

# RF Power Field Effect Transistors

## N-Channel Enhancement-Mode Lateral MOSFETs

RF power transistors designed for applications operating at frequencies from 900 to 1215 MHz. These devices are suitable for use in defense and commercial pulse applications, such as IFF and DME.

- Typical Pulse Performance:  $V_{DD} = 50$  Vdc,  $I_{DQ} = 200$  mA, Pulse Width = 128  $\mu$ sec, Duty Cycle = 10%

| Application | $P_{out}$ (W) | f (MHz)  | $G_{ps}$ (dB) | $\eta_D$ (%) |
|-------------|---------------|----------|---------------|--------------|
| Narrowband  | 500 Peak      | 1030     | 19.7          | 62.0         |
| Broadband   | 500 Peak      | 960-1215 | 18.5          | 57.0         |

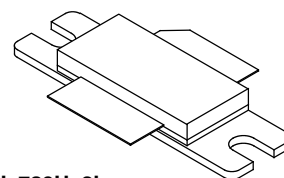
- Capable of Handling 10:1 VSWR, @ 50 Vdc, 1030 MHz, 500 W Peak Power

### Features

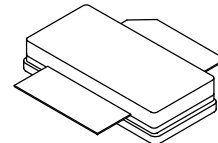
- Characterized with Series Equivalent Large-Signal Impedance Parameters
- Internally Matched for Ease of Use
- Qualified Up to a Maximum of 50  $V_{DD}$  Operation
- Integrated ESD Protection
- Greater Negative Gate-Source Voltage Range for Improved Class C Operation
- In Tape and Reel. R5 Suffix =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

**MMRF1009HR5**  
**MMRF1009HSR5**

**960-1215 MHz, 500 W, 50 V PULSE**  
**LATERAL N-CHANNEL**  
**RF POWER MOSFETs**



**NI-780H-2L**  
**MMRF1009HR5**



**NI-780S-2L**  
**MMRF1009HSR5**

**Table 1. Maximum Ratings**

| Rating  | Symbol    | Value       | Unit         |
|---|-----------|-------------|--------------|
| Drain-Source Voltage                          | $V_{DSS}$ | -0.5, +110  | Vdc          |
| Gate-Source Voltage                           | $V_{GS}$  | -6.0, +10   | Vdc          |
| Storage Temperature Range                     | $T_{stg}$ | -65 to +150 | $^{\circ}$ C |
| Case Operating Temperature                    | $T_C$     | 150         | $^{\circ}$ C |
| Operating Junction Temperature <sup>(1)</sup> | $T_J$     | 225         | $^{\circ}$ C |

**Table 2. Thermal Characteristics**

| Characteristic  | Symbol          | Value <sup>(2)</sup> | Unit           |
|---|-----------------|----------------------|----------------|
| Thermal Impedance, Junction to Case<br>Case Temperature 80 $^{\circ}$ C, 500 W Pulse, 128 $\mu$ sec Pulse Width, 10% Duty Cycle | $Z_{\theta JC}$ | 0.044                | $^{\circ}$ C/W |

1. Continuous use at maximum temperature will affect MTTF.
2. Refer to AN1955, *Thermal Measurement Methodology of RF Power Amplifiers*. Go to <http://www.freescale.com/rf>. Select Documentation/Application Notes - AN1955.

**Table 3. ESD Protection Characteristics**

| Test Methodology                      | Class             |
|---------------------------------------|-------------------|
| Human Body Model (per JESD22-A114)    | 2, passes 2600 V  |
| Machine Model (per EIA/JESD22-A115)   | B, passes 200 V   |
| Charge Device Model (per JESD22-C101) | IV, passes 2000 V |

**Table 4. Electrical Characteristics** ( $T_A = 25^\circ\text{C}$  unless otherwise noted)

| Characteristic | Symbol | Min | Typ | Max | Unit |
|----------------|--------|-----|-----|-----|------|
|----------------|--------|-----|-----|-----|------|

**Off Characteristics**

|   |               |     |   |     |                 |
|---|---------------|-----|---|-----|-----------------|
| Gate-Source Leakage Current<br>( $V_{GS} = 5\text{ Vdc}$ , $V_{DS} = 0\text{ Vdc}$ )              | $I_{GSS}$     | —   | — | 10  | $\mu\text{Adc}$ |
| Drain-Source Breakdown Voltage<br>( $V_{GS} = 0\text{ Vdc}$ , $I_D = 200\text{ mA}$ )             | $V_{(BR)DSS}$ | 110 | — | —   | Vdc             |
| Zero Gate Voltage Drain Leakage Current<br>( $V_{DS} = 50\text{ Vdc}$ , $V_{GS} = 0\text{ Vdc}$ ) | $I_{DSS}$     | —   | — | 20  | $\mu\text{Adc}$ |
| Zero Gate Voltage Drain Leakage Current<br>( $V_{DS} = 90\text{ Vdc}$ , $V_{GS} = 0\text{ Vdc}$ ) | $I_{DSS}$     | —   | — | 200 | $\mu\text{Adc}$ |

**On Characteristics**

|   |              |     |      |     |     |
|---|--------------|-----|------|-----|-----|
| Gate Threshold Voltage<br>( $V_{DS} = 10\text{ Vdc}$ , $I_D = 1.32\text{ mA}$ )                               | $V_{GS(th)}$ | 0.9 | 1.7  | 2.4 | Vdc |
| Gate Quiescent Voltage<br>( $V_{DD} = 50\text{ Vdc}$ , $I_D = 200\text{ mAdc}$ , Measured in Functional Test) | $V_{GS(Q)}$  | 1.7 | 2.4  | 3.2 | Vdc |
| Drain-Source On-Voltage<br>( $V_{GS} = 10\text{ Vdc}$ , $I_D = 3.26\text{ Adc}$ )                             | $V_{DS(on)}$ | —   | 0.25 | —   | Vdc |

