Freescale Semiconductor
Technical Data

Document Number: MMRF1016H
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RoHS

RF Power LDMOS Transistor

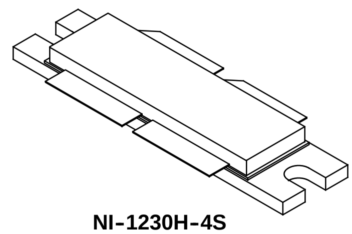
N-Channel Enhancement-Mode Lateral MOSFET

MMRF1016HR5

2-500 MHz, 600 W, 50 V
BROADBAND
RF POWER MOSFET

This 600 W RF power LDMOS transistor is designed primarily for wideband RF power amplifiers with frequencies up to 500 MHz. This device is unmatched and is suitable for use in high power military applications.

- Typical DVB-T OFDM Performance: V_{DD} = 50 Vdc, I_{DQ} = 2600 mA, P_{out} = 125 W Avg., f = 225 MHz, Channel Bandwidth = 7.61 MHz, Input Signal PAR = 9.3 dB @ 0.01% Probability on CCDF.
  - Power Gain — 25 dB
  - Drain Efficiency — 28.5%
  - ACPR @ 4 MHz Offset — -61 dBc @ 4 kHz Bandwidth
- Typical Pulse Performance: V_{DD} = 50 Vdc, I_{DQ} = 2600 mA, P_{out} = 600 W Peak, f = 225 MHz, Pulse Width = 100 μsec, Duty Cycle = 20%
  - Power Gain — 25.3 dB
  - Drain Efficiency — 59%
- Capable of Handling 10:1 VSWR @ 50 Vdc, 225 MHz, 600 W Peak Power, Pulse Width = 100 μsec, Duty Cycle = 20%

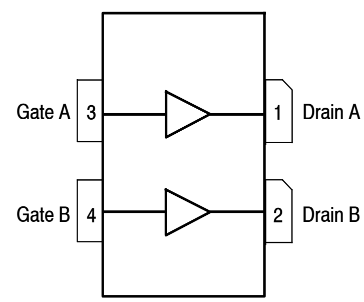


NI-1230H-4S

PART IS PUSH-PULL

Features

- Characterized with Series Equivalent Large-Signal Impedance Parameters
- CW Operation Capability with Adequate Cooling
- Qualified Up to a Maximum of 50 V_{DD} Operation
- Integrated ESD Protection
- Designed for Push-Pull Operation
- Greater Negative Gate-Source Voltage Range for Improved Class C Operation
- In Tape and Reel. R5 Suffix = 50 Units, 56 mm Tape Width, 13-inch Reel.



(Top View)

Note: The backside of the package is the source terminal for the transistors.

Figure 1. Pin Connections

Table 1. Maximum Ratings

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DSS}	-0.5, +120	Vdc
Gate-Source Voltage	V_{GS}	-6.0, +10	Vdc
Storage Temperature Range	T_{stg}	- 65 to +150	°C
Case Operating Temperature	T_C	150	°C
Operating Junction Temperature (1,2)	T_J	225	°C

Table 2. Thermal Characteristics

Characteristic	Symbol	Value (2,3)	Unit
Thermal Resistance, Junction to Case Case Temperature 99°C, 125 W CW, 225 MHz, 50 Vdc, I_{DQ} = 2600 mA Case Temperature 64°C, 610 W CW, 352.2 MHz, 50 Vdc, I_{DQ} = 150 mA Case Temperature 81°C, 610 W CW, 88-108 MHz, 50 Vdc, I_{DQ} = 150 mA	$R_{\theta JC}$	 0.20 0.14 0.16	°C/W

1. Continuous use at maximum temperature will affect MTTF.
2. MTTF calculator available at http://www.freescale.com/rf. Select Software & Tools/Development Tools/Calculators to access MTTF calculators by product.
3. Refer to AN1955, *Thermal Measurement Methodology of RF Power Amplifiers.* Go to http://www.freescale.com/rf. Select Documentation/Application Notes - AN1955.

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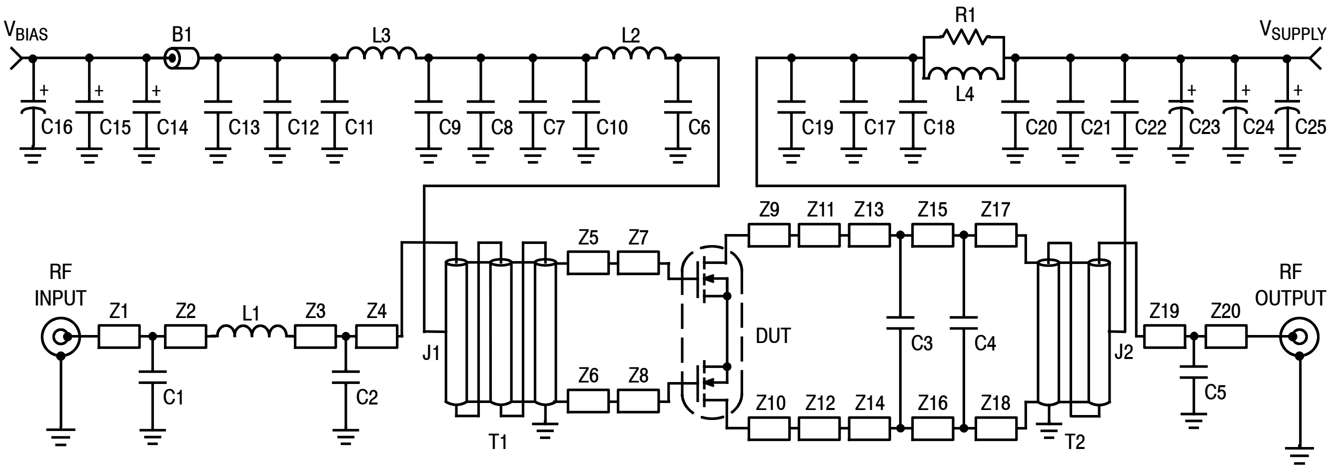
Table 3. ESD Protection Characteristics

Test Methodology	Class
Human Body Model (per JESD22-A114)	2
Machine Model (per EIA/JESD22-A115)	A
Charge Device Model (per JESD22-C101)	IV

Table 4. Electrical Characteristics (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Off Characteristics (1)					
Gate-Source Leakage Current (V_{GS} = 5 Vdc, V_{DS} = 0 Vdc)	I_{GSS}	—	—	10	μAdc
Drain-Source Breakdown Voltage (I_D = 150 mA, V_{GS} = 0 Vdc)	$V_{(BR)DSS}$	120	—	—	Vdc
Zero Gate Voltage Drain Leakage Current (V_{DS} = 50 Vdc, V_{GS} = 0 Vdc)	I_{DSS}	—	—	50	μAdc
Zero Gate Voltage Drain Leakage Current (V_{DS} = 100 Vdc, V_{GS} = 0 Vdc)	I_{DSS}	—	—	2.5	mA
On Characteristics					
Gate Threshold Voltage (1) (V_{DS} = 10 Vdc, I_D = 800 μAdc)	$V_{GS(th)}$	1	1.65	3	Vdc
Gate Quiescent Voltage (2) (V_{DD} = 50 Vdc, I_D = 2600 mAdc, Measured in Functional Test)	$V_{GS(Q)}$	1.5	2.7	3.5	Vdc
Drain-Source On-Voltage (1) (V_{GS} = 10 Vdc, I_D = 2 Adc)	$V_{DS(on)}$	—	0.25	—	Vdc
Dynamic Characteristics (1)					
Reverse Transfer Capacitance (V_{DS} = 50 Vdc ± 30 mV(rms)ac @ 1 MHz, V_{GS} = 0 Vdc)	C_{rss}	—	1.7	—	pF
Output Capacitance (V_{DS} = 50 Vdc ± 30 mV(rms)ac @ 1 MHz, V_{GS} = 0 Vdc)	C_{oss}	—	101	—	pF
Input Capacitance (V_{DS} = 50 Vdc, V_{GS} = 0 Vdc ± 30 mV(rms)ac @ 1 MHz)	C_{iss}	—	287	—	pF
Functional Tests (2) (In Freescale Test Fixture, 50 ohm system) V_{DD} = 50 Vdc, I_{DQ} = 2600 mA, P_{out} = 125 W Avg., f = 225 MHz, DVB-T OFDM Single Channel. ACPR measured in 7.61 MHz Channel Bandwidth @ ±4 MHz Offset.					
Power Gain	G_{ps}	24	25	27	dB
Drain Efficiency	η_D	27	28.5	—	%
Adjacent Channel Power Ratio	ACPR	—	-61	-59	dBc
Input Return Loss	IRL	—	-18	-9	dB
Typical Performance — 352.2 MHz (In Freescale 352.2 MHz Test Fixture, 50 ohm system) V_{DD} = 50 Vdc, I_{DQ} = 150 mA, P_{out} = 600 W CW					
Power Gain	G_{ps}	—	22	—	dB
Drain Efficiency	η_D	—	68	—	%
Input Return Loss	IRL	—	-15	—	dB
Typical Performance — 88-108 MHz (In Freescale 88-108 MHz Test Fixture, 50 ohm system) V_{DD} = 50 Vdc, I_{DQ} = 150 mA, P_{out} = 600 W CW					
Power Gain	G_{ps}	—	24.5	—	dB
Drain Efficiency	η_D	—	74	—	%
Input Return Loss	IRL	—	-5	—	dB

