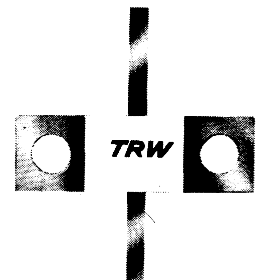
TRW

MICROAMP

- 1400-1700 MHz
- Full "MRA" performance at 22 volts V_{CC}
- Gold metalization
- Diffused ballast resistors
- Common Base
- ∞ VSWR
- 2 to 25 W



MRA .25

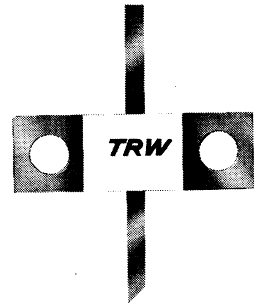
Electrical Characteristics at T_{FLANGE} = 25°C

SYMBOL	CHARACTERISTICS	MRAL1417-2	MRAL1417-6	MRAL1417-11	MRAL1417-25
BV_{CES}	Collector-Base Breakdown Voltage	I_C = 20mA 42V Min	I_C = 40mA 42V Min	I_C = 80mA 42V Min	I_C = 160mA 42V Min
BV_{EBO}	Emitter-Base Breakdown Voltage	I_E = 0.25mA 3.5V Min	I_E = 0.5mA 3.5V Min	I_E = 1.0mA 3.5V Min	I_E = 2.0mA 3.5V Min
I_{CBO}	Collector Cutoff Current I_E = 0	V_{CB} = 22V 0.5mA	V_{CB} = 22V 1.0mA	V_{CB} = 22V 2.0mA	V_{CB} = 22V 4.0mA
		V_{CB} = 38V 1.0mA	V_{CB} = 38V 2.0mA	V_{CB} = 38V 4.0mA	V_{CB} = 38V 8.0mA
I_C	Max. Continuous Collector Current V_{CE} = 4V	0.5A	1.0A	4.0A	8.0A
h_{FE}	Forward Current Transfer Ratio V_{CE} = 5V	I_C = 0.1A 10-100	I_C = 0.2A 10-100	I_C = 0.4A 10-100	I_C = 0.8A 10-100
P_O	Min. Broadband Power Output	2.0W	6.0W	11.0W	25.0W
$P_{G(dB)}$	Min. Power Gain in dB V_{CB} = 22V	P_O = 2.0W 8.0dB	P_O = 6.0W 7.4dB	P_O = 11.0W 7.4dB	P_O = 25.0W 7.0dB
η_C	Min. Broadband Collector Efficiency	P_O = 2.0W 40%	P_O = 6.0W 45%	P_O = 11.0W 45%	P_O = 25.0W 45%
T_j		−65 to +200°C			
T_{STG}		−65 to +150°C			

*The concept of input and/or output matching using MOS capacitors, wire bonds and other techniques is patented by TRW, Inc. (US # 3,713,006).

MICROAMP

- Internally Compensated*
- Gold Metalized
- Diffused Ballast Resistors
- MTTF Data
- 22 V Operation
- 1700-2000 MHz
- 2 to 20 W
- ∞ VSWR
- Common Base



MRA .25

E

Electrical Characteristics at T_{FLANGE} = 25°C

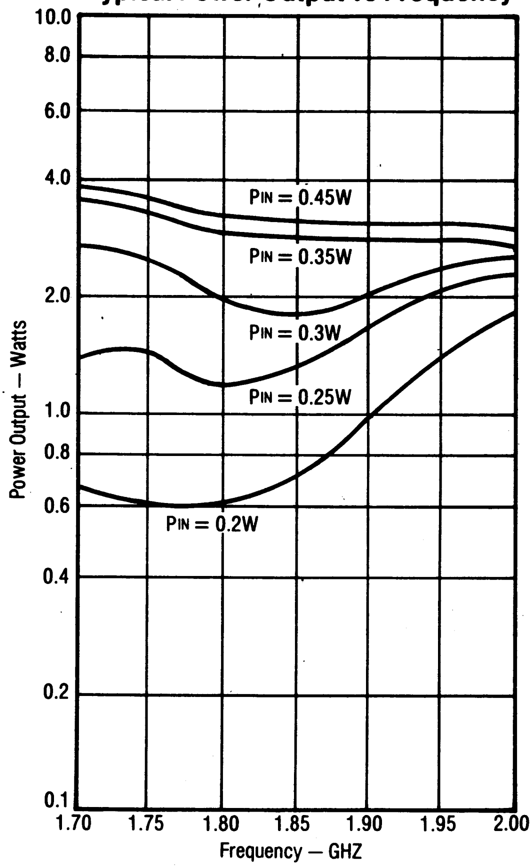
SYMBOL	CHARACTERISTICS	MRAL1720-2	MRAL1720-5	MRAL1720-9	MRAL1720-20
BV_{CES}	Collector-Base Breakdown Voltage	I_C = 20mA 42V Min	I_C = 40mA 42V Min	I_C = 80mA 42V Min	I_C = 160mA 42V Min
BV_{EBO}	Emitter-Base Breakdown Voltage	I_E = 0.25mA 3.5V Min	I_E = 0.5mA 3.5V Min	I_E = 1.0mA 3.5V Min	I_E = 2.0mA 3.5V Min
I_{CBO}	Collector Cutoff Current I_E = 0	V_{CB} = 22V 0.5mA	V_{CB} = 22V 1.0mA	V_{CB} = 22V 2.0mA	V_{CB} = 22V 4.0mA
		V_{CB} = 38V 1.0mA	V_{CB} = 38V 2.0mA	V_{CB} = 38V 4.0mA	V_{CB} = 38V 8.0mA
I_C	Max. Continuous Collector Current V_{CE} = 4V	0.5A	1.0A	4.0A	8.0A
h_{FE}	Forward Current Transfer Ratio V_{CE} = 5V	I_C = 0.1A 10-100	I_C = 0.2A 10-100	I_C = 0.4A 10-100	I_C = 0.8A 10-100
θ_{jF}	Thermal Resistance Junction to Flange	15°C/W	8°C/W	4.5°C/W	2.5°C/W
P_O	Min. Broadband Power Output	2.0W	5.0W	9.0W	20.0W
C_{OB}	Max. Collector-Base Capacitance V_{CB} = 28V; f = 1MHz	4.5pF	8pF	12pF	24pF(1)
$P_{G(dB)}$	Min. Power Gain in dB V_{CB} = 22V	P_O = 2.0W 7.5dB	P_O = 5.0W 6.5dB	P_O = 9.0W 6.5dB	P_O = 20.0W 6.0dB
η_C	Min. Broadband Collector Efficiency	P_O = 2.0W 35%	P_O = 5.0W 40%	P_O = 9.0W 40%	P_O = 20.0W 40%
T_{STG}	Maximum Storage Temperature: -65 to +150°C				
T_j	Maximum Junction Temperature: -65 to +200°C				

*The concept of input and/or output matching using MOS capacitors, wire bonds and other techniques is patented by TRW, Inc. (US #3,713,006).

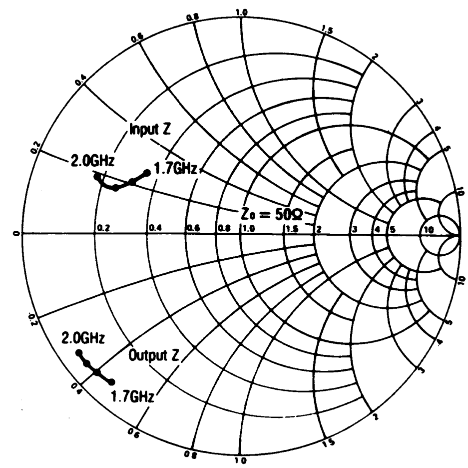
(1)Nominal value, not measurable due to shunt inductor bypass.