**Dynamic Characteristics (1)**

|   |           |   |      |   |    |
|---|-----------|---|------|---|----|
| Reverse Transfer Capacitance<br>( $V_{DS} = 50\text{ Vdc} \pm 30\text{ mV(rms)ac}$ @ 1 MHz, $V_{GS} = 0\text{ Vdc}$ ) | $C_{rss}$ | — | 0.2  | — | pF |
| Output Capacitance<br>( $V_{DS} = 50\text{ Vdc} \pm 30\text{ mV(rms)ac}$ @ 1 MHz, $V_{GS} = 0\text{ Vdc}$ )           | $C_{oss}$ | — | 697  | — | pF |
| Input Capacitance<br>( $V_{DS} = 50\text{ Vdc}$ , $V_{GS} = 0\text{ Vdc} \pm 30\text{ mV(rms)ac}$ @ 1 MHz)            | $C_{iss}$ | — | 1391 | — | pF |

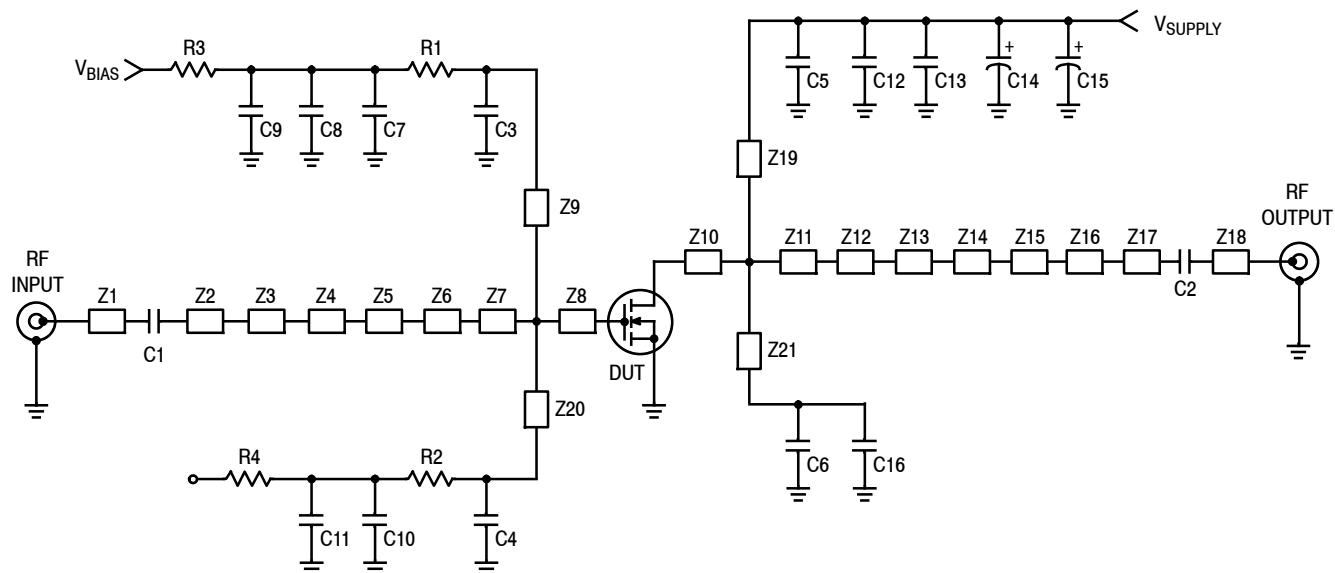
**Functional Tests** (In Freescale Narrowband Test Fixture, 50 ohm system)  $V_{DD} = 50\text{ Vdc}$ ,  $I_{DQ} = 200\text{ mA}$ ,  $P_{out} = 500\text{ W Peak}$  (50 W Avg.),  $f = 1030\text{ MHz}$ , 128  $\mu\text{sec}$  Pulse Width, 10% Duty Cycle

|                   |          |      |      |      |    |
|-------------------|----------|------|------|------|----|
| Power Gain        | $G_{ps}$ | 18.5 | 19.7 | 22.0 | dB |
| Drain Efficiency  | $\eta_D$ | 58.0 | 62.0 | —    | %  |
| Input Return Loss | IRL      | —    | -18  | -9   | dB |

**Typical Broadband Performance — 960-1215 MHz** (In Freescale 960-1215 MHz Test Fixture, 50 ohm system)  $V_{DD} = 50\text{ Vdc}$ ,  $I_{DQ} = 200\text{ mA}$ ,  $P_{out} = 500\text{ W Peak}$  (50 W Avg.),  $f = 960\text{-}1215\text{ MHz}$ , 128  $\mu\text{sec}$  Pulse Width, 10% Duty Cycle

|                  |          |   |      |   |    |
|------------------|----------|---|------|---|----|
| Power Gain       | $G_{ps}$ | — | 18.5 | — | dB |
| Drain Efficiency | $\eta_D$ | — | 57.0 | — | %  |

