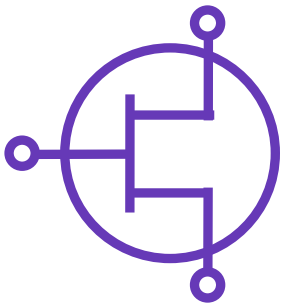
GaN HEMT MODEL

HMT-QOR-TGF2977-SM-001

Model Features

- Broadband (DC to 12 GHz)
- Large-signal model (Angelov-based)
- Valid for Class AB Operation.
- Measurement Validations using Qorvo data:
  - Multi-biased S-parameters (25C)
  - Single Tone Power and Load Pull (6, 8, 9, 10 & 11 GHz)
- Advanced model feature: enabling intrinsic I-V sensing

This model was last revised in Modelithics' Qorvo GaN Library ver. 1.7.0



HMT-QOR-TGF2977-SM-001
Qorvo TGF2977-SM
GaN on SiC HEMT

Model Description

The HMT-QOR-TGF2977-SM-001 is a non-linear model for the Qorvo TGF2977-SM in a 3x3mm QFN package, a discrete 5W (P3dB) GaN on SiC HEMT using Qorvo's TQGaN25 process (additional information is available at www.qorvo.com). The model is based on the extraction of a customized Angelov non-linear model that is validated against the following Qorvo measurement data: S-parameters & large signal load pull in the 6-11 GHz band. Model validated under high drain bias operation.

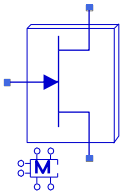
Technical Notes

- Model is optimized for 32V, 25mA operation.
- Model Parameters:
  - **Temperature:** represents the backside ambient temperature, validated at 25C only.
  - **Self_heat_factor:** scaling factor for the electrothermal model (range from 0 to 1), 0= self-heating is turned off, 1 (default)= self-heating is fully turned on, and a value of 0.1 is representative of 10% thermal duty cycle.
- Device was characterized in a test fixture with 2.25 mm line width (Zo=15 Ohm). Reference planes are 3 mm apart. Test Fixture has a ground paddle with 10mil vias for grounding the source.
- Board used is a 8-mil Rogers 4003C with a dielectric constant of 3.66.

Model Simulation Settings

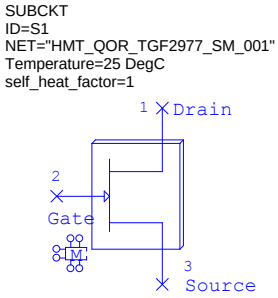
- **S-Parameters:** self_heat_factor: 1 for CW bias, Temperature=25C
- **Load Pull Validations and Single-tone Power Sweeps:** self_heat_factor: 0.1 for 10% thermal duty cycle; Temperature: 25C.

Model Representation



HMT_QOR_TGF2977_SM_001
X5
self_heat_factor=1
Temperature=25

Keysight ADS

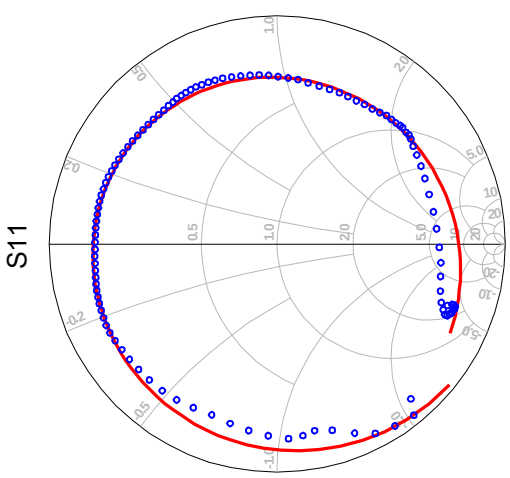


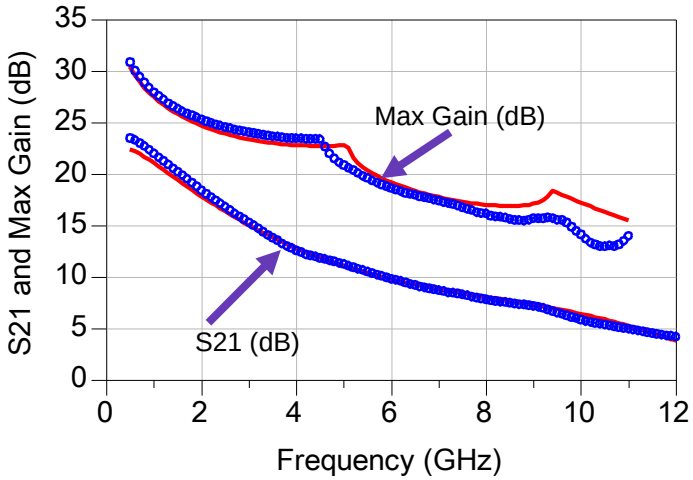
NI AWR

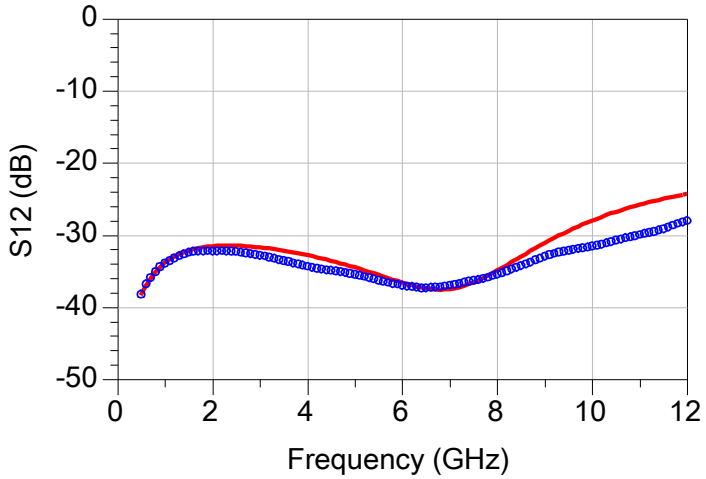
Reference Planes

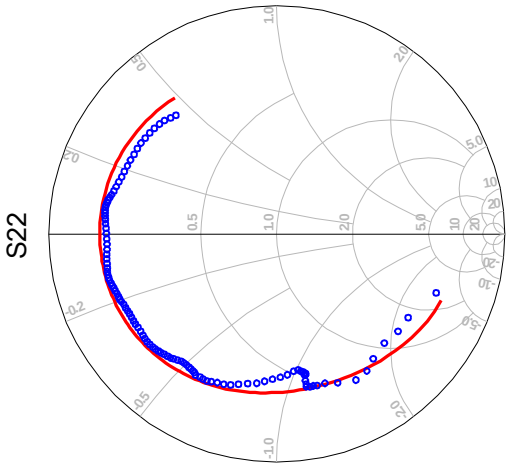
Model and Measurement Reference Planes at package edge

S-Parameters Model vs. Measured: VDS = 32V, IDS = 25mA, 25C









Legend: Red Solid lines - Model data, O Symbols - Measured data
Simulated at 25C with the frequency range from 0.5 – 12GHz. 50Ω Smith Charts

Measured data provided by Qorvo.

