TRW
RF SEMICONDUCTORS

CATALOG

1979

EUROPEAN EDITION

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INTRODUCTION

— SCOPE

This catalog is issued by TRW Composants Electroniques.
It provides complete information on all the TRW high-frequency transistors, modules and integrated circuits available from our plant in Bordeaux.

The book is up-dated in timely intervals in order to reflect the latest developments of new products. It has proven to be an excellent aid and reference to numerous project and design engineers.

— MARKET SEGMENTS

1) HF-SSB

Market

2 to 30 MHz, high power linear transmitters.

Products

12, 28 and 50 V up to 150 watts linear transistors.

2) MOBILE

Market

VHF (88 and 175 MHz) and UHF (470 MHz) transmitters for use in commercial and industrial mobile radio applications.

Products

7.5, 12 and 28 volts discrete transistors.
12 V power modules.

3) VHF/UHF BROADBAND

Market

Airbone and ground VHF/UHF transmitters — Navigation aids (ILS, VOR, GLIDE).

Products

Discrete and internally matched (JO) broadband transistors up to 100 watts.

4) BROADBAND HYBRID AMPLIFIERS

Market

General purpose up to 400 MHz for Instrumentation and Drivers for SSB/VHF/UHF transmitters and TV transposers.

Products

High performance hybrids.

5) MATV

Market

Master Antenna Television Amplifiers — 40 to 860 MHz.
Cheap general purpose broadband amplifiers for small houses.
Higher price channel amplifiers for apartment buildings.

Products

Low noise, high fT, linear transistors in plastic T-package for low price and in stud packages for higher performance.

6) CATV

Market

Cable Antenna Television amplifiers — 40 to 300 MHz.

Products

High performance hybrids amplifiers for super linearity and cascability.

7) TV TRANSPOSERS AND TRANSMITTERS

Market

Equipment for TV land coverage : transposers and transmitters.

Products

High power linear transistors specified in two bands : VHF 170 to 225 MHz, UHF 470 to 860 MHz.

8) FM

Market

High power FM transmitters (88-108 MHz).

Products

High power transistors up to 175 W.

9) MICROWAVE

Market

1 to 4 GHz transmitters.

Products

1 to 4 GHz discretes and internally matched (MRA) transistors specified as :

— Linear (common emitter).
— Class C, Pulse (common base).
— Oscillators (common collector).

— TRW COMPOSANTS ELECTRONIQUES

This european facility was established in 1971 in order to provide optimum service to the european market. The advantages to our customers are numerous :

- MARKETING — TRW Bordeaux has an experienced team of product managers ready to discuss your needs and to serve your interests.
- MANUFACTURING — Most TRW products supplied by TRW Bordeaux are manufactured localy. The plant is equipped with the most modern machinery and has complete DC and RF testing facilities including highly specialized test stations for ultra-linear devices.

  Manufacture and stocking in Bordeaux assures quick response to our customers needs.
- QUALITY ASSURANCE — An independant Quality Assurance Department polices the design, manufacturing and testing procedures and guarantees the highest possible product quality.
- SPECIAL PRODUCTS — Should the products listed in this catalog fail to match your requirements exactly, there is always the possibility of a specially designed or modified device.

  Once we have defined what the transistor should be for your application, a specification will be written by you, reviewed by TRW and a special part number assigned. This procedure will insure proper operation of the devices in your equipment.

- APPLICATION ENGINEERING — One of the most important functions of TRW Bordeaux is the applications assitance which can be rendered promptly, efficiently and in a professional manner. The plant houses a well-equiped applications laboratory, which is staffed by RF engineers specialized in all areas of solid-state circuitry, applications and systems. Computer aided design is widely used.
  In order to illustrate the level of expertise prevailing, some of the recent developments are listed below :

- **MOBILE**
  - 68-88 MHz — 100 W — 28 V Booster amplifiers.
  - 7.5 V broadband amplifier for portable radio.
- **VHF/UHF**
  - 100-400 MHz push-pull amplifier.
- **MATV**
  - 1.5 volt — 40-960 MHz amplifier.
- **TV TRANSPOSERS AND TRANSMITTERS**
  - Band 4-5 — Broadband — 7 watt — 60 dB IMD.
  - Band 4-5 — Broadband — 12 watt — 60 dB IMD.
- **MICROWAVE**
  - Broadband microwave amplifier — 10 W up to 3 GHz.
  - MARISAT amplifier — 50 W at 1.6 GHz.
  - Common collector oscillator transistor up to 4 GHz.
- **FM**
  - High efficiency transistor.
- **THERMAL RESISTANCE**
  - Measurement of the thermal resistances and time constants of the mains high power transistors by the ΔVEBF method.

ALPHANUMERICAL INDEX

Part Number	Page	Application	Frequency	Power or gain (dB)	Supply Voltage (V)	Package
2 N 3866	51	MOBILE	175 MHz	1 W	12.5	TO 39
2 N 4427	55	MOBILE	175 MHz	1 W	12.5	TO 39
2 N 4428	55	MOBILE	175 MHz	1 W	12.5	TO 39
2 N 4429	375	MICROWAVE	1 GHz	1 W	28	TO 117
2 N 4430	375	MICROWAVE	1 GHz	2.5 W	28	TO 129
2 N 4431	375	MICROWAVE	1 GHz	5 W	28	TO 129
2 N 5589	59	MOBILE	175 MHz	3 W	13.6	380 SOE
2 N 5590	59	MOBILE	175 MHz	10 W	13.6	380 SOE
2 N 5591	59	MOBILE	175 MHz	25 W	13.6	380 SOE
2 N 6080	63	MOBILE	175 MHz	4 W	12.5	380 SOE
2 N 6081	63	MOBILE	175 MHz	15 W	12.5	380 SOE
2 N 6082	63	MOBILE	175 MHz	25 W	12.5	380 SOE
2 N 6083	63	MOBILE	175 MHz	30 W	12.5	380 SOE
2 N 6084	63	MOBILE	175 MHz	40 W	12.5	380 SOE
CA 2150	289	CATV	40-300 MHz	17 dB	24	CA
CA 2152	291	CATV	40-300 MHz	12 dB	24	CA
CA 2250	289	CATV	40-300 MHz	17 dB	24	CA
CA 2252	291	CATV	40-300 MHz	12 dB	24	CA
CA 2270	293	CATV	40-300 MHz	17 dB	24	CA
CA 2272	293	CATV	40-300 MHz	12 dB	24	CA
CA 2350 A	295	CATV	40-300 MHz	22 dB	24	CA
CA 2350 B	295	CATV	40-300 MHz	22 dB	24	CA
CA 2418	297	CATV	5-120 MHz	18 dB	24	CA
CA 2603	299	CATV	40-300 MHz	33 dB	24	CA
CA 2650	301	CATV	40-300 MHz	33 dB	24	CA
CA 2750	303	CATV	40-300 MHz	38 dB	24	CA
CA 2800	221	GEN. PURP.	10-400 MHz	17 dB/800 mW	24	CA
CA 2810	225	GEN. PURP.	10-350 MHz	33 dB/800 mW	24	CA
CA 2818	229	GEN. PURP.	1-200 MHz	18 dB/800 mW	24	CA
CA 2820	233	GEN. PURP.	1-520 MHz	30 dB/400 mW	24	CA
CA 2830	237	GEN. PURP.	5-200 MHz	34 dB/1 W	24	CA
CA 2832	239	GEN. PURP.	1-200 MHz	35 dB/2 W	24	CA
CA 2833	237	GEN. PURP.	5-200 MHz	34 dB/1 W	24	CA
CA 2840	241	GEN. PURP.	30-300 MHz	22 dB/1 W	24	CA
CA 2842	241	GEN. PURP.	30-300 MHz	22 dB/1 W	24	CA
CA 2850	243	GEN. PURP.	40-100 MHz	17 dB/250 mW	24	CA
CA 2870	245	GEN. PURP.	20-400 MHz	34 dB/400 mW	24	CA
CA 2875	249	GEN. PURP.	40-100 MHz	17 dB/310 mW	24	CA
CA 2876	251	GEN. PURP.	40-100 MHz	22 dB/100 mW	24	CA
CA 2880	251	GEN. PURP.	40-100 MHz	22 dB/100 mW	24	CA
CA 2883	251	GEN. PURP.	40-100 MHz	22 dB/100 mW	24	CA
JO 1006	185	VHF, AM, FM	100-175 MHz	100 W	28	J-ZERO-C
JO 2015 A	189	UHF, AM, FM	200-400 MHz	70 W	28	J-ZERO-C
JO 3025	67	MOBILE	470 MHz	25 W	12.5	J-ZERO-C
JO 3055	67	MOBILE	470 MHz	55 W	12.5	J-ZERO-C
JO 4020	69	MOBILE	175 MHz	20 W	12.5	J-ZERO-C
JO 4030	69	MOBILE	175 MHz	30 W	12.5	J-ZERO-C
JO 4040	69	MOBILE	175 MHz	40 W	12.5	J-ZERO-C
JO 4045	73	MOBILE	175 MHz	45 W	12.5	J-ZERO-C
JO 4070	73	MOBILE	175 MHz	70 W	12.5	J-ZERO-C
MF 20	353	FM	88-108 MHz	20 W	12	MVM
ML 20	75	MOBILE	68-88 MHz	20 W	12.5	MVM
MRA 0610-3	379	MICROW. CLASS C	0.6-1.0 GHz	3 W	28	MRA
MRA 0610-9	379	MICROW. CLASS C	0.6-1.0 GHz	9 W	28	MRA

ALPHANUMERICAL INDEX

Part Number	Page	Application	Frequency	Power or gain (dB)	Supply Voltage (V)	Package
MRA 0610-18	379	MICROW. CLASS C	0.6-1.0 GHz	18 W	28	MRA
MRA 0610-40	379	MICROW. CLASS C	0.6-1.0 GHz	40 W	28	MRA
MRA 1014-2	387	MICROW. CLASS C	1.0-1.4 GHz	2 W	28	MRA
MRA 1014-6	387	MICROW. CLASS C	1.0-1.4 GHz	6 W	28	MRA
MRA 1014-12	387	MICROW. CLASS C	1.0-1.4 GHz	12 W	28	MRA
MRA 1014-35	387	MICROW. CLASS C	1.0-1.4 GHz	35 W	28	MRA
MRA 1417-2	395	MICROW. CLASS C	1.4-1.7 GHz	2 W	28	MRA
MRA 1417-6	395	MICROW. CLASS C	1.4-1.7 GHz	6 W	28	MRA
MRA 1417-11	395	MICROW. CLASS C	1.4-1.7 GHz	11 W	28	MRA
MRA 1417-25	395	MICROW. CLASS C	1.4-1.7 GHz	25 W	28	MRA
MRA 1720-2	403	MICROW. CLASS C	1.7-2.0 GHz	2 W	28	MRA
MRA 1720-5	403	MICROW. CLASS C	1.7-2.0 GHz	5 W	28	MRA
MRA 1720-9	403	MICROW. CLASS C	1.7-2.0 GHz	9 W	28	MRA
MRA 1720-20	403	MICROW. CLASS C	1.7-2.0 GHz	20 W	28	MRA
MRAL 2023-1.5	411	MICROW. CLASS C	2.0-2.3 GHz	1.5 W	22	MRA
MRAL 2023-3	411	MICROW. CLASS C	2.0-2.3 GHz	3 W	22	MRA
MRAL 2023-6	411	MICROW. CLASS C	2.0-2.3 GHz	6 W	22	MRA
MRAL 2023-12	411	MICROW. CLASS C	2.0-2.3 GHz	12 W	22	MRA
MRP 0912-50	419	MICROW. PULSE	0.9-1.2 GHz	50 W	50	MRA
MRP 0912-75	423	MICROW. PULSE	0.9-1.2 GHz	75 W	50	MRA
MRP 0912-150	427	MICROW. PULSE	0.9-1.2 GHz	150 W	50	MRP
MRP 0912-250	431	MICROW. PULSE	0.9-1.2 GHz	250 W	50	MRP
MRP 1115-1.5E	435	MICROW. PULSE	1.2-1.4 GHz	1.5 W	28	MRA
MRP 1214-8	435	MICROW. PULSE	1.2-1.4 GHz	8 W	28	MRP
MRP 1214-12 A	436	MICROW. PULSE	1.2-1.4 GHz	12 W	28	MRP
MRP 1214-30	435	MICROW. PULSE	1.2-1.4 GHz	30 W	28	MRP
MRP 1214-40 A	436	MICROW. PULSE	1.2-1.4 GHz	40 W	28	MRP
MRP 1214-60	435	MICROW. PULSE	1.2-1.4 GHz	60 W	28	MRP
MRP 1214-85 A	436	MICROW. PULSE	1.2-1.4 GHz	85 W	28	MRP
MV 20	77	MOBILE	140-175 MHz	20 W	12.5	MVM
MV 30	77	MOBILE	150-160 MHz	30 W	13.5	MVM
MVB 6	81	MOBILE	140-175 MHz	6 W	10.5	MVM
MX 7.5	83	MOBILE	400-512 MHz	7.5 W	12.5	MXM
MX 12	83	MOBILE	400-512 MHz	12 W	12.5	MXM
MX 15	83	MOBILE	400-470 MHz	15 W	12.5	MXM
PT 8740	85	MOBILE	175 MHz	1.8 W	12.5	TO 39
PT 8809	89	MOBILE	470 MHz	2 W	12.5	280 SOE
PT 8810	89	MOBILE	470 MHz	5 W	12.5	280 SOE
PT 8811	89	MOBILE	470 MHz	10 W	12.5	280 SOE
PT 8828	93	MOBILE	175 MHz	9 W	12.5	380 SOE
PT 9700	193	UHF, FM, AM	400 MHz	1.5 W	28	280 SOE
PT 9701	193	UHF, FM, AM	400 MHz	4 W	28	280 SOE
PT 9702	193	UHF, FM, AM	400 MHz	20 W	28	280 SOE
PT 9703	193	UHF, FM, AM	400 MHz	10 W	28	280 SOE
PT 9704	193	UHF, FM, AM	400 MHz	30 W	28	280 SOE
PT 9704 A	193	UHF, FM, AM	400 MHz	30 W	28	280 SOE
PT 9730	201	VHF, FM, AM	175 MHz	4 W	28	380 SOE
PT 9731	201	VHF, FM, AM	175 MHz	25 W	28	380 SOE
PT 9732	201	VHF, FM, AM	175 MHz	8 W	28	380 SOE
PT 9733	201	VHF, FM, AM	175 MHz	50 W	28	380 SOE
PT 9734	201	VHF, FM, AM	175 MHz	15 W	28	380 SOE
PT 9780	33	SSB	2-30 MHz	100 W	28	500 SOE Flange
PT 9780 A	33	SSB	2-30 MHz	100 W	28	500 SOE Stud