1. Part internally matched both on input and output.

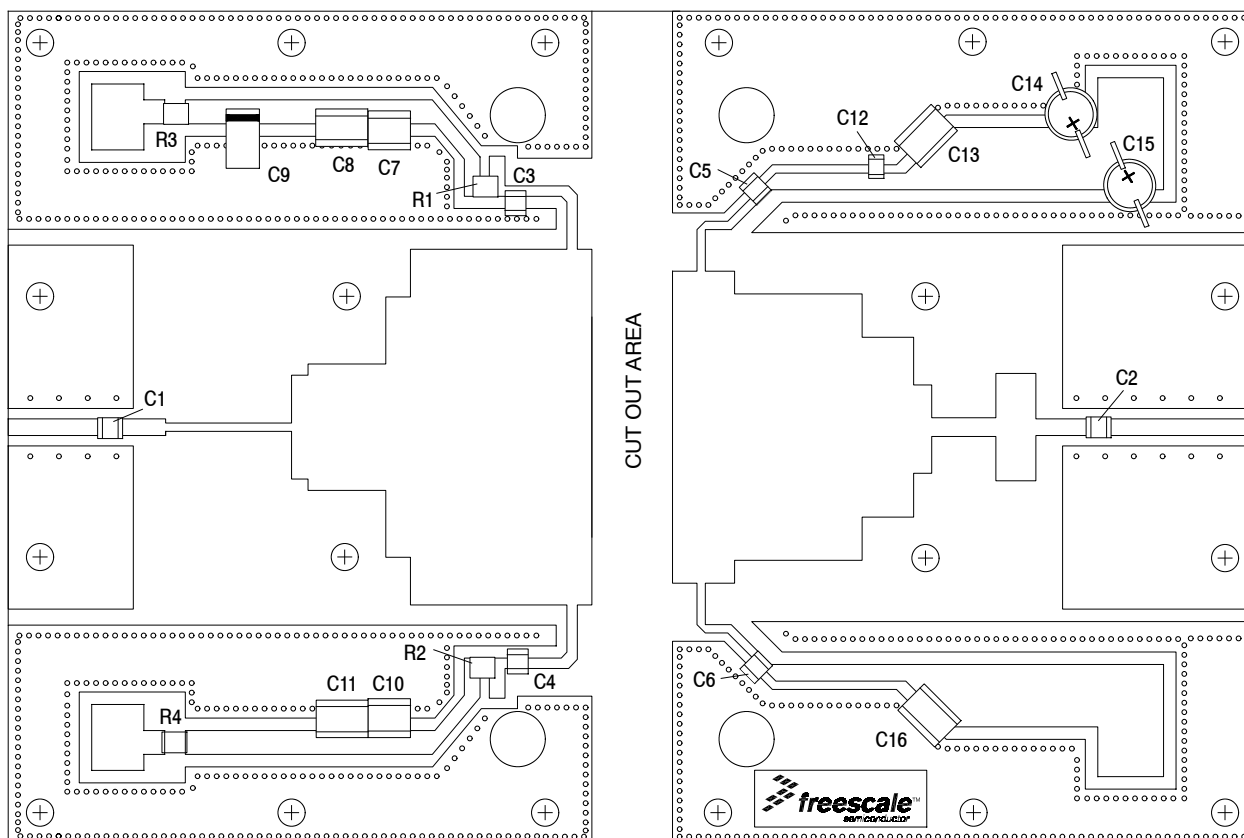


|         |                            |          |  |
|---------|----------------------------|----------|--|
| Z1      | 0.457" x 0.080" Microstrip | Z11      | 0.161" x 1.500" Microstrip                                 |
| Z2      | 0.250" x 0.080" Microstrip | Z12      | 0.613" x 1.281" Microstrip                                 |
| Z3      | 0.605" x 0.040" Microstrip | Z13      | 0.248" x 0.865" Microstrip                                 |
| Z4      | 0.080" x 0.449" Microstrip | Z14      | 0.087" x 0.425" Microstrip                                 |
| Z5      | 0.374" x 0.608" Microstrip | Z15      | 0.309" x 0.090" Microstrip                                 |
| Z6      | 0.118" x 1.252" Microstrip | Z16      | 0.193" x 0.516" Microstrip                                 |
| Z7      | 0.778" x 1.710" Microstrip | Z17      | 0.279" x 0.080" Microstrip                                 |
| Z8      | 0.095" x 1.710" Microstrip | Z18      | 0.731" x 0.080" Microstrip                                 |
| Z9, Z20 | 0.482" x 0.050" Microstrip | Z19, Z21 | 0.507" x 0.040" Microstrip                                 |
| Z10     | 0.138" x 1.500" Microstrip | PCB      | Arlon CuClad 250GX-0300-55-22, 0.030", $\epsilon_r = 2.55$ |

Figure 1. MMRF1009HR5(HSR5) Test Circuit Schematic

Table 5. MMRF1009HR5(HSR5) Test Circuit Component Designations and Values

| Part              | Description                               | Part Number          | Manufacturer |
|-------------------|---|----------------------|--------------|
| C1, C2            | 5.1 pF Chip Capacitors                    | ATC100B5R1CT500XT    | ATC          |
| C3, C4, C5, C6    | 33 pF Chip Capacitors                     | ATC100B330JT500XT    | ATC          |
| C7, C10           | 10 $\mu$ F, 50 V Chip Capacitors          | GRM55DR61H106KA88L   | Murata       |
| C8, C11, C13, C16 | 2.2 $\mu$ F, 100 V Chip Capacitors        | 2225X7R225KT3AB      | ATC          |
| C9                | 22 $\mu$ F, 25 V Chip Capacitor           | TPSD226M025R0200     | AVX          |
| C12               | 1 $\mu$ F, 100 V Chip Capacitor           | GRM31CR72A105KA01L   | Murata       |
| C14, C15          | 470 $\mu$ F, 63 V Electrolytic Capacitors | MCGPR63V477M13X26-RH | Multicomp    |
| R1, R2            | 56 $\Omega$ , 1/4 W Chip Resistors        | CRCW120656R0FKEA     | Vishay       |
| R3, R4            | 0 $\Omega$ , 3 A Chip Resistors           | CRCW12060000Z0EA     | Vishay       |