Model and Measurement
Reference Planes

Load Pull Validation:

Frequency = 6GHz, VDS = 32V, IDS = 25mA,

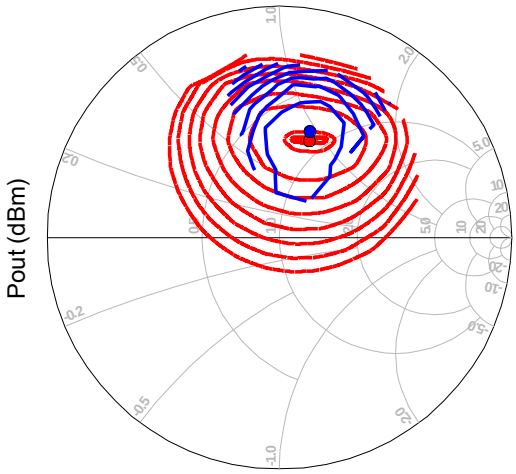
3dB Gain Compression, Z0 = 15Ω Center, 25C

Model and Measurement Reference Planes

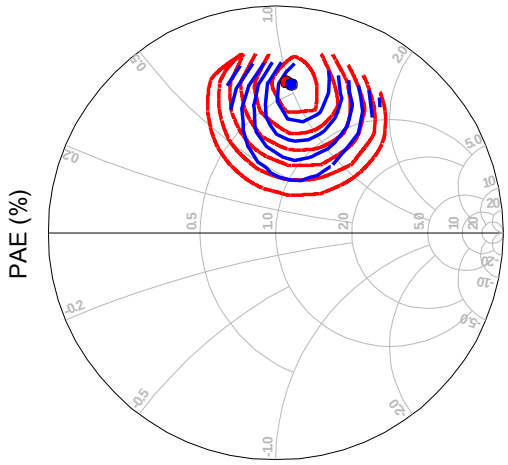
Test Bench Impedances (Ohms):

ZS = 6.603 - j*22.505
ZS2 = 53.323 + j*35.822
ZS3 = 14.102 + j*15.890
ZLoad2 = 7.078 - j*9.984
ZLoad3 = 19.537 + j*17.097

Power Tuning (0.5dB contour step)



Efficiency Tuning (5% contour step)



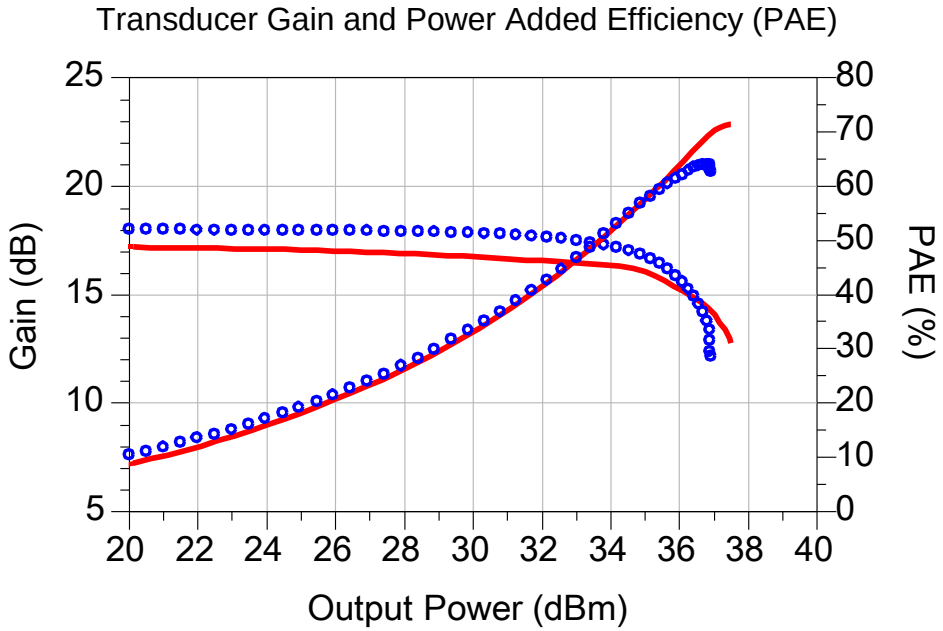
Legend: Red Solid lines – Model, Blue Solid lines – Measured.

Pulsed Biased conditions for measurements: duty cycle = 10% with pulse length = 500us.

Load Pull Summary	Max Power Load Impedance (Ohms)	Max Power Value (dBm)	Max PAE Load Impedance (Ohms)	Max PAE Value (%)
Measured	12.052 + j*14.213	37.3	6.531 + j*15.083	63.0
Model	14.148 + j*15.190	38.1	6.188 + j*14.770	68.2

Measured data provided by Qorvo.

