

RF Power LDMOS Transistors

High Ruggedness N-Channel Enhancement-Mode Lateral MOSFETs

Designed for mobile two-way radio applications with frequencies from 764 to 941 MHz. The high gain, ruggedness and broadband performance of these devices make them ideal for large-signal, common source amplifier applications in mobile radio equipment.

Narrowband Performance (13.6 Vdc, $I_{DQ} = 500$ mA, $T_A = 25^\circ\text{C}$, CW)

Frequency (MHz)	G_{ps} (dB)	η_D (%)	P1dB (W)
764	18.0	74.1	32
870	17.2	71.0	31
941	15.7	68.1	31

800 MHz Broadband Performance (13.6 Vdc, $I_{DQ} = 100$ mA, $T_A = 25^\circ\text{C}$, CW)

Frequency (MHz)	G_{ps} (dB)	η_D (%)	P1dB (W)
760	15.7	62.0	44
820	15.7	63.0	37
870	15.5	61.0	36

Load Mismatch/Ruggedness

Frequency (MHz)	Signal Type	VSWR	P_{out} (W)	Test Voltage	Result
870	CW	>65:1 at all Phase Angles	54 (3 dB Overdrive)	17	No Device Degradation

Features

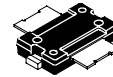
- Characterized for Operation from 764 to 941 MHz
- Unmatched Input and Output Allowing Wide Frequency Range Utilization
- Integrated ESD Protection
- Integrated Stability Enhancements
- Wideband — Full Power Across the Band (764–870 MHz)
- 225°C Capable Plastic Package
- Exceptional Thermal Performance
- High Linearity for: TETRA, SSB, LTE
- Cost-effective Over-molded Plastic Packaging
- In Tape and Reel. R1 Suffix = 500 Units, 24 mm Tape Width, 13 inch Reel.

Typical Applications

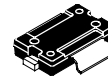
- Output Stage 800 MHz Trunking Band Mobile Radio
- Output Stage 900 MHz Trunking Band Mobile Radio

AFT09MS031NR1
AFT09MS031GNR1

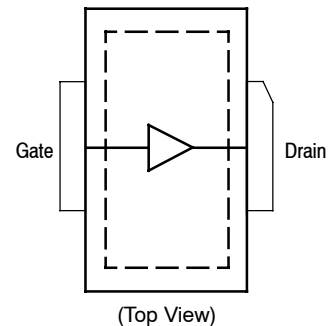
764–941 MHz, 31 W, 13.6 V
WIDEBAND
RF POWER LDMOS TRANSISTORS



**TO-270-2
PLASTIC**
AFT09MS031NR1



**TO-270-2 GULL
PLASTIC**
AFT09MS031GNR1



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

Figure 1. Pin Connections

Table 1. Maximum Ratings

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	-0.5, +40	Vdc
Gate-Source Voltage	V_{GS}	-6.0, +12	Vdc
Operating Voltage	V_{DD}	17, +0	Vdc
Storage Temperature Range	T_{stg}	-65 to +150	°C
Case Operating Temperature	T_C	-40 to +150	°C
Operating Junction Temperature (1,2)	T_J	-40 to +225	°C
Total Device Dissipation @ $T_C = 25^\circ\text{C}$ Derate above 25°C	P_D	317 1.59	W W/°C

Table 2. Thermal Characteristics

Characteristic	Symbol	Value (2,3)	Unit
Thermal Resistance, Junction to Case Case Temperature 81°C , 31 W CW, 13.6 Vdc, $I_{DQ} = 500\text{ mA}$, 870 MHz	$R_{\theta JC}$	0.63	°C/W

Table 3. ESD Protection Characteristics

Test Methodology	Class
Human Body Model (per JESD22-A114)	2, passes 2500 V
Machine Model (per EIA/JESD22-A115)	A, passes 100 V
Charge Device Model (per JESD22-C101)	IV, passes 1200 V

Table 4. Moisture Sensitivity Level

Test Methodology	Rating	Package Peak Temperature	Unit
Per JESD22-A113, IPC/JEDEC J-STD-020	3	260	°C

Table 5. Electrical Characteristics ($T_A = 25^\circ\text{C}$ unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
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Off Characteristics

Zero Gate Voltage Drain Leakage Current ($V_{DS} = 40\text{ Vdc}$, $V_{GS} = 0\text{ Vdc}$)	I_{DSS}	—	—	2	μAdc
Zero Gate Voltage Drain Leakage Current ($V_{DS} = 13.6\text{ Vdc}$, $V_{GS} = 0\text{ Vdc}$)	I_{DSS}	—	—	1	μAdc
Gate-Source Leakage Current ($V_{GS} = 5\text{ Vdc}$, $V_{DS} = 0\text{ Vdc}$)	I_{GSS}	—	—	600	nAdc

On Characteristics

Gate Threshold Voltage ($V_{DS} = 10\text{ Vdc}$, $I_D = 115\text{ }\mu\text{Adc}$)	$V_{GS(th)}$	1.6	2.1	2.6	Vdc
Drain-Source On-Voltage ($V_{GS} = 10\text{ Vdc}$, $I_D = 1.2\text{ Adc}$)	$V_{DS(on)}$	—	0.1	—	Vdc
Forward Transconductance ($V_{GS} = 10\text{ Vdc}$, $I_D = 10\text{ Adc}$)	g_{fs}	—	7.8	—	S

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.

(continued)

Table 5. Electrical Characteristics ($T_A = 25^\circ\text{C}$ unless otherwise noted) (continued)

Characteristic	Symbol	Min	Typ	Max	Unit
Dynamic Characteristics					
Reverse Transfer Capacitance ($V_{DS} = 13.6\text{ Vdc} \pm 30\text{ mV(rms)ac}$ @ 1 MHz, $V_{GS} = 0\text{ Vdc}$)	C_{rss}	—	2.1	—	pF
Output Capacitance ($V_{DS} = 13.6\text{ Vdc} \pm 30\text{ mV(rms)ac}$ @ 1 MHz, $V_{GS} = 0\text{ Vdc}$)	C_{oss}	—	63	—	pF
Input Capacitance ($V_{DS} = 13.6\text{ Vdc}$, $V_{GS} = 0\text{ Vdc} \pm 30\text{ mV(rms)ac}$ @ 1 MHz)	C_{iss}	—	140	—	pF
Functional Tests ⁽¹⁾ (In Freescale Narrowband Test Fixture, 50 ohm system) $V_{DD} = 13.6\text{ Vdc}$, $I_{DQ} = 500\text{ mA}$, $P_{out} = 31\text{ W}$, $f = 870\text{ MHz}$					
Common-Source Amplifier Power Gain	G_{ps}	16.0	17.2	18.5	dB
Drain Efficiency	η_D	68.0	71.0	—	%
Load Mismatch/Ruggedness (In Freescale Test Fixture, 50 ohm system, $I_{DQ} = 500\text{ mA}$)					
Frequency (MHz)	Signal Type	VSWR	P_{out} (W)	Test Voltage, V_{DD}	Result
870	CW	>65:1 at all Phase Angles	54 (3 dB Overdrive)	17	No Device Degradation

1. Measurement made with device in straight lead configuration before any lead forming operation is applied. Lead forming is used for gull wing (GN) parts.