MRAL 1720-2, 2 WATTS BROADBAND

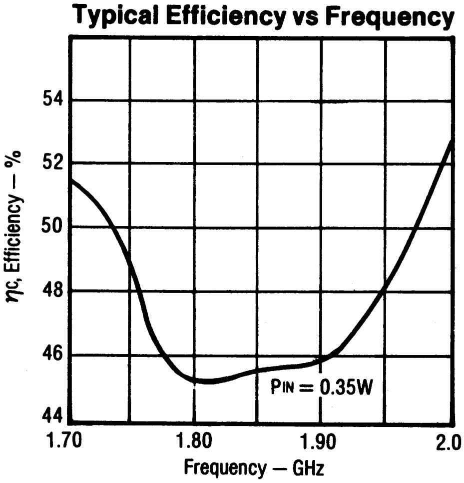
Typical Power Output vs Frequency



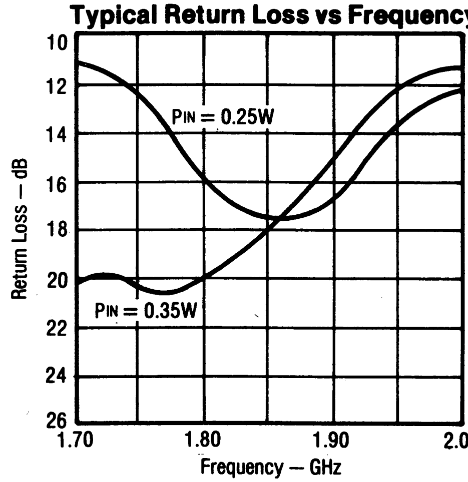
Impedance Data
Vcc = 22V



Typical Efficiency vs Frequency

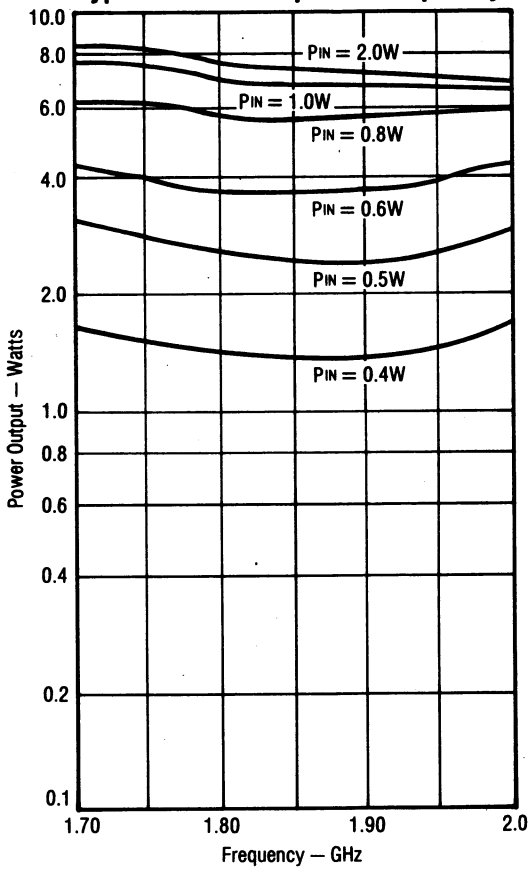


Typical Return Loss vs Frequency

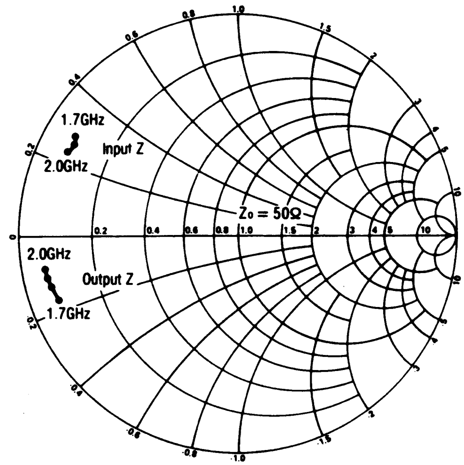


MRAL 1720-5, 5 WATTS BROADBAND

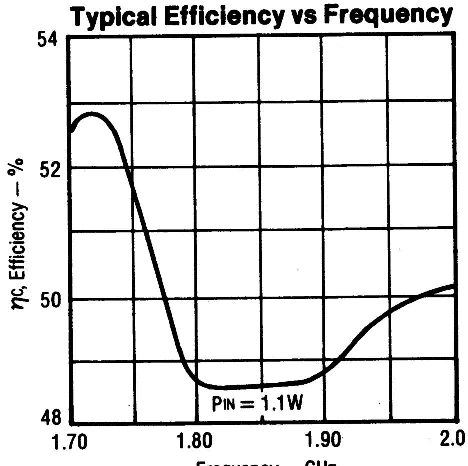
Typical Power Output vs Frequency



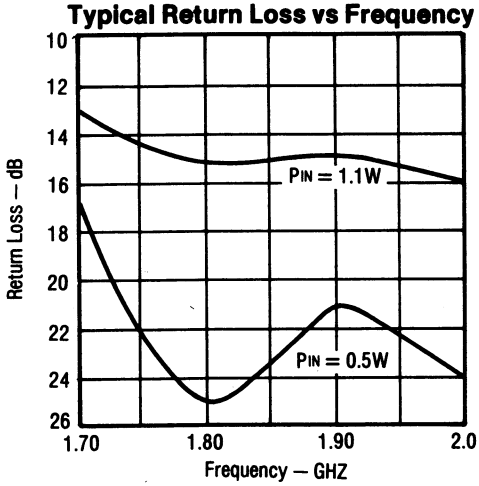
Impedance Data
Vcc = 22V



Typical Efficiency vs Frequency

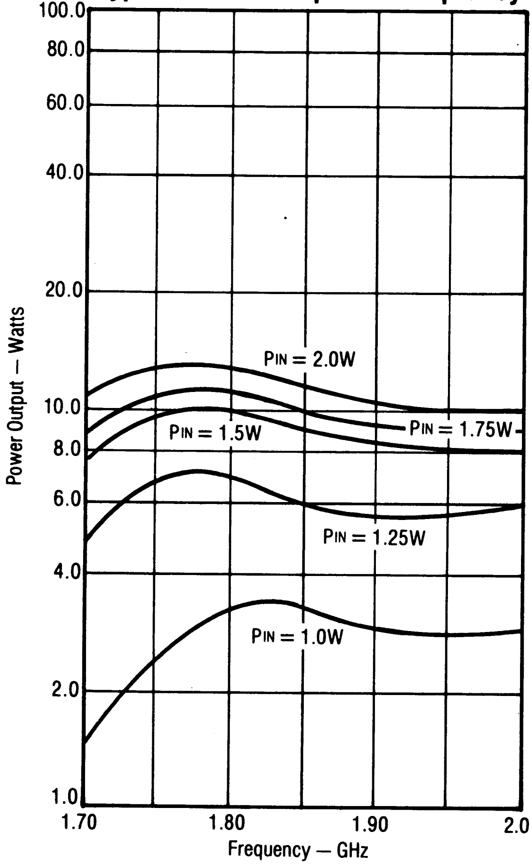


Typical Return Loss vs Frequency

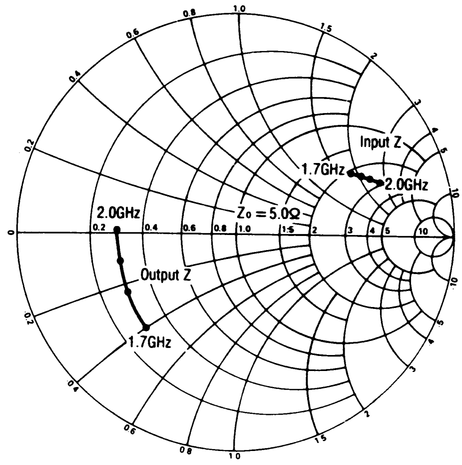


MRAL 1720-9, 9 WATTS BROADBAND

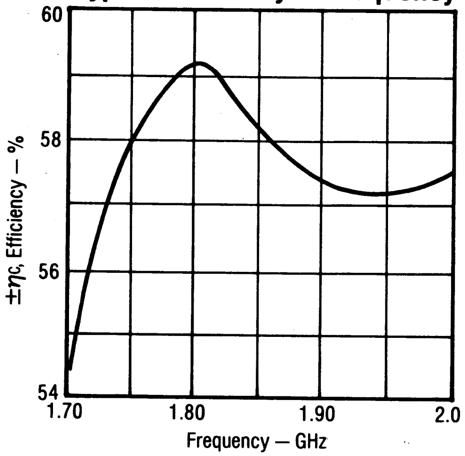
Typical Power Output vs Frequency



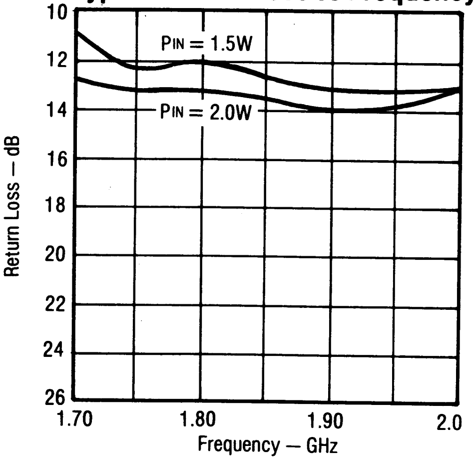
Impedance Data
Vcc = 22V



Typical Efficiency vs Frequency

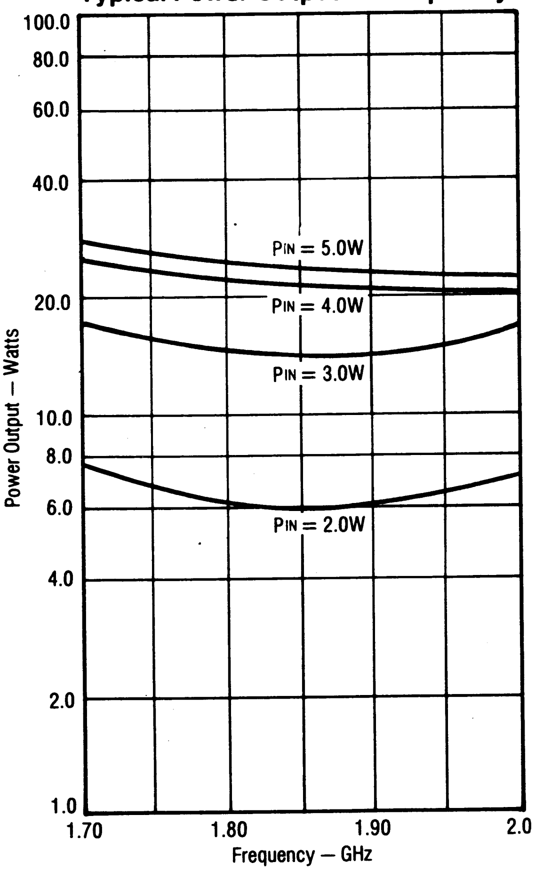


Typical Return Loss vs Frequency

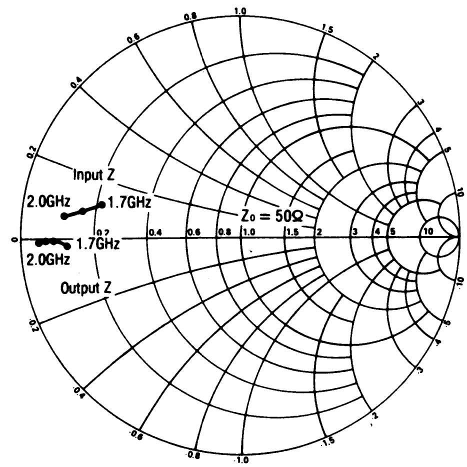


MRAL 1720-20, 20 WATTS BROADBAND

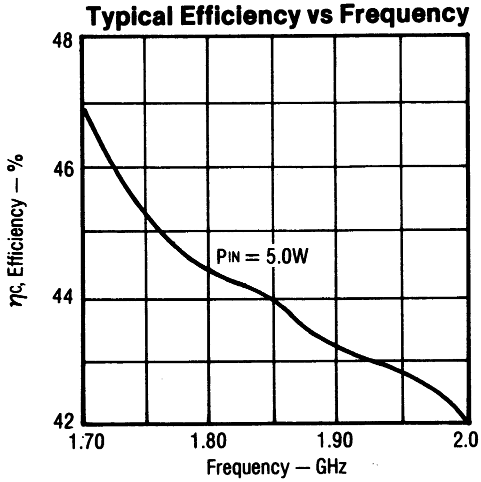
Typical Power Output vs Frequency



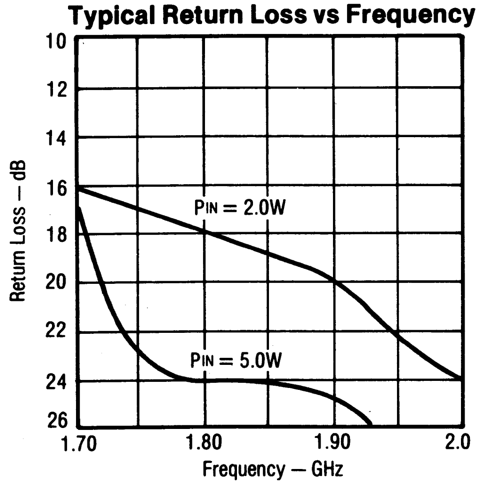
Impedance Data Vcc = 22V



Typical Efficiency vs Frequency



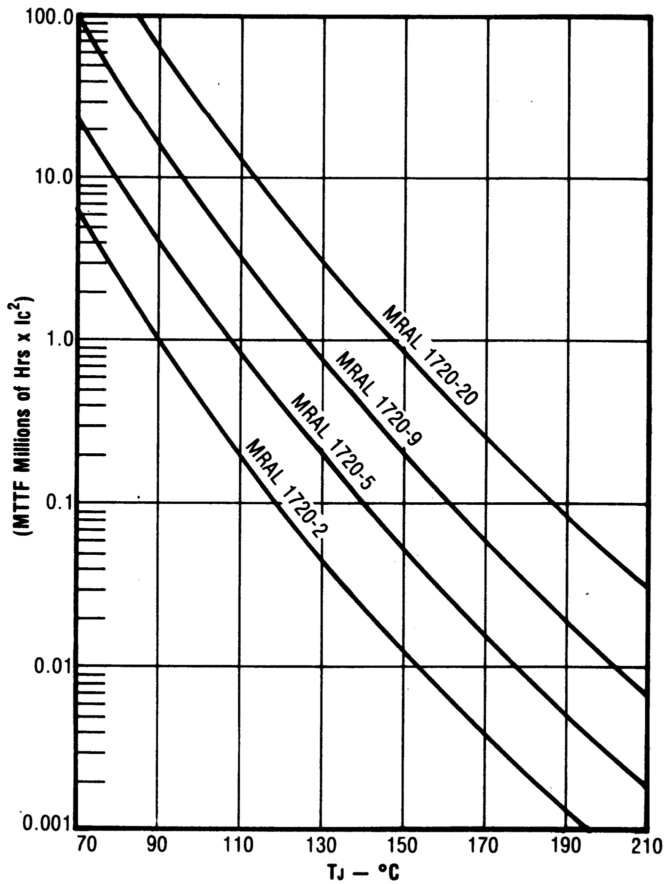
Typical Return Loss vs Frequency



Note: Test circuit details are available from TRW Semiconductors.

MTTF FACTOR (Normalized to 1 Ampere² Continuous Duty)

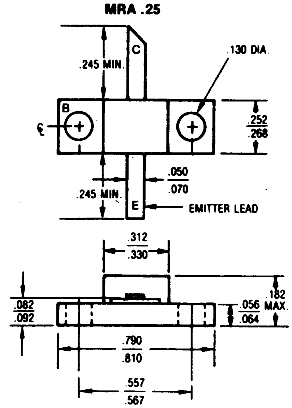
The graph shown below displays MTTF in hours x ampere² emitter current for each of the devices. Life tests at elevated temperatures have correlated to better than ±10% to the theoretical prediction for metal failure. Sample MTTF calculations based on operating conditions are included below.



Example of MTTF for MRA1720-9 Conditions

$$P_O = 9.0W$$
$$P_{IN} = 2.0W$$
$$V_{CC} = 28V$$
$$\eta_C = 40\%$$
$$T_{FLANGE} = 70°C$$
$$I_C \simeq I_E = \frac{100\ P_O}{\eta_C \times V_{CC}} = 0.803A$$