Single Tone Power Sweep: Frequency = 6GHz
VDS = 32V, IDS = 25mA, 25C
Load Condition: PAE Tuned

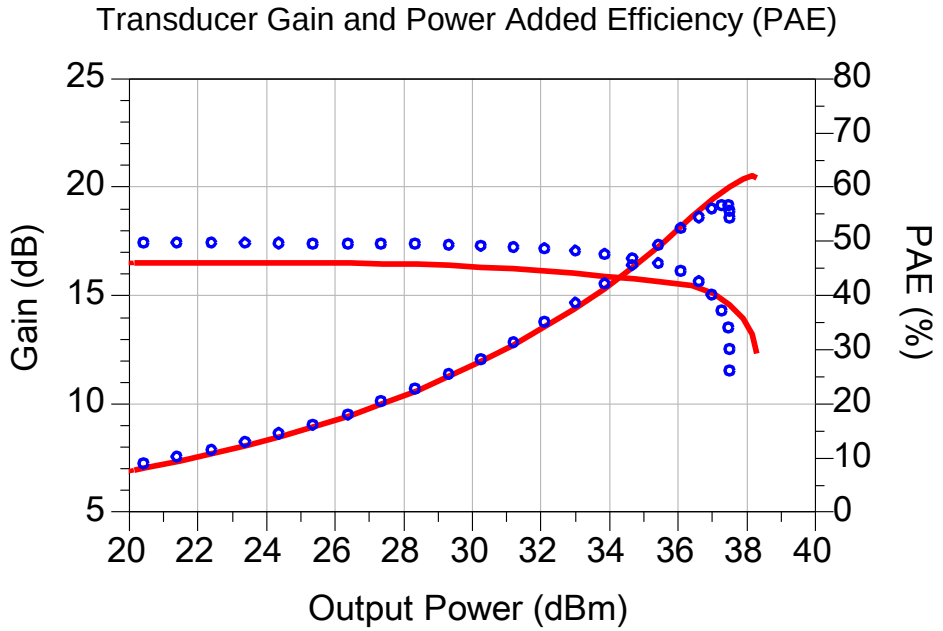


Legend: Red Solid lines - Model data, O Symbols - Measured data

Load Condition: PAE Tuned
Test Bench Impedances (Ohms):

ZS = 6.601 - j*22.501
ZS2 = 53.125 + j*35.264
ZS3 = 14.159 + j*15.797
ZLoad = 7.652 + j*16.683
ZLoad2 = 6.680 - j*15.550
ZLoad3 = 8.378 + j*14.389

Load Condition: Power Tuned



Legend: Red Solid lines - Model data, O Symbols - Measured data

Load Condition: Power Tuned
Test Bench Impedances (Ohms):

ZS = 6.601 - j*22.501
ZS2 = 53.125 + j*35.264
ZS3 = 14.159 + j*15.797
ZLoad = 12.052 + j*14.213
ZLoad2 = 7.087 - j*9.984
ZLoad3 = 19.537 + j*17.097

Model and Measurement Reference Planes

Pulsed Biased conditions for measurements: duty cycle = 10% with pulse length = 500us.

Measured data provided by Qorvo.

Load Pull Validation:

Frequency = 8GHz, VDS = 32V, IDS = 25mA,

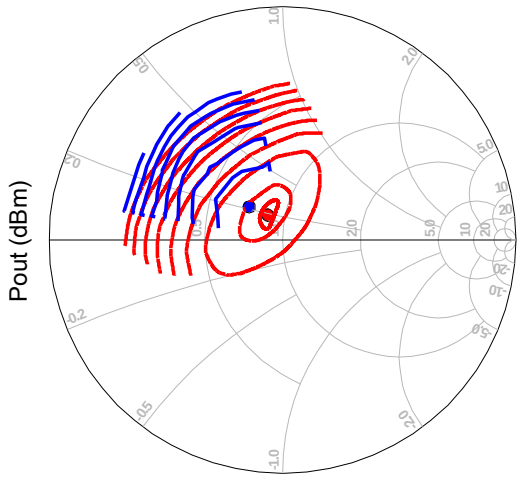
3dB Gain Compression, Z0 = 15Ω Center, 25C

Model and Measurement Reference Planes

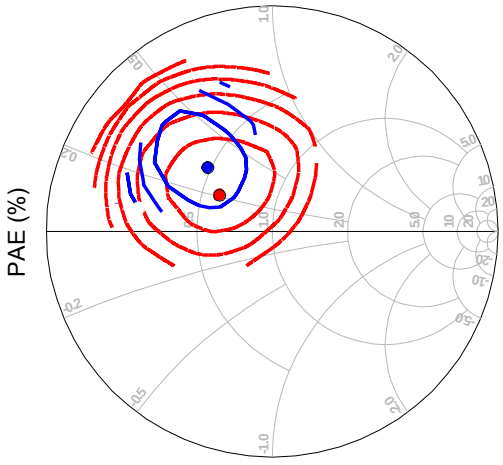
Test Bench Impedances (Ohms):

ZS = 22.505 - j*40.728
ZS2 = 10.506 + j*20.031
ZS3 = 9.522 - j*6.196
ZLoad2 = 21.209 - j*3.278
ZLoad3 = 10.551 - j*1.978

Power Tuning (0.5dB contour step)



Efficiency Tuning (5% contour step)



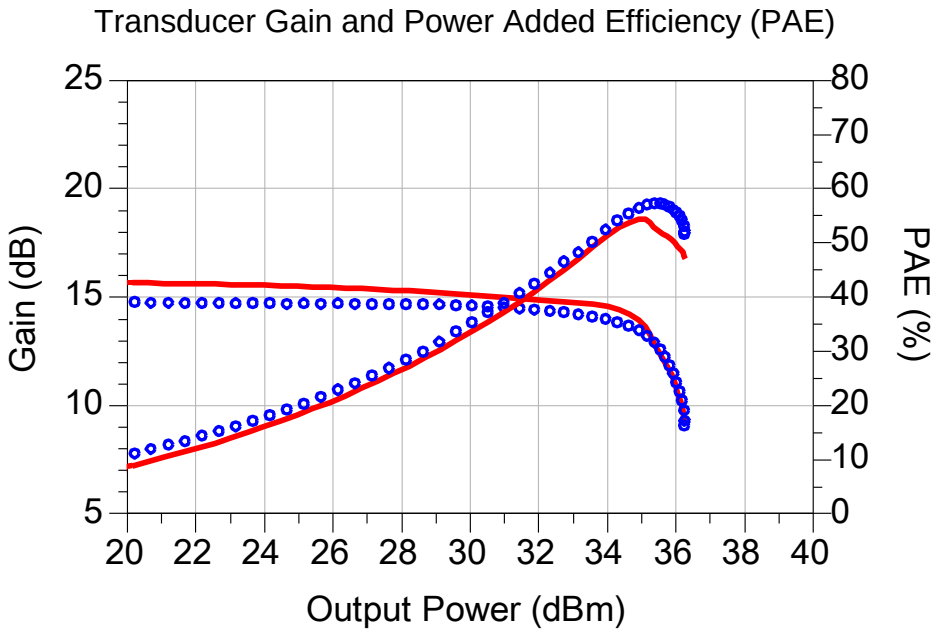
Legend: Red Solid lines – Model, Blue Solid lines – Measured.