TYPICAL CHARACTERISTICS

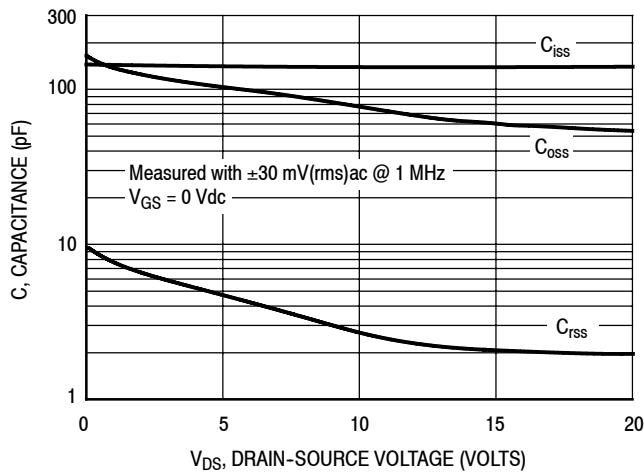
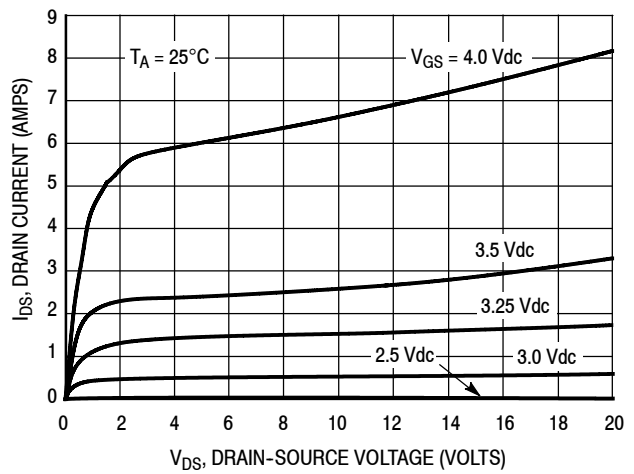
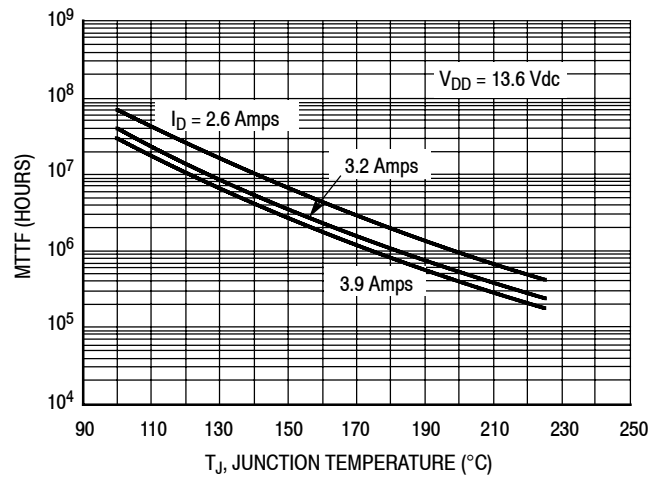


Figure 2. Capacitance versus Drain-Source Voltage



Note: Measured with both sides of the transistor tied together.

Figure 3. Drain Current versus Drain-Source Voltage



Note: MTTF value represents the total cumulative operating time under indicated test conditions.

Figure 4. MTTF versus Junction Temperature - CW

870 MHz NARROWBAND PRODUCTION TEST FIXTURE

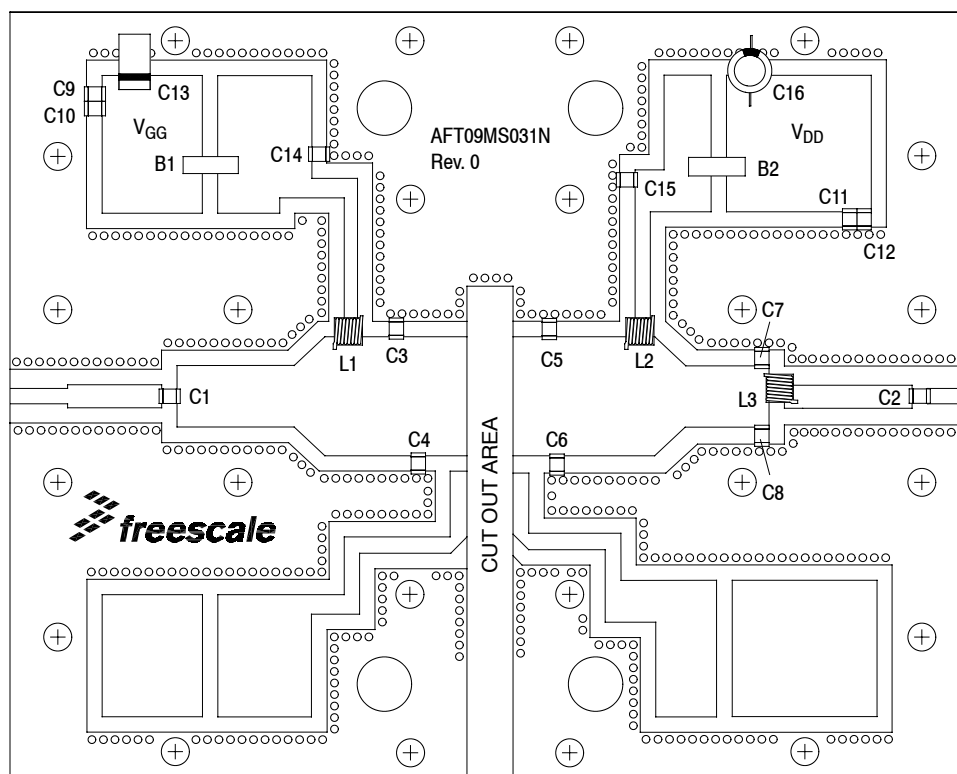


Figure 5. AFT09MS031NR1 Narrowband Test Circuit Component Layout — 870 MHz

Table 6. AFT09MS031NR1 Narrowband Test Circuit Component Designations and Values — 870 MHz

Part	Description	Part Number	Manufacturer
B1, B2	RF Beads, Long	2743021447	Fair-Rite
C1	3.9 pF Chip Capacitor	ATC100B3R9CT500XT	ATC
C2, C14, C15	56 pF Chip Capacitors	ATC100B560CT500XT	ATC
C3, C4, C5, C6	10 pF Chip Capacitors	ATC100B100JT500XT	ATC
C7, C8	3.6 pF Chip Capacitors	ATC100B3R6CT500XT	ATC
C9	2.5 μ F Chip Capacitor	GRM31CR71H225KA88L	Murata
C10, C11	0.1 μ F Chip Capacitors	C1206C104K1RAC-TU	Kemet
C12	10,000 pF Chip Capacitor	ATC200B103KT50XT	ATC
C13	22 μ F, 25 V Tantalum Capacitor	TPSD226M025R0200	AVX
C16	330 μ F, 35 V Electrolytic Capacitor	MCGPR35V337M10X16-RH	Multicomp
L1	8.0 nH, 3 Turn Inductor	A03TKLC	Coilcraft
L2	18.5 nH, 5 Turn Inductor	A05TKLC	Coilcraft
L3	5.0 nH, 2 Turn Inductor	A02TKLC	Coilcraft
PCB	0.030", $\epsilon_r = 3.5$	RO4350B	Rogers