ALPHANUMERICAL INDEX

Part Number	Page	Application	Frequency	Power or gain (dB)	Supply Voltage (V)	Package
PT 9783	33	SSB	2-30 MHz	50 W	28	380 SOE Flange
PT 9783 A	33	SSB	2-30 MHz	50 W	28	380 SOE Stud
PT 9784 A	25	SSB	2-30 MHz	75 W	12.5	380 SOE Flange
PT 9785	25	SSB	2-30 MHz	100 W	12.5	500 SOE Flange
PT 9787	33	SSB	2-30 MHz	8 W	28	380 SOE Flange
PT 9787 A	33	SSB	2-30 MHz	8 W	28	380 SOE Stud
PT 9788	33	SSB	2-30 MHz	20 W	28	380 SOE Flange
PT 9788 A	33	SSB	2-30 MHz	20 W	28	380 SOE Stud
PT 9790	41	SSB	2-30 MHz	150 W	50	500 SOE Flange
PT 9790 A	41	SSB	2-30 MHz	150 W	50	500 SOE 1/2 inch Stud
PT 9795 A	25	SSB	2-30 MHz	15 W	12.5	380 SOE
PT 9796	25	SSB	2-30 MHz	30 W	12.5	380 SOE Flange
PT 9797	25	SSB	2-30 MHz	50 W	12.5	380 SOE Flange
TP 210	97	MOBILE, PORTABLE	88 MHz	50 mW	7.5	T-PACK
TP 212	101	MOBILE, PORTABLE	88 MHz	5.0 W	7.5	280 SOE
TP 250	105	MOBILE, PORTABLE	470 MHz	10 mW	7.5	T-PACK
TP 251	109	MOBILE, PORTABLE	470 MHz	175 mW	7.5	200 SOE Studless
TP 252	113	MOBILE, PORTABLE	470 MHz	1.5 W	7.5	280 SOE
TP 312	259	MATV, GEN. PURPOSE	1 GHz	600 mV	8	T-PACK
TP 390	263	MATV, GEN. PURPOSE	1 GHz	100 mV	5	T-PACK
TP 393	265	MATV, GEN. PURPOSE	1 GHz	300 mV	5	T-PACK
TP 394	269	MATV, GEN. PURPOSE	1 GHz	700 mV	15	T-PACK
TP 491	273	MATV, GEN. PURPOSE	1 GHz	400 mV	5	T-PACK
TP 1010	117	MOBILE	88 MHz	22 W	12.5	380 SOE
TP 1028	121	MOBILE	88 MHz	5 W	12.5	380 SOE
TP 1045	125	MOBILE	88, 175, 470 MHz	2 W	12.5	280 SOE Studless
TP 2180	129	MOBILE	88 MHz	5 W	12.5	380 SOE
TP 2301	133	MOBILE	175 MHz	3 W	12.5	TP 131
TP 2304	137	MOBILE	175 MHz	40 W	12.5	380 SOE
TP 2310	141	MOBILE	175 MHz	2.5 W	12.5	TO 39
TP 2312	145	MOBILE	175 MHz	2.75 W	12.5	TO 39-GE
TP 2314	149	MOBILE	175 MHz	4 W	12.5	TO 39-GE
TP 2320	153	MOBILE	175 MHz	17 W	12.5	380 SOE
TP 2404	157	VHF, FM, AM	175 MHz	50 W	28	500 SOE
TP 2405	161	VHF, FM, AM	175 MHz	90 W	27	500 SOE
TP 2500	165	MOBILE	175, 470 MHz	900, 350 mW	12.5	TO 46

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Part Number	Page	Application	Frequency	Power or gain (dB)	Supply Voltage (V)	Package
TP 2503	169	MOBILE	175, 470 MHz	5 W	12.5	280 SOE Studless
TP 3093	277	MATV, GEN. PURPOSE	1 GHz	1 V	15	TO 39
TP 3094	281	MATV, GEN. PURPOSE	1 GHz	1 V	15	TO 117
TP 5695	173	MOBILE	88 MHz	10 W	12.5	SOE 380
TP 8706	177	MOBILE	175 MHz	7 W	28	SOE 380
TP 9140/A	21	HF	27 MHz	15 W	12	SOE 380
TP 9150/A	21	HF	27 MHz	30 W	12	SOE 380
TP 9160/A	21	HF	27 MHz	50 W	12	SOE 380
TP 9170/A	21	HF	27 MHz	75 W	12	SOE 380
TP 9180	21	HF	27 MHz	100 W	12	SOE 380
TP 9380	355	FM	108 MHz	75 W	28	SOE 500
TP 9381	359	FM	108 MHz	100 W	28	SOE 500
TP 9382	363	FM	108 MHz	175 W	28	SOE 500
TP 9383	367	FM	108 MHz	150 W	28	SOE 500
TPM 401	209	BROADBAND V-UHF	100-400 MHz	1 W	20	SOE 280
TPM 405	213	BROADBAND V-UHF	100-400 MHz	5 W	20	SOE 280
TPM 425	217	BROADBAND V-UHF	100-400 MHz	25 W	20	SOE 280
TPV 364	309	TV BAND 3	225 MHz	10 W	25	SOE 380
TPV 366	313	TV BAND 3	225 MHz	2.5 W	20	SOE 280
TPV 375	317	TV BAND 3	225 MHz	14 W	25	SOE 500 1/2 inch
TPV 376	321	TV BAND 3	225 MHz	20 W	25	SOE 500
TPV 394	325	TV BAND 3	225 MHz	5 W	28	SOE 280
TPV 502	329	TV BAND 4-5	860 MHz	2 W	20	SOE 280
TPV 590	333	TV BAND 4-5	860 MHz	250 mW	20	SOE 200
TPV 591	337	TV BAND 4-5	860 MHz	0.5 W	20	SOE 200
TPV 596	341	TV BAND 4-5	860 MHz	0.5 W	20	SOE 280
TPV 597	345	TV BAND 4-5	860 MHz	1.0 W	20	SOE 280
TPV 598	349	TV BAND 4-5	860 MHz	4.0 W	20	SOE 280
TPV 599	350	TV BAND 4-5	860 MHz	7.5 W	20	MRA
TRW 2001	437	MICROW. CLASS C	2.0 GHz	1 W	28	HLP-8
TRW 2003	437	MICROW. CLASS C	2.0 GHz	3 W	28	HLP-8
TRW 2005	437	MICROW. CLASS C	2.0 GHz	5 W	28	HLP-8
TRW 2010	437	MICROW. CLASS C	2.0 GHz	10 W	28	HLP-8
TRW 2015	437	MICROW. CLASS C	2.0 GHz	15 W	28	HLP-11
TRW 2020	437	MICROW. CLASS C	2.0 GHz	20 W	28	HLP-11
TRW 2301	449	MICROW. CLASS C	2.3 GHz	1 W	22	HLP-8
TRW 2304	450	MICROW. CLASS C	2.3 GHz	4 W	22	HLP-8
TRW 2307	451	MICROW. CLASS C	2.3 GHz	7 W	22	HLP-8
TRW 3001	453	MICROW. CLASS C	3.0 GHz	1 W	28	HLP-8
TRW 3003	453	MICROW. CLASS C	3.0 GHz	3 W	28	HLP-8
TRW 3005	453	MICROW. CLASS C	3.0 GHz	5 W	28	HLP-8
TRW 52001	461	MICROW. CLASS A	2 GHz	1.5 W	20	TW 200
TRW 52101	461	MICROW. CLASS A	2 GHz	1.5 W	20	HLP-8 Flangeless
TRW 52102	465	MICROW. CLASS A	2 GHz	3.0 W	20	HLP-8 Flangeless
TRW 52104	469	MICROW. CLASS A	2 GHz	6.0 W	20	HLP-8 Flangeless

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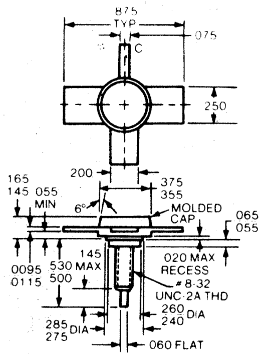
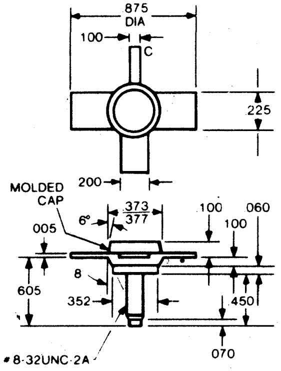
Part Number	Page	Application	Frequency	Power or gain (dB)	Supply Voltage (V)	Package
TRW 52601	461	MICROW. CLASS A	2 GHz	1.5 W	20	HLP-8
TRW 52602	465	MICROW. CLASS A	2 GHz	3.0 W	20	HLP-8
TRW 52604	469	MICROW. CLASS A	2 GHz	6.0 W	20	HLP-8
TRW 53001	473	MICROW. CLASS A	3 GHz	0.8 W	20	TW 200
TRW 53101	473	MICROW. CLASS A	3 GHz	0.8 W	20	HLP-8 Flangeless
TRW 53102	477	MICROW. CLASS A	3 GHz	1.6 W	20	HLP-8 Flangeless
TRW 53601	473	MICROW. CLASS A	3 GHz	0.8 W	20	HLP-8
TRW 53602	477	MICROW. CLASS A	3 GHz	1.6 W	20	HLP-8
TRW 54001	481	MICROW. CLASS A	4 GHz	0.5 W	20	TW 200
TRW 54101	481	MICROW. CLASS A	4 GHz	0.5 W	20	HLP-8 Flangeless
TRW 54601	481	MICROW. CLASS A	4 GHz	0.5 W	20	HLP-8
TRW 62601	485	MICR. OSCILLATOR	2 GHz	1.2 W	20	HLP-8
TRW 62602	489	MICR. OSCILLATOR	2 GHz	2 W	20	HLP-8
TRW 63601	493	MICR. OSCILLATOR	3 GHz	430 mW	20	HLP-8
TRW 63602	497	MICR. OSCILLATOR	3 GHz	850 mW	20	HLP-8
TRW 64601	501	MICR. OSCILLATOR	4 GHz	300 mW	20	HLP 8
TRW 64602	505	MICR. OSCILLATOR	4 GHz	600 mW	20	HLP-8

package designs

B-Band-1



B-Band-2



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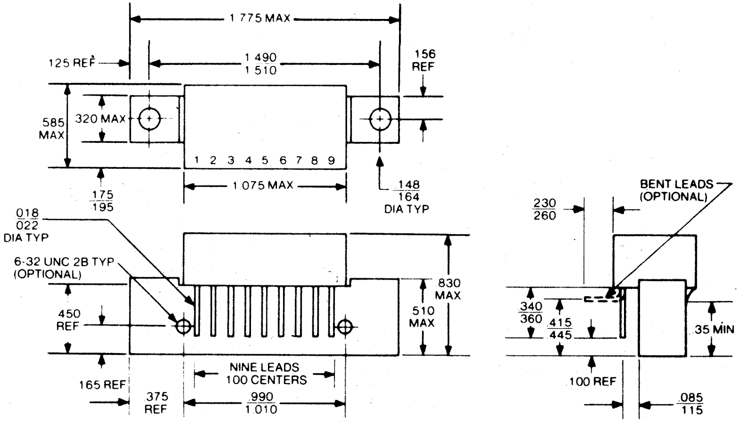
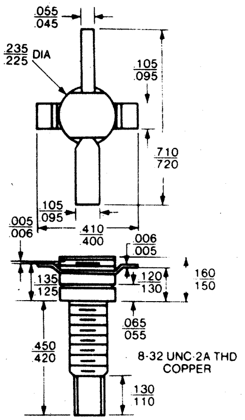
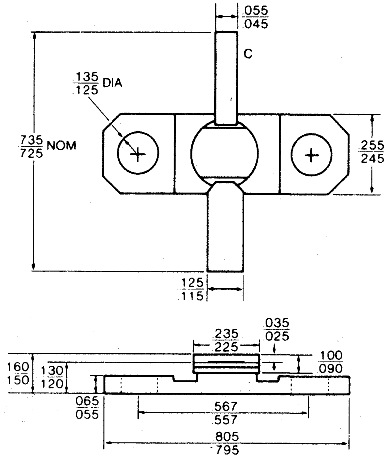