Pulsed Biased conditions for measurements: duty cycle = 10% with pulse length = 500us.

Load Pull Summary	Max Power Load Impedance (Ohms)	Max Power Value (dBm)	Max PAE Load Impedance (Ohms)	Max PAE Value (%)
Measured	10.870 + j*3.226	37.2	7.285 + j*4.923	56.1
Model	13.394 + j*4.072	37.6	8.720 + j*2.824	54.0

Measured data provided by Qorvo.

Single Tone Power Sweep: Frequency = 8GHz
VDS = 32V, IDS = 25mA, 25C
Load Condition: PAE Tuned

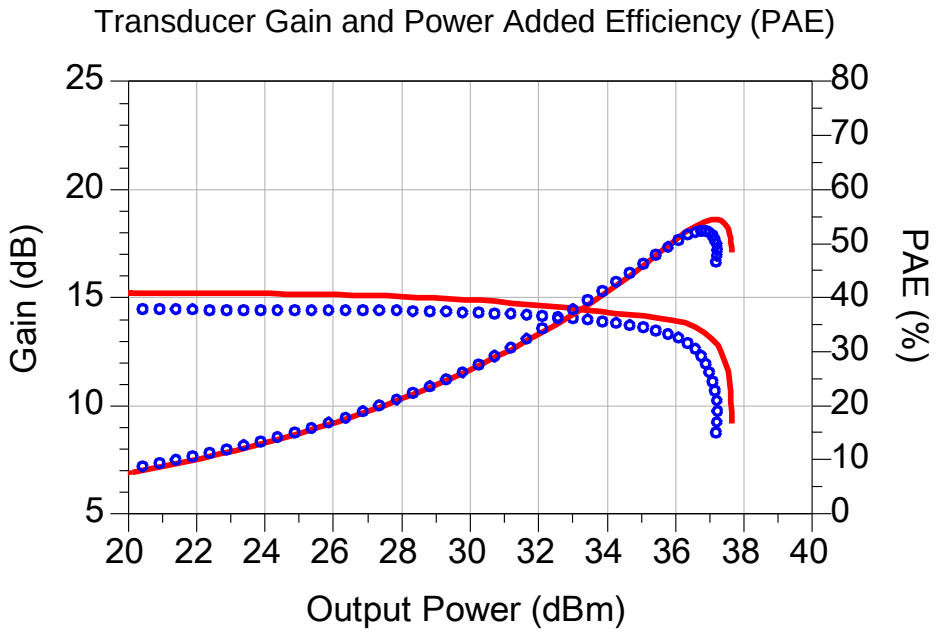


Legend: Red Solid lines - Model data, O Symbols - Measured data

Load Condition: PAE Tuned
Test Bench Impedances (Ohms):

ZS = 22.505 - j*40.728
ZS2 = 10.506 + j*20.031
ZS3 = 9.522 - j*6.196
ZLoad = 5.920 + j*5.233
ZLoad2 = 31.876 + j*6.631
ZLoad3 = 14.148 + j*2.114

Load Condition: Power Tuned



Legend: Red Solid lines - Model data, O Symbols - Measured data

Model and Measurement Reference Planes

Load Condition: Power Tuned
Test Bench Impedances (Ohms):

ZS = 22.505 - j*40.728
ZS2 = 10.506 + j*20.031
ZS3 = 9.522 - j*6.196
ZLoad = 10.514 + j*3.633
ZLoad2 = 20.252 + j*0.054
ZLoad3 = 10.629 - j*1.501

Pulsed Biased conditions for measurements: duty cycle = 10% with pulse length = 500us.

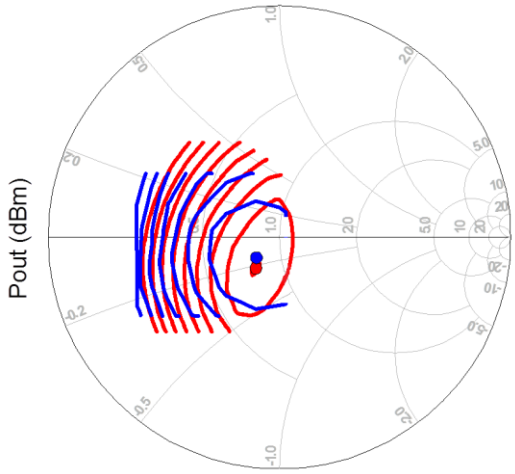
Measured data provided by Qorvo.

Load Pull Validation:

Frequency = 9GHz, VDS = 32V, IDS = 25mA,

3dB Gain Compression, Z0 = 15Ω Center, 25C

Power Tuning (0.5dB contour step)

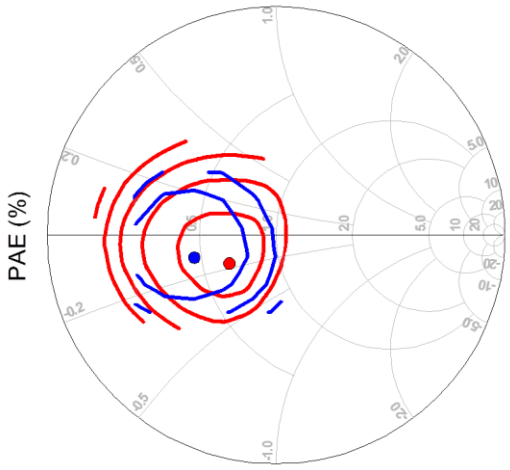


Model and Measurement Reference Planes

Test Bench Impedances (Ohms):

ZS = 27.849 - j*42.543
ZS2 = 31.385 + j*22.690
ZS3 = 10.806 + j*0.743
ZLoad2 = 15.190 + j*11.058
ZLoad3 = 10.421 + j*3.104

Efficiency Tuning (5% contour step)



Legend: Red Solid lines – Model, Blue Solid lines – Measured.