$$P_{DISS} = P_{IN} + V_{CC}.\ I_C - B = 15.48W$$
$$T_{JUNC} = T_{FLANGE} + \theta JF \times 15.48 = 139.6\ °C$$
$$MTTF = \frac{0.4 \times 10^6\ \text{Hrs Amp}^2}{I_C^2} = 620{,}338\ \text{Hrs}$$
$$MTTF = 70.8\ \text{Yrs}$$

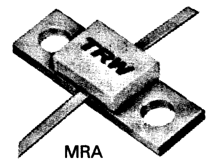
MRA .25



TRW

MICroAMP

- 1.5-3-6-12 W
- 22 V Operation
- Broadband 2000-2300 MHz
- Internally Compensated*
- Gold Metalized
- Diffused Ballast Resistors
- MTTF Data



E

Electrical Characteristics at T_{flange} = 25 °C

Symbol	Characteristic	MRAL2023-1.5	MRAL2023-3	MRAL2023-6	MRAL2023-12
BV_{CER}	Collector-Base Breakdown Voltage R_{BE} = 10 Ω	I_C = 10 mA 42 V Min	I_C = 20 mA 42 V Min	I_C = 50 mA 42 V Min	I_C = 100 mA 42 V Min
BV_{EBO}	Emitter-Base Breakdown Voltage	I_E = 0.2 mA 3.5 V Min	I_E = 0.4 mA 3.5 V Min	I_E = 1.0 mA 3.5 V Min	I_E = 2.0 mA 3.5 V Min
I_{CBO}	Collector Cutoff Current I_E = 0	V_{CB} = 22 V 0.25 mA	V_{CB} = 22 V 0.5 mA	V_{CB} = 22 V 1.25 mA	V_{CB} = 22 V 2.5 mA
		V_{CB} = 38 V 0.5 mA	V_{CB} = 38 V 1.0 mA	V_{CB} = 38 V 2.5 mA	V_{CB} = 38 V 5.0 mA
I_C	Max Continuous Collector Current V_{CE} = 4 V	0.25 A	0.5 A	1.25 A	2.5 A
h_{FE}	Forward Current Transfer Ratio V_{CE} = 5 V	I_C = 0.1 A 10-90	I_C = 0.2 A 10-90	I_C = 0.5 A 10-90	I_C = 1.0 A 10-90
θ_{jF}	Thermal Resistance Junction to Flange	30 °C/W	16 °C/W	8 °C/W	4.5 °C/W
P_o	Min Broadband Power Output	1.5 W	3.0 W	6.0 W	12.0 W
C_{ob}	Max Collector-Base Capacitance V_{CB} = 22 V, f = 1 MHz	3.5 pF	5 pF	10 pF	18 pF
$P_{G(dB)}$	Min Power Gain in dB V_{CB} = 22 V	P_o = 1.5 W 8.0 dB	P_o = 3.0 W 8.0 dB	P_o = 6.0 W 7.0 dB	P_o = 12.0 W 7.0 dB
η_c	Min Broadband Collector Efficiency	P_o = 1.5 W 35 %	P_o = 3.0 W 40 %	P_o = 6.0 W 40 %	P_o = 12.0 W 40 %
T_j & T_{STG}	Maximum Junction and Storage Temperatures : — 65 to + 200 °C				

* Based on Black's Equation and using φ = .96 EV, $\beta = 1.07 \times 10^{-12}$ for unpassivated A_u. Empirical data indicates a 3-10 times improvement for glass passivated units. These units are glass passivated.

