 and (M1+M2)

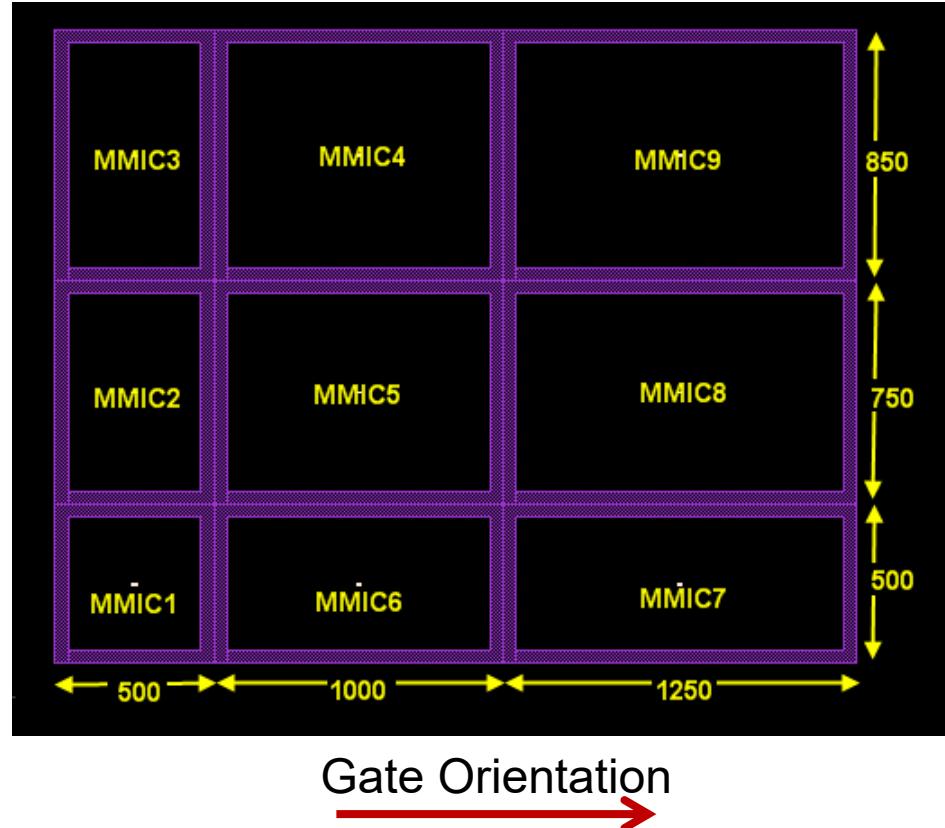
TLINE discontinuities: Bends, Tee, Cross etc.



TLINEs with Thick metal (M1+M2) are used in applications demanding high current. Other microstrip discontinuities are available in the Demo kit. These offer finite inductance, though small.

MMIC Design Considerations

Tiling of various MMIC designs – Gate orientation.



It is a good practice to refer Foundry manual & familiarize yourself with the PDK components before proceeding with MMIC design to have an idea on the substrate stack up, Metal layers, GDS numbers etc.