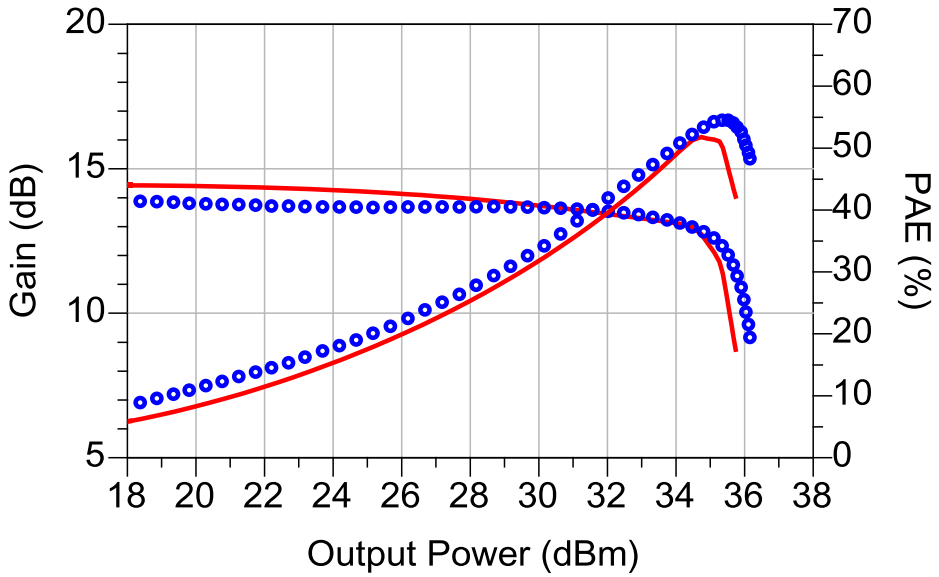
Pulsed Biased conditions for measurements: duty cycle = 10% with pulse length = 500us.

Load Pull Summary	Max Power Load Impedance (Ohms)	Max Power Value (dBm)	Max PAE Load Impedance (Ohms)	Max PAE Value (%)
Measured	12.036 - j*2.288	36.8	6.972 - j*1.522	51.5
Model	11.584 - j*3.261	37.5	9.541 - j*2.772	52.9

Measured data provided by Qorvo.

Single Tone Power Sweep: Frequency = 9GHz
VDS = 32V, IDS = 25mA, 25C
Load Condition: PAE Tuned

Transducer Gain and Power Added Efficiency (PAE)



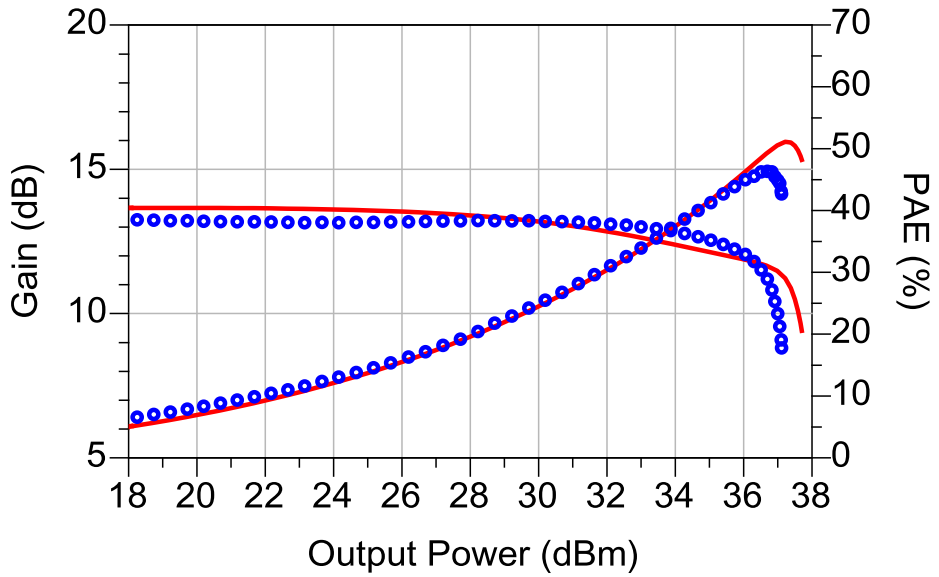
Legend: Red Solid lines - Model data, O Symbols - Measured data

Load Condition: PAE Tuned
Test Bench Impedances (Ohms):

ZS = 27.814 - j*42.939
ZS2 = 26.664 + j*23.160
ZS3 = 11.237 + j*0.857
ZLoad = 6.232 - j*0.637
ZLoad2 = 12.895 + j*1.778
ZLoad3 = 9.654 + j*4.164

Load Condition: Power Tuned

Transducer Gain and Power Added Efficiency (PAE)



Legend: Red Solid lines - Model data, O Symbols - Measured data

Load Condition: Power Tuned
Test Bench Impedances (Ohms):

ZS = 27.814 - j*42.939
ZS2 = 26.664 + j*23.160
ZS3 = 11.237 + j*0.857
ZLoad = 12.105 - j*2.121
ZLoad2 = 14.495 + j*5.967
ZLoad3 = 12.016 + j*2.649

Model and Measurement Reference Planes

Pulsed Biased conditions for measurements: duty cycle = 10% with pulse length = 500us.

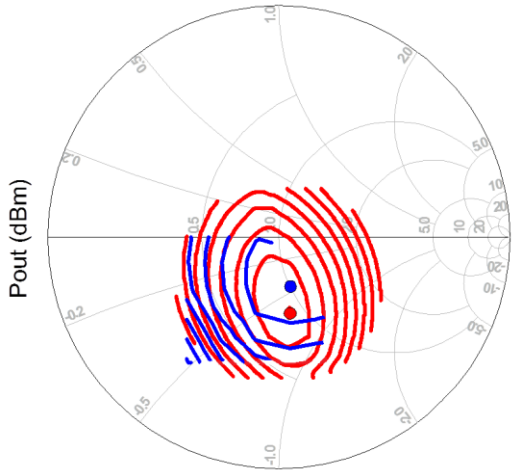
Measured data provided by Qorvo.