1. Each side of device measured separately.
2. Measurement made with device in push-pull configuration.



Z1	1.049″ x 0.080″ Microstrip	Z13, Z14	0.224″ x 0.253″ Microstrip
Z2*	0.143″ x 0.080″ Microstrip	Z15*, Z16*	0.095″ x 0.253″ Microstrip
Z3*	0.188″ x 0.080″ Microstrip	Z17, Z18	0.052″ x 0.253″ Microstrip
Z4	0.192″ x 0.133″ Microstrip	Z19	0.053″ x 0.080″ Microstrip
Z5, Z6	0.418″ x 0.193″ Microstrip	Z20	1.062″ x 0.080″ Microstrip
Z7, Z8	0.217″ x 0.518″ Microstrip	PCB	Arlon CuClad 250GX-0300-55-22, 0.030″, ε_r = 2.55
Z9, Z10	0.200″ x 0.518″ Microstrip		
Z11, Z12	0.375″ x 0.214″ Microstrip		

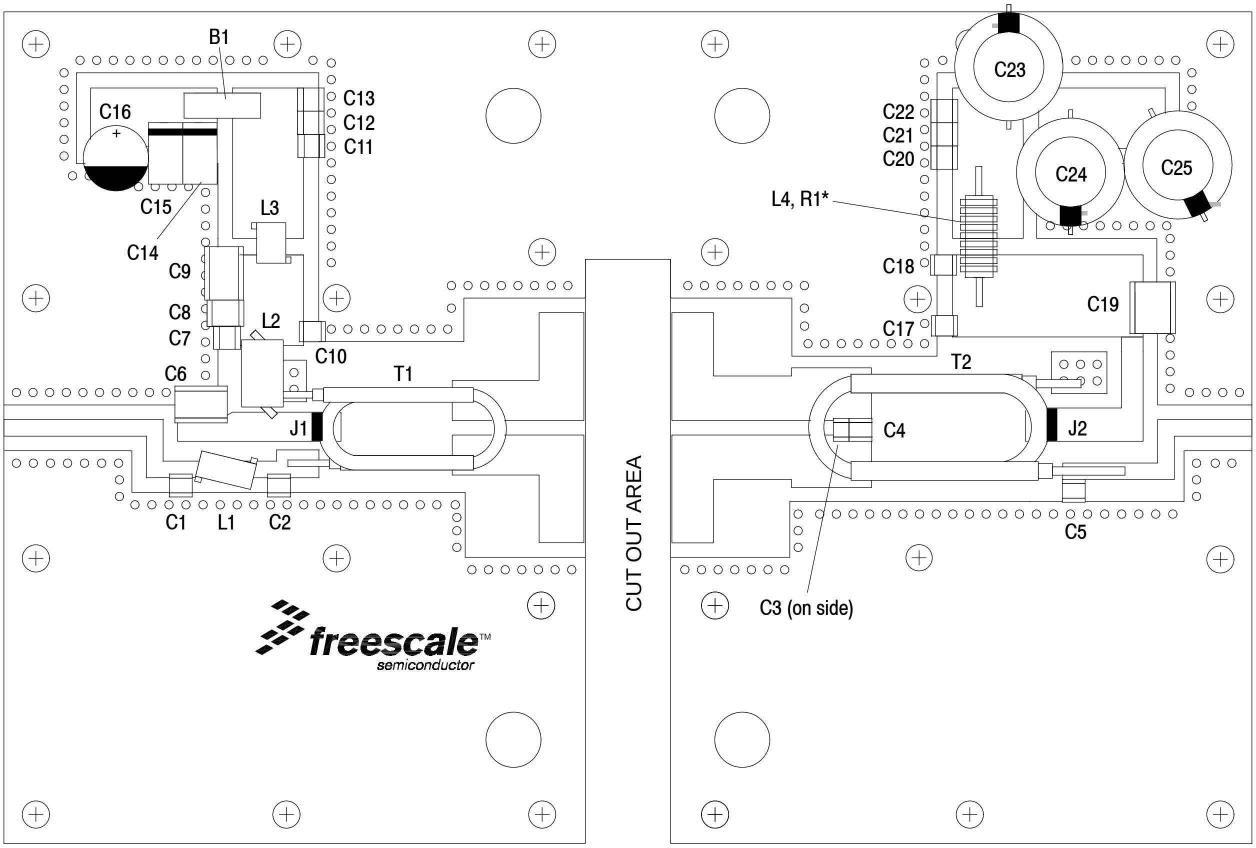
* Line length includes microstrip bends

Figure 2. MMRF1016HR5 Test Circuit Schematic

Table 5. MMRF1016HR5 Test Circuit Component Designations and Values

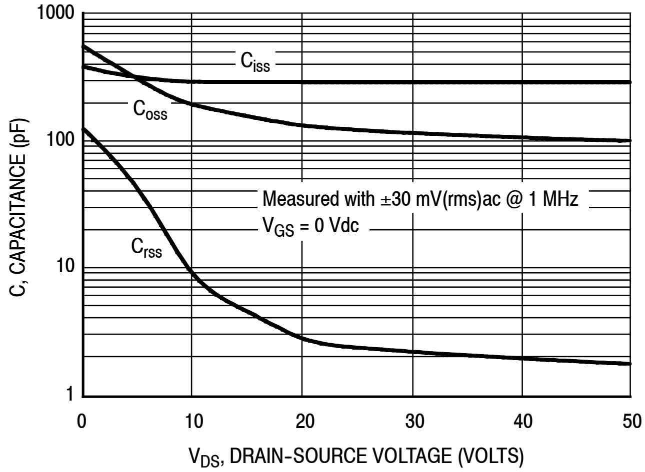
Part	Description	Part Number	Manufacturer
B1	95 Ω, 100 MHz Long Ferrite Bead	2743021447	Fair-Rite
C1	47 pF Chip Capacitor	ATC100B470JT500XT	ATC
C2, C4	43 pF Chip Capacitors	ATC100B430JT500XT	ATC
C3	100 pF Chip Capacitor	ATC100B101JT500XT	ATC
C5	10 pF Chip Capacitor	ATC100B7R5CT500XT	ATC
C6, C9	2.2 μF, 50 V Chip Capacitors	C1825C225J5RAC	Kemet
C7, C13, C20	10K pF Chip Capacitors	ATC200B103KT50XT	ATC
C8	220 nF, 50 V Chip Capacitor	C1812C224J5RAC	Kemet
C10, C17, C18	1000 pF Chip Capacitors	ATC100B102JT50XT	ATC
C11, C22	0.1 μF, 50 V Chip Capacitors	CDR33BX104AKYS	Kemet
C12, C21	20K pF Chip Capacitors	ATC200B203KT50XT	ATC
C14	10 μF, 35 V Tantalum Capacitor	T491D106K035AT	Kemet
C15	22 μF, 35 V Tantalum Capacitor	T491X226K035AT	Kemet
C16	47 μF, 50 V Electrolytic Capacitor	476KXM050M	Illinois Cap
C19	2.2 μF, Chip Capacitor	2225X7R225KT3AB	ATC
C23, C24, C25	470 μF 63V Electrolytic Capacitors	MCGPR63V477M13X26-RH	Multicomp
J1, J2	Jumpers from PCB to T1 & T2	Copper Foil	
L1	17.5 nH, 6 Turn Inductor	B06T	CoilCraft
L2	8 Turn, #20 AWG ID = 0.125″ Inductor, Hand Wound	Copper Wire	
L3	82 nH, Inductor	1812SMS-82NJ	CoilCraft
L4*	9 Turn, #18 AWG Inductor, Hand Wound	Copper Wire	
R1	20 Ω, 3 W Axial Leaded Resistor	5093NW20R00J	Vishay
T1	Balun	TUI-9	Comm Concepts
T2	Balun	TUO-4	Comm Concepts

*L4 is wrapped around R1.