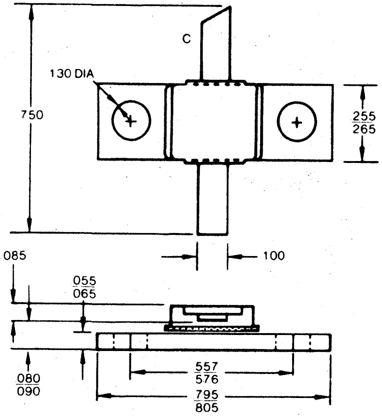
GP-14



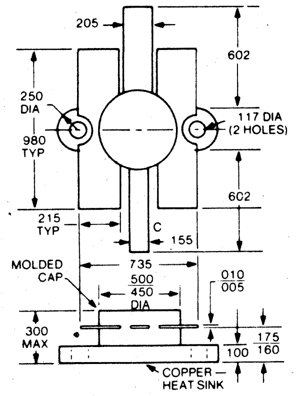
HLP-8/GP 13



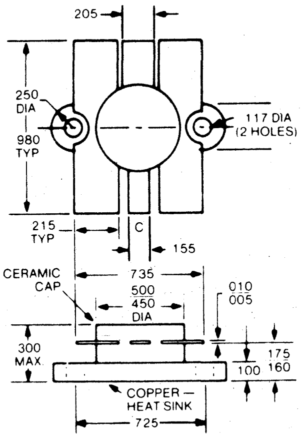
HLP-11



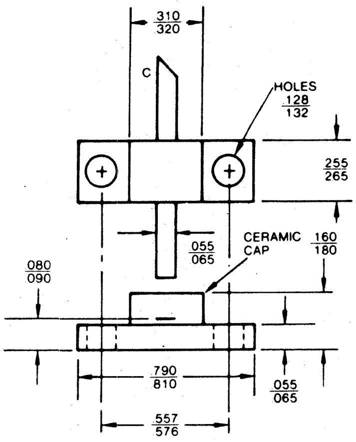
J-Zero



J-Zero-C



MRA



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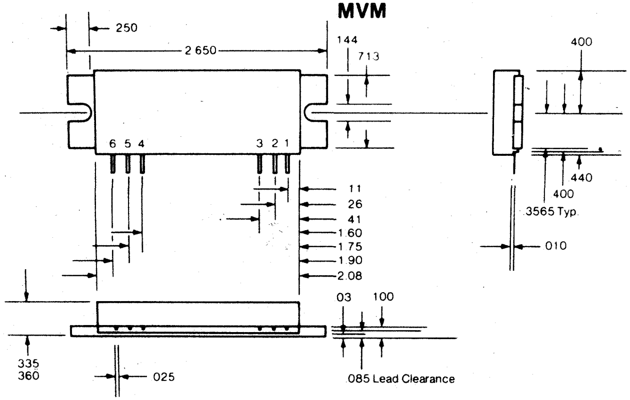

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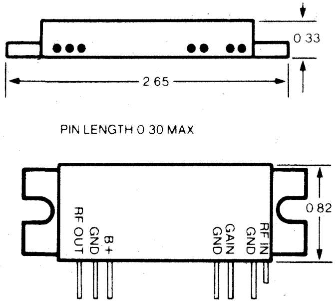

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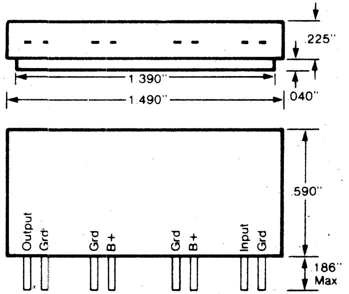
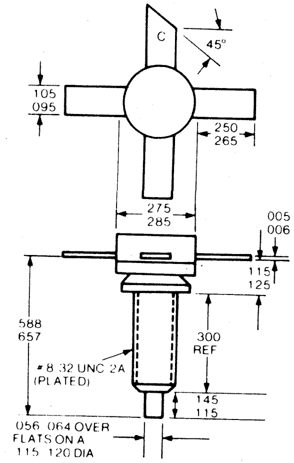
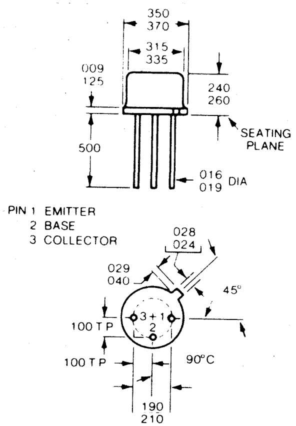


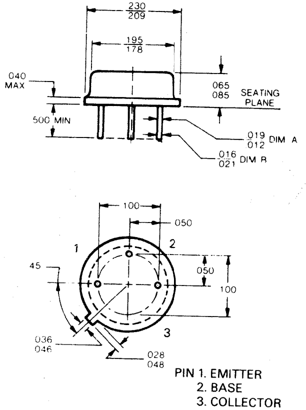
RT-3



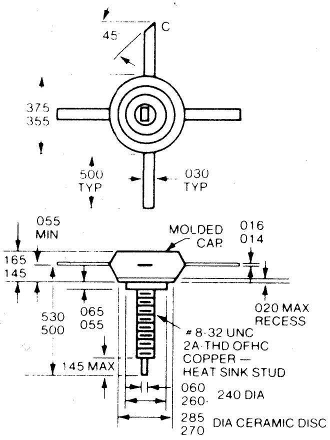
TO 39/TO 39 GE



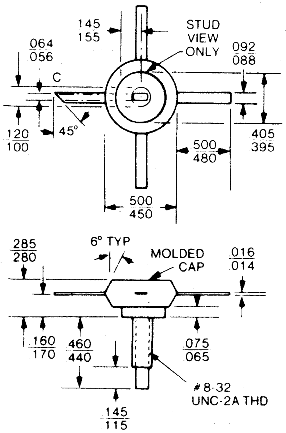
TO46



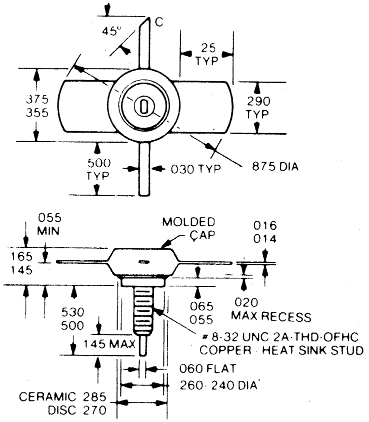
TO-117/TO-131



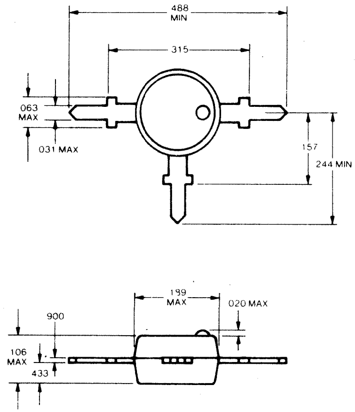
TO-128



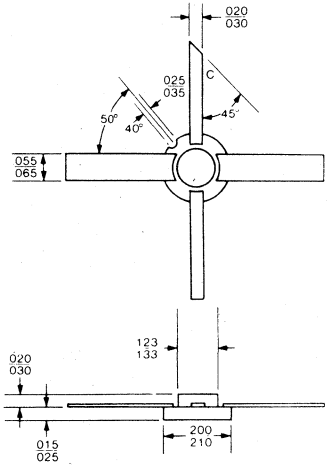
TO-129



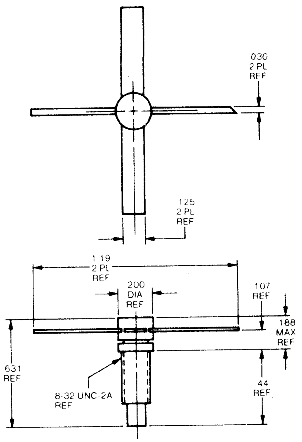
T-PAK
NPN Silicon Transistor



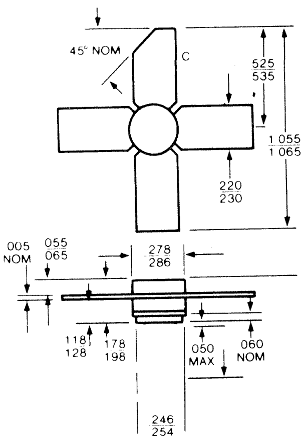
TW-200



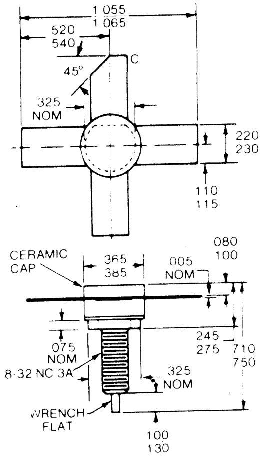
.200 SOE STUD



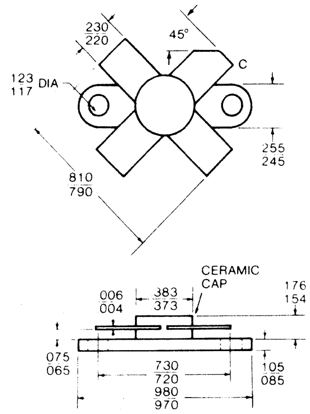
280 SOE/STUDLESS



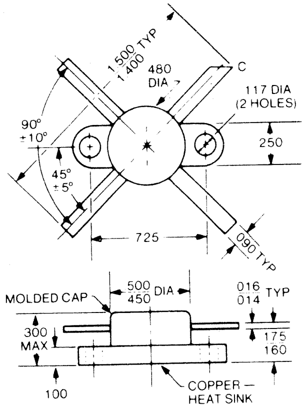
.380 SOE



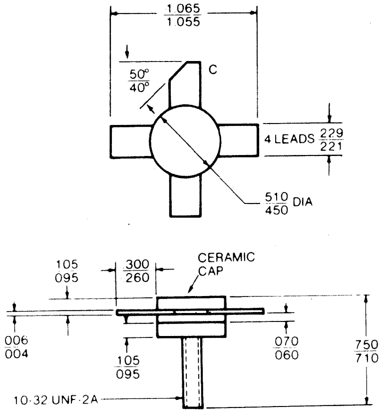
.380 SOE F



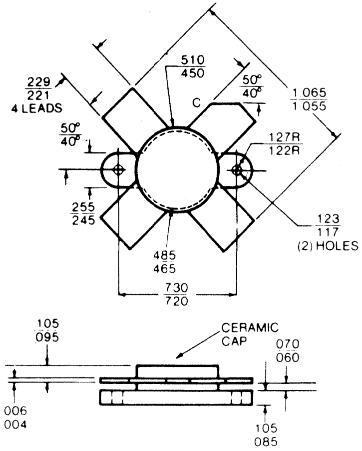
4L-DIA



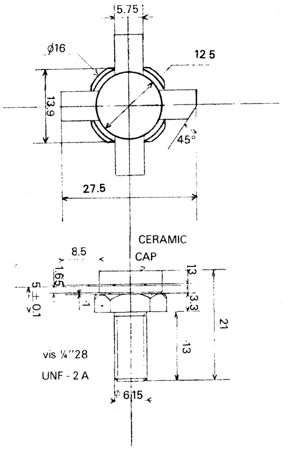
.500 SOE



.500 SOE F



500 SOE 1/4" STUD



HF-SSB

HF — SSB POWER TRANSISTORS

PRODUCT SUMMARY

13,5 V - HF SERIES

		PAGE
TP 9180	100 W PEP	**21**
TP 9170/A	75 W PEP	**21**
TP 9160/A	50 W PEP	**21**
TP 9150/A	30 W PEP	**21**
TP 9140/A	15 W PEP	**21**

13,5 V - HF - SSB SERIES

PT 9795/A	15 W PEP	**25**
PT 9796/A	30 W PEP	**25**
PT 9797/A	50 W PEP	**25**
PT 9784/A	75 W PEP	**25**
PT 9785	100 W PEP	**25**