Load Pull Validation:

Frequency = 10GHz, VDS = 32V, IDS = 25mA,

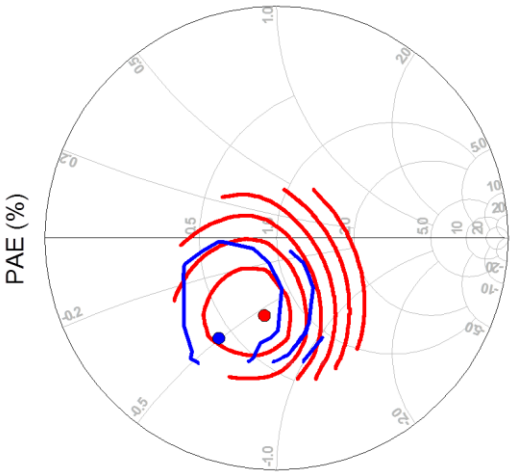
3dB Gain Compression, Z0 = 15Ω Center, 25C

Power Tuning (0.5dB contour step)



Model and Measurement Reference Planes

Efficiency Tuning (5% contour step)



Test Bench Impedances (Ohms):

ZS = 41.999 - j*41.301
ZS2 = 13.117 + j*18.138
ZS3 = 23.889 - j*11.769
ZLoad2 = 8.666 + j*1.660
ZLoad3 = 27.257 - j*8.148

Legend: Red Solid lines – Model, Blue Solid lines – Measured.

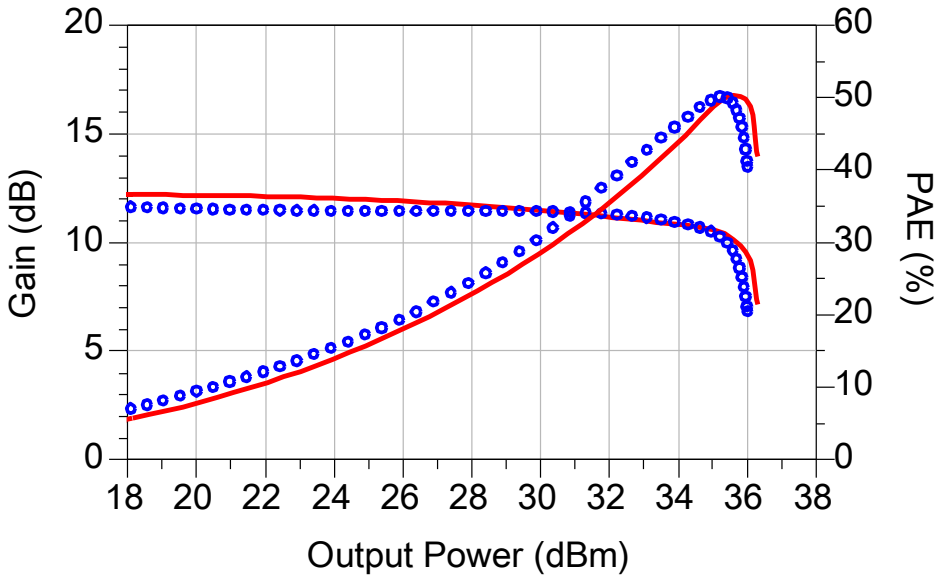
Pulsed Biased conditions for measurements: duty cycle = 10% with pulse length = 500us.

Load Pull Summary	Max Power Load Impedance (Ohms)	Max Power Value (dBm)	Max PAE Load Impedance (Ohms)	Max PAE Value (%)
Measured	15.039 - j*6.807	36.9	6.444 - j*7.417	46.2
Model	13.007 - j*9.892	37.5	10.960 - j*8.335	53.8

Measured data provided by Qorvo.

Single Tone Power Sweep: Frequency = 10GHz
VDS = 32V, IDS = 25mA, 25C
Load Condition: PAE Tuned

Transducer Gain and Power Added Efficiency (PAE)



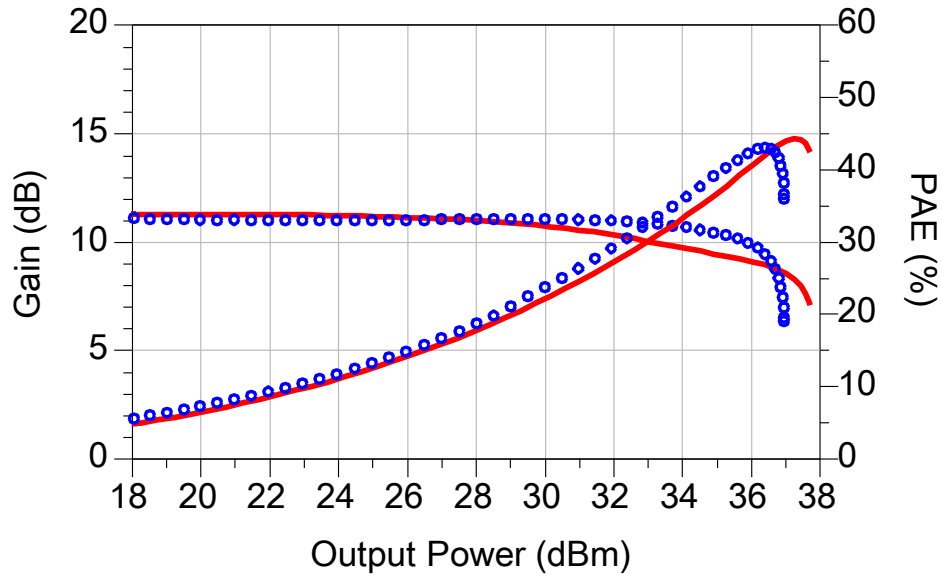
Legend: Red Solid lines - Model data, O Symbols - Measured data

Load Condition: PAE Tuned
Test Bench Impedances (Ohms):

ZS = 41.999 - j*41.301
ZS2 = 13.117 + j*18.138
ZS3 = 23.889 - j*11.769
ZLoad = 8.190 - j*5.791
ZLoad2 = 9.007 + j*1.621
ZLoad3 = 24.355 - j*10.916

Load Condition: Power Tuned

Transducer Gain and Power Added Efficiency (PAE)



Legend: Red Solid lines - Model data, O Symbols - Measured data

Model and Measurement Reference Planes

Load Condition: Power Tuned
Test Bench Impedances (Ohms):

ZS = 41.999 - j*41.301
ZS2 = 13.117 + j*18.138
ZS3 = 23.889 - j*11.769
ZLoad = 15.316 - j*5.602
ZLoad2 = 7.616 + j*1.303
ZLoad3 = 32.332 - j*1.244

Pulsed Biased conditions for measurements: duty cycle = 10% with pulse length = 500us.