* The concept of input and/or output matching using MOS capacitors, wire bonds and other techniques is patented by TRW, In. (US # 3,713,006).

The TRW MRAL2023 series offers a complete family of broadband, high-gain transistors for applications in the 2.0-2.3GHz band.

Using internal compensation (a patented* technique developed and first offered for sale by TRW), the MRAL2023 series is intended for use in a variety of military and industrial applications including ECM, radio relay and telemetry.

The smooth, broadband transfer characteristics of the MRAL2023 series makes it attractive for semi-linear applications without the need for bias. Power leveling within a broad range can be accomplished simply through control of low-level drive, thus eliminating brute force control of collector voltage.

Device output power levels of 1.5, 3, 6 and 12 watts allow a wide choice of lineup configurations. Excellent device-to-device phase tracking characteristics permit hybrid combination for higher powers with negligible combining loss.

Complete data and broadband circuitry, suitable to photograph for circuit boards, are contained herein.

DIFFUSED BALLASTING AND RELIABILITY

Microwave transistor devices are universally constructed using multiple cell combinations for higher power. A number of advantages are obtained using the cellular concept including better thermal balance and the ability to adjust power output capability using more or less cells to construct a device. Unless proper ballasting techniques are employed, some difficulty can be encountered in the act of combining cells. Ballasting makes cell combining practical. The alternative to ballasted cells is an operator-dependent assembly technique called "contour-bonding." Herein, bond wires of varying lengths are employed to adjust inductance and thereby achieve the expected balance. TRW has decided in favor of ballasting rather than contour-bonding because it is a controlled, repeatable and totally reliable technique.

While ballasting is desirable, certain techniques for creating ballast resistors in fine geometry microwave transistors have proven unreliable. Such an example is "metal" ballast resistors. Such resistors are incorporated by introducing an exposed section of barrier metal between the emitter finger and feeder bar. This type of resistor, of necessity, lies on top of an oxide layer. Because the metal resistor is required to dissipate as much as $10KW/CM^2$, extreme temperatures are generated in the resistor material. With this construction there is no adequate means of removing heat from the metal resistor. Therefore, the ballast resistor undergoes radical changes in physical dimension during its operating profile. This results in separation from the oxide layer or micro-cracking, or both.

Given that ballasting is desirable, a better solution, **diffused ballast resistors**, is incorporated in the MRAL2023 series. Several advantages accrue from this approach. It is integral in the silicon carrier, has the same coefficient of expansion and is heat sinked. Experience has shown that the diffused ballast resistor has none of the metal resistor disadvantages, yet offers an additional advantage. In the MRAL2023 series, the diffused resistor is designed to current limit (because of limited carriers) before destructive current levels at the junction occur. Diffused ballast resistors are definitely superior in performance and reliability. Test data is available to verify this fact.

METALIZATION AND RELIABILITY

Metal migration is the main concern when considering a metal system. In fine geometry devices common to all microwave transistors, the use of aluminum having sufficiently large grain size to provide an activation energy equal to that of gold is not possible since geometrical definition would be impossible. In order to adequately define small geometries, one must use aluminum with a grain size (1 micron or less) which has a very unattractive activation energy. Activation energy has an exponential relationship to metal migration.

A fair comparison of two metal systems (aluminum versus gold) would be to construct the same transistor using both metal systems and calculate the anticipated metal failure point using Black's equation. The following example is based upon the same transistor cell as is used in the TRW MRAL2023 series.

Junction Temperature	Times Improvement of MTTF with Gold vs Aluminum
100°C	691
125°C	370
150°C	168
175°C	56
200°C	30

For this very obvious reason TRW RF Semiconductors uses a gold metalization system on all microwave transistors including the MRAL2023 series.

TRW'S PATENTED* MICroAMP

Since power microwave transistors became feasible, the bandwidth limiting problem of excessively high input "Q's" has vexed the solid state microwave amplifier designer.

Parasitic reactances (primarily due to the package) become increasingly more significant past 200MHz and impose severe limitations on band width past 1GHz. Additionally, the real component of input Z(Rbb) becomes smaller as higher drive power and higher power outputs are achieved.

Microwave power transistors generally employ several emitter ballasted cells in parallel to obtain power outputs required with the small cell geometry necessary to realize a microwave transistor. Figure 1 shows the schematic representation of such a device.

Note that all components of the input impedance are in parallel, which compounds the "Q" and bandwidth problem as more cells are used to achieve power, or the operating frequency is raised (or both). Figure 2 illustrates a more acceptable solution which combines inputs after an impedance transformation at the input of each device cell. It is convenient to do this all or partially within the package.

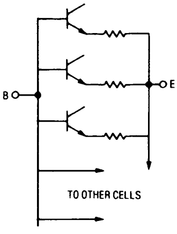


Figure 1. Elementary Method of Cell Combining

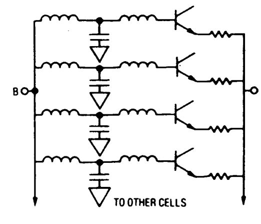


Figure 2. Cells Combined with Transformers

Correct input circuitry design can yield a device which is broadbandable over a broad range of frequencies (40 percent or more).

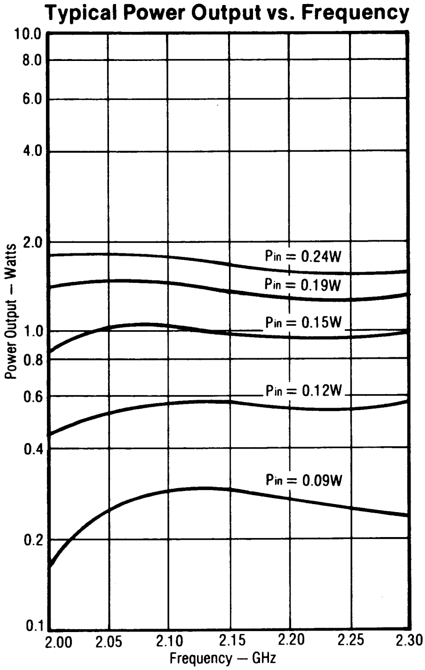
Because of the nature of source impedance driving the transistor cell (essentially a voltage source), as much as 10dB additional usable dynamic range without noticeably altering bandwidth or tuning is possible with the MICroAMP.

Additional gain and bandwidth advantage can be obtained by operation of the MICroAMP device cells in a common base configuration. The devices described therein are so configured.