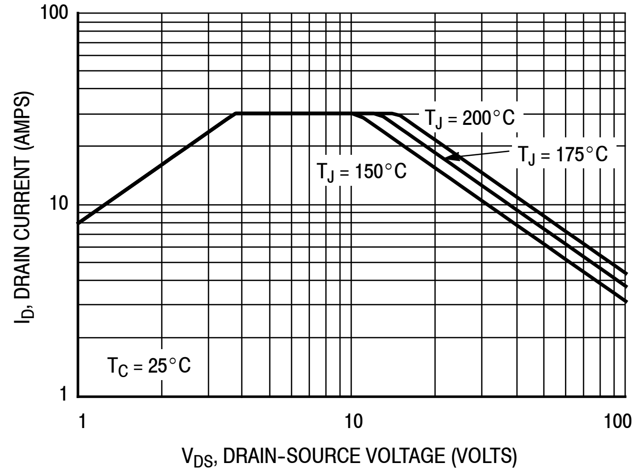
* L4 is wrapped around R1.

Figure 3. MMRF1016HR5 Test Circuit Component Layout



Note: Each side of device measured separately.

Figure 4. Capacitance versus Drain-Source Voltage



Note: Each side of device measured separately.

Figure 5. DC Safe Operating Area

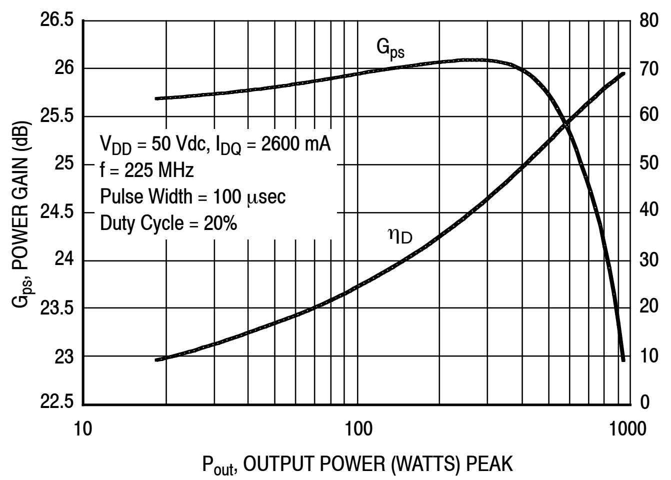


Figure 6. Power Gain and Drain Efficiency versus Output Power

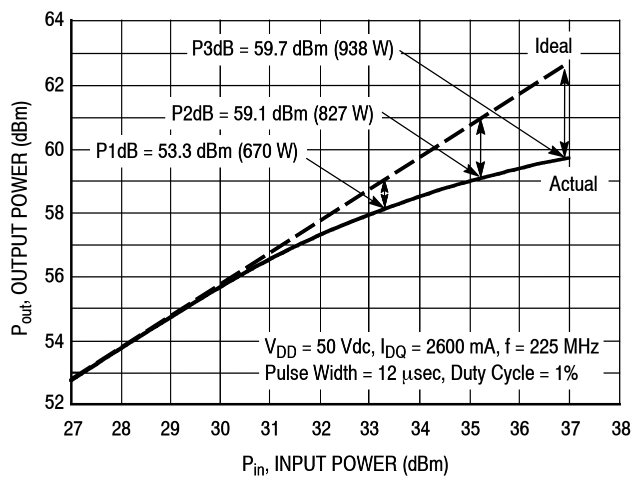


Figure 7. CW Output Power versus Input Power

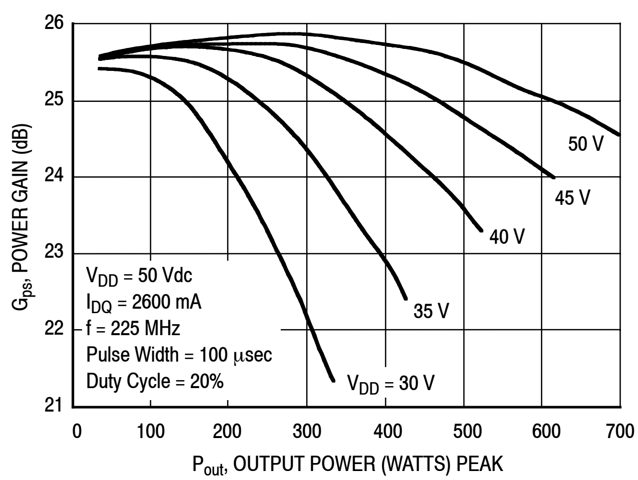


Figure 8. Power Gain versus Output Power

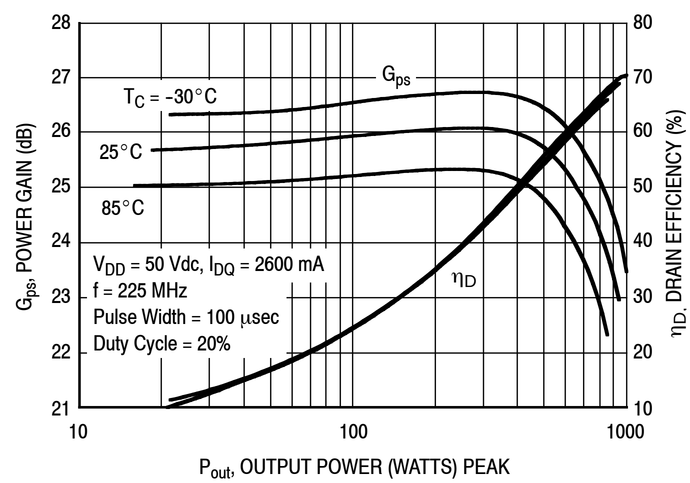


Figure 9. Power Gain and Drain Efficiency versus Output Power

TYPICAL CHARACTERISTICS — TWO-TONE

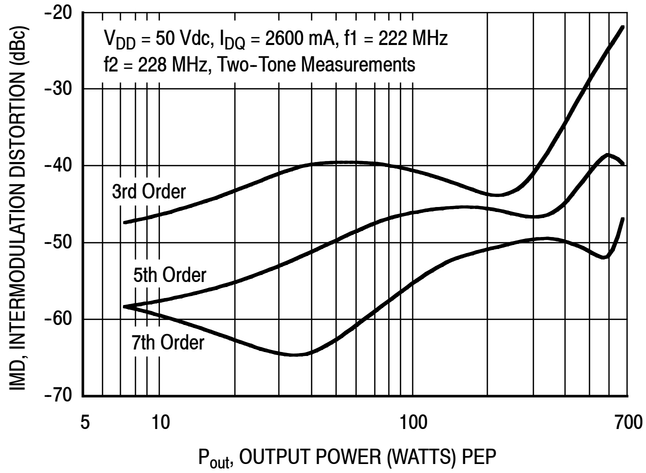


Figure 10. Intermodulation Distortion Products versus Output Power