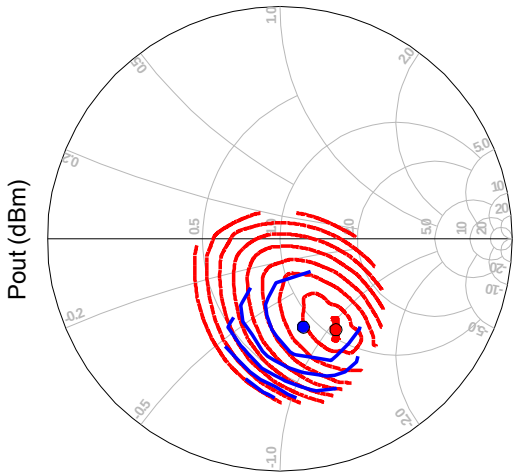
Measured data provided by Qorvo.

Load Pull Validation:

Frequency = 11GHz, VDS = 32V, IDS = 25mA,

3dB Gain Compression, Z0 = 15Ω Center, 25C

Power Tuning (0.5dB contour step)

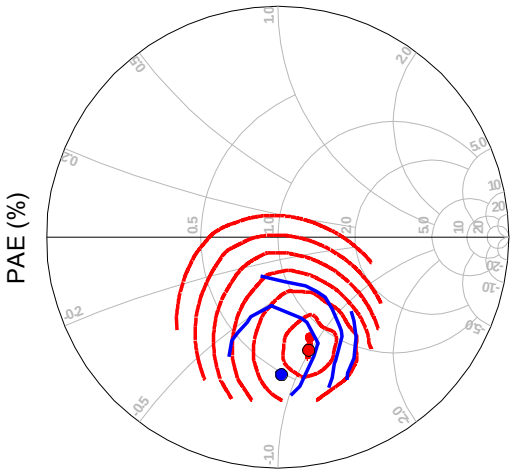


Model and Measurement Reference Planes

Test Bench Impedances (Ohms):

ZS = 75.810 - j*20.873
ZS2 = 11.987 + j*1.759
ZLoad2 = 10.707 + j*4.019

Efficiency Tuning (5% contour step)



Legend: Red Solid lines – Model, Blue Solid lines – Measured.

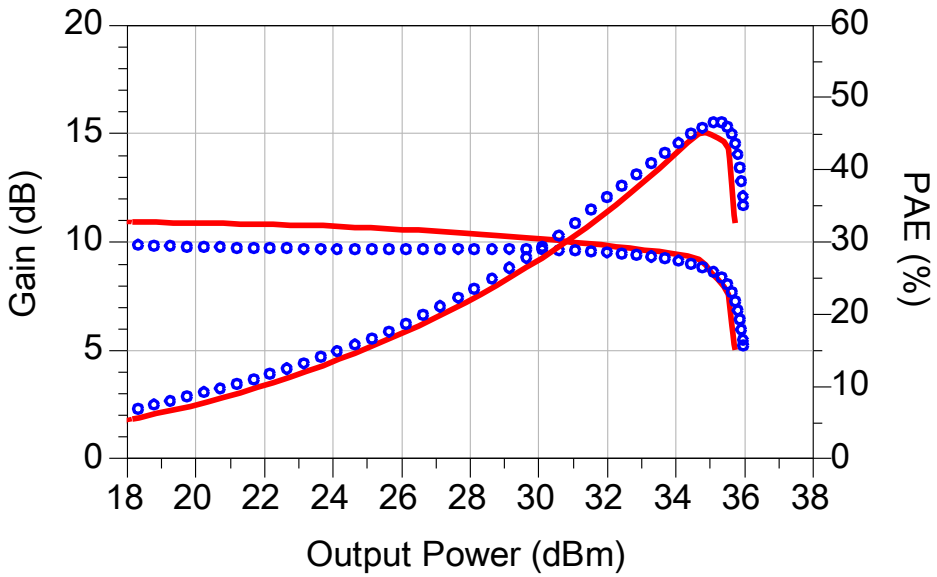
Pulsed Biased conditions for measurements: duty cycle = 10% with pulse length = 500us.

Load Pull Summary	Max Power Load Impedance (Ohms)	Max Power Value (dBm)	Max PAE Load Impedance (Ohms)	Max PAE Value (%)
Measured	13.306 - j*12.067	36.7	7.442 - j*13.558	43.0
Model	14.652 - j*16.986	37.4	12.798 - j*14.153	51.8

Measured data provided by Qorvo.

Single Tone Power Sweep: Frequency = 11GHz
VDS = 32V, IDS = 25mA, 25C
Load Condition: PAE Tuned

Transducer Gain and Power Added Efficiency (PAE)



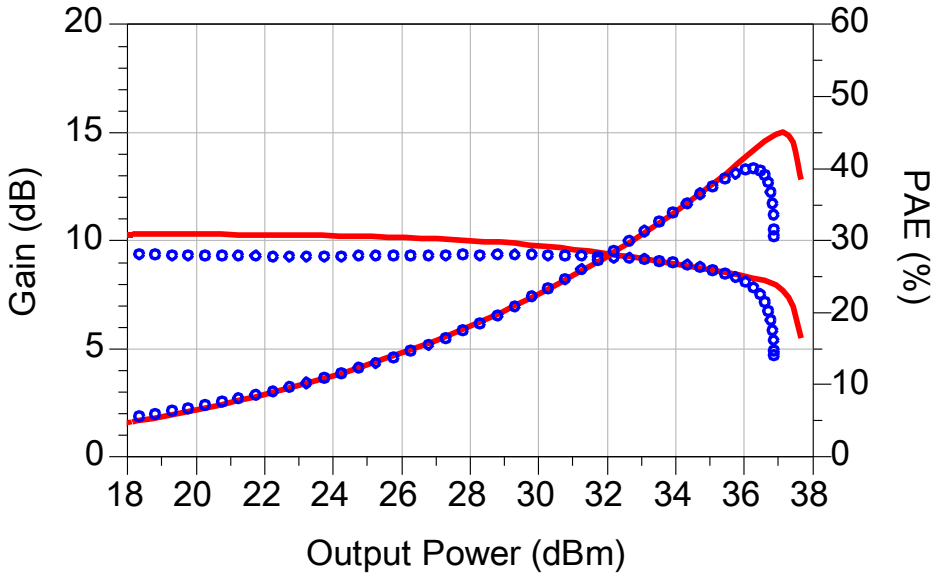
Legend: Red Solid lines - Model data, O Symbols - Measured data