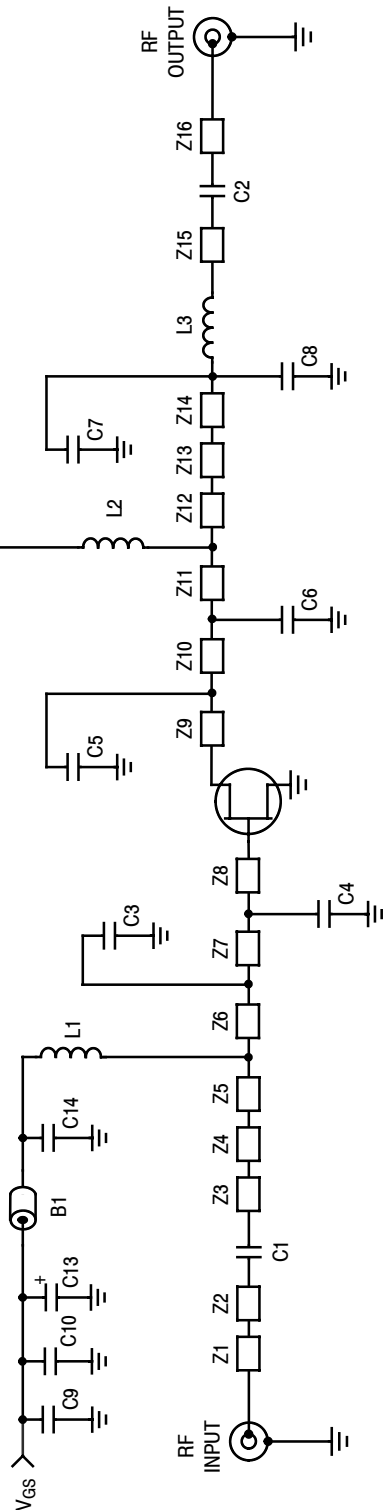


Figure 6. AFT09MS031NR1 Narrowband Test Circuit Schematic — 870 MHz

Table 7. AFT09MS031NR1 Narrowband Test Circuit Microstrips — 870 MHz

Microstrip	Description	Microstrip	Description
Z1	0.280" × 0.080" Microstrip	Z9	0.190" × 0.080" Microstrip
Z2	0.490" × 0.120" Microstrip	Z10	0.040" × 0.080" Microstrip
Z3	0.610" × 0.320" Microstrip	Z11	0.454" × 0.520" Microstrip
Z4	0.320" × 0.155" × 0.620" Microstrip Taper	Z12	0.054" × 0.520" Microstrip
Z5	0.139" × 0.620" Microstrip	Z13	0.620" × 0.420" × 0.620" Microstrip Taper
Z6	0.225" × 0.620" Microstrip	Z14	0.433" × 0.420" Microstrip
Z7	0.121" × 0.620" Microstrip	Z15	0.665" × 0.420" Microstrip
Z8	0.254" × 0.620" Microstrip	Z16	0.200" × 0.420" Microstrip

TYPICAL CHARACTERISTICS — 870 MHz

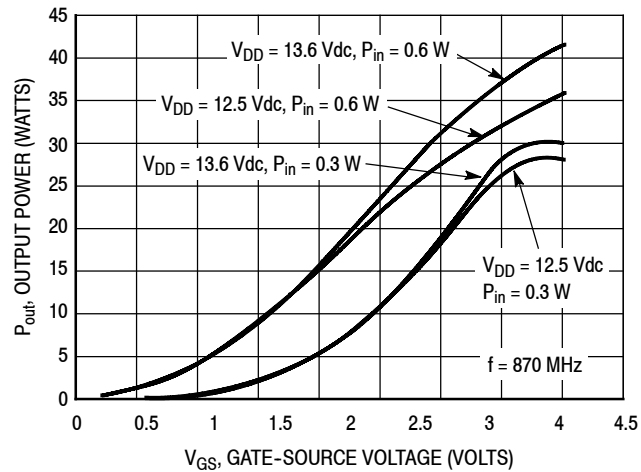


Figure 7. CW Output Power versus Gate-Source Voltage

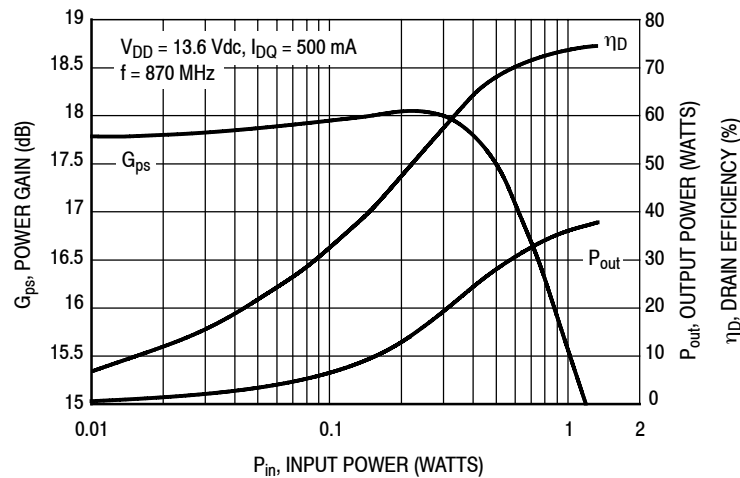


Figure 8. Power Gain, CW Output Power and Drain Efficiency versus Input Power

$V_{DD} = 13.6 \text{ Vdc}$, $I_{DQ} = 500 \text{ mA}$, $P_{out} = 31 \text{ W Avg.}$

f MHz	Z_{source} Ω	Z_{load} Ω
870	$0.28 - j0.71$	$0.98 - j0.52$

Z_{source} = Test circuit impedance as measured from gate to ground.

Z_{load} = Test circuit impedance as measured from drain to ground.

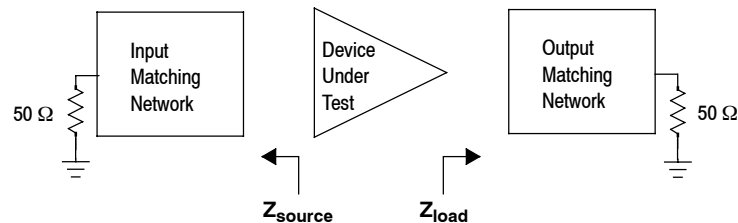


Figure 9. Narrowband Series Equivalent Source and Load Impedance — 870 MHz

760-870 MHz BROADBAND REFERENCE CIRCUIT, 50 OHM SYSTEM

Table 8. 760-870 MHz Broadband Performance (13.6 Vdc, I_{DQ} = 100 mA, T_A = 25°C, CW)

Frequency (MHz)	G _{ps} (dB)	η _D (%)	P _{1dB} (W)
760	15.7	62.0	44
820	15.7	63.0	37
870	15.5	61.0	36

Table 9. Load Mismatch/Ruggedness (In Freescale Reference Circuit)

Frequency (MHz)	Signal Type	VSWR	P _{out} (W)	Test Voltage, V _{DD}	Result
870	CW	>65:1 at all Phase Angles	64 (3 dB Overdrive)	17	No Device Degradation

760-870 MHz BROADBAND REFERENCE CIRCUIT

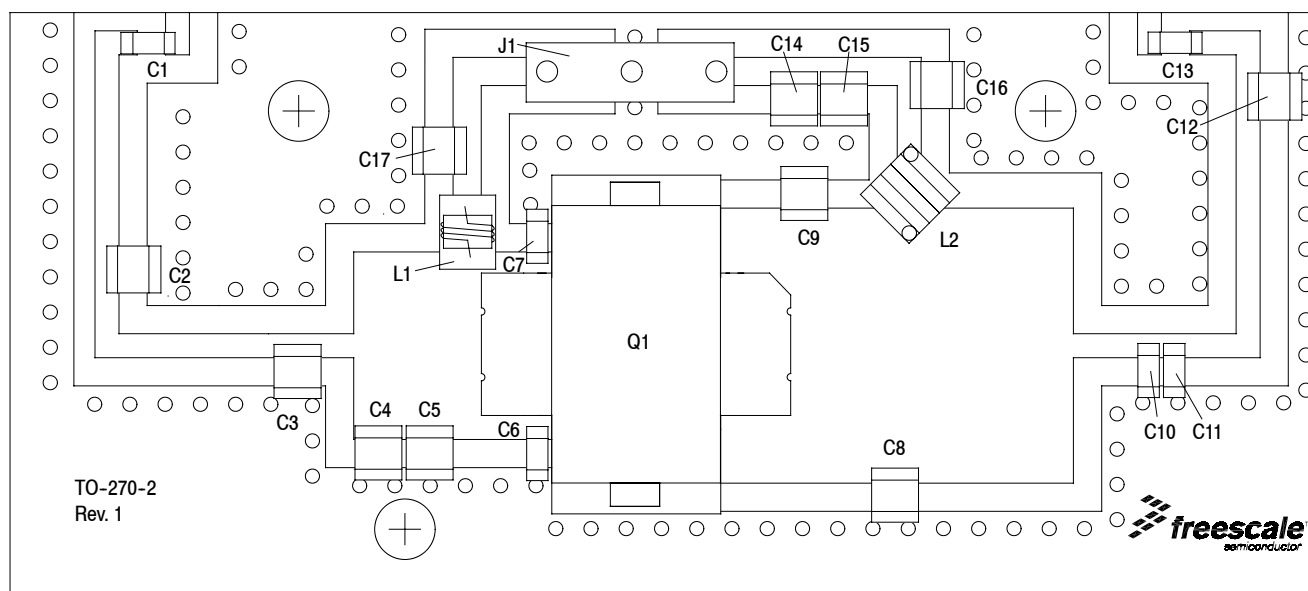


Figure 10. AFT09MS031NR1 Broadband Reference Circuit Component Layout — 760-870 MHz