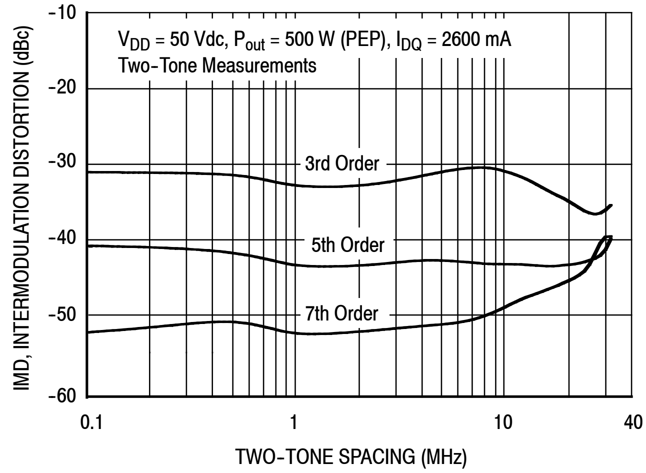


Figure 11. Intermodulation Distortion Products versus Tone Spacing

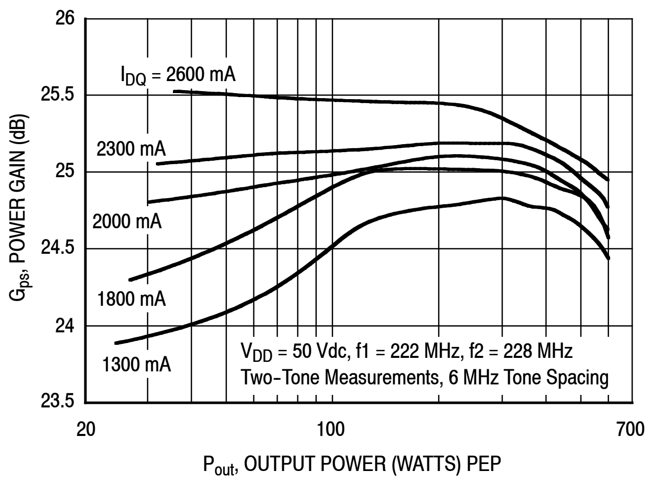


Figure 12. Two-Tone Power Gain versus Output Power

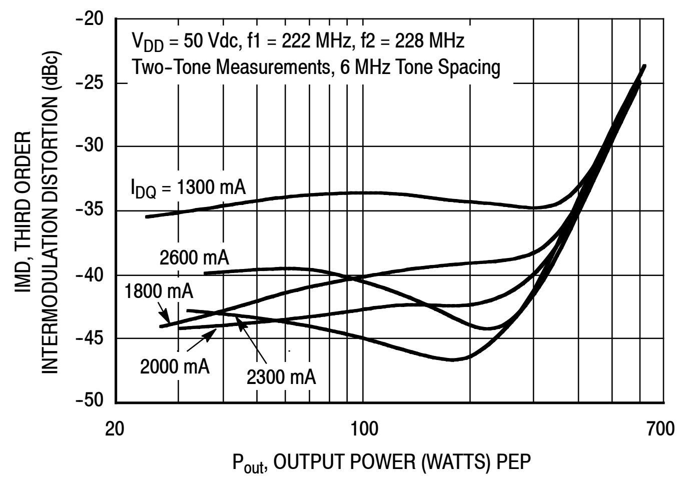


Figure 13. Third Order Intermodulation Distortion versus Output Power

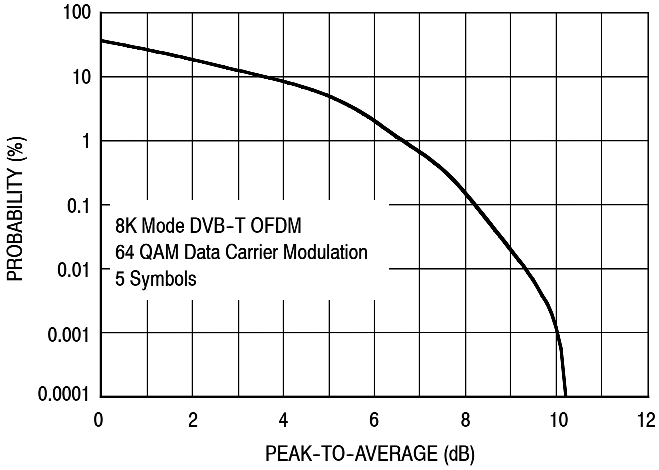


Figure 14. Single-Carrier DVB-T OFDM

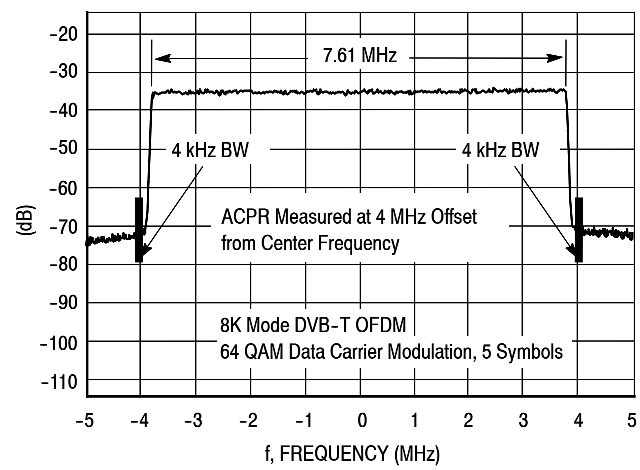


Figure 15. 8K Mode DVB-T OFDM Spectrum

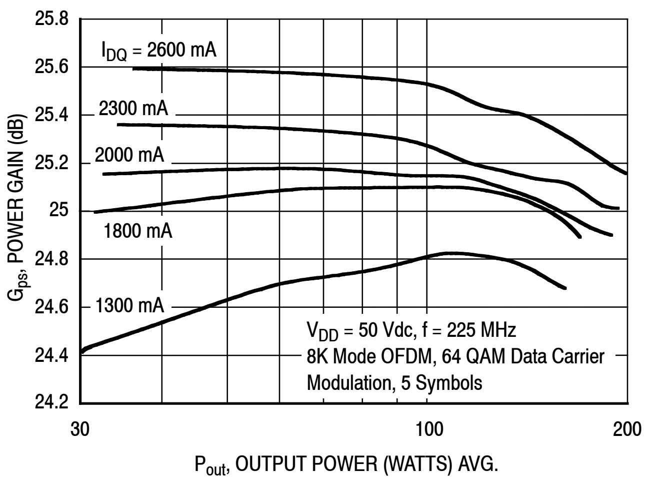


Figure 16. Single-Carrier DVB-T OFDM Power Gain versus Output Power

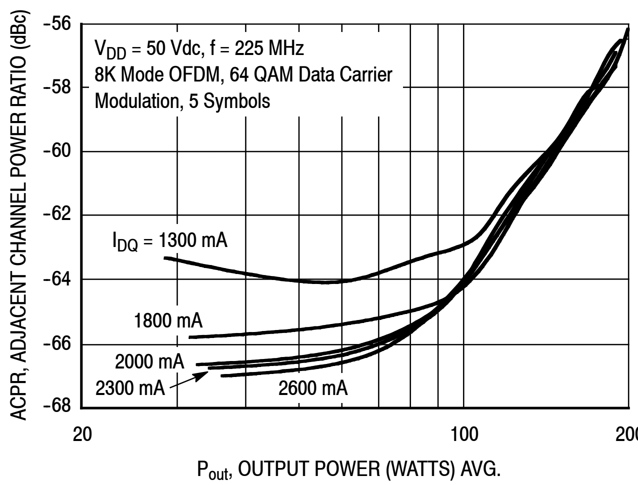


Figure 17. Single-Carrier DVB-T OFDM ACPR versus Output Power

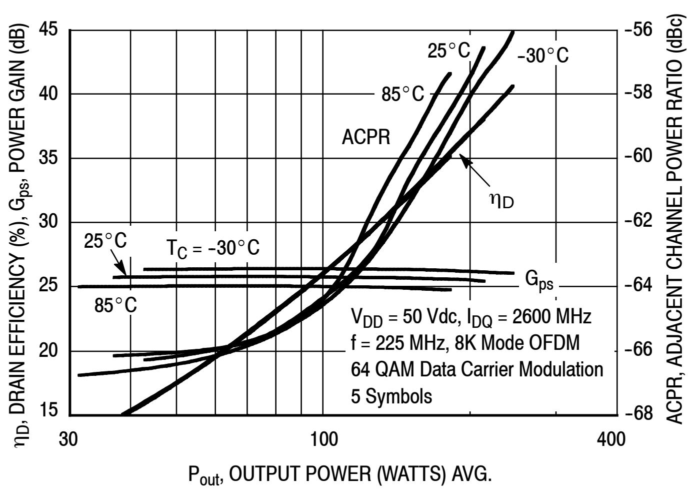
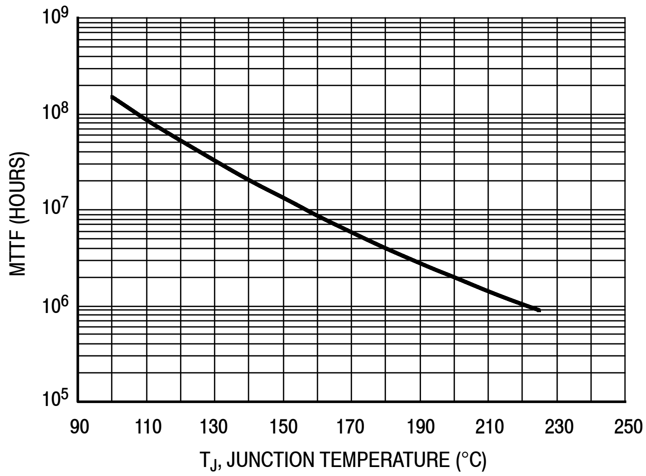