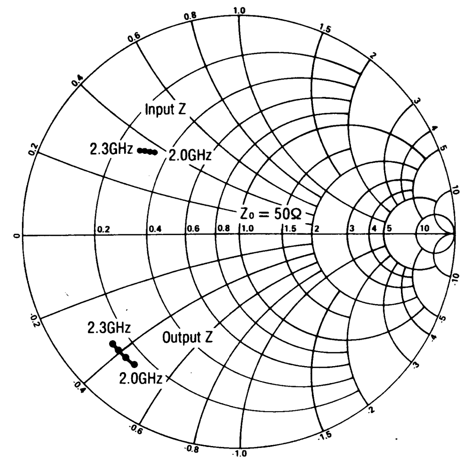
*TRW U.S. Patent #3,713,006

MRAL2023-1.5 WATTS BROADBAND

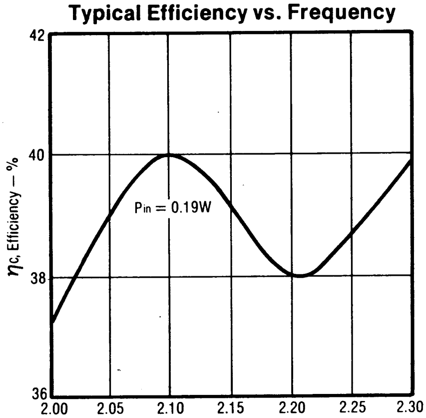
Typical Power Output vs. Frequency



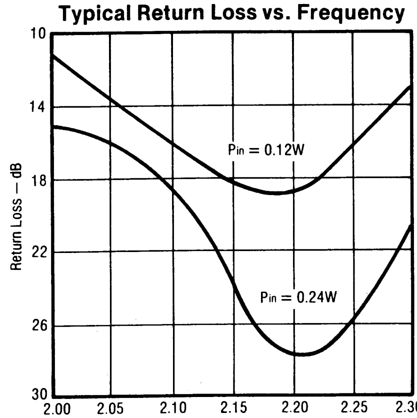
Impedance Data
Vcc = 22V



Typical Efficiency vs. Frequency

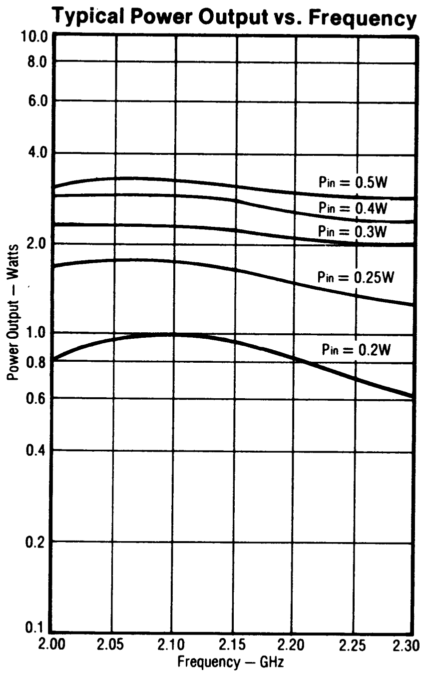


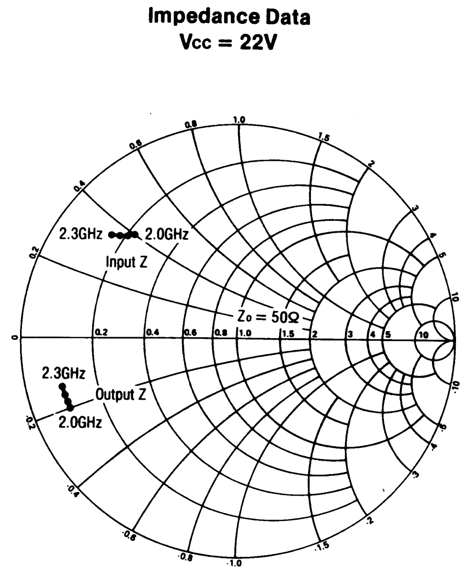
Typical Return Loss vs. Frequency

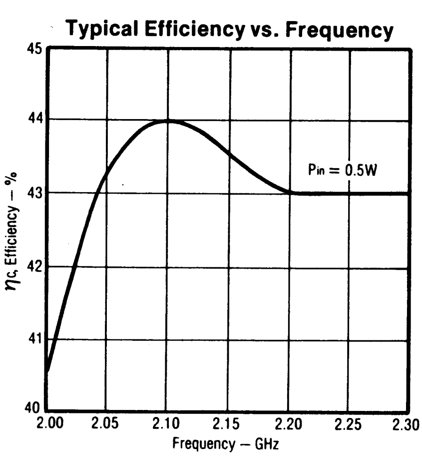


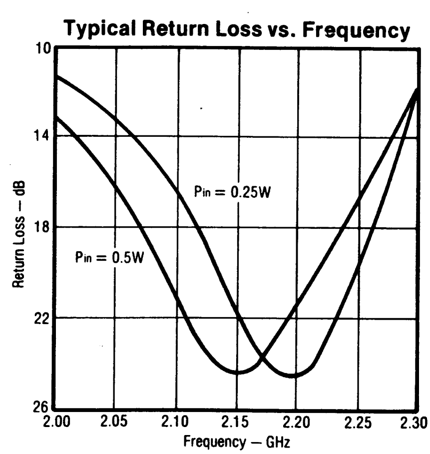
E

MRAL2023-3 — 3 WATTS BROADBAND





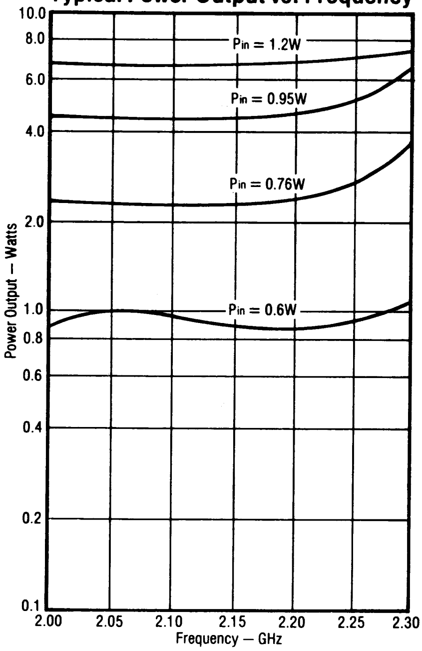




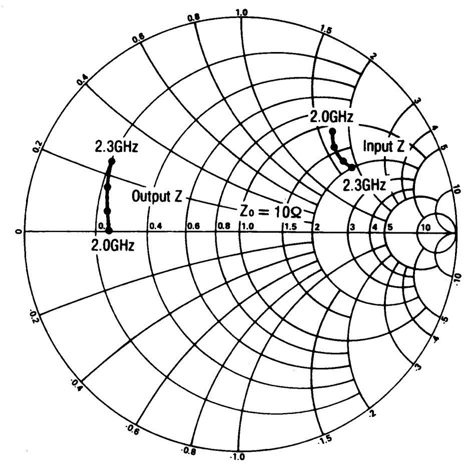
E

MRAL2023-6 — 6 WATTS BROADBAND

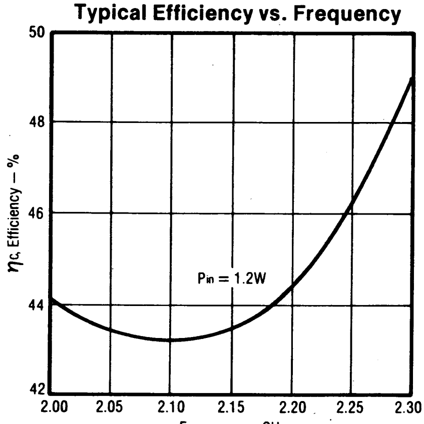
Typical Power Output vs. Frequency



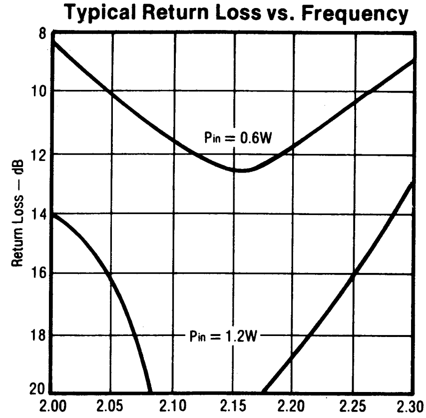
Impedance Data
Vcc = 22V



Typical Efficiency vs. Frequency

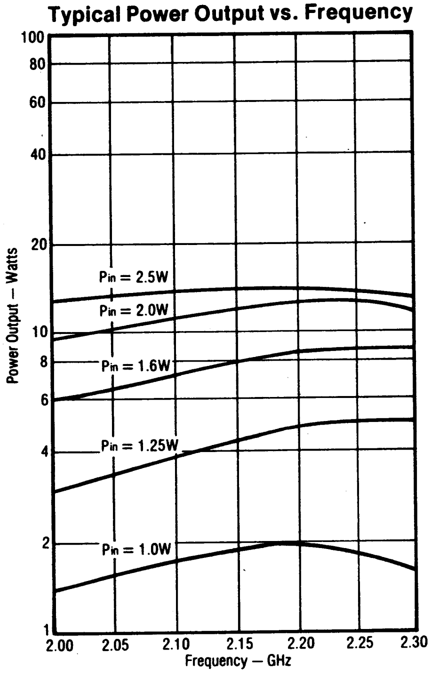


Typical Return Loss vs. Frequency

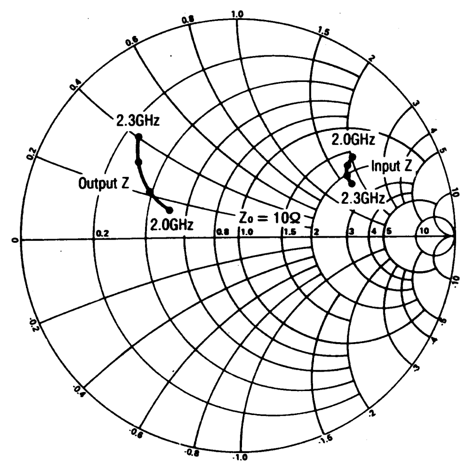


MRAL2023-12 — 12 WATTS BROADBAND

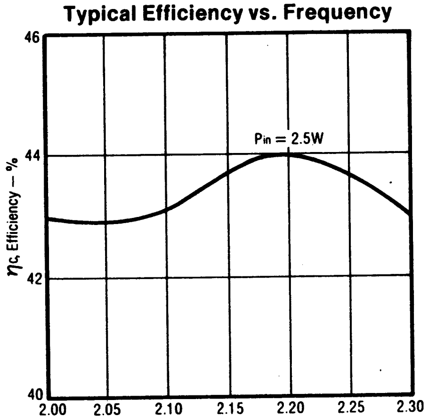
Typical Power Output vs. Frequency



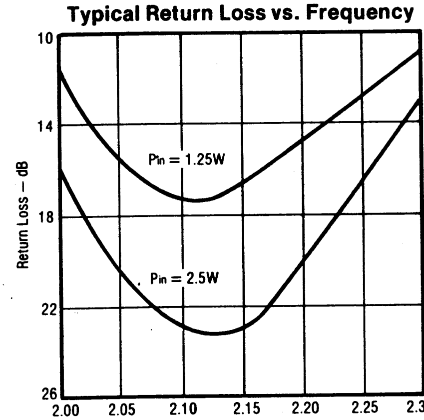
Impedance Data
Vcc = 22V



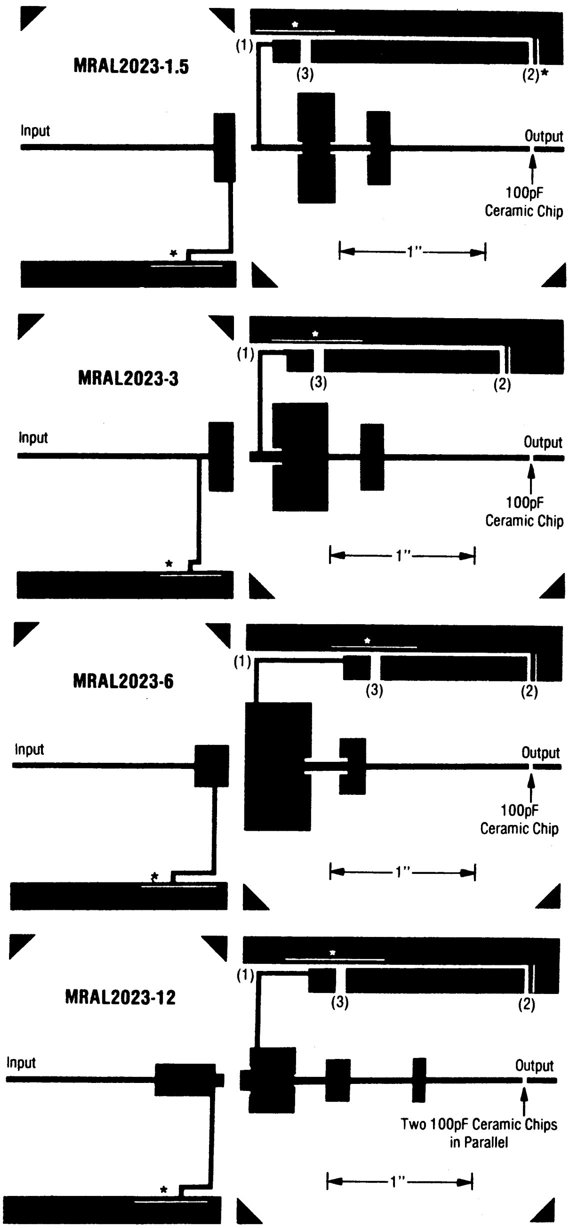
Typical Efficiency vs. Frequency



Typical Return Loss vs. Frequency



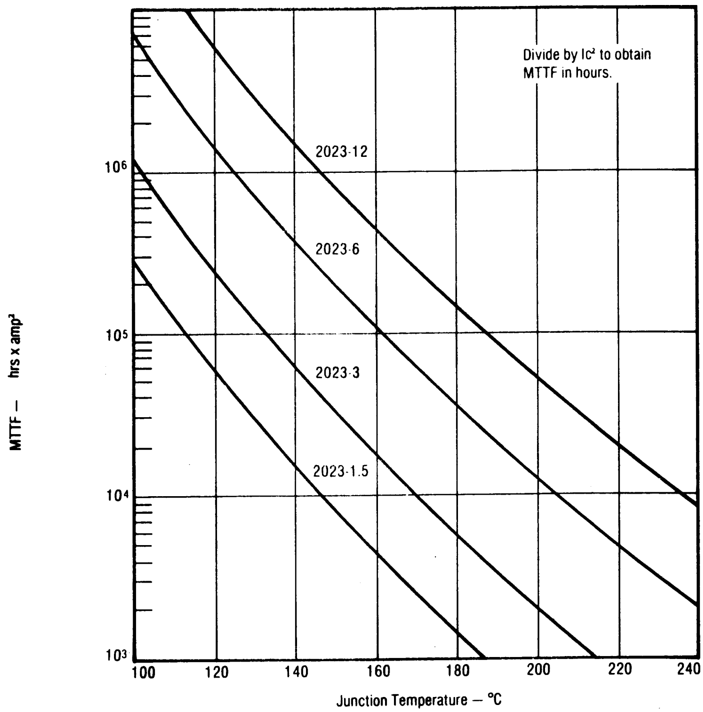
TEST CIRCUIT BOARDS FOR MRAL2023 SERIES



*Foil wrap or plate around to ground plane.
(1) Bypass capacitor to ground (100pF ceramic chip).
(2) Use Vcc bypass of 100pF chip, 0.1μF chip and 5μF.
(3) RF choke 10 turns #28 enam. close bound.
Board material 0.020 inch glass-teflon $\varepsilon_r = 2.55$.

MTTF FACTOR (Normalized to 1 Ampere² Continuous Duty)

The graph shown below displays MTTF in hours x ampere² emitter current for each of the devices. Life tests at elevated temperatures have correlated to better than ±10% to the theoretical prediction for metal failure. Sample MTTF calculations based on operating conditions are included below.



Example of MTTF for MRAL2023 Conditions