Table 10. AFT09MS031NR1 Broadband Reference Circuit Component Designations and Values — 760-870 MHz

Part	Description	Part Number	Manufacturer
C1, C10, C11, C12	5.6 pF Chip Capacitors	ATC600F5R6BT250XT	ATC
C2	6.8 pF Chip Capacitor	ATC600F6R8BT250XT	ATC
C3	8.2 pF Chip Capacitor	ATC600F8R2BT250XT	ATC
C4	12 pF Chip Capacitor	ATC600F120JT250XT	ATC
C5	10 pF Chip Capacitor	ATC600F100JT250XT	ATC
C6, C7	30 pF Chip Capacitors	ATC600F300JT250XT	ATC
C8, C9	22 pF Chip Capacitors	ATC600F220JT250XT	ATC
C13, C16	240 pF Chip Capacitors	ATC600F241JT250XT	ATC
C14	0.10 μ F Chip Capacitor	GRM21BR71H104KA01B	Murata
C15	0.01 μ F Chip Capacitor	GRM21BR72A103KA01B	Murata
C17	22 pF Chip Capacitor	ATC100A220JT150XT	ATC
L1	6.8 nH Inductor	0805WL6R8KT	ATC
L2	17 nH Inductor	0908SQ17NJLC	Coilcraft
Q1	RF Power LDMOS Transistor	AFT09MS031NR1	Freescaler
J1	3 Pin	AMP-9-146305-0	TE Connectivity
PCB	0.020", $\epsilon_r = 4.8$	S1000-2, FR4	Shengyi

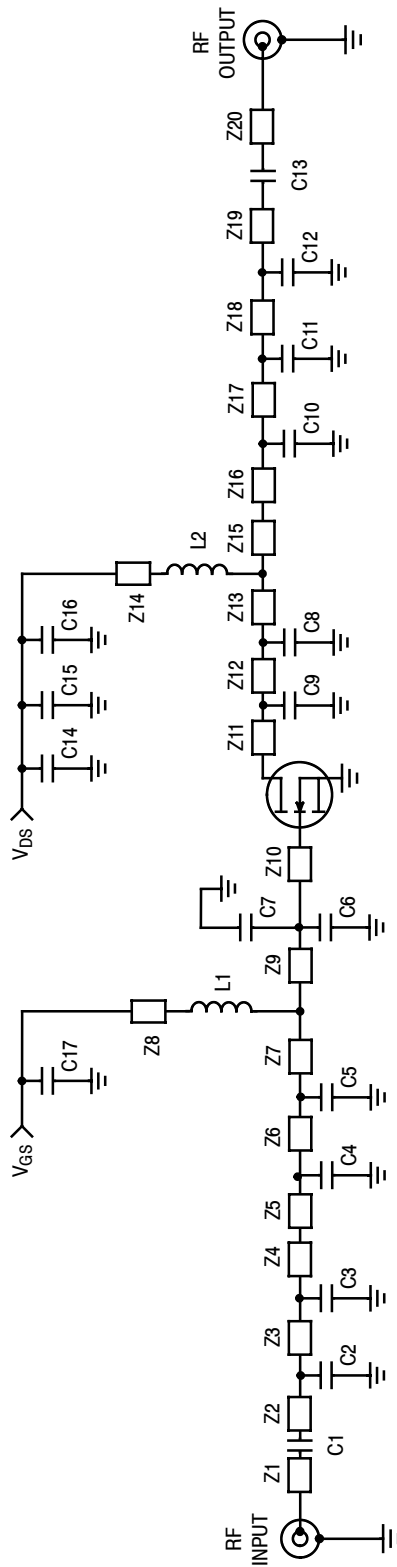


Figure 11. AFT09MS031NR1 Broadband Reference Circuit Schematic — 760-870 MHz

Table 11. AFT09MS031NR1 Broadband Reference Circuit Microstrips — 760-870 MHz

Microstrip	Description	Microstrip	Description
Z1, Z20	0.034" x 0.060" Microstrip	Z11, Z12	0.390" x 0.120" Microstrip
Z2*	0.034" x 0.380" Microstrip	Z13	0.390" x 0.080" Microstrip
Z3*	0.034" x 0.215" Microstrip	Z14	0.034" x 0.100" Microstrip
Z4	0.034" x 0.054" Microstrip	Z15	0.390" x 0.200" Microstrip
Z5, Z6	0.266" x 0.025" Microstrip	Z16	0.034" x 0.110" Microstrip
Z7, Z9	0.266" x 0.080" Microstrip	Z17	0.034" x 0.010" Microstrip
Z8	0.034" x 0.050" Microstrip	Z18*	0.034" x 0.190" Microstrip
Z10	0.266" x 0.015" Microstrip	Z19*	0.034" x 0.110" Microstrip

* Line length includes microstrip bends

TYPICAL CHARACTERISTICS — 760-860 MHz BROADBAND REFERENCE CIRCUIT

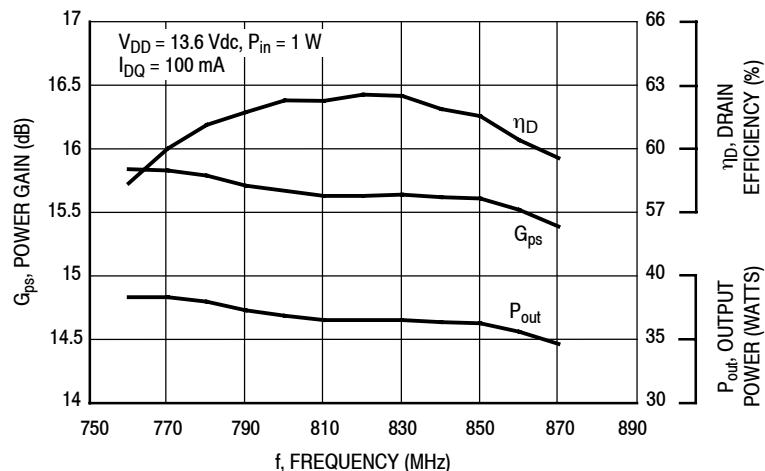


Figure 12. Power Gain, CW Output Power and Drain Efficiency versus Frequency at a Constant Input Power

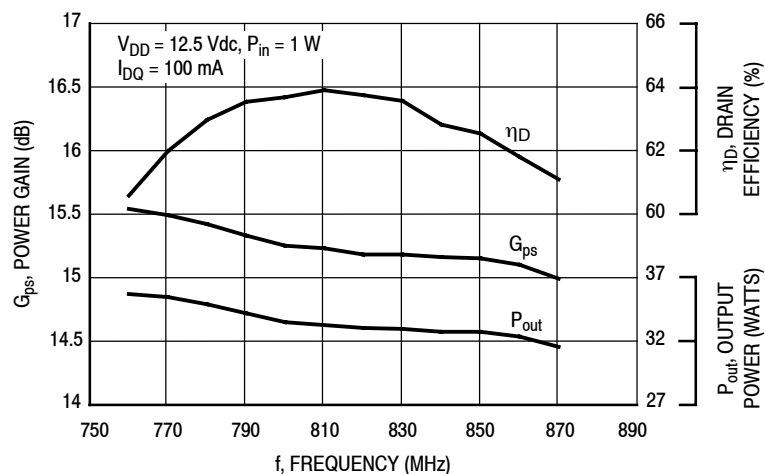


Figure 13. Power Gain, CW Output Power and Drain Efficiency versus Frequency at a Constant Input Power