Figure 18. Single-Carrier DVB-T OFDM ACPR Power Gain and Drain Efficiency versus Output Power

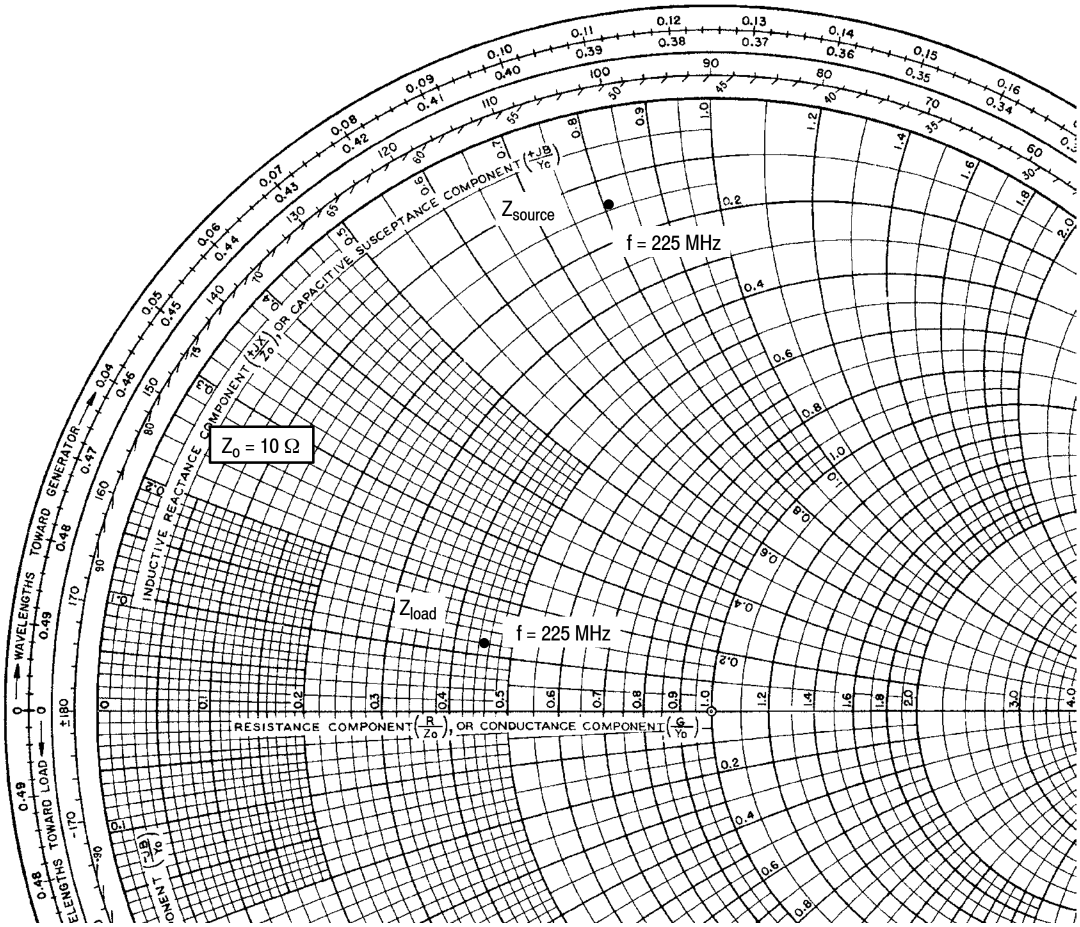
TYPICAL CHARACTERISTICS



This above graph displays calculated MTTF in hours when the device is operated at V_{DD} = 50 Vdc, P_{out} = 125 W Avg., and η_D = 28.5%.

MTTF calculator available at http://www.freescale.com/rf. Select Software & Tools/Development Tools/Calculators to access MTTF calculators by product.

Figure 19. MTTF versus Junction Temperature – CW



V_{DD} = 50 Vdc, I_{DQ} = 2600 mA, P_{out} = 125 W Avg.

f MHz	Z_{source} Ω	Z_{load} Ω
225	1.42 + j8.09	4.45 + j1.16

Z_{source} = Test circuit impedance as measured from gate to gate, balanced configuration.

Z_{load} = Test circuit impedance as measured from drain to drain, balanced configuration.