28 V - HF - SSB SERIES

PT 9787/A	8 W PEP	**33**
PT 9788/A	20 W PEP	**33**
PT 9783/A	50 W PEP	**33**
PT 9780/A	100 W PEP	**33**

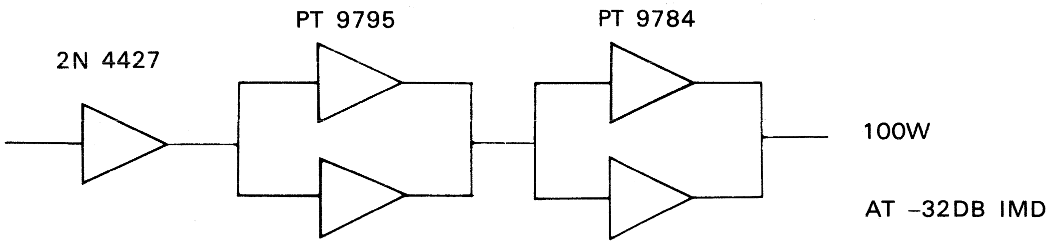
50 V - HF - SSB SERIES

PT 9790/A	150 W PEP	**41**
LOT 1000	200 W PEP	**32**

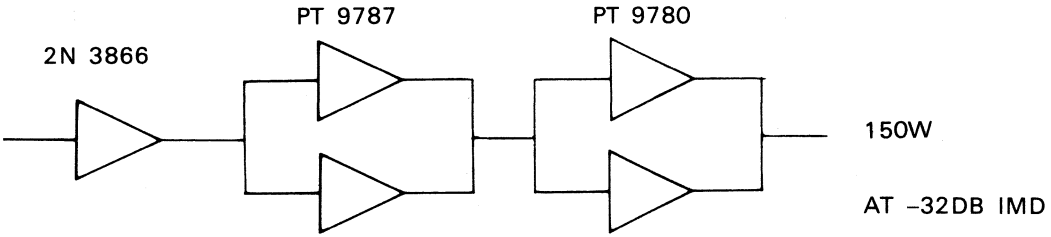
HF – SSB 1.5 – 30 MHz

LINE-UP SUGGESTIONS

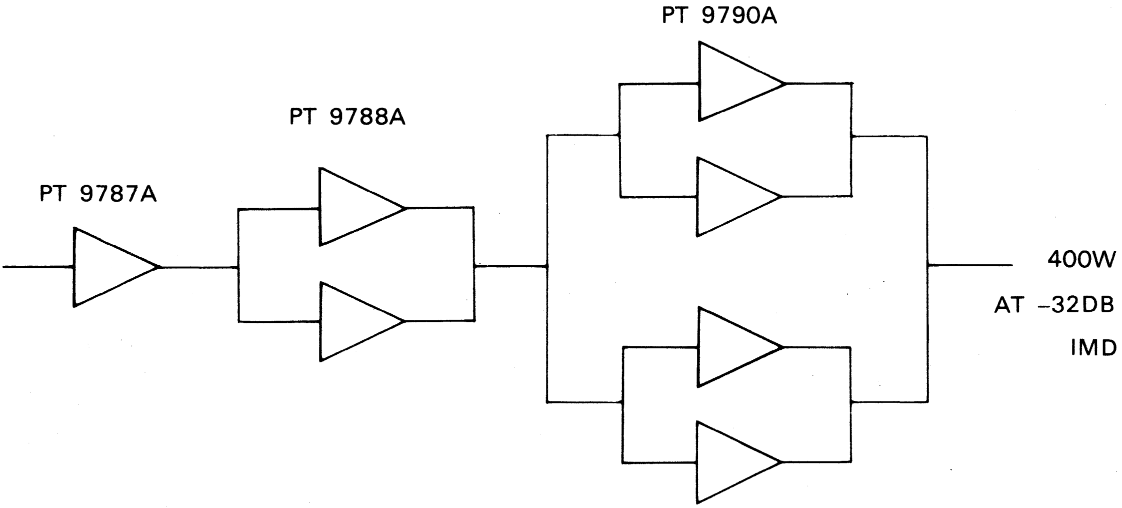
100 W – 12V – SSB RADIO FOR VEHICLE



100 W – 28 V – SSB RADIO – GROUND EQUIPEMENT



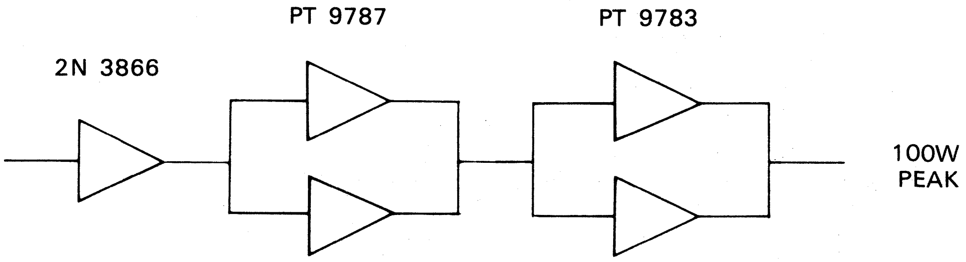
400 W – SSB TRANSMITTER – MILITARY OR MARINE



VHF

LINE-UP SUGGESTIONS

30-70 MHz – AM – 100W PEAK – TACTICAL RADIO



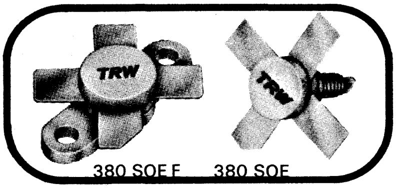
TRW® **SEMICONDUCTORS**

HF
13,5 V SERIES

High Frequency Power Transistors

TP 9180 100 W
TP 9170/A 75 W
TP 9160/A 50 W
TP 9150/A 30 W
TP 9140/A 15 W
∞ VSWR

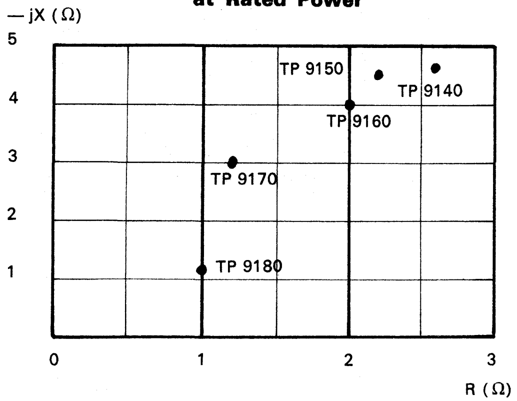
These power transistors are ballasted for ruggedness and will withstand infinite VSWR at all phase angles. A unique emitter structure provides high gain with wider emitter and base fingers resulting in high reliability. Ballast resistor design enables operation at Class A, AB and C.


380 SOE F 380 SOE

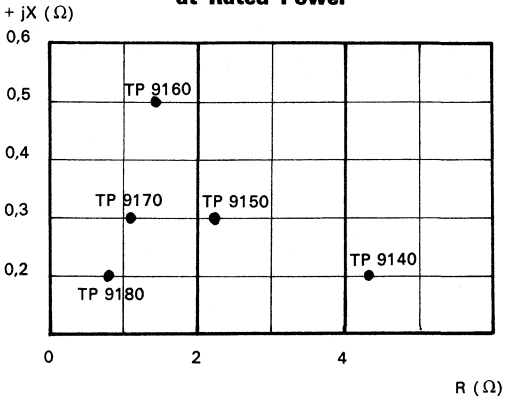
Electrical Characteristics (T_{case} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	TP9140/A	TP9150/A	TP9160/A	TP9170/A	TP9180	UNIT
DC TEST	I_{EBO}	Emitter Base Leakage Current	V_{EB} = 4 V	2	4	6	10	10	mA Max
	I_{CBO}	Collector Base Leakage Current	V_{CB} = 50 V	50	100	100	200	200	mA Max
	I_{CES}	Collector Base cut off current	V_{CE} = 13,5 V Emitter base short circuited	5	10	10	20	20	mA Max
	h_{FE}	DC Current Gain	V_{CE} = 13,5 V I_C = 500 mA I_C = 1 A I_C = 2 A	25	25	25	20	20	— Min
RF TEST	P_{out}	Commun Emitter Power output	V_{CE} = 13,5 V F = 27 MHz	15	30	50	75	100	W Min
	P_G	Power Gain	V_{CE} = 13,5 V F = 27 MHz P_{out} at Rated Power	12	12	12	11.5	11	dB Min
	VSWR	Mismatch Tolerance	V_{CE} = 13,5 V F = 27 MHz P_{out} at Rated Power	∞	∞	∞	∞	∞	—
MAXIMUM RATING	V_{EB}	Emitter Base Voltage		4	4	4	4	4	V
	V_{CE}	Collector Emitter Voltage		20	20	20	20	20	V
	V_{CB}	Collector Base Voltage		50	50	50	50	50	V
	I_C	Collector current		4	8	12	15	20	A
	Pd	Power Dissipation	t_{case} = 25 °C	35	70	115	150	200	W
	T_{STG}	Storage Temperature		— 65 to + 200 °C					

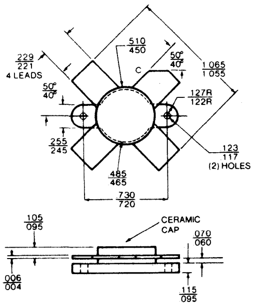
Typical Series Input Impedance at Rated Power



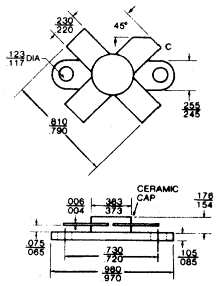
Typical Series Load Impedance at Rated Power



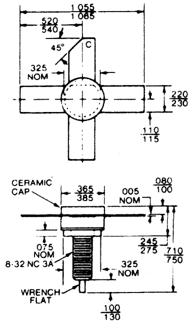
TP 9180



TP 9140
TP 9150
TP 9160
TP 9170



TP 9140 A
TP 9180 A
TP 9160 A
TP 9170 A

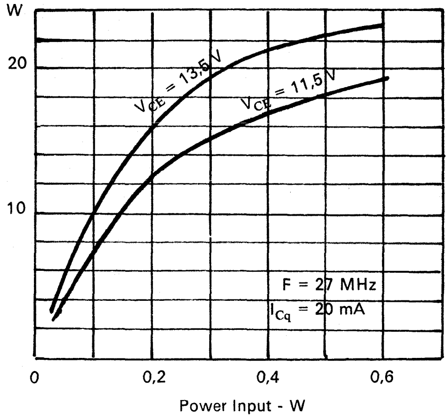


Mechanical Specifications

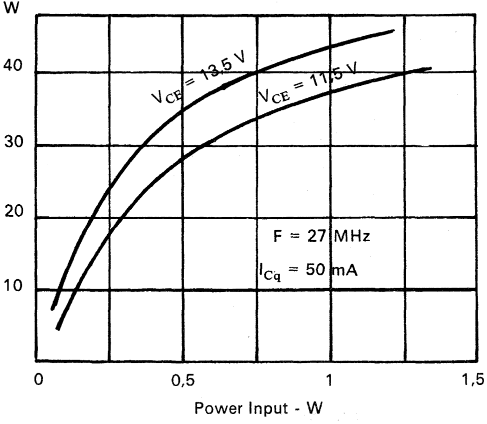
- Stud Torque, 10 in. lbs., max.
- Lead Soldering, 300°C, 15 sec. max.
- Lead Fatique, 3 bends @ 90°
- Flange Flatness, 0.0008 in. typ.