TYPICAL CHARACTERISTICS — 760-870 MHz BROADBAND REFERENCE CIRCUIT

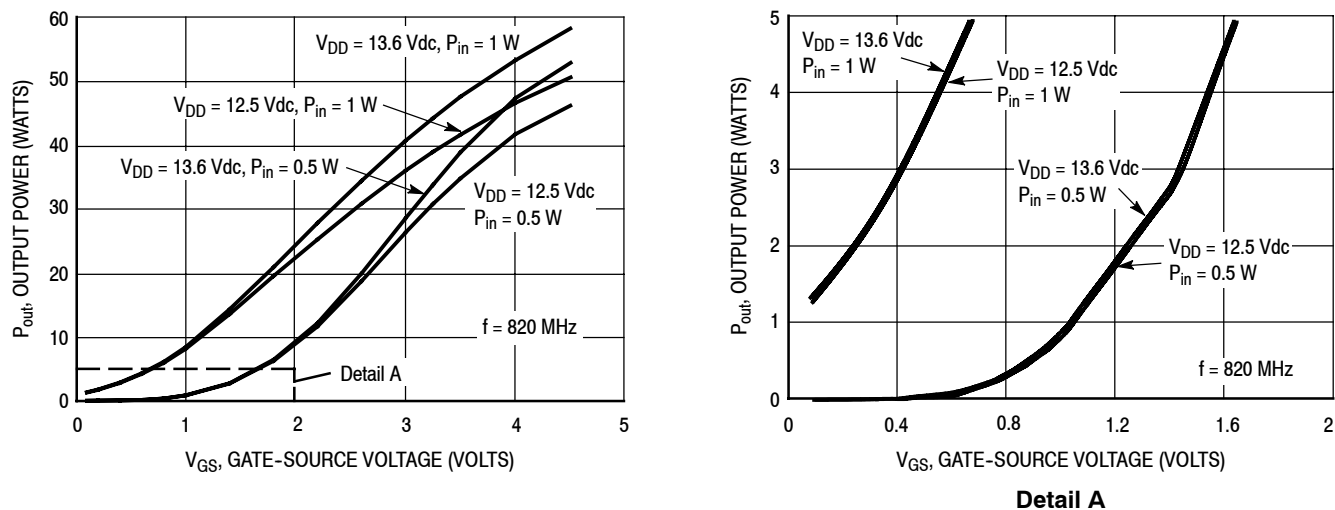


Figure 14. CW Output Power versus Gate-Source Voltage

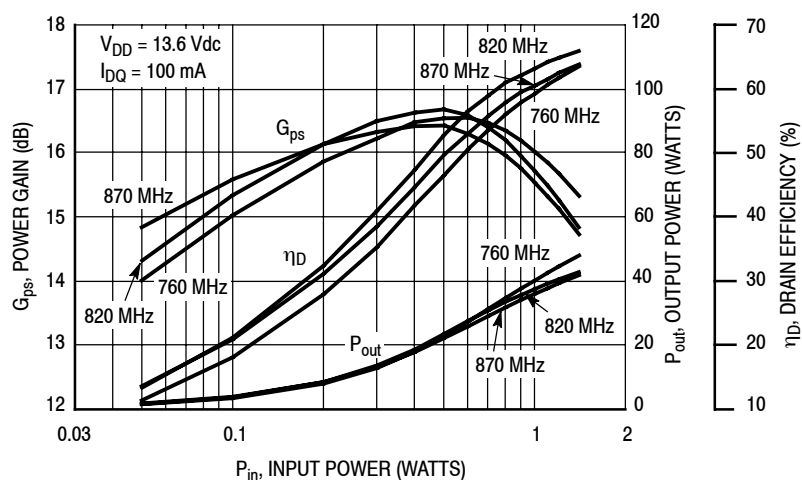
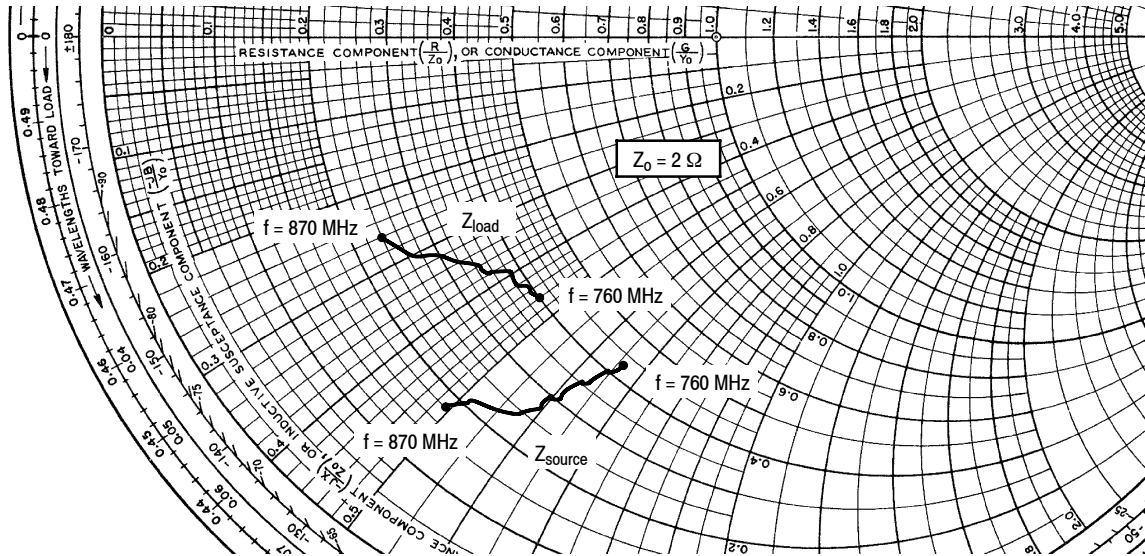


Figure 15. Power Gain, CW Output Power and Drain Efficiency versus Input Power and Frequency

760-870 MHz BROADBAND REFERENCE CIRCUIT



$V_{DD} = 13.6 \text{ Vdc}$, $I_{DQ} = 100 \text{ mA}$, $P_{out} = 31 \text{ W Avg.}$

f MHz	Z_{source} Ω	Z_{load} Ω
760	$0.85 - j1.31$	$0.80 - j0.92$
770	$0.80 - j1.30$	$0.78 - j0.88$
780	$0.75 - j1.28$	$0.78 - j0.85$
790	$0.69 - j1.26$	$0.76 - j0.81$
800	$0.65 - j1.24$	$0.76 - j0.78$
810	$0.59 - j1.21$	$0.72 - j0.75$
820	$0.55 - j1.18$	$0.70 - j0.73$
830	$0.51 - j1.15$	$0.67 - j0.70$
840	$0.46 - j1.11$	$0.62 - j0.66$
850	$0.42 - j1.01$	$0.57 - j0.62$
860	$0.39 - j1.02$	$0.52 - j0.57$
870	$0.36 - j0.97$	$0.48 - j0.52$

Z_{source} = Test circuit impedance as measured from gate to ground.

Z_{load} = Test circuit impedance as measured from drain to ground.