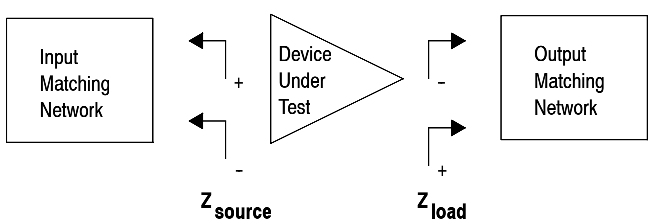


Figure 20. Series Equivalent Source and Load Impedance

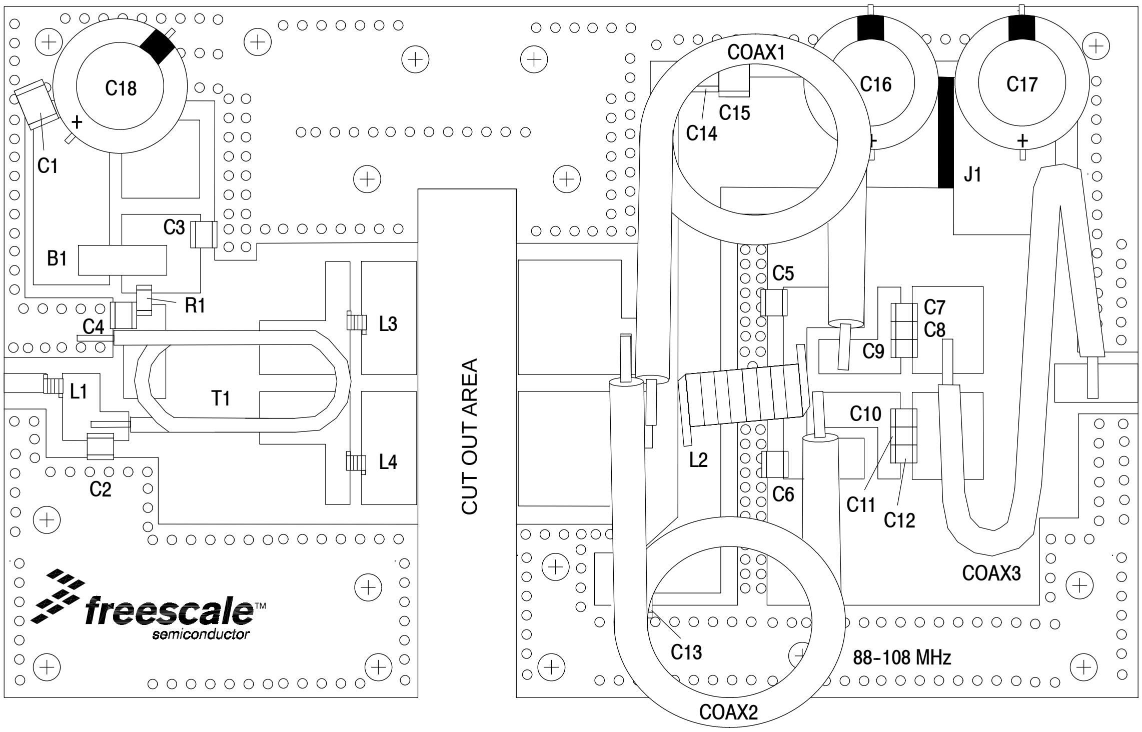


Figure 21. MMRF1016HR6 Test Circuit Component Layout — 88-108 MHz

Table 6. MMRF1016HR6 Test Circuit Component Designations and Values — 88-108 MHz

Part	Description	Part Number	Manufacturer
B1	95 Ω, 100 MHz Long Ferrite Bead	2743021447	Fair-Rite
C1	6.8 μF, 50 V Chip Capacitor	C4532X7R1H685K	TDK
C2	30 pF Chip Capacitor	ATC100B300JT500XT	ATC
C3, C13, C14	1000 pF Chip Capacitors	ATC100B102JT50XT	ATC
C4, C5, C6	1 μF, 100 V Chip Capacitors	GRM31CR72A105KA01L	Murata
C7, C8, C9, C10, C11, C12	3900 pF Chip Capacitors	ATC700B392JT50X	ATC
C15	4.7 μF, 100 V Chip Capacitor	GRM55ER72A475KA01B	Murata
C16, C17	470 μF, 63 V Electrolytic Capacitors	MCGPR63V477M13X26-RH	Multicomp
C18	220 μF, 100 V Electrolytic Capacitor	MCGPR100V227M16X26-RH	Multicomp
J1	Jumper with Copper Tape		
L1	82 nH Inductor	1812SMS-82NJ	CoilCraft
L2	8 Turn, #14 AWG ID=0.250″ Inductor, Hand Wound	Copper Wire	Freescale
L3, L4	8 nH Inductors	A03TKLC	CoilCraft
R1	15 Ω, 1/4 W Chip Resistor	CRCW120615R0FKEA	Vishay
T1	Balun Transformer	TUI-LF-9	Comm Concepts
Coax1, Coax2	25 Ω, Semi Rigid RF Cable, 3 mm Line, 16 cm Length	UT-141C-25	Micro-Coax
Coax3	25 Ω, Semi Rigid RF Cable, 3 mm Line, 15 cm Length	UT-141C-25	Micro-Coax
PCB	0.030″, ε_r = 2.55	GX0300-55-22	Arlon

TYPICAL CHARACTERISTICS — 88-108 MHz

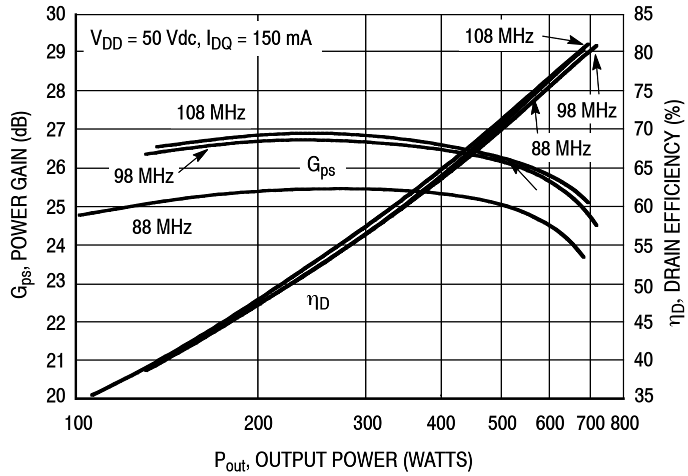


Figure 22. Broadband CW Power Gain and Drain Efficiency versus Output Power — 88-108 MHz

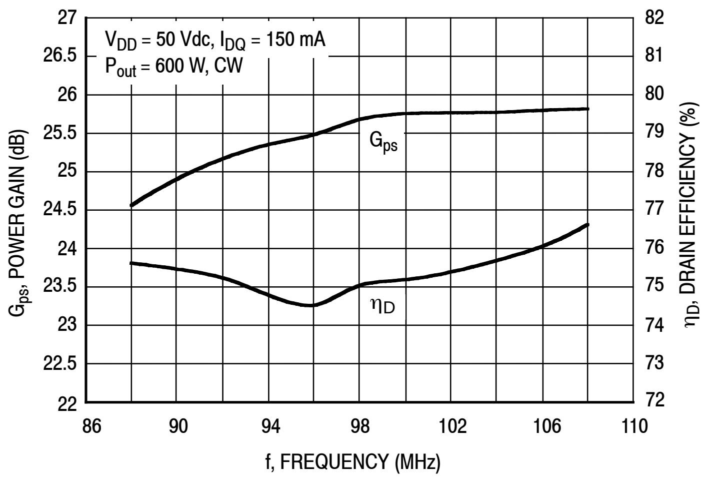
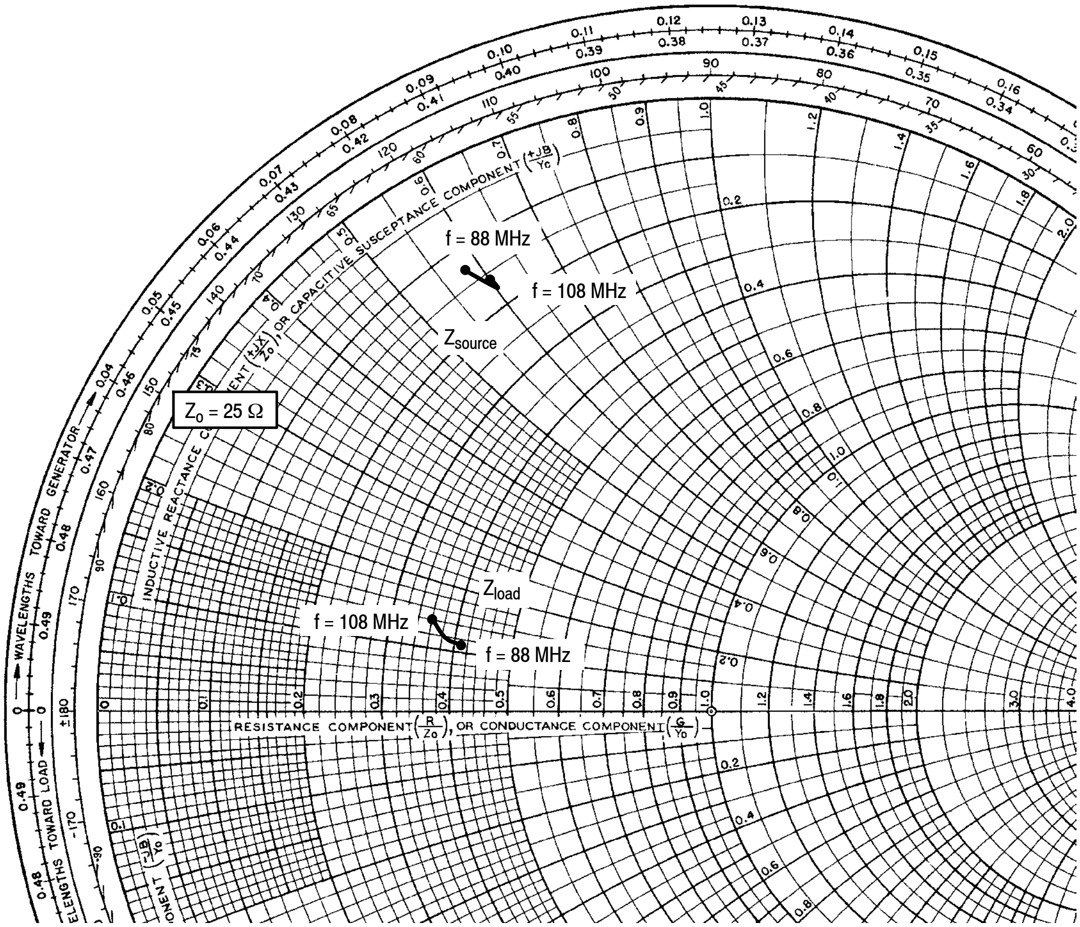


Figure 23. CW Power Gain and Drain Efficiency versus Frequency — 88-108 MHz



V_{DD} = 50 Vdc, I_{DQ} = 150 mA, P_{out} = 600 W Avg.

f MHz	Z_{source} Ω	Z_{load} Ω
88	3.20 + j14.50	10.35 + j2.80
98	4.20 + j15.00	9.50 + j3.00
108	4.00 + j15.00	8.90 + j3.50

Z_{source} = Test circuit impedance as measured from gate to gate, balanced configuration.

Z_{load} = Test circuit impedance as measured from drain to drain, balanced configuration.