where:

$P_o = 12W$
$P_{in} = 2.4W$
$V_{CC} = 22V$
$\eta_C = 40\%$
$T_{flange} = 70°C$

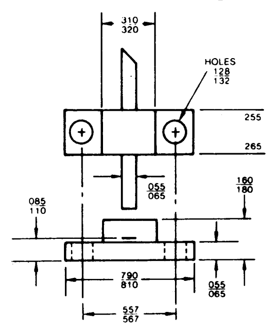
$$I_C \cong I_E = \frac{100\,P_o}{\eta_C \times V_{CC}} = 1.36A$$

$$P_{diss} = P_{in} + V_{CC}\,I_C - P_o = 20.40W$$

$$T_{junc} = T_{flange} + \theta_{JF} \times P_{diss} = 161.4°C$$

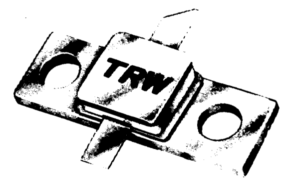
$$MTTF = \frac{4.3 \times 10^5 \text{ hrs amp}^2}{I_C^2} = 232{,}482 \text{ hrs} = 26.5 \text{ yrs}$$

MRA Series Package



MICROAMP

- 1.5-3-6-12 W, 22 V Operation
- Broadband 2000-2300 MHz
- Internally Compensated*
- Gold Metalized
- Diffused Ballast Resistors
- MTTF Data



HLP-11

E

Electrical Characteristics at T_{FLANGE} = 25°C

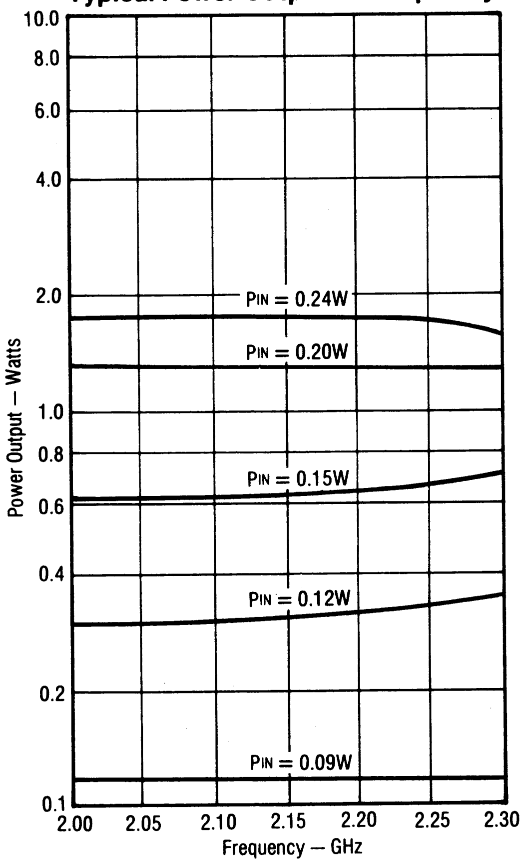
SYMBOL	CHARACTERISTICS	MRAL2023-1.5H	MRAL2023-3H	MRAL2023-6H	MRAL2023-12H
BV_{CES}	Collector-Base Breakdown Voltage	I_C = 10mA 42V Min	I_C = 20mA 42V Min	I_C = 50mA 42V Min	I_C = 100mA 42V Min
BV_{EBO}	Emitter-Base Breakdown Voltage	I_E = 0.2mA 3.5V Min	I_E = 0.4mA 3.5V Min	I_E = 1.0mA 3.5V Min	I_E = 2.0mA 3.5V Min
I_{CBO}	Collector Cutoff Current $I_E = 0$	V_{CB} = 22V 0.25mA	V_{CB} = 22V 0.5mA	V_{CB} = 22V 1.25mA	V_{CB} = 22V 2.5mA
		V_{CB} = 38V 0.5mA	V_{CB} = 38V 1.0mA	V_{CB} = 38V 2.5mA	V_{CB} = 38V 5.0mA
I_C	Max. Continuous Collector Current V_{CE} = 4V	0.25A	0.5A	1.25A	2.5A
h_{FE}	Forward Current Transfer Ratio V_{CE} = 5V	I_C = 0.1A 10-90	I_C = 0.2A 10-90	I_C = 0.5A 10-90	I_C = 1.0A 10-90
θ_{jF}	Thermal Resistance Junction to Flange	30°C/W	16°C/W	8°C/W	4.5°C/W
P_O	Min. Broadband Power Output	1.5W	3.0W	6.0W	12.0W
C_{OB}	Max. Collector-Base Capacitance V_{CB} = 22V; f = 1MHz	3.5pF	5pF	Internal Shunt L	Internal Shunt L
$P_{G(dB)}$	Min. Power Gain in dB V_{CB} = 22V	P_O = 1.5W 8.0dB	P_O = 3.0W 8.0dB	P_O = 6.0W 7.0dB	P_O = 12.0W 7.0dB
η_C	Min. Broadband Collector Efficiency	P_O = 1.5W 35%	P_O = 3.0W 40%	P_O = 6.0W 40%	P_O = 12.0W 40%
T_j & T_{STG}	Maximum Junction and Storage Temperatures: -65 to +200°C				