**Figure 2. MMRF1009HR5(HSR5) Test Circuit Component Layout**

## TYPICAL CHARACTERISTICS

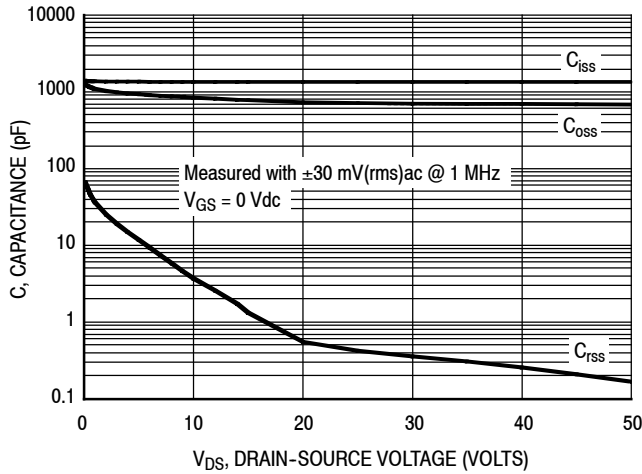


Figure 3. Capacitance versus Drain-Source Voltage

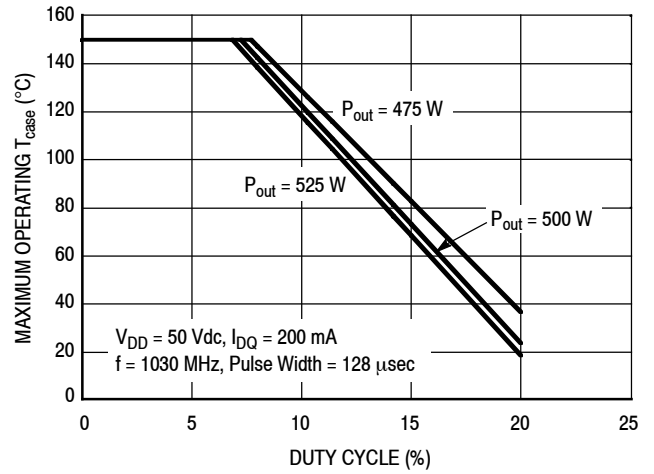


Figure 4. Safe Operating Area

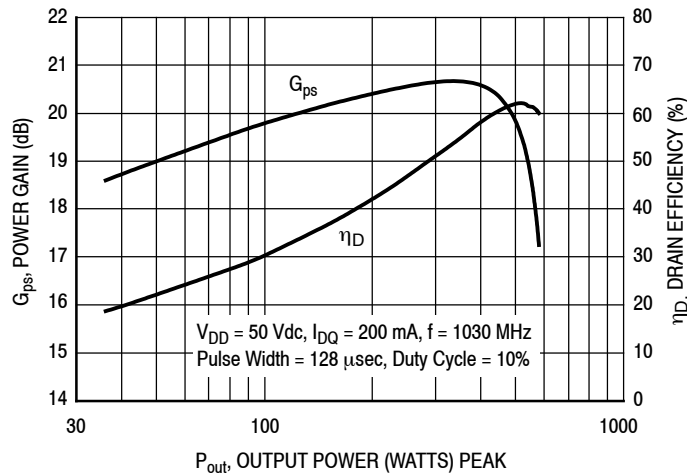


Figure 5. Power Gain and Drain Efficiency versus Output Power

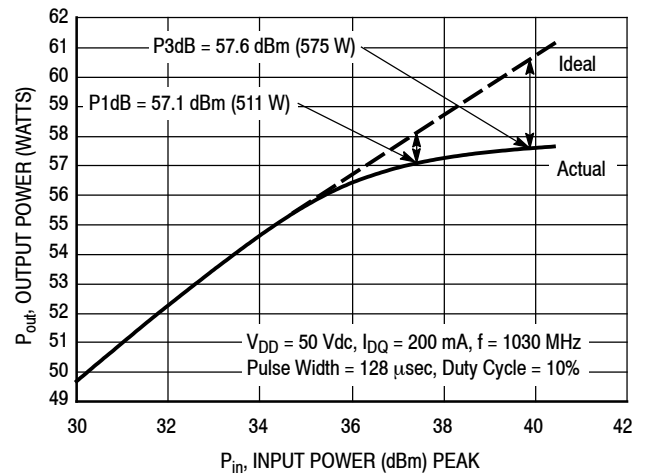


Figure 6. Output Power versus Input Power

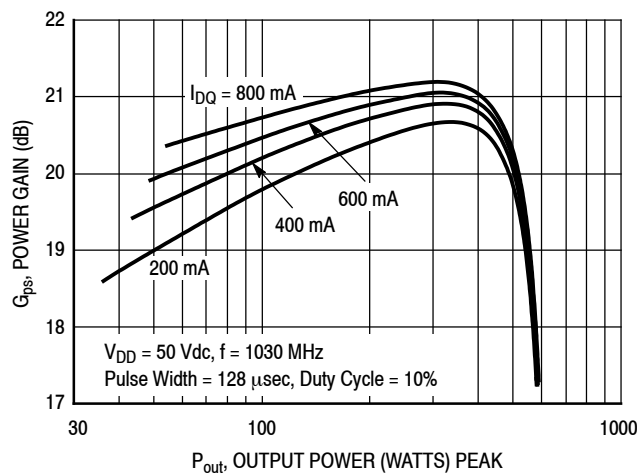


Figure 7. Power Gain versus Output Power

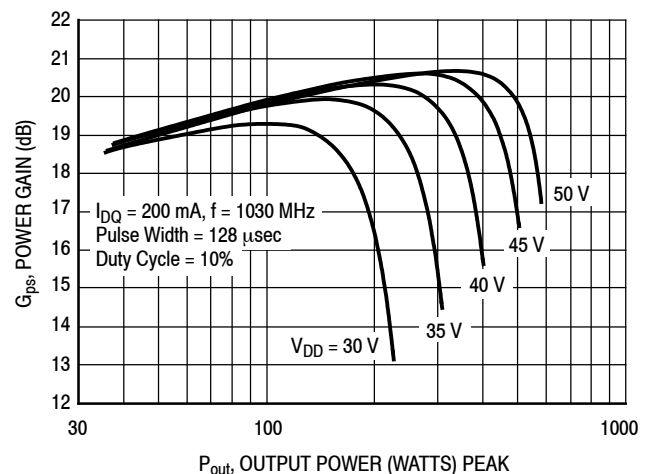


Figure 8. Power Gain versus Output Power

### TYPICAL CHARACTERISTICS

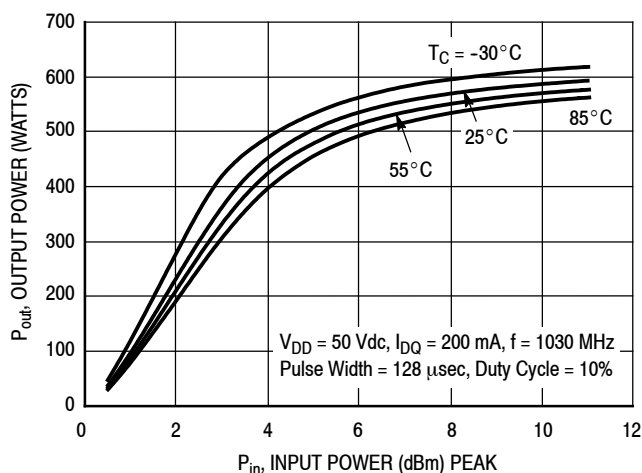


Figure 9. Output Power versus Input Power

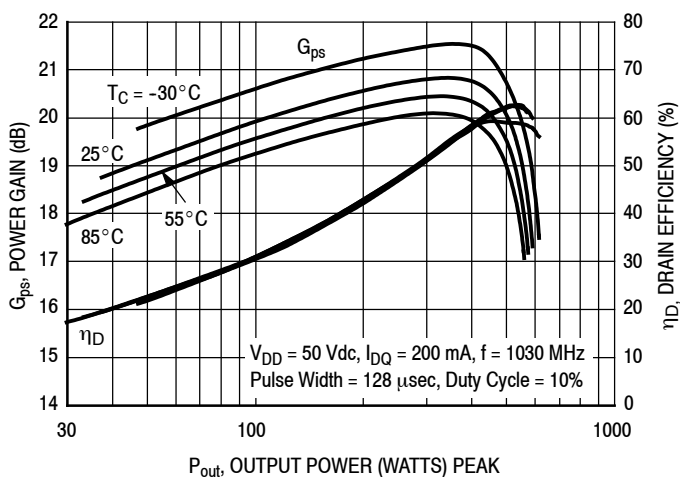