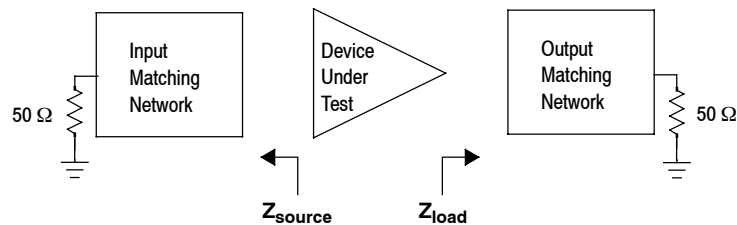
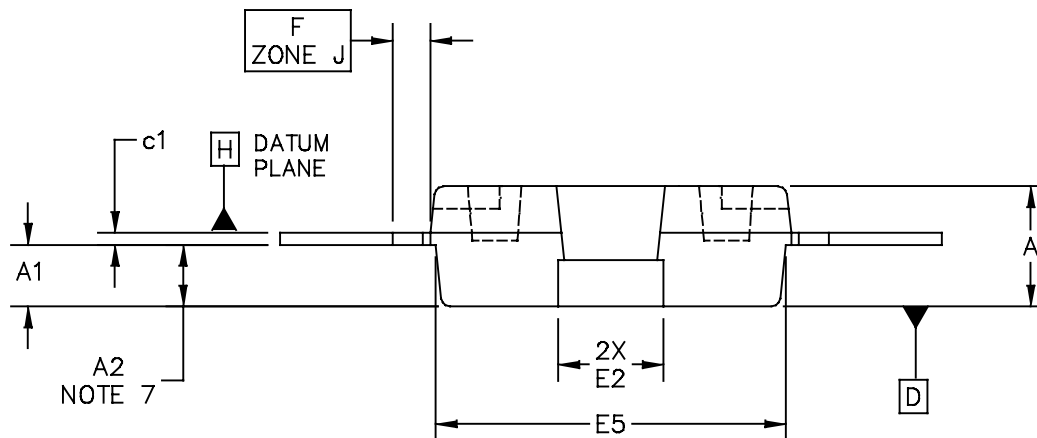
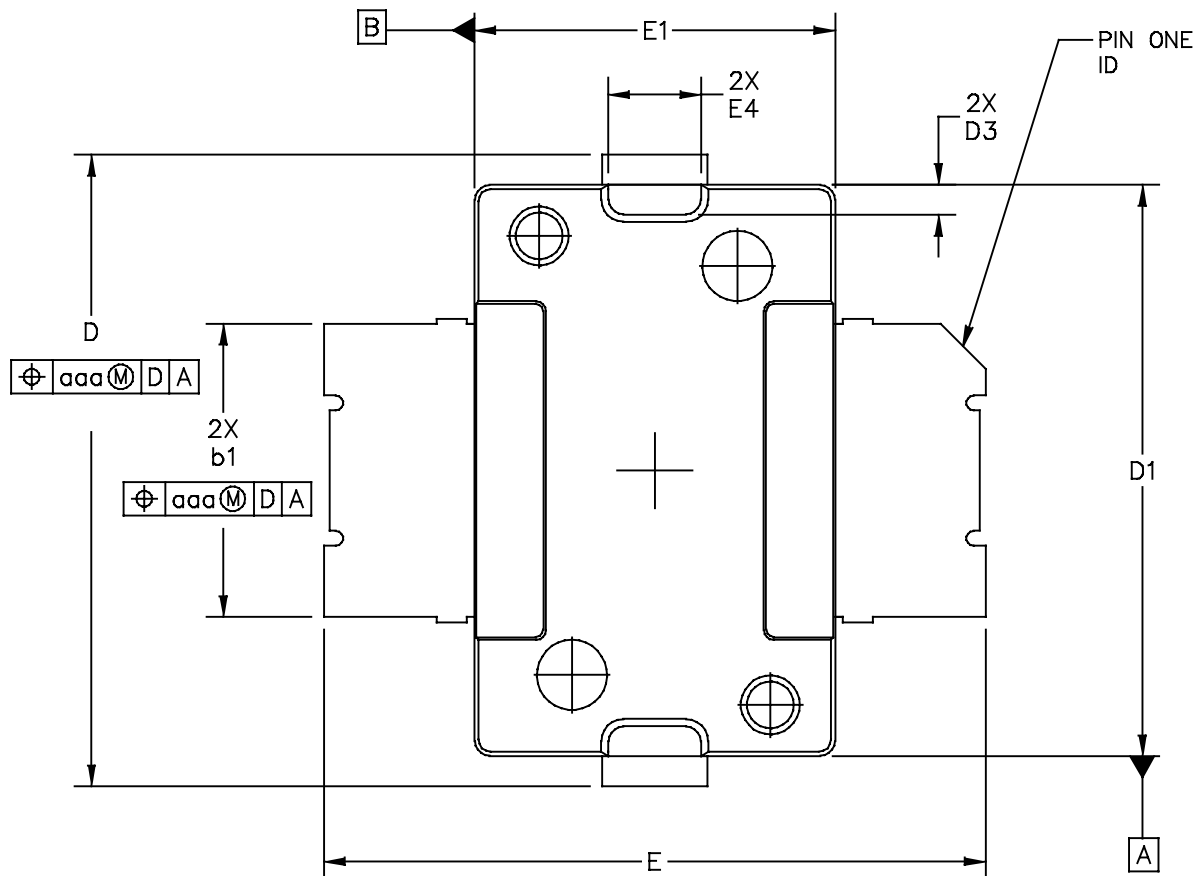
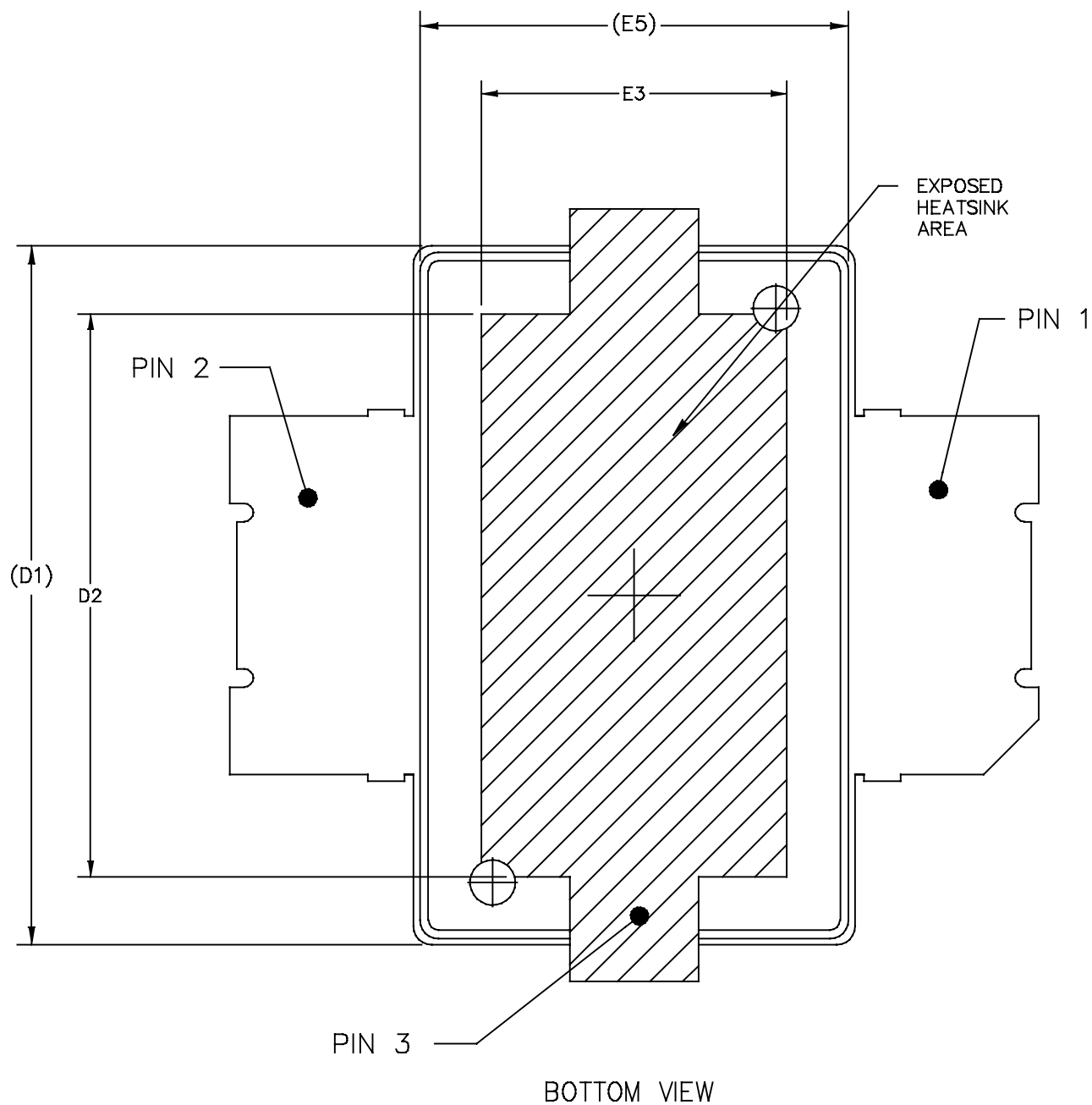