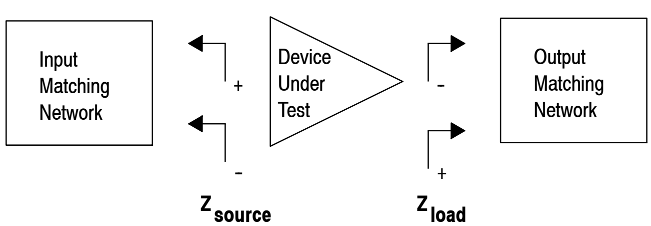
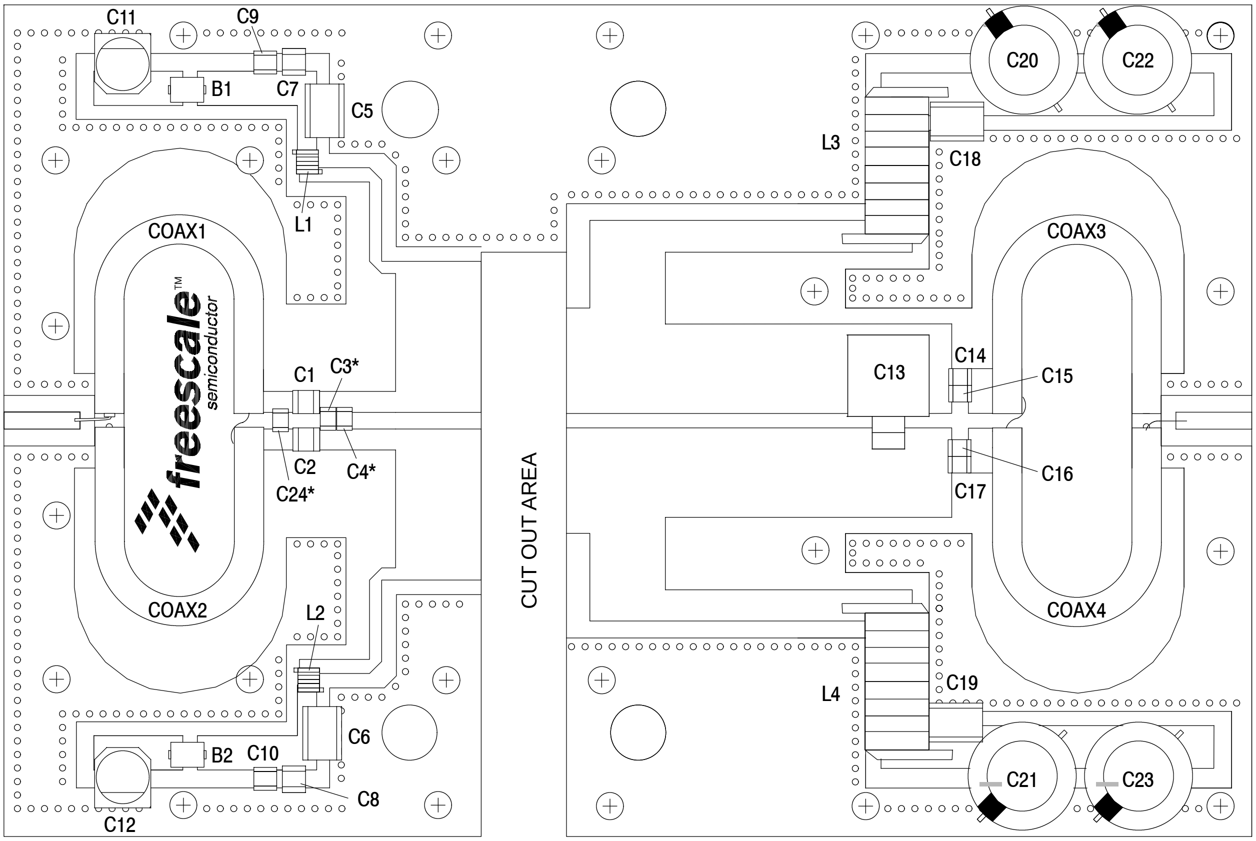


Figure 24. Series Equivalent Source and Load Impedance — 88-108 MHz



*Mounted on side

Figure 25. MMRF1016HR6 Test Circuit Component Layout — 352.2 MHz

Table 7. MMRF1016HR6 Test Circuit Component Designations and Values — 352.2 MHz

Part	Description	Part Number	Manufacturer
B1, B2	47 Ω, 100 MHz Short Ferrite Beads	2743019447	Fair-Rite
C1, C2	100 pF Chip Capacitors	ATC100B101JT500XT	ATC
C3*, C24*	22 pF Chip Capacitors	ATC100B221JT300XT	ATC
C4*	20 pF Chip Capacitor	ATC100B200JT500XT	ATC
C5, C6	2.2 μF Chip Capacitors	C1825C225J5RAC-TU	Kemet
C7, C8	220 nF Chip Capacitors	C1812C224K5RAC-TU	Kemet
C9, C10	0.1 μF Chip Capacitors	CDR33BX104AKWS	AVX
C11, C12	47 μF, 50 V Electrolytic Capacitors	476KXM050M	Illinois Cap
C13	39 pF, 500 V Chip Capacitor	MCM01-009DD390J-F	CDE
C14, C15, C16, C17	240 pF Chip Capacitors	ATC100B241JT200XT	ATC
C18, C19	2.2 μF Chip Capacitors	G2225X7R225KT3AB	ATC
C20, C21, C22, C23	470 μF, 63 V Electrolytic Capacitors	MCGPR63V477M13X26-RH	Multicomp
Coax1, 2, 3, 4	25 Ω, Semi Rigid Coax, 2.2″ Shield Length	UT141-25	Precision Tube Company
L1, L2	2.5 nH, 1 Turn Inductors	A01TLC	Coilcraft
L3, L4	10 Turn, #16 AWG ID=0.160″ Inductors, Hand Wound	Copper Wire	Freescale

*Mounted on side

TYPICAL CHARACTERISTICS — 352.2 MHz

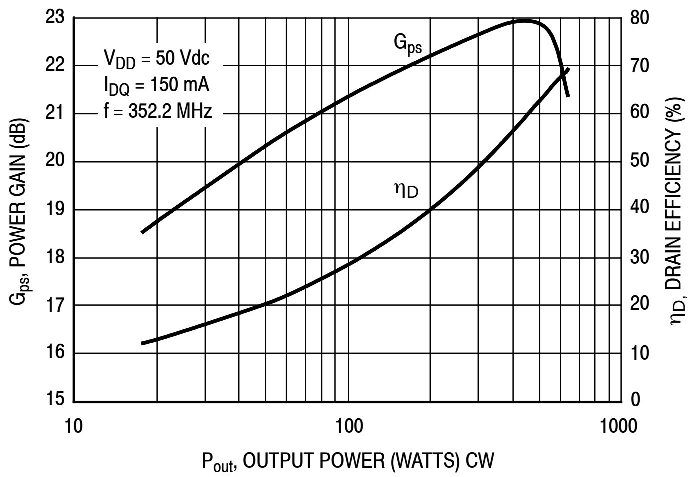
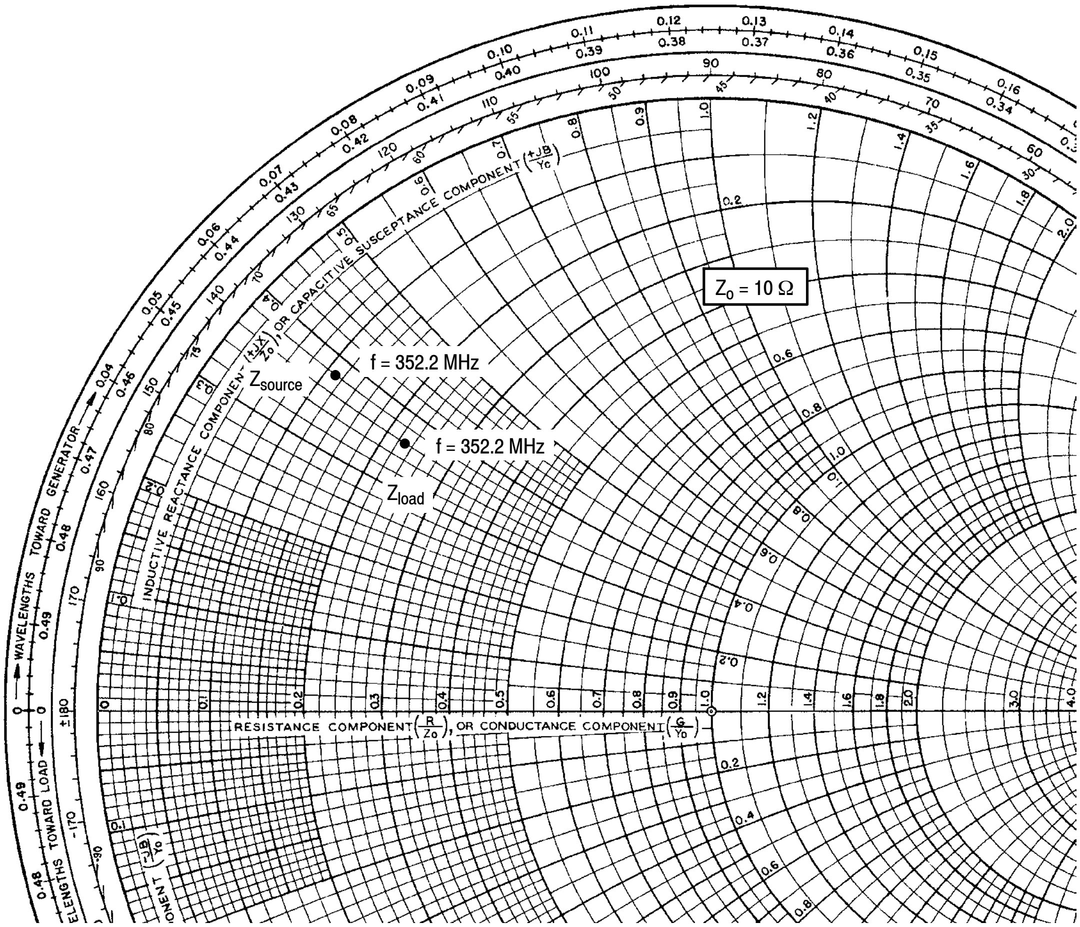