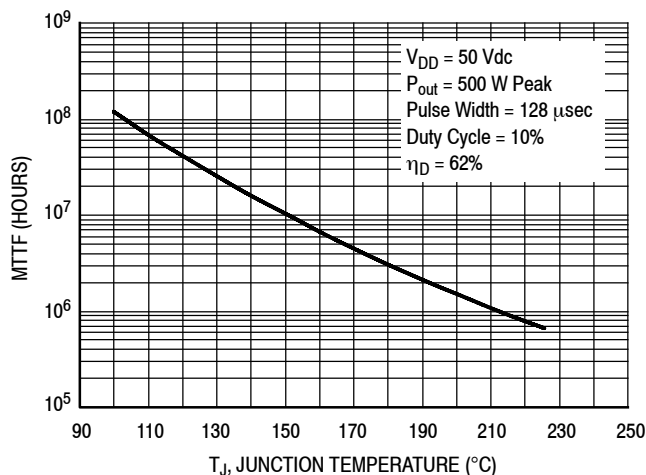


Figure 10. Power Gain and Drain Efficiency versus Output Power



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

Figure 11. MTTF versus Junction Temperature

$V_{DD} = 50 \text{ Vdc}$ ,  $I_{DQ} = 200 \text{ mA}$ ,  $P_{out} = 500 \text{ W Peak}$

| f<br>MHz | $Z_{source}$<br>Ω | $Z_{load}$<br>Ω |
|----------|-------------------|-----------------|
| 1030     | 1.36 - j1.27      | 2.50 - j0.17    |

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

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

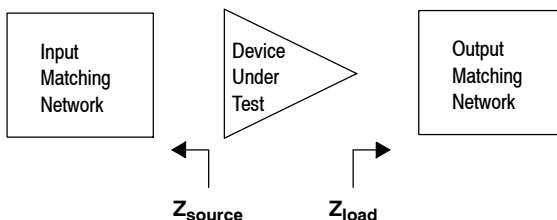


Figure 12. Series Equivalent Source and Load Impedance

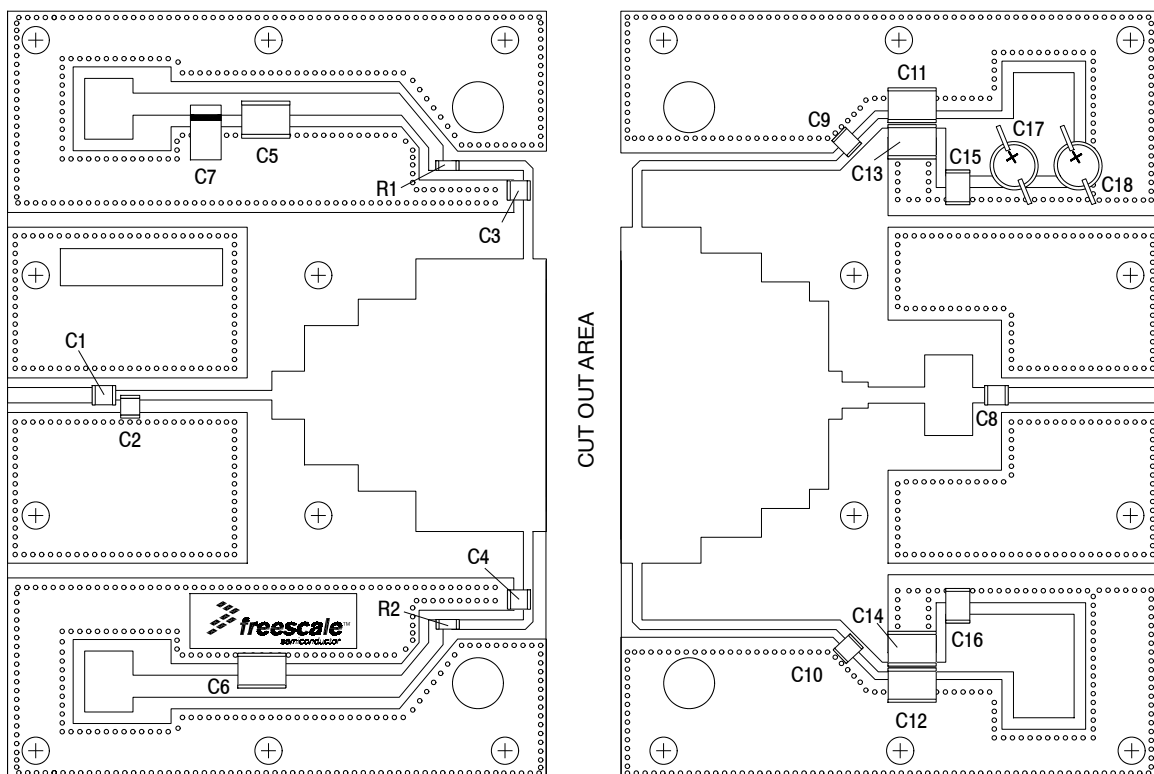
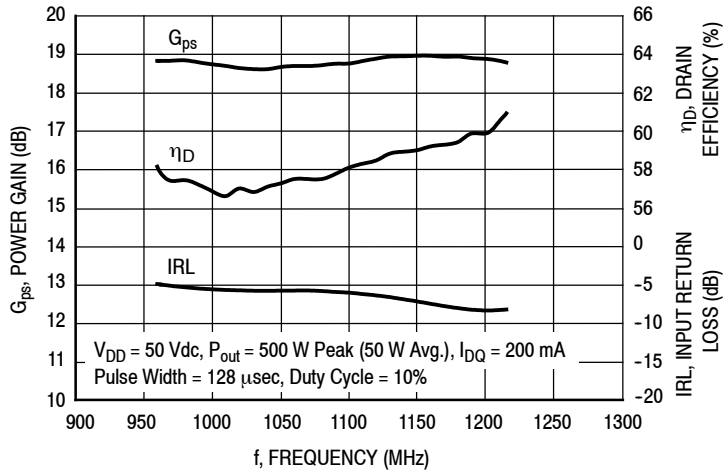