Typical Power Output vs Power Input

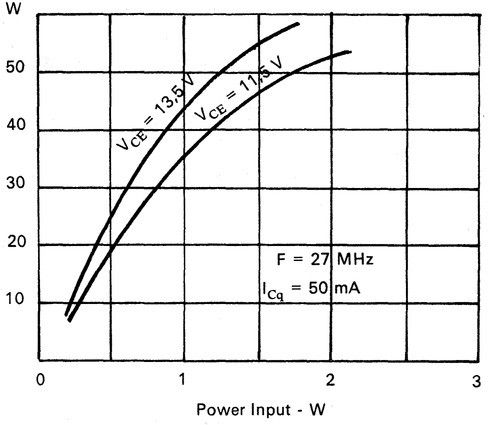
TP 9140



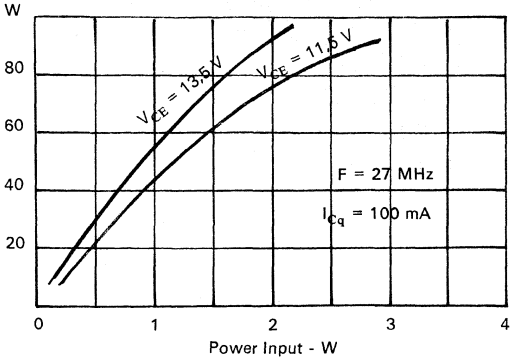
TP 9150



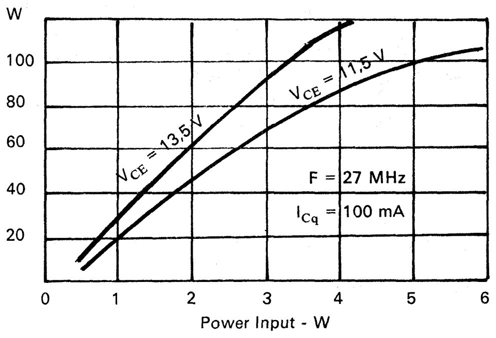
TP 9160



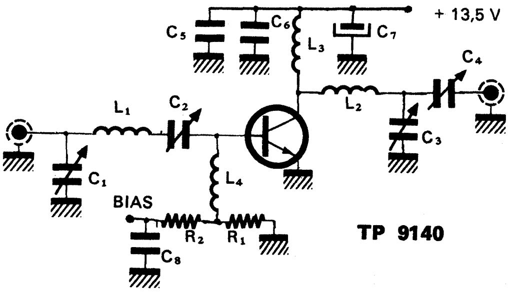
TP 9170



TP 9180



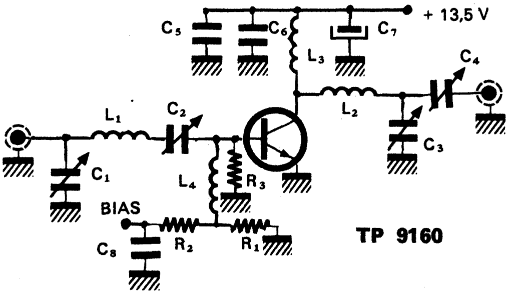
TYPICAL APPLICATIONS



TP 9140

15 W Power Amplifier

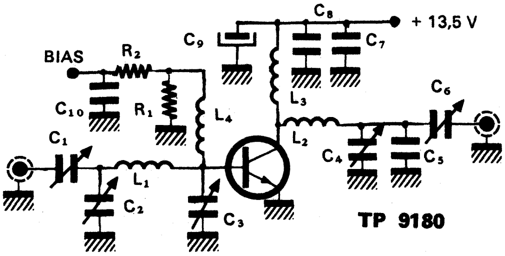
C_1	ARCO 469 170-780 pF
C_2	ARCO 427 55-300 pF
C_3	ARCO 427 55-300 pF
C_3	ARCO 427 55-300 pF
C_4	ARCO 427 55-300 pF
C_5	1000 pF UNELCO
C_6	0,1 µF Disc
C_7	50 µF Electrolytic
C_8	0,1 µF Disc
L_1	6 turns ∅ 8 mm 1 mm wire
L_2	4 turns ∅ 11 mm 1,2 mm wire
L_3	10 turns ∅ 12 mm 1,2 mm wire
L_4	VK 200 ferrite chocke
R_1	1,5 Ω
R_2	10 Ω/5 W



TP 9160

50 W Power Amplifier

C_1	ARCO 427 55-300 pF + 400 pF UNELCO
C_2	ARCO 469 170-680 pF
C_3	ARCO 427 55-300 pF
C_4	ARCO 425 24-200 pF
C_5	1000 pF UNELCO
C_6	0,1 µF Disc
C_7	470 µF Electrolytic
C_8	0,1 µF Disc
L_1	3 turns ∅ 10 mm 1,4 mm wire
L_2	3 turns ∅ 10 mm 1,8 mm wire L = 13 mm
L_3	8 turns ∅ 12 mm 1,2 mm wire
L_4	VK 200 ferrite chocke
R_1	1,5 Ω
R_2	10 Ω/5 W
R_3	39 Ω



TP 9180

100 W Power Amplifier

C_1	ARCO 423 7-100 pF
C_2	ARCO 467 110-680 pF
C_3	ARCO 469 170-780 pF
C_4	ARCO 466 80-480 pF
C_5	400 pF UNELCO
C_6	0,1 µF Disc
C_7	1000 pF UNELCO
C_8	0,1 µF Disc
C_9	470 µF Electrolytic
R_1	1,5 Ω
R_2	10 Ω/5 W

L_1	3 turns ∅ 11 mm 1 mm wire L = 15 mm
L_2	3 turns ∅ 15 mm 1,8 mm wire L = 20 mm
L_3	5 turns ∅ 12 mm 1,8 mm wire
L_4	VK 200 ferrite chocke

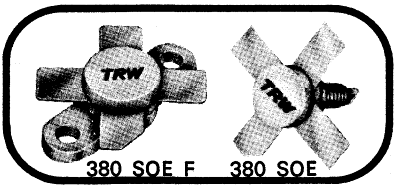
TRW® SEMICONDUCTORS

HF - SSB
13,5 V SERIES

SSB Power Transistors

PT 9785 - 100 W
PT 9784/A - 75 W
PT 9797/A - 50 W
PT 9796/A - 30 W
PT 9795/A - 15 W
∞ VSWR

This Series features both high gain and high power, providing the desired power output with fewer devices. These power transistors are ballasted for ruggedness and will withstand infinite VSWR at all phase angles. A unique emitter structure provides high gain with wider emitter and base fingers resulting in high reliability. Ballast resistor design enables operation at Class A, AB and C. These rugged units are suitable for both narrow band and broadband HF communications and instrumentation service.



380 SOE F 380 SOE

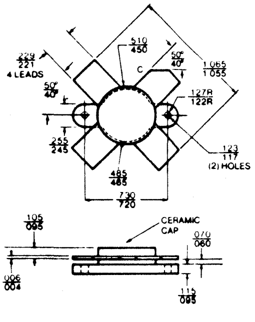
Electrical Characteristics (T_{case} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	PT 9795/A	PT 9796/A	PT 9797/A	PT 9784/A	PT 9785	UNIT
D C TESTS	BV_{CBO}	Collector - Base Breakdown	I_C = 100 mA I_C = 200 mA	50	50	50	50	50	V Min
	BV_{EBO}	Emitter - Base Breakdown	I_E = 6 mA I_E = 10 mA	4.0	4.0	4.0	4.0	4.0	V Min
	I_{CES}	Collector - Emitter Cutoff Current	V_{CE} = 13,5 V	5	10	10	20	20	mA Max
	HF_E	DC Current Gain	V_{CE} = 5 V	25-150	25-150	25-150	20-100	20-100	—
	ΔHF_E	Matched Pairs	I_C = 1 A	Δ 10	Δ 10	Δ 10	Δ 5	Δ 5	—
R F TESTS	P_{out}	Output Power PEP	V_{CE} = 13,5 V P = 28 MHz	15	30	50	75	100	W PEP
	P_G	Power Gain	V_{CE} = 13.5 V F = 28 MHz P_{out} = Rated PEP	15	15	15	15	13	dB Min
	IMD	Intermodulation Distorsion	V_{CE} = 13.5 V F = 28 MHz P_{out} = Rated PEP	— 32	— 32	— 32	— 32	— 32	dB Max
	VSWR	Mismatch Tolerance	V_{CE} = 13.5 V F = 28 MHz P_{out} = Rated PEP	∞	∞	∞	∞	∞	—
THERMAL	Rth	Thermal Resistance Jonction to Heatsink (Including Contact)	V_{CE} = 13,5 V Pd = 6 W Pd = 18 W th = 40 °C Pd = 30 W Pd = 50 W Pd = 60 W	3,0	2,5	2,0	1,4	0,9	°C/W

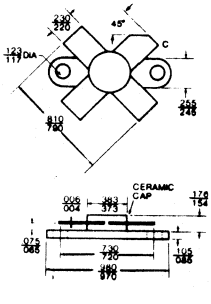
Absolute Maximum Ratings (T_{case} = 25 °C)

Part number	V_{CBO} V	V_{CEO} V	V_{CBO} V	$T_{storage}$ °C
PT 9795/A	50	20.0	4.0	— 65 to 200
PT 9796/A	50	20.0	4.0	— 65 to 200
PT 9797/A	50	20.0	4.0	— 65 to 200
PT 9784/A	50	20.0	4.0	— 65 to 200
PT 9785	50	20.0	4.0	— 65 to 200
The « A » suffix on part number denotes stud package				

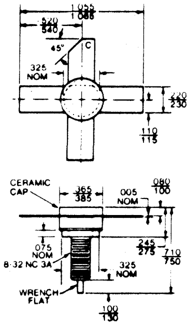
PT 9785



PT 9795
PT 9796
PT 9797
PT 9784



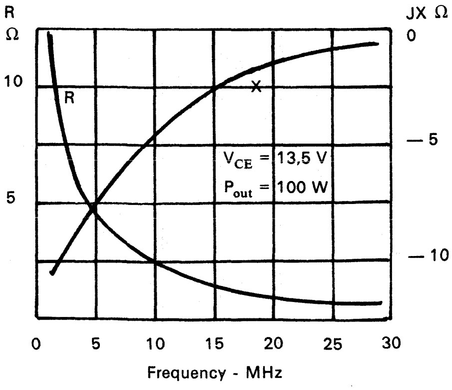
PT 9795 A
PT 9796 A
PT 9797 A
PT 9784 A



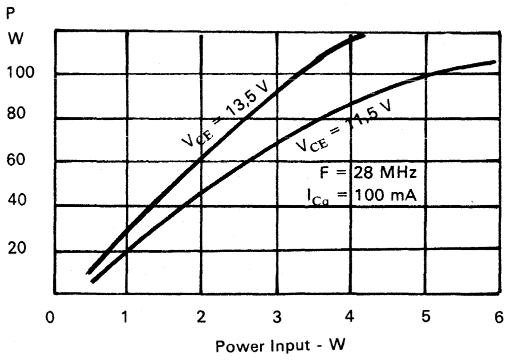
Mechanical Specifications

- Stud Torque, 10 in. lbs., max.
- Lead Soldering, 300°C, 15 sec. max.
- Lead Fatique, 3 bends @ 90°
- Flange Flatness, 0.0008 in. typ.

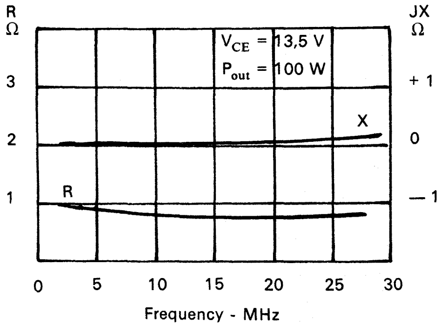
Series Input Impedance vs Frequency



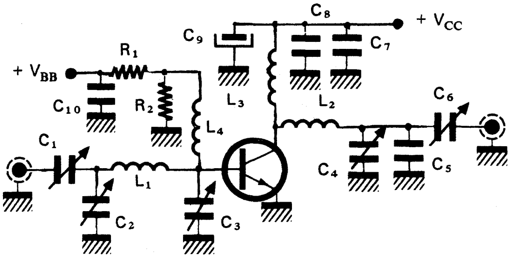
Power Output vs Power Input



Series Load Impedances vs Frequency



28 MHz Test Circuit



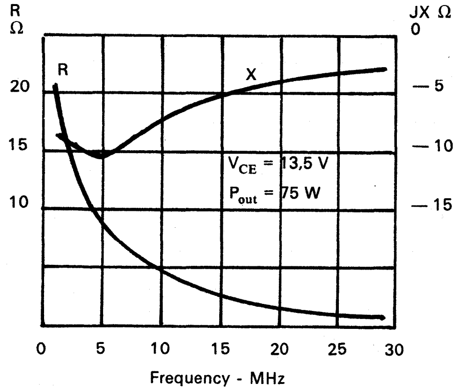
Test Circuit Ports List

C_1	ARCO 423 7-100 pF
C_2	ARCO 467 110-680 pF
C_3	ARCO 469 170-780 pF
C_4	ARCO 466 80-480 pF
C_5	400 pF UNELCO
C_6	ARCO 423 7-100 pF
C_7	1000 pF UNELCO
C_8	0,1 μF
C_9	470 μF Electrolytic
C_{10}	0,1 μF

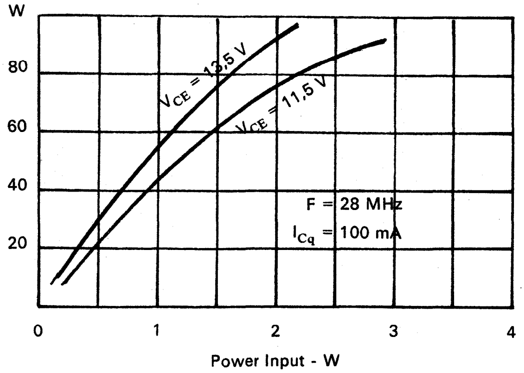
L_1	3 turns ∅ 11 mm 1 mm wire L = 15 mm
L_2	3 turns ∅ 15 mm 1,8 mm wire L = 20 mm
L_3	Sturns ∅ 12 mm 1,8 mm wire
L_4	VK 200 ferrite choke