Load Condition: PAE Tuned
Test Bench Impedances (Ohms):

ZS = 75.810 - j*20.873
ZS2 = 11.987 + j*1.759
ZLoad = 8.385 - j*12.153
ZLoad2 = 10.450 + j*4.786

Load Condition: Power Tuned

Transducer Gain and Power Added Efficiency (PAE)



Legend: Red Solid lines - Model data, O Symbols - Measured data

Model and Measurement Reference Planes

Load Condition: Power Tuned
Test Bench Impedances (Ohms):

ZS = 75.810 - j*20.873
ZS2 = 11.987 + j*1.759
ZLoad = 15.457 - j*12.426
ZLoad2 = 10.546 + j*3.514

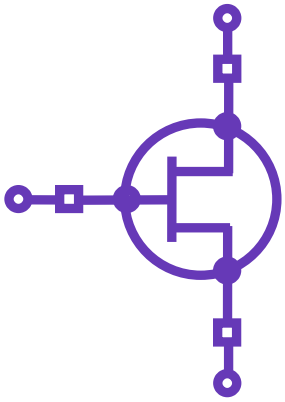
Pulsed Biased conditions for measurements: duty cycle = 10% with pulse length = 500us.

Measured data provided by Qorvo.

Advanced Model Features:

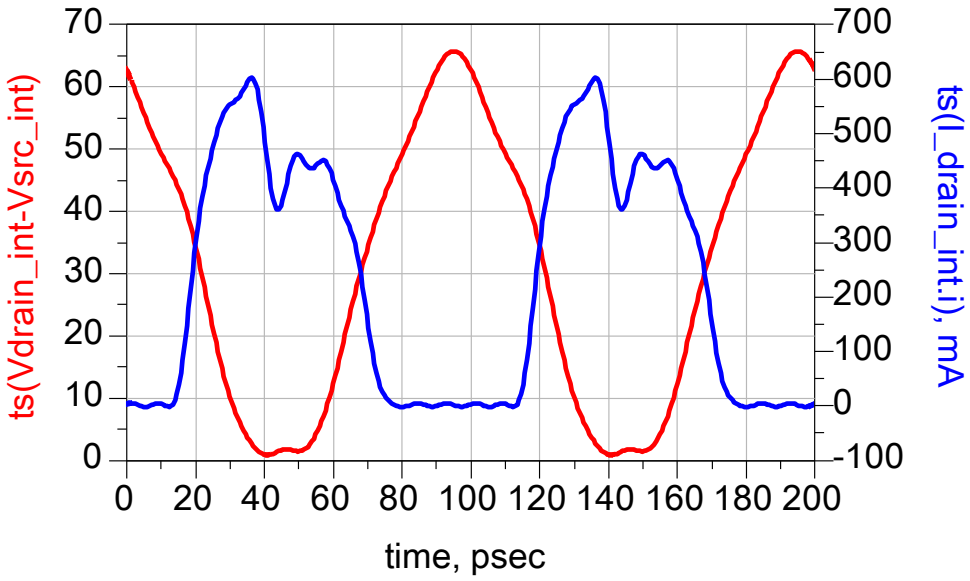
Intrinsic Voltage/Current Sensing

Get Vds and Ids model data near current generator intrinsic planes while tuning.



- External Model Planes
- Internal Model Planes for I/V waveform analysis
- Parasitic networks available separately from intrinsic I/V model

Example Plot of internal node Ids and Vds



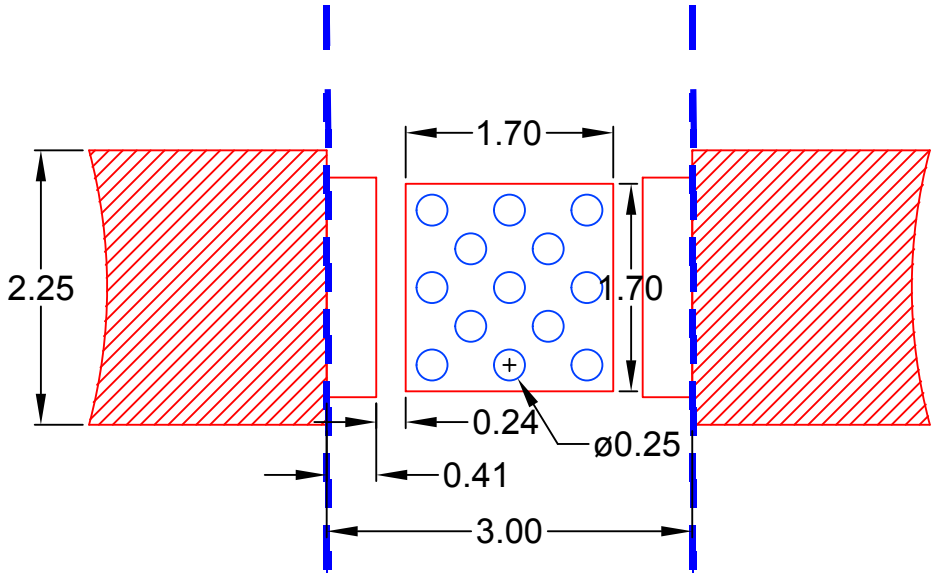
Results based on harmonic balance simulation at 27dBm input power, efficiency matched at 10GHz, 32V, and 25mA. ZS = 41.999 - j*41.301, ZS2 = 13.117 + j*18.138, ZS3 = 23.889 - j*11.769, ZLoad = 8.190 - j*5.791, ZLoad2 = 9.002 + j*1.621, ZLoad3 = 24.355 - j*10.916.

Model and Datasheet Revision Notes

07/11/2016	Original model and datasheet development
08/19/2016	Corrected Model Inputs and Model Representations
10/26/2016	Updated test fixture information

Device Layout, units: mm

Model and Measurement Reference Planes
Distance between Reference Planes = 3mm



Conducting and ground pads for gate, drain and source

2.25 mm wide PCB trace on 8-mil Rogers 4003C
PCB top metal thickness = 0.043mm

Ground Paddle with 0.25mm filled vias
for best heat sink applications

CONTROLLING DIMENSIONS - mm
FOR REFERENCE ONLY

Modelithics		Title: Modelithics, INC.	
Scale: NOT TO SCALE	Drawn by: MDLX	File Name: HMT-QOR-TGF2977-SM-001.dwg	Rev: 1
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