Figure 13. MMRF1009HR5(HSR5) Test Circuit Component Layout — 960-1215 MHz

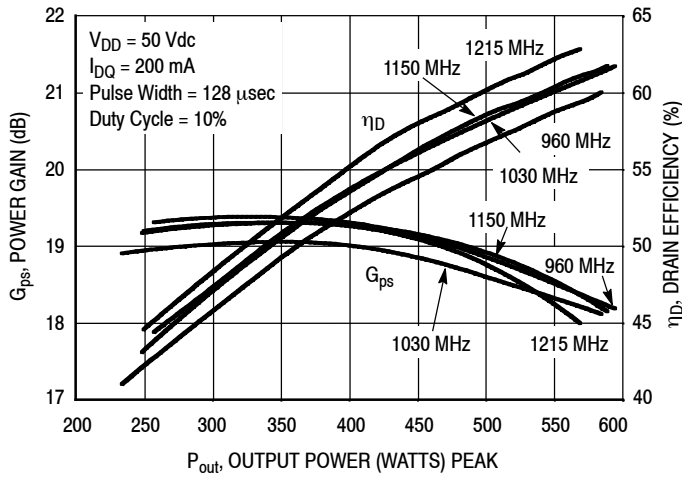
Table 6. MMRF1009HR5(HSR5) Test Circuit Component Designations and Values — 960-1215 MHz

| Part             | Description                               | Part Number          | Manufacturer |
|------------------|---|----------------------|--------------|
| C1               | 2.2 pF Chip Capacitor                     | ATC100B2R2JT500XT    | ATC          |
| C2               | 0.2 pF Chip Capacitor                     | ATC100B0R2BT500XT    | ATC          |
| C3, C4           | 33 pF Chip Capacitors                     | ATC100B330JT500XT    | ATC          |
| C5, C6, C11, C12 | 2.2 $\mu$ F, 100 V Chip Capacitors        | G2225X7R225KT3AB     | ATC          |
| C7               | 22 $\mu$ F, 35 V Tantalum Capacitor       | T491X226K035AT       | Kemet        |
| C8               | 8.2 pF Chip Capacitor                     | ATC100B8R2CT500XT    | ATC          |
| C9, C10          | 39 pF Chip Capacitors                     | ATC100B390JT500XT    | ATC          |
| C13, C14         | 0.022 $\mu$ F, 100 V Chip Capacitors      | C1825C223K1GAC       | Kemet        |
| C15, C16         | 0.10 $\mu$ F, 100 V Chip Capacitors       | C1812F104K1RAC       | Kemet        |
| C17, C18         | 470 $\mu$ F, 63 V Electrolytic Capacitors | MCGPR63V477M13X26-RH | Multicomp    |
| R1, R2           | 22 $\Omega$ , 1/4 W Chip Resistors        | CRCW120622R0FKEA     | Vishay       |
| PCB              | 0.030", $\epsilon_r = 2.55$               | AD255A               | Arlon        |

**TYPICAL CHARACTERISTICS — 960-1215 MHz**

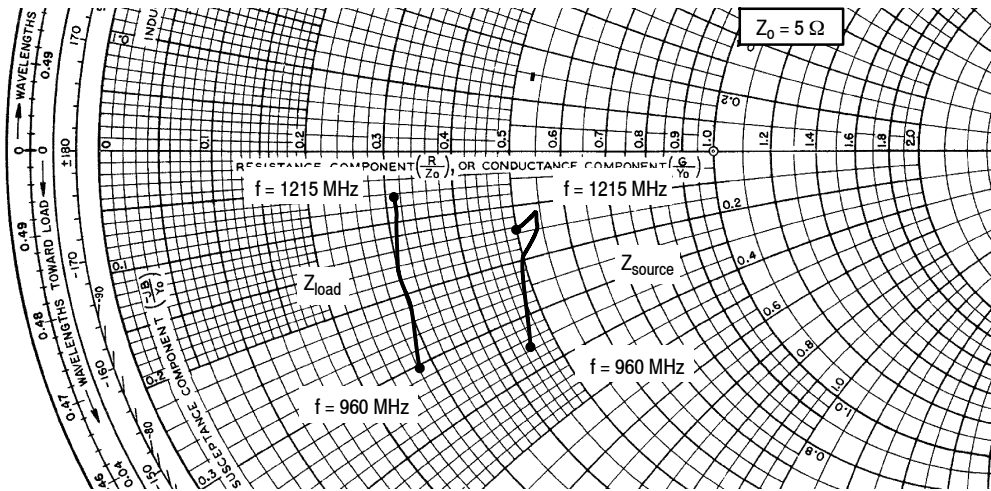


**Figure 14. Power Gain, Drain Efficiency and IRL versus Frequency**



**Figure 15. Power Gain and Drain Efficiency versus Output Power**





$V_{DD} = 50 \text{ Vdc}$ ,  $I_{DQ} = 200 \text{ mA}$ ,  $P_{out} = 500 \text{ W Peak}$

| f<br>MHz | $Z_{source}$<br>$\Omega$ | $Z_{load}$<br>$\Omega$ |
|----------|--------------------------|------------------------|
| 960      | $2.25 - j1.78$           | $1.38 - j1.53$         |
| 1030     | $2.51 - j1.02$           | $1.48 - j1.11$         |
| 1090     | $2.69 - j0.73$           | $1.51 - j0.78$         |
| 1150     | $2.71 - j0.65$           | $1.53 - j0.49$         |
| 1215     | $2.48 - j0.76$           | $1.53 - j0.33$         |