R_1	1,5 Ω
R_2	10 Ω/5 W

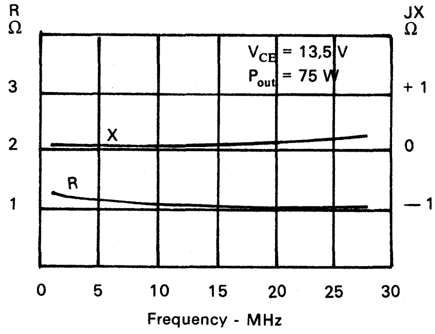
Series Input Impedance vs Frequency



Power Output vs Power Input



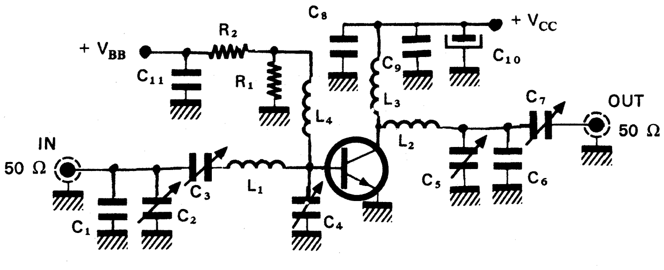
Series Load Impedance vs Frequency



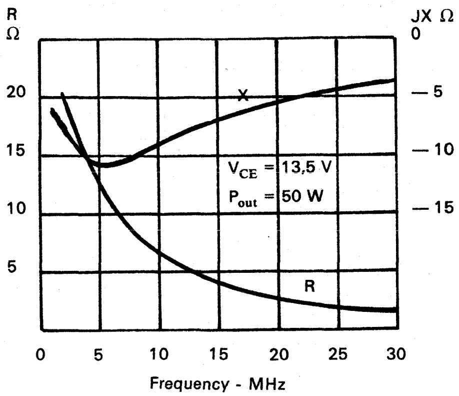
Test Circuit Parts List

L_1	3 turns ⌀ 12 mm 1,4 mm wire
L_2	2 turns ⌀ 13 mm 1,8 mm wire L = 10 mm
L_3	8 turns ⌀ 12 mm 1,2 mm wire
L_3	VK 200 ferrite choke
C_1	400 pF UNELCO
C_2	ARCO 427 55-300 pF
C_3	ARCO 469 170-780 pF
C_4	ARCO 469 170-780 pF
C_5	ARCO 427 55-300 pF
C_6	300 pF UNELCO
C_7	ARCO 425 24-200 pF
C_8	1000 pF UNELCO
C_9	0,1 μF
C_{10}	470 μF Electrolytic
C_{11}	0,1 μF
R_1	1,5 Ω
R_2	10 Ω/5 W

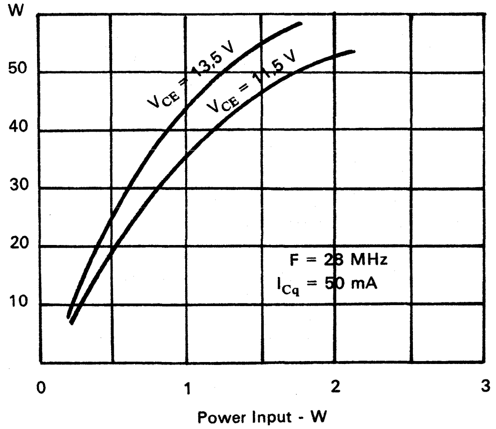
28 MHz Test Circuit



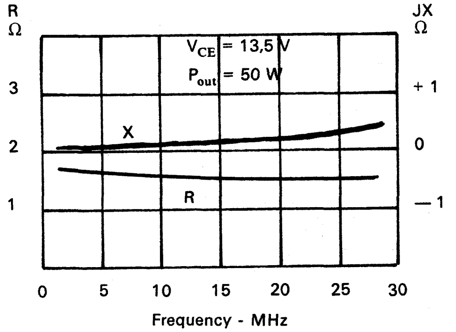
Series Input Impedance vs Frequency



Power Output vs Power Input



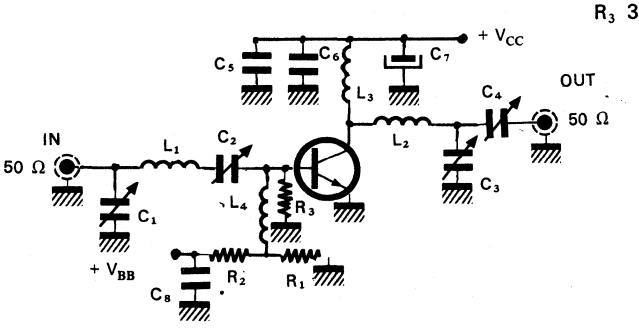
Series Load Impedance vs Frequency



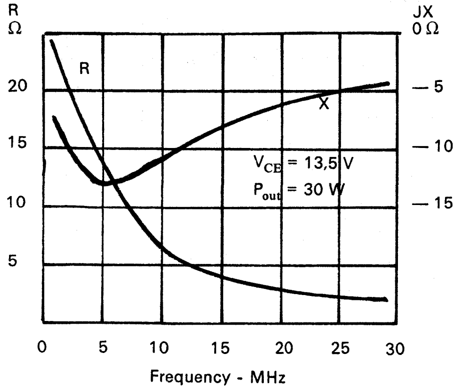
Test Circuit Parts List

L_1	3 turns ∅ 10 mm 1,4 mm wire
L_2	3 turns ∅ 10 mm 1,8 mm wire L = 13 mm
L_3	8 turns ∅ 12 mm 1,2 mm wire
L_4	VK 200 ferrite choke
C_1	ARCO 427 55-300 pF + 400 pF UNELCO
C_2	ARCO 469 170-780 pF
C_3	ARCO 427 55-300 pF
C_4	ARCO 425 24-200 pF
C_5	1000 pF UNELCO
C_6	0,1 μF
C_7	470 μF Electrolytic
C_8	0,1 μF
R_1	1,5 Ω
R_2	10 Ω/5 W
R_3	39 Ω

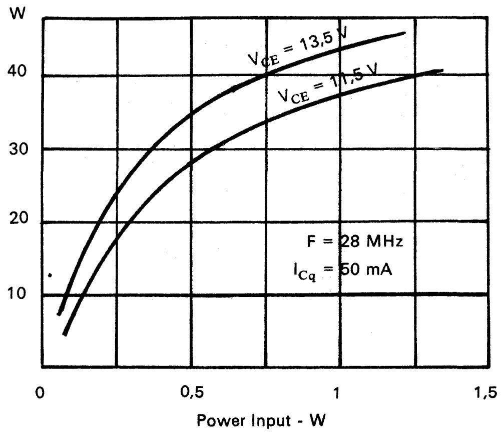
28 MHz Test Circuit



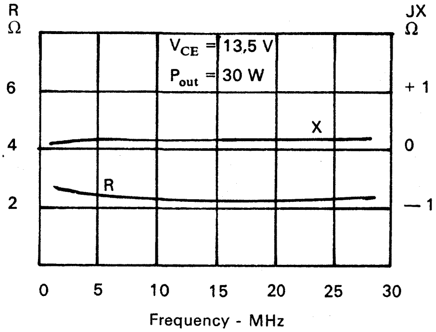
Series Input Impedance vs Frequency



Power Output vs Power Input



Series Load Impedance vs Frequency



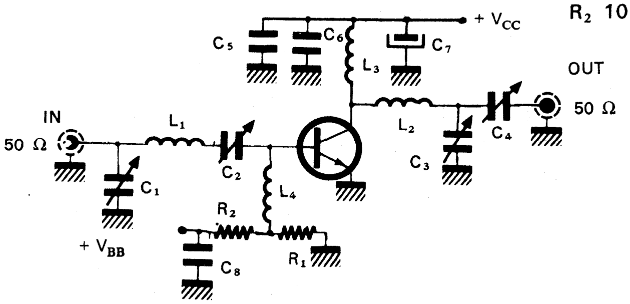
Test Circuit Parts List

L_1 4 turns ∅ 12 mm 1 mm wire
L_2 4 turns ∅ 12 mm wire L = 8 mm
L_3 10 turns ∅ 12 mm 1 mm wire
L_4 VK 200 ferrite choke

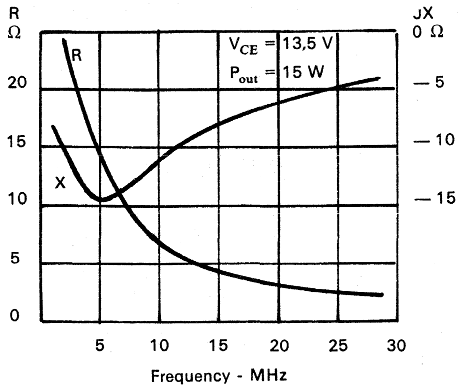
C_1 ARCO 469 170-780 pF + 200 pF UNELCO
C_2 ARCO 469 170-780 pF
C_3 ARCO 427 55-300 pF
C_4 ARCO 427 55-300 pF
C_5 1000 pF UNELCO
C_6 0,1 μF
C_7 50 μF Electrolytic
C_8 0,1 μF

R_1 1,5 Ω
R_2 10 Ω/5 W

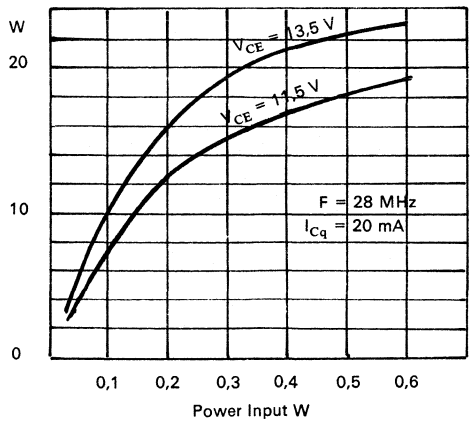
28 MHz Test Circuit



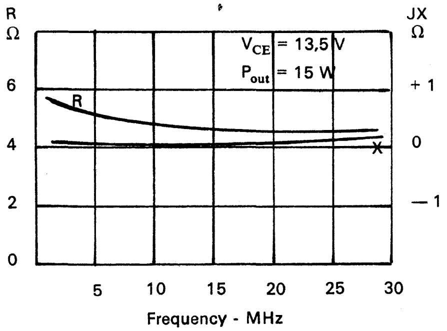
Series Input Impedance vs Frequency



Power Output vs Power Input



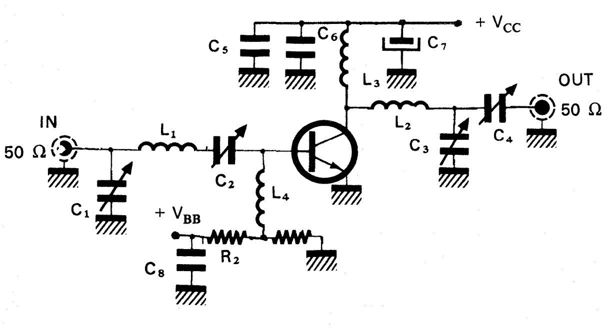
Series Load Impedance vs Frequency



Test Circuit Parts List

C_1	ARCO 469 170-780 pF
C_2	ARCO 427 55-300 pF
C_3	ARCO 427 55-300 pF
C_4	ARCO 427 55-300 pF
C_5	1000 pF UNELCO
C_6	0,1 μF Disc
C_7	50 μF Electrolytic
C_8	0,1 μF
L_1	6 turns ∅ 8 mm 1 mm wire
L_2	4 turns ∅ 11 mm 1,2 mm wire
L_3	10 turns ∅ 12 mm 1,2 mm wire
L_4	VK 200 ferrite choke
R_1	1,5 Ω
R_2	10 Ω/5 W

28 MHz Test Circuit



TRW® SEMICONDUCTORS

LΘT 1000

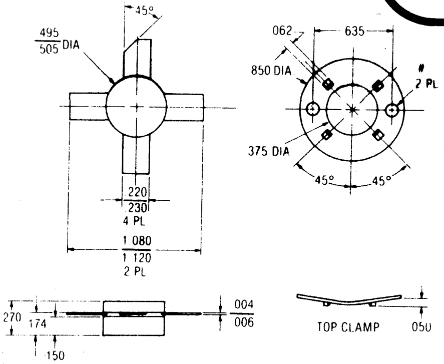
HIGH POWER LINEAR RF POWER TRANSISTOR

PRELIMINARY

The LΘT 1000 Low Θ_{JC} transistor is intended for use in Marine, Military, and Commercial high power SSB and CW RF transmitter designs. The combined die and package state-of-the-art technology enables reliable operation at elevated case temperatures.