Figure 26. CW Power Gain and Drain Efficiency versus Output Power



V_{DD} = 50 Vdc, I_{DQ} = 150 mA, P_{out} = 600 W CW

f MHz	Z_{source} Ω	Z_{load} Ω
352.2	1.10 + j3.80	2.26 + j3.57

Z_{source} = Test circuit impedance as measured from gate to gate, balanced configuration.

Z_{load} = Test circuit impedance as measured from drain to drain, balanced configuration.

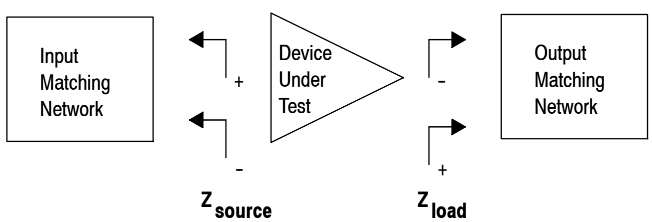
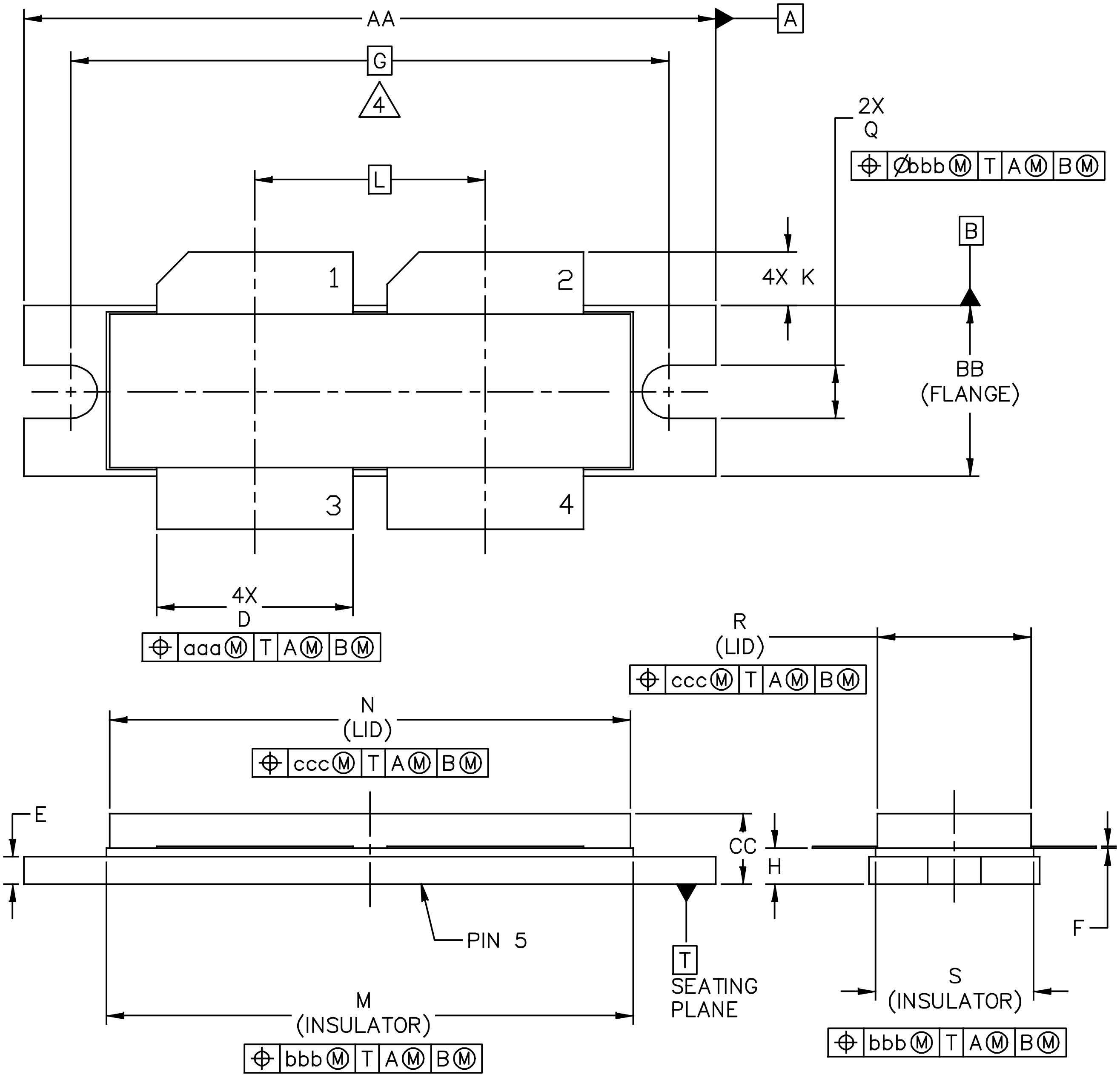


Figure 27. Series Equivalent Source and Load Impedance — 352.2 MHz

PACKAGE DIMENSIONS



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NOTES:

1. INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M-1994.
2. CONTROLLING DIMENSION: INCH
3. DIMENSION H IS MEASURED .030 INCH (0.762 MM) AWAY FROM PACKAGE BODY.
4. RECOMMENDED BOLT CENTER DIMENSION OF 1.52 INCH (38.61 MM) BASED ON M3 SCREW.

DIM	INCH MIN	INCH MAX	MILLIMETER MIN	MILLIMETER MAX	DIM	INCH MIN	INCH MAX	MILLIMETER MIN	MILLIMETER MAX
AA	1.615	1.625	41.02	41.28	N	1.218	1.242	30.94	31.55
BB	.395	.405	10.03	10.29	Q	.120	.130	3.05	3.30
CC	.170	.190	4.32	4.83	R	.355	.365	9.02	9.27
D	.455	.465	11.56	11.81	S	.365	.375	9.27	9.53
E	.062	.066	1.57	1.68					
F	.004	.007	0.10	0.18					
G	1.400 BSC		35.56 BSC		aaa	.013		0.33	
H	.082	.090	2.08	2.29	bbb	.010		0.25	
K	.117	.137	2.97	3.48	ccc	.020		0.51	
L	.540 BSC		13.72 BSC						
M	1.219	1.241	30.96	31.52					

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PRODUCT DOCUMENTATION AND SOFTWARE

Refer to the following resources to aid your design process.

Application Notes

- AN1955: Thermal Measurement Methodology of RF Power Amplifiers

Engineering Bulletins

- EB212: Using Data Sheet Impedances for RF LDMOS Devices

Software

- Electromigration MTTF Calculator

For Software, do a Part Number search at http://www.freescale.com, and select the “Part Number” link. Go to the Software & Tools tab on the part’s Product Summary page to download the respective tool.

REVISION HISTORY

The following table summarizes revisions to this document.

Revision	Date	Description
0	July 2014	• Initial Release of Data Sheet

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Document Number: MMRF1016H
Rev. 0, 7/2014

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