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

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

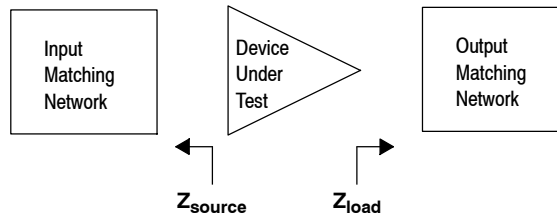
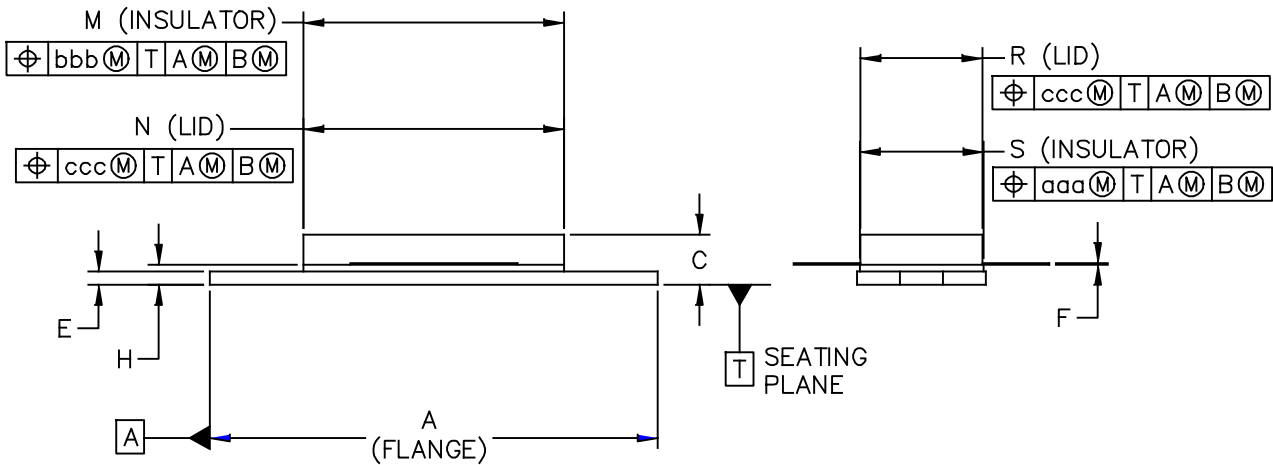
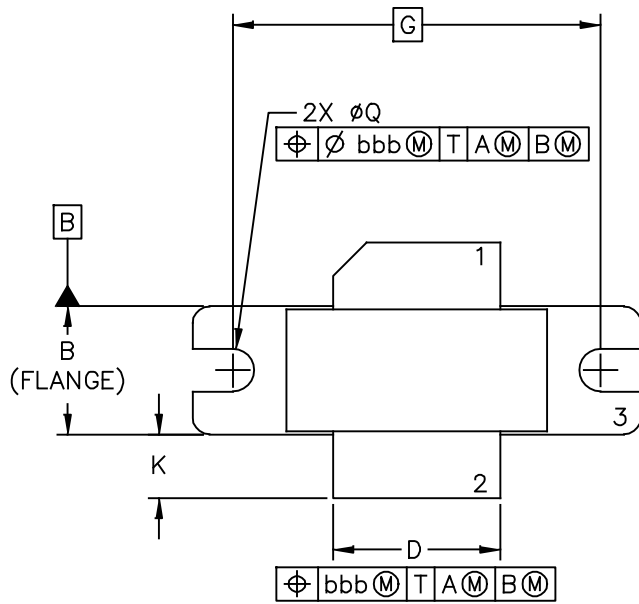


Figure 16. Series Equivalent Source and Load Impedance — 960-1215 MHz

PACKAGE DIMENSIONS



|   |                          |                    |                            |
|---|--------------------------|--------------------|----------------------------|
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| TITLE:<br><br>NI-780                                    | DOCUMENT NO: 98ASB15607C |                    | REV: G                     |
|   | CASE NUMBER: 465-06      |                    | 31 MAR 2005                |
|   | STANDARD: NON-JEDEC      |                    |                            |

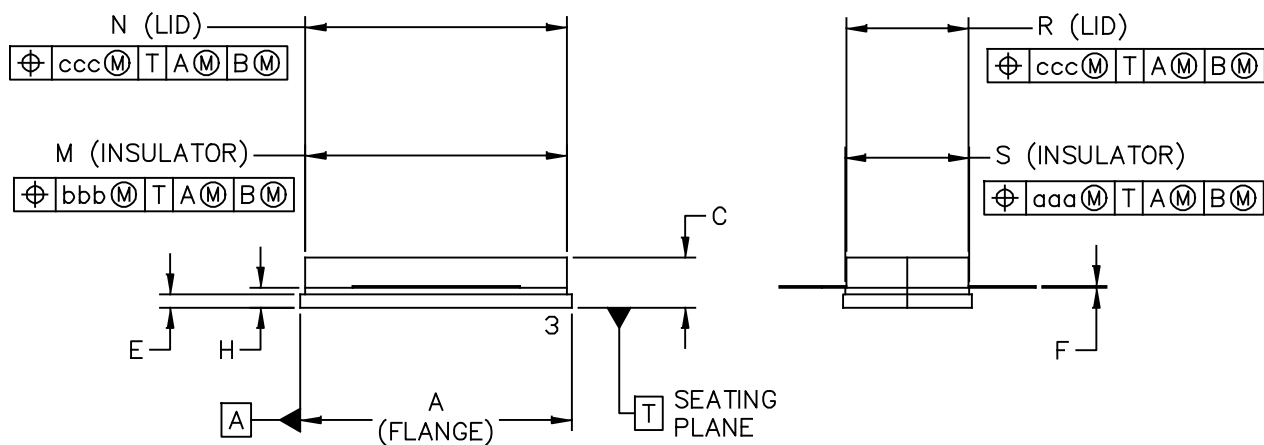
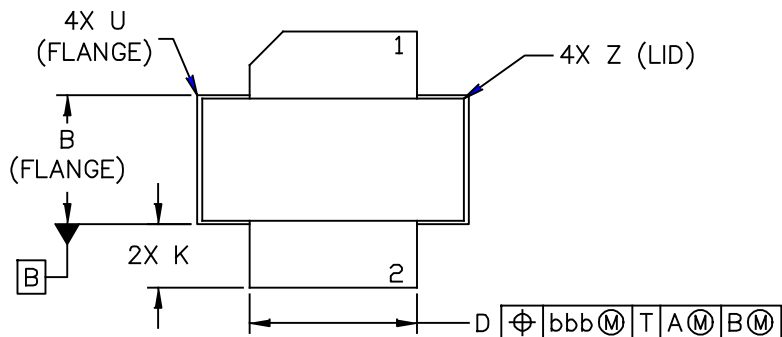
NOTES:

1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M-1994.
2. CONTROLLING DIMENSION: INCH.
3. DELETED
4. DIMENSION H IS MEASURED .030 (.762) AWAY FROM PACKAGE BODY.

STYLE 1:

- PIN
1. DRAIN
  2. GATE
  3. SOURCE

| DIM   | INCH      |       | MILLIMETER         |       | DIM                      | INCH                       |      | MILLIMETER  |       |
|---|-----------|-------|--------------------|-------|--------------------------|----------------------------|------|-------------|-------|
|   | MIN       | MAX   | MIN                | MAX   |                          | MIN                        | MAX  | MIN         | MAX   |
| A   | 1.335     | 1.345 | 33.91              | 34.16 | R                        | .365                       | .375 | 9.27        | 9.53  |
| B   | .380      | .390  | 9.65               | 9.91  | S                        | .365                       | .375 | 9.27        | 9.52  |
| C   | .125      | .170  | 3.18               | 4.32  | aaa                      | —                          | .005 | —           | 0.127 |
| D   | .495      | .505  | 12.57              | 12.83 | bbb                      | —                          | .010 | —           | 0.254 |
| E   | .035      | .045  | 0.89               | 1.14  | ccc                      | —                          | .015 | —           | 0.381 |
| F   | .003      | .006  | 0.08               | 0.15  | —                        | —                          | —    | —           | —     |
| G   | 1.100 BSC |       | 27.94 BSC          |       | —                        | —                          | —    | —           | —     |
| H   | .057      | .067  | 1.45               | 1.7   | —                        | —                          | —    | —           | —     |
| K   | .170      | .210  | 4.32               | 5.33  | —                        | —                          | —    | —           | —     |
| M   | .774      | .786  | 19.66              | 19.96 | —                        | —                          | —    | —           | —     |
| N   | .772      | .788  | 19.6               | 20    | —                        | —                          | —    | —           | —     |
| Q   | ∅.118     | ∅.138 | ∅3                 | ∅3.51 | —                        | —                          | —    | —           | —     |
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| TITLE:<br><br>NI-780                                    |           |       |                    |       | DOCUMENT NO: 98ASB15607C |                            |      | REV: G      |       |
|   |           |       |                    |       | CASE NUMBER: 465-06      |                            |      | 31 MAR 2005 |       |
|   |           |       |                    |       | STANDARD: NON-JEDEC      |                            |      |             |       |



|   |                          |                            |  |
|---|--------------------------|----------------------------|--|
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| TITLE:<br><br>NI-780S                                   | DOCUMENT NO: 98ASB16718C | REV: H                     |  |
|   | CASE NUMBER: 465A-06     | 31 MAR 2005                |  |
|   | STANDARD: NON-JEDEC      |                            |  |

NOTES:

1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M-1994.
2. CONTROLLING DIMENSION: INCH.
3. DELETED
4. DIMENSION H IS MEASURED .030 (0.762) AWAY FROM PACKAGE BODY.

STYLE 1:

- PIN 1. DRAIN
2. GATE
3. SOURCE

| DIM | INCH |       | MILLIMETER |       | DIM | INCH  |     | MILLIMETER |       |
|-----|------|-------|------------|-------|-----|-------|-----|------------|-------|
|     | MIN  | MAX   | MIN        | MAX   |     | MIN   | MAX | MIN        | MAX   |
| A   | .805 | -.815 | 20.45      | 20.7  | U   | -.040 | -   | -          | 1.02  |
| B   | .380 | -.390 | 9.65       | 9.91  | Z   | -.030 | -   | -          | 0.76  |
| C   | .125 | -.170 | 3.18       | 4.32  | aaa | -.005 | -   | -          | 0.127 |
| D   | .495 | -.505 | 12.57      | 12.83 | bbb | -.010 | -   | -          | 0.254 |
| E   | .035 | -.045 | 0.89       | 1.14  | ccc | -.015 | -   | -          | 0.381 |
| F   | .003 | -.006 | 0.08       | 0.15  | -   | -     | -   | -          | -     |
| H   | .057 | -.067 | 1.45       | 1.7   | -   | -     | -   | -          | -     |
| K   | .170 | -.210 | 4.32       | 5.33  | -   | -     | -   | -          | -     |
| M   | .774 | -.786 | 19.61      | 20.02 | -   | -     | -   | -          | -     |
| N   | .772 | -.788 | 19.61      | 20.02 | -   | -     | -   | -          | -     |
| R   | .365 | -.375 | 9.27       | 9.53  | -   | -     | -   | -          | -     |
| S   | .365 | -.375 | 9.27       | 9.52  | -   | -     | -   | -          | -     |

|   |  |                          |  |                            |  |
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## PRODUCT DOCUMENTATION

Refer to the following documents 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

## REVISION HISTORY

The following table summarizes revisions to this document.

| Revision | Date      | Description                     |
|----------|-----------|---------------------------------|
| 0        | Jan. 2014 | • Initial Release of Data Sheet |

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Телефон: 8 (812) 309-75-97 (многоканальный)

Факс: 8 (812) 320-03-32

Электронная почта: [ocean@oceanchips.ru](mailto:ocean@oceanchips.ru)

Web: <http://oceanchips.ru/>

Адрес: 198099, г. Санкт-Петербург, ул. Калинина, д. 2, корп. 4, лит. А