Figure 14. Broadband Series Equivalent Source and Load Impedance — 760-870 MHz

PACKAGE DIMENSIONS



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TITLE: TO-270 SURFACE MOUNT		DOCUMENT NO: 98ASH98117A	REV: K
		CASE NUMBER: 1265-09	29 JUN 2007
		STANDARD: JEDEC TO-270 AA	



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TITLE: TO-270 SURFACE MOUNT		DOCUMENT NO: 98ASH98117A		REV: K	
		CASE NUMBER: 1265-09		29 JUN 2007	
		STANDARD: JEDEC TO-270 AA			

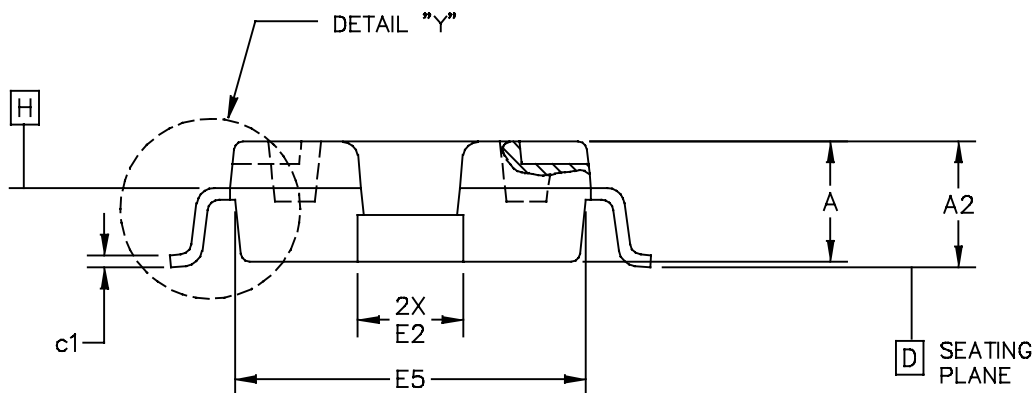
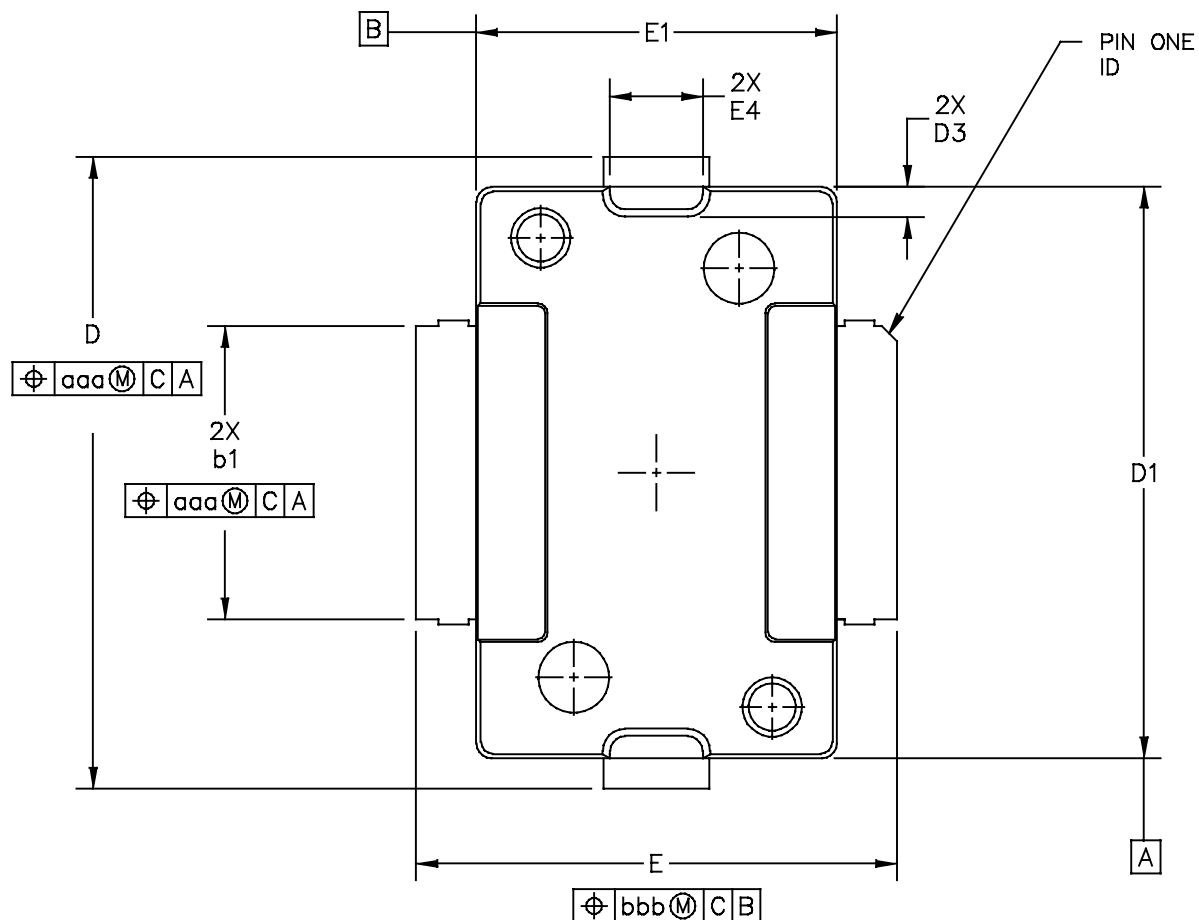
NOTES:

1. CONTROLLING DIMENSION: INCH
2. INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M-1994.
3. DATUM PLANE -H- IS LOCATED AT TOP OF LEAD AND IS COINCIDENT WITH THE LEAD WHERE THE LEAD EXITS THE PLASTIC BODY AT THE TOP OF THE PARTING LINE.
4. DIMENSIONS "D1" AND "E1" DO NOT INCLUDE MOLD PROTRUSION. ALLOWABLE PROTRUSION IS .006 PER SIDE. DIMENSIONS "D1" AND "E1" DO INCLUDE MOLD MISMATCH AND ARE DETERMINED AT DATUM PLANE -H-.
5. DIMENSION "b1" DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE .005 TOTAL IN EXCESS OF THE "b1" DIMENSION AT MAXIMUM MATERIAL CONDITION.
6. DATUMS -A- AND -B- TO BE DETERMINED AT DATUM PLANE -H-.
7. DIMENSION "A2" APPLIES WITHIN ZONE "J" ONLY.
8. DIMENSIONS "D" AND "E2" DO NOT INCLUDE MOLD PROTRUSION. OVERALL LENGTH INCLUDING MOLD PROTRUSION SHOULD NOT EXCEED 0.430 INCH FOR DIMENSION "D" AND 0.080 INCH FOR DIMENSION "E2". DIMENSIONS "D" AND "E2" DO INCLUDE MOLD MISMATCH AND ARE DETERMINED AT DATUM PLANE -D-.