200 WATTS PEP,
2-30MHz, 50V,
LOW Θ_{JC},
0-42°C/W
@100° HEATSINK

.5 Low Theta Package



Electrical Characteristics (T_{case} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC TEST	BV_{CBO}	Collector Base Voltage	I_C = 100mA I_E = 0	110			V
	BV_{CER}	Collector Emitter	I_C = 50mA R = 1Ω	110			V
	I_{CER}	Collector Emitter Leakage	V_{CE} = 80 R = 1Ω			20	mA
	BV_{EBO}	Emitter Base Voltage	I_E = 10mA I_C = 0	3.60			V
	h_{FE}	D.C. Current Gain	V_{CE} = 5.0V I_C = 5.0A	10		70	
RF TEST	P_{OUT}	Power Output	V_{CE} = 50V f = 30MHz P_{IN} = 7.0	200			W
	IMD	3rd Order	V_{CE} = 50V f = 30MHz P_O = 200W	−35			dB
	$VSWR_L$	Collector Load	V_{CE} = 50V f = 30MHz P_O = 200W PEP	3:1			
	*Phase angle s varied >360° during 3- second test						
THERMAL	Θ_{JC}	Thermal Resistance	100°C Case		0.42		c/w

TRW® **SEMICONDUCTORS**

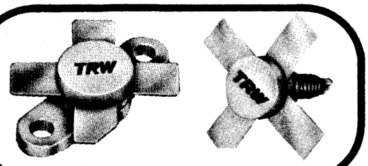
HF - SSB
28 V SERIES

SSB Power Transistors

PT 9780/A - 100 W
PT 9783/A - 50 W
PT 9788/A - 20 W
PT 9787/A - 8 W
∞ VSWR

The PT 9780 SSB/VHF Series features both high gain and high power, providing the desired power output with fewer devices. These power transistors are ballasted for ruggedness and will withstand infinite VSWR at all phase angles. A unique emitter structure provides high gain with wider emitter and base fingers resulting in high reliability. Diffused ballast resistors design enables operation at Class A, AB, and C. These rugged units are suitable for both narrow band and broadband SSB and VHF communications and instrumentation service. They are suitable for the following applications :

2-30 MHz	SSB, FM, AM
2-76 MHz	SSB, FM, AM
2-100 MHz	Linear Class A, SSB, FM, AM



Electrical Characteristics (T_{flange} = 25 °C)

	SYMBOL	CHARACTERISTICS	CONDITIONS	PT 9787/A	PT 9788/A	PT9783/A	PT 9780/A	UNIT
D C Tests	BV_{CBO}	Collector to Base Breakdown Voltage	I_C = 100 mA I_E = 0	70	70	70	70	V Min
	BV_{CEO}	Collector to Emitter Breakdown Voltage	I_C = 50 mA I_B = 0	40	40	40	40	V Min
	I_{CES}	Collector - Emitter Cutoff Current	V_{CE} = 28 V	25	50	100	100	mA Max
	I_{EBO}	Emitter - Base Leakage Current	V_{BE} = 4 V	1.0	1.0	2.5	5.0	mA Max
	H_{FE}	D.C Current Gain	V_{CE} = 5 V	10-100	10-100	10-100	10-100	
	ΔH_{FE}	Matched Pairs	I_C = 1 A	Δ 5	Δ 5	Δ 5	Δ 5	
R F Tests	G_P	Power Gain	V_{CE} = 28 V F = 28 MHz PEP 8 W 20 W 50 W 100 W	14	14	14	14	dB Min
	IMD	Intermodulation Distortion	V_{CE} = 28 V F = 28 MHz PEP 8 W 20 W 50 W 100 W	— 32	— 32	— 32	— 32	dB Max
	VSWR	Mismatch Tolerance	V_{CE} = 28 V F = 28 MHz PEP 8 W 20 W 50 W 100 W	∞	∞	∞	∞	—

PT 9780 - PT 9783 - PT 9787 - PT 9788

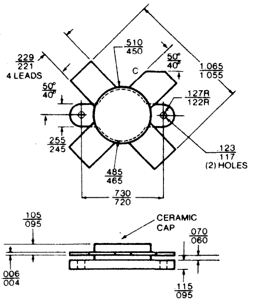
Absolute Maximum Ratings ($T_{CASE} = 25°C$)

Part Number*	V_{CBO} Volts	V_{CEO} Volts	V_{EBO} Volts	I_C Max Amps	P_T @ 25°C Watts	θ_{jc} °C/W	$T_{STORAGE}$ °C
PT9780	70	40	4.0	20.0	350	0.50	-65 to 200
PT9780A	70	40	4.0	20.0	250	0.70	-65 to 200
PT9783	70	40	4.0	10.0	175	1.0	-65 to 200
PT9783A	70	40	4.0	10.0	100	1.75	-65 to 200
PT9788/A	70	40	4.0	4.0	70	2.5	-65 to 200
PT9787/A	60	40	4.0	2.0	25	7.0	-65 to 200

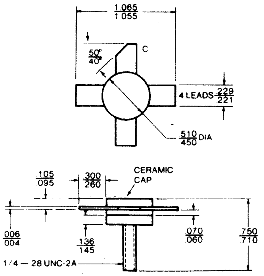
*The "A" suffix on part number denotes stud package.

Package Outlines

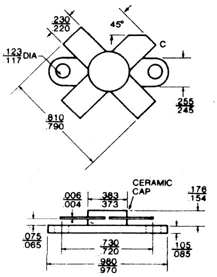
PT9780



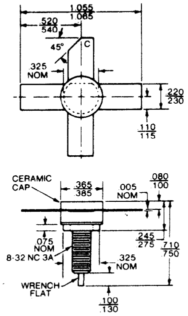
PT9780A



PT9783
PT9788
PT9787



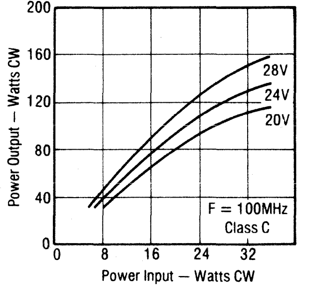
PT9783A
PT9788A
PT9787A



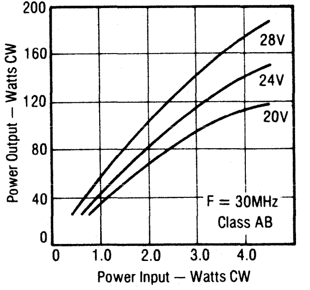
Mechanical Specifications

- Stud Torque, 10 in. lbs., max.
- Lead Soldering, 300°C, 15 sec. max.
- Lead Fatique, 3 bends @ 90°
- Flange Flatness, 0.0008 in. typ.