Based on Black's Equation and using ϕ = .96EV, $\beta = 1.07 \times 10^{-12}$ for unpassivated Au. Empirical data indicates a 3-10 times improvement for glass passivated units. These units are glass passivated.

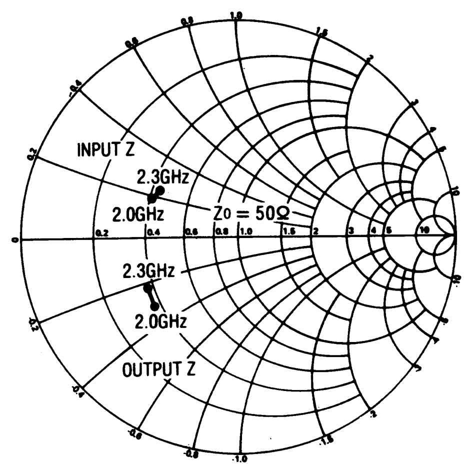
*The concept of input and/or matching using MOS capacitors, wire bonds and other techniques is patented by TRW, Inc. (US #3,713,006).

MRAL 2023-1.5H, 1.5 Watts Broadband Hermetic

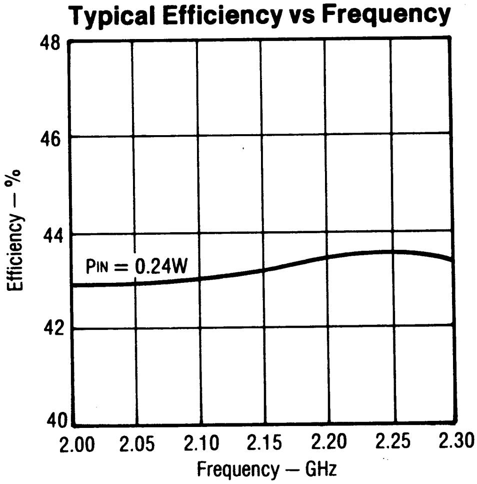
Typical Power Output vs Frequency



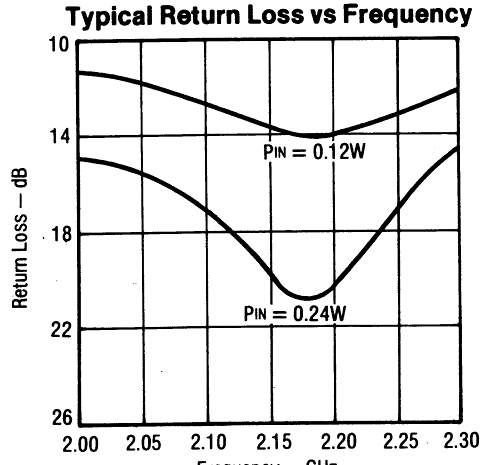
Impedance Data



Typical Efficiency vs Frequency

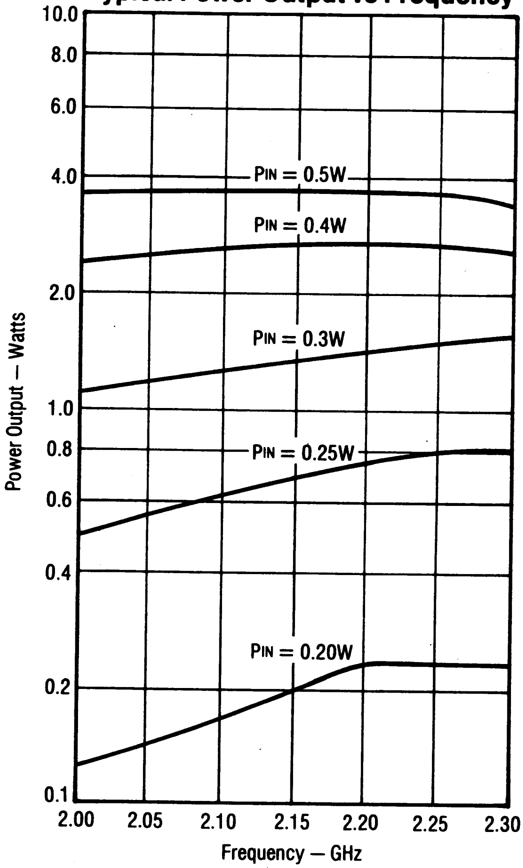


Typical Return Loss vs Frequency

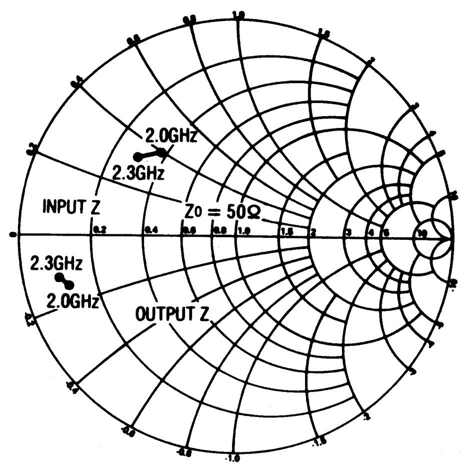


MRAL 2023-3H, 3 Watts Broadband Hermetic

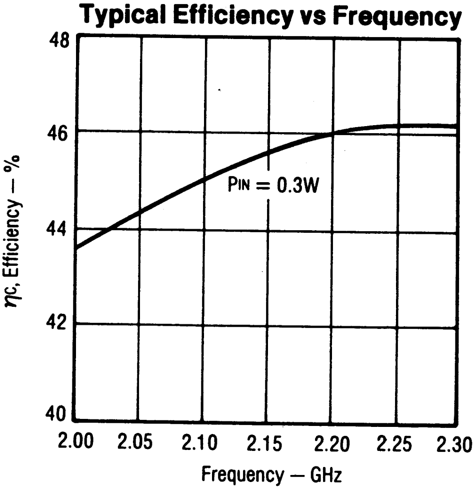
Typical Power Output vs Frequency



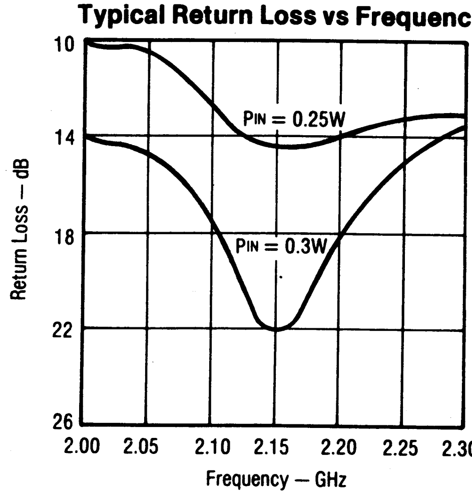
Impedance Data



Typical Efficiency vs Frequency