STYLE 1:

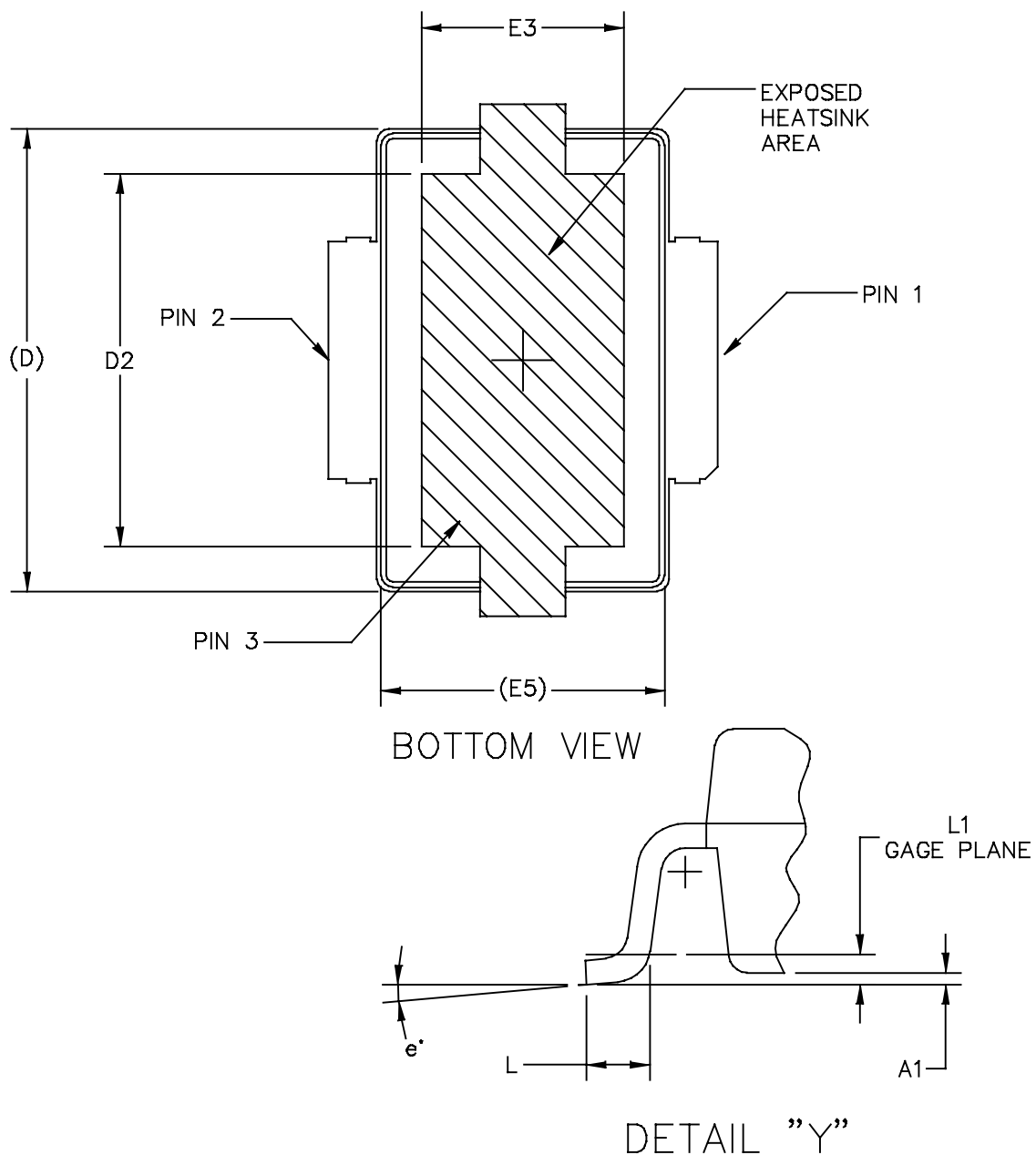
PIN 1 - DRAIN
PIN 2 - GATE
PIN 3 - SOURCE

INCH			MILLIMETER		DIM	INCH		MILLIMETER	
DIM	MIN	MAX	MIN	MAX		MIN	MAX	MIN	MAX
A	.078	.082	1.98	2.08	F	.025 BSC		0.64 BSC	
A1	.039	.043	0.99	1.09	b1	.193	.199	4.90	5.06
A2	.040	.042	1.02	1.07	c1	.007	.011	0.18	0.28
D	.416	.424	10.57	10.77	aaa	.004		0.10	
D1	.378	.382	9.60	9.70					
D2	.290	----	7.37	----					
D3	.016	.024	0.41	0.61					
E	.436	.444	11.07	11.28					
E1	.238	.242	6.04	6.15					
E2	.066	.074	1.68	1.88					
E3	.150	----	3.81	----					
E4	.058	.066	1.47	1.68					
E5	.231	.235	5.87	5.97					
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TITLE: TO-270 SURFACE MOUNT					DOCUMENT NO: 98ASH98117A			REV: K	
					CASE NUMBER: 1265-09			29 JUN 2007	
					STANDARD: JEDEC TO-270 AA				



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TITLE: TO-270 GULL WING		DOCUMENT NO: 98ASA99301D		REV: C	
		CASE NUMBER: 1265A-03		02 JUL 2007	
		STANDARD: JEDEC TO-270 BA			

AFT09MS031NR1 AFT09MS031GMR1



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TITLE: TO-270 GULL WING	DOCUMENT NO: 98ASA99301D		REV: C
	CASE NUMBER: 1265A-03		02 JUL 2007
	STANDARD: JEDEC TO-270 BA		

NOTES:

1. CONTROLLING DIMENSION: INCH
2. INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M–1994.
3. DATUM PLANE –H– IS LOCATED AT TOP OF LEAD AND IS COINCIDENT WITH THE LEAD WHERE THE LEAD EXITS THE PLASTIC BODY AT THE TOP OF THE PARTING LINE.
4. DIMENSIONS "D1" AND "E1" DO NOT INCLUDE MOLD PROTRUSION. ALLOWABLE PROTRUSION IS .006 PER SIDE. DIMENSIONS "D1 AND "E1" DO INCLUDE MOLD MISMATCH AND ARE DETERMINED AT DATUM PLANE –H–.
5. DIMENSION b1 DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE .005 TOTAL IN EXCESS OF THE b1 DIMENSION AT MAXIMUM MATERIAL CONDITION.
6. DATUMS –A– AND –B– TO BE DETERMINED AT DATUM PLANE –H–.
7. DIMENSIONS "D" AND "E2" DO NOT INCLUDE MOLD PROTRUSION. ALLOWABLE PROTRUSION IS .003 PER SIDE. DIMENSIONS "D AND "E2" DO INCLUDE MOLD MISMATCH AND ARE DETERMINED AT DATUM PLANE –D–.

STYLE 1:

PIN 1 – DRAIN
PIN 2 – GATE
PIN 3 – SOURCE

INCH			MILLIMETER		INCH			MILLIMETER	
DIM	MIN	MAX	MIN	MAX	DIM	MIN	MAX	MIN	MAX
A	.078	.082	1.98	2.08	L	.018	.024	0.46	0.61
A1	.001	.004	0.02	0.10	L1	.01 BSC		0.25 BSC	
A2	.077	.088	1.96	2.24	b1	.193	.199	4.90	5.06
D	.416	.424	10.57	10.77	c1	.007	.011	0.18	0.28
D1	.378	.382	9.60	9.70	e	2"	8"	2"	8"
D2	.290	—	7.37	—	aaa	.004		0.10	
D3	.016	.024	0.41	0.61					
E	.316	.324	8.03	8.23					
E1	.238	.242	6.04	6.15					
E2	.066	.074	1.68	1.88					
E3	.150	—	3.81	—					
E4	.058	.066	1.47	1.68					
E5	.231	.235	5.87	5.97					
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TITLE: TO—270 GULL WING					DOCUMENT NO: 98ASA99301D				REV: C
					CASE NUMBER: 1265A—03				02 JUL 2007
					STANDARD: JEDEC TO—270 BA				

PRODUCT DOCUMENTATION, SOFTWARE AND TOOLS

Refer to the following documents, software and tools to aid your design process.

Application Notes

- AN1907: Solder Reflow Attach Method for High Power RF Devices in Over-Molded Plastic Packages
- AN1955: Thermal Measurement Methodology of RF Power Amplifiers
- AN3263: Bolt Down Mounting Method for High Power RF Transistors and RFICs in Over-Molded Plastic Packages
- AN3789: Clamping of High Power RF Transistors and RFICs in Over-Molded Plastic Packages

Engineering Bulletins

- EB212: Using Data Sheet Impedances for RF LDMOS Devices

Software

- Electromigration MTTF Calculator
- RF High Power Model
- .s2p File

Development Tools

- Printed Circuit Boards

For Software and Tools, 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	May 2012	• Initial Release of Data Sheet

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