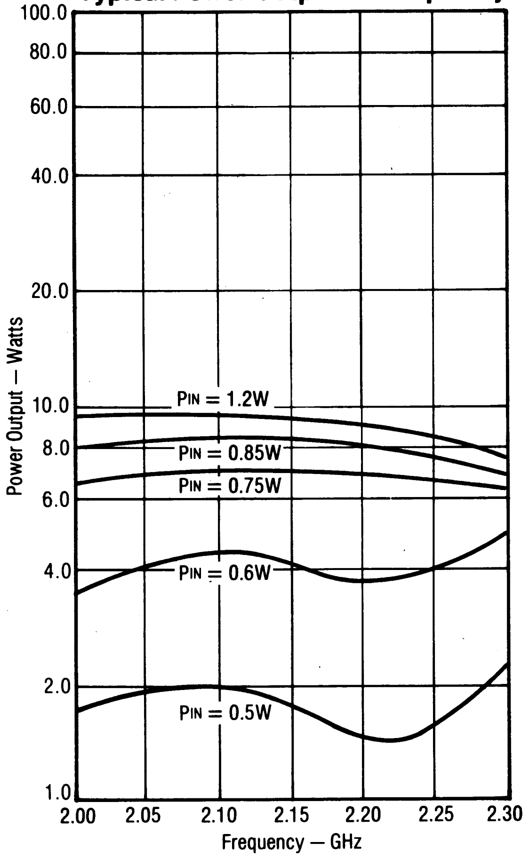
Typical Return Loss vs Frequency



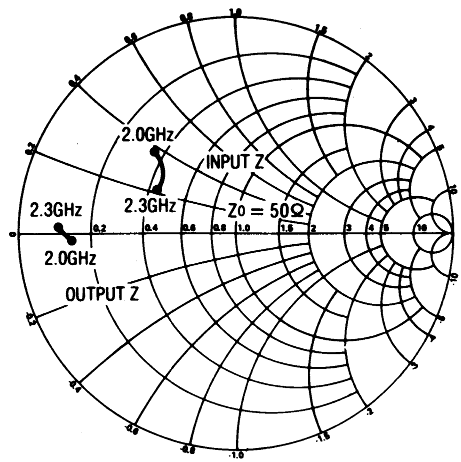
E

MRAL 2023-6H, 6 Watts Broadband Hermetic

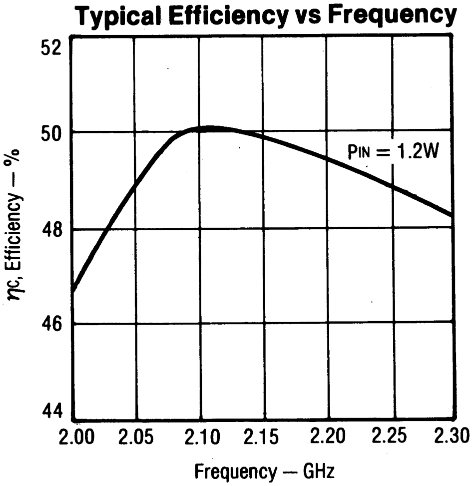
Typical Power Output vs Frequency



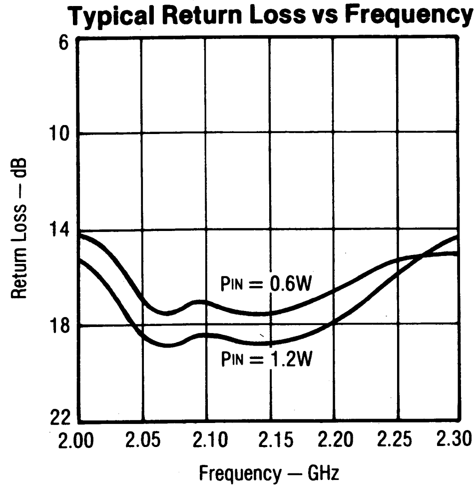
Impedance Data



Typical Efficiency vs Frequency

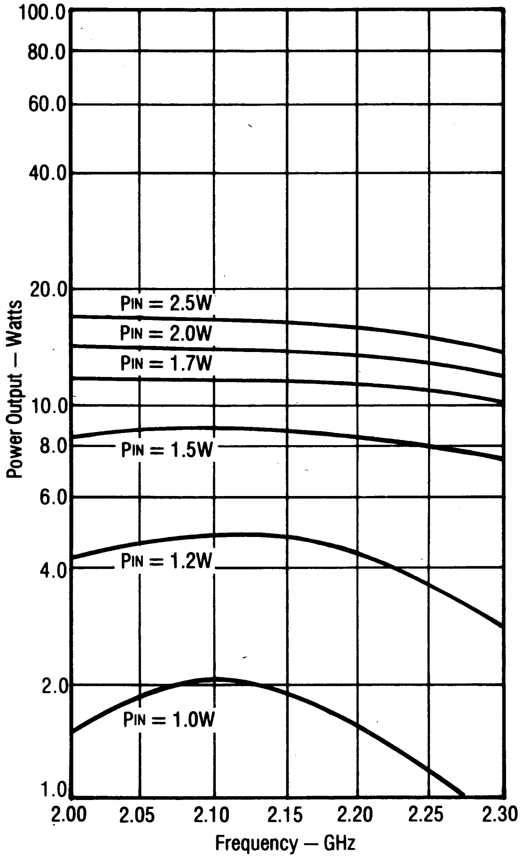


Typical Return Loss vs Frequency

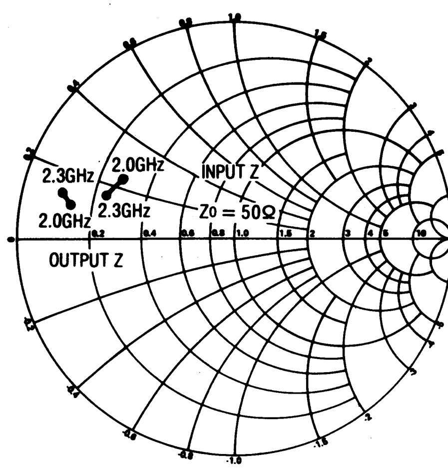


MRAL 2023-12H, 12 Watts Broadband Hermetic

Typical Power Output vs Frequency

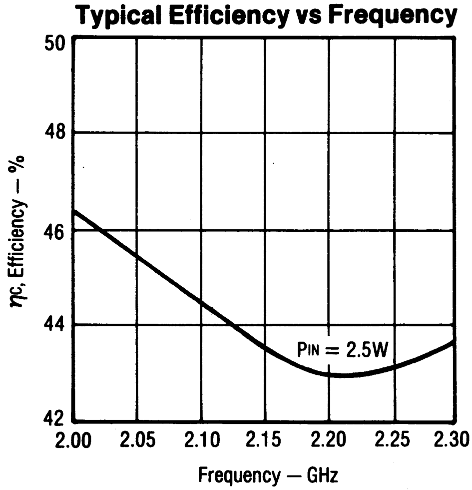


Impedance Data

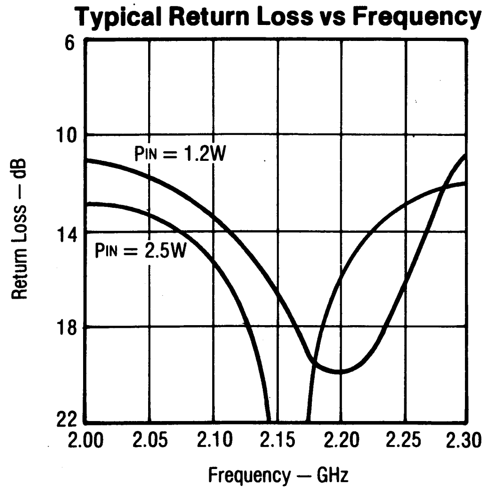


Test circuit details available from TRW Semiconductors.

Typical Efficiency vs Frequency



Typical Return Loss vs Frequency



MTTF FACTOR (Normalized to 1 Ampere² Continuous Duty)

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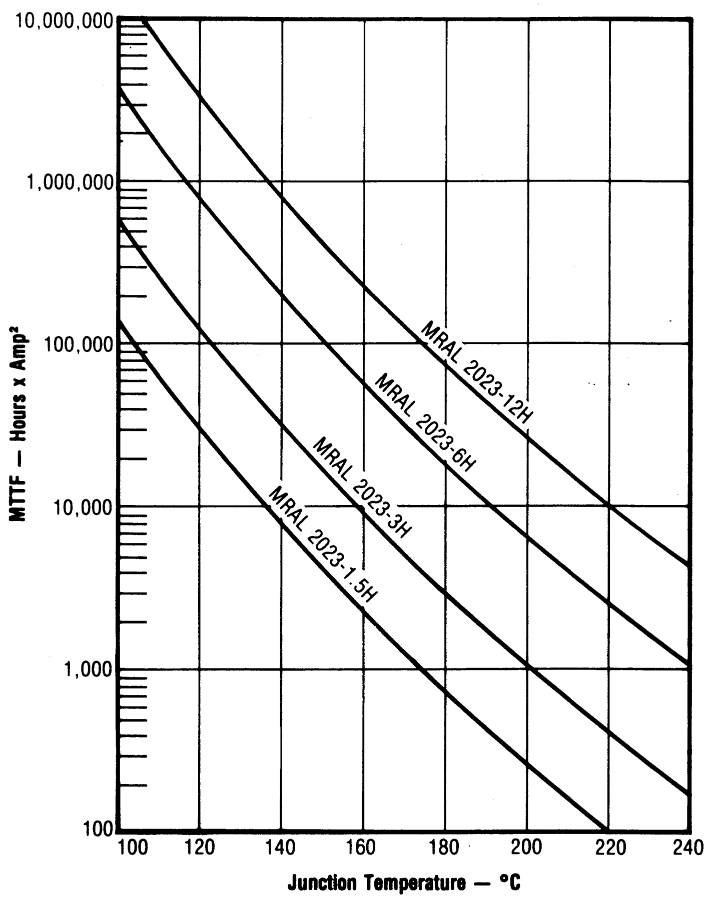

HLP-11 Series Package