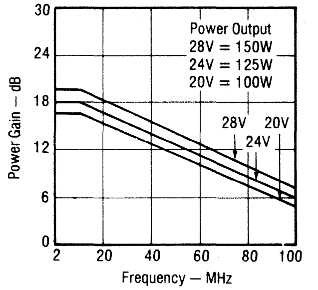
PT9780 and PT9780A



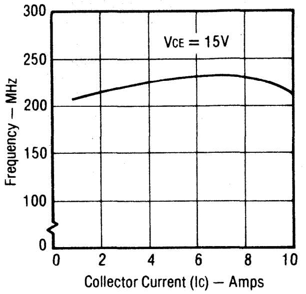
Power Output vs Power Input



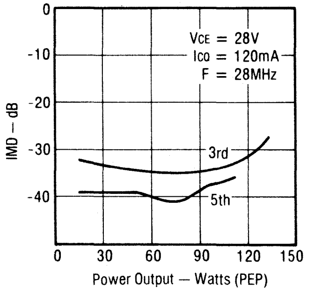
Power Output vs Power Input



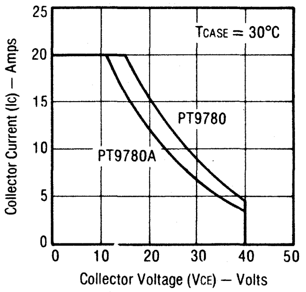
Power Gain vs Frequency



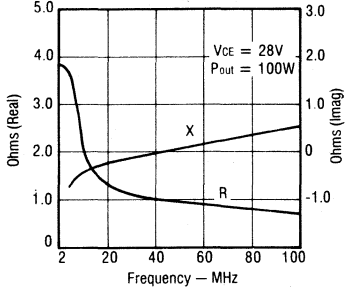
ft vs Ic



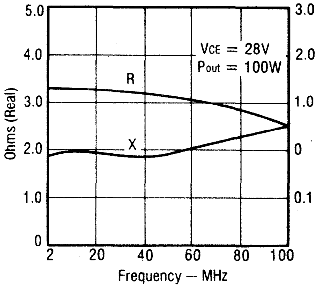
IMD vs Power Output



DC Safe Operating Area



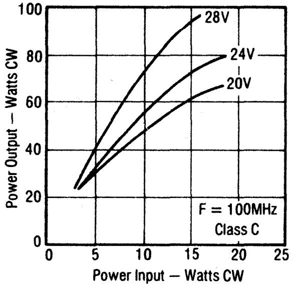
Series Input Impedance vs Frequency



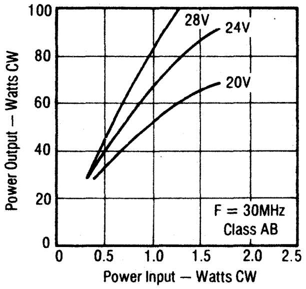
Series Load Impedance vs Frequency

PT9783 and PT9783A

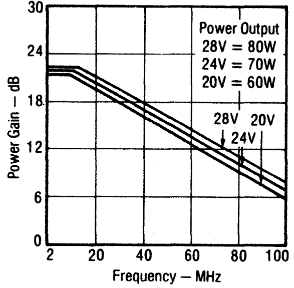
Power Output vs Power Input



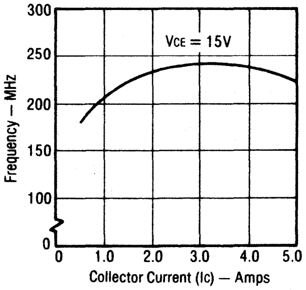
Power Output vs Power Input



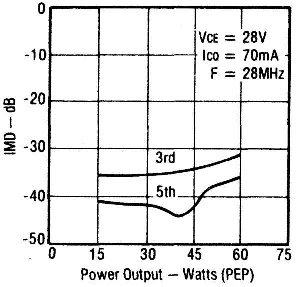
Power Gain vs Frequency



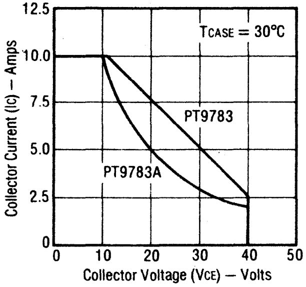
ft vs Ic



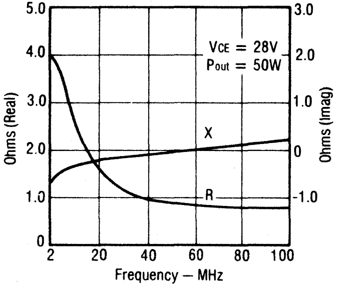
IMD vs Power Output



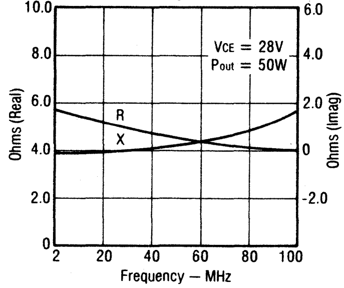
DC Safe Operating Area



Series Input Impedance vs Frequency

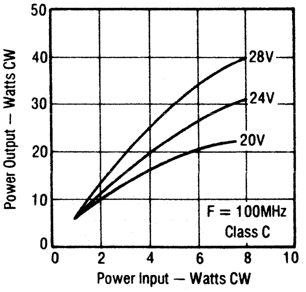


Series Load Impedance vs Frequency

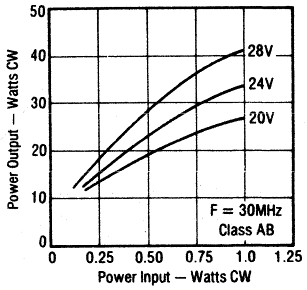


PT9788 and PT9788A

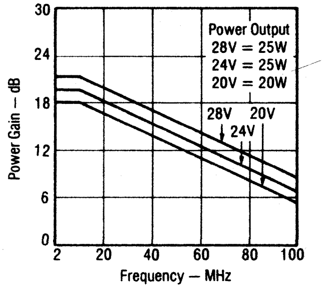
Power Output vs Power Input



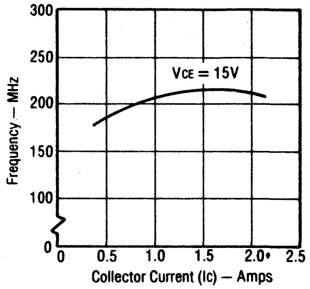
Power Output vs Power Input



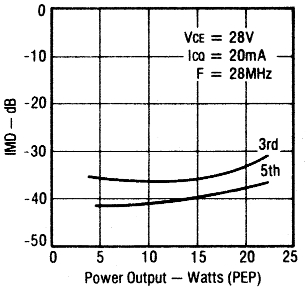
Power Gain vs Frequency



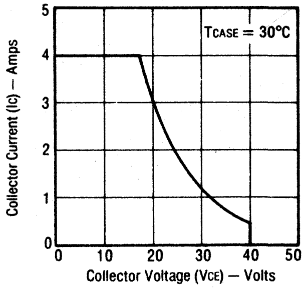
ft vs Ic



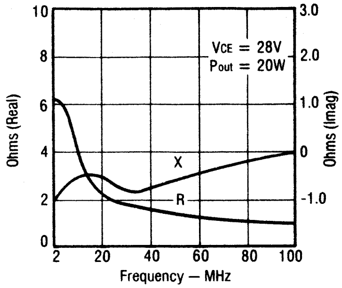
IMD vs Power Output



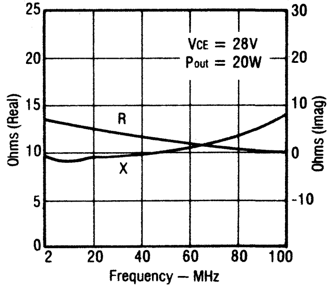
DC Safe Operating Area



Series Input Impedance vs Frequency

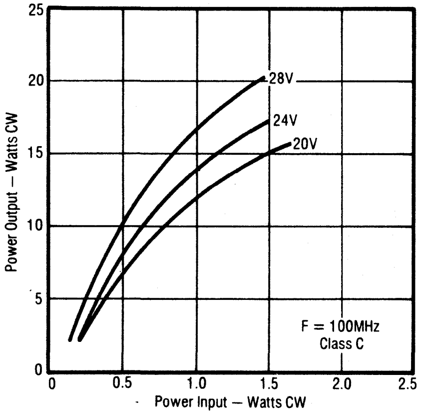


Series Load Impedance vs Frequency

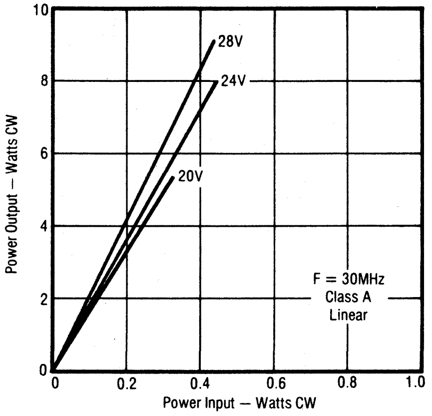


PT9787 and PT9787A

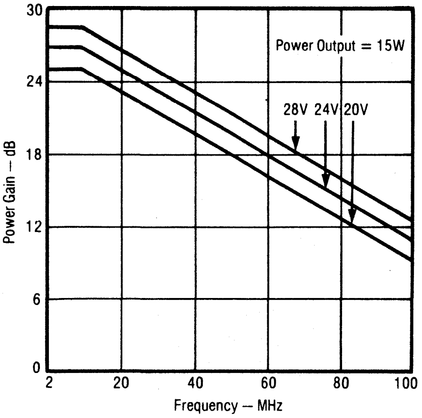
Power Output vs Power Input



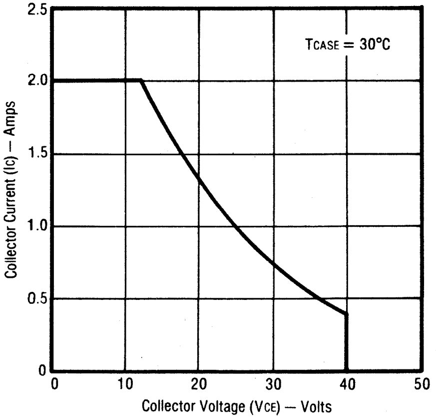
Power Output vs Power Input



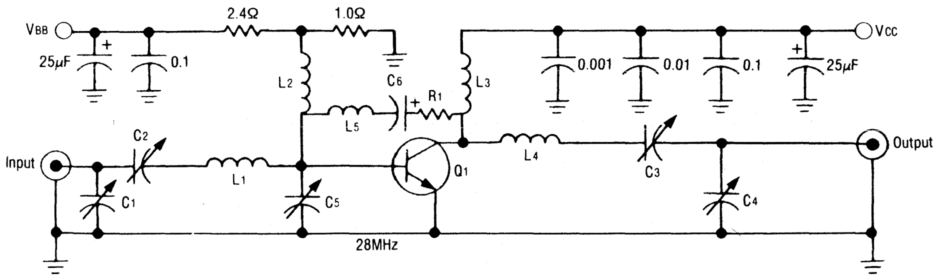
Power Gain vs Frequency



DC Safe Operating Area

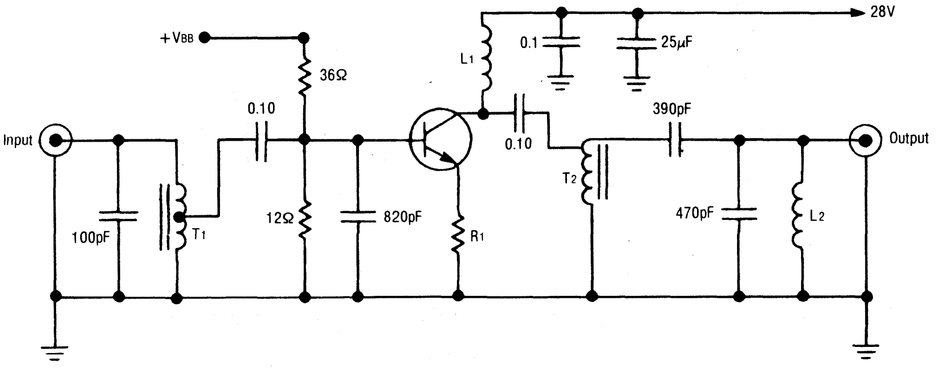


28MHz Test Circuit for PT9780/A, PT9783/A, PT9788/A



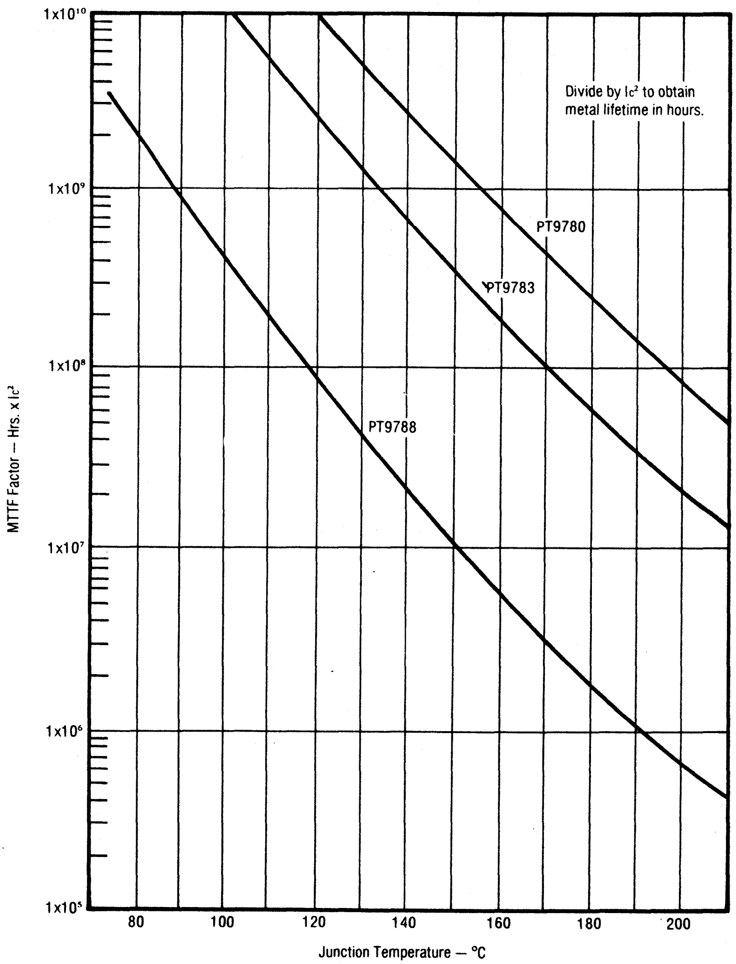
C_1	ARCO #467, 110-580pF
$C_{2,3,4}$	ARCO #466, 80-480pF
C_5	ARCO #469, 170-780pF
C_6	5μF, 50V ELE
R_1	50Ω, 2W
$L_{1,4}$	5 turns #14 tinned copper, 0.5" mean diameter, 1 equals 1.0"
L_2	10 turns #18AWG, 0.5" mean diameter
L_3	4 turns #20AWG through two Stackpole #23-1838 cores
L_5	6.8μH molded
V_{CC}	28V
V_{BB}	1.6 volts (Ic[Quies] = 100mA)

28MHz Test Circuit for PT9787 and PT9787A



R_1	1.0Ω on each emitter (0.5Ω)
T_1	6 turns, #22 wire tapped 2 turns from ground, on Fairrite Products #43 bead.
T_2	4 turns, #20 wire tapped 3½ turns from ground, on Fairrite Products #43 bead.
L_1	1.0μH
L_2	0.05μH

MTTF Factor vs Junction Temperature



TRW® SEMICONDUCTORS

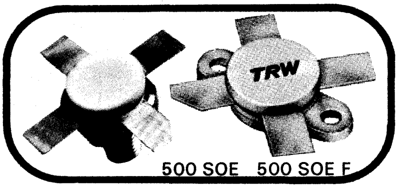
PT 9790
PT 9790 A

SSB POWER TRANSISTORS

The PT 9790 SSB/VHF Series features both high gain and high power, providing the desired power output with fewer devices. These power transistors are ballasted for ruggedness and will withstand infinite VSWR at all phase angles. A unique emitter structure provides high gain with wider emitter and base fingers resulting in high reliability. Diffused ballast resistor design enables operation at Class A, AB, and C. These rugged units are suitable for both narrow band and broadband SSB and VHF communications and instrumentation service. They are suitable for the following applications :

2-30 MHz	SSB, FM, AM
2-76 MHz	SSB, FM, AM
2-100 MHz	Linear Class A, SSB, FM, AM

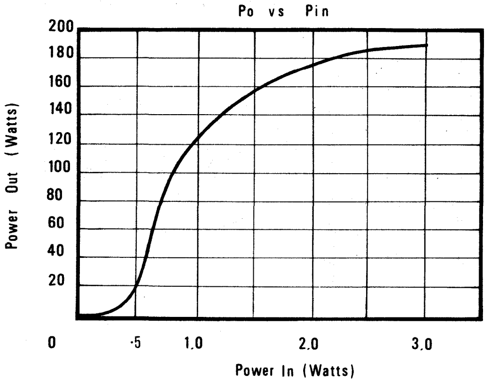
HF - SSB
150 W - 50 V
∞ VSWR


500 SOE 500 SOE F

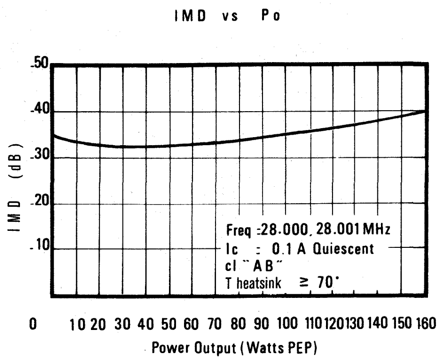
Electrical characteristics (25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC Tests	BV_{CBO}	Collector - Base Breakdown	I_C = 100 mA I_E = 0	110			V
	BV_{CEO}	Collector - Emitter Breakdown	I_C = 100 mA I_B = 0	55			V
	BV_{CER}	Collector - Emitter Breakdown	I_C = 100 mA I_B = 0 R_{BE} = 10 Ω	110			V
	BV_{EBO}	Emitter - Base Breakdown	I_E = 20 mA I_C = 0	4.0			V
	H_{FE}	D.C Current Gain	V_{CE} = 6 V I_C = 1.4 A	15		50	
	ΔH_{FE}	Matched Pairs	V_{CE} = 6 V I_C = 1.4 A			Δ 5	
RF Tests	P_G	Power Gain	V_{CE} = 50 V F = 28 MHz P_{out} = 150 W	15	17		dB
	IMD	Intermodulation Distortion	V_{CE} = 50 V F = 28 MHz P_{out} = 150 W PEP		— 35	— 32	dB
	VSWR	Mismatch Tolerance	V_{CE} = 50 V F = 28 MHz P_{out} = 150 W PEP			∞ 3 sec any angle	
Operating	I_{Cmax}	Collector Current				20	A
	θ_{j-C}	Thermal Resistance Junction - Case				0.5	°C/W
	θ_{C-H}	Thermal Resistance Case - Case - Heatsink				0.2	°C/W
	T_{stg}	Storage Temperature		— 65		+ 200	°C

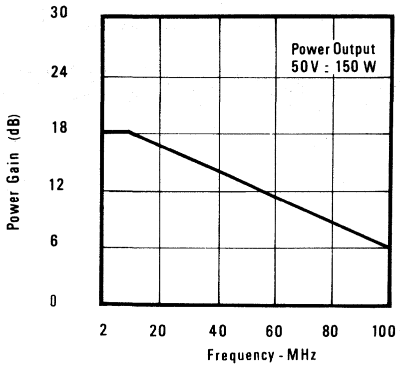
Power Out Put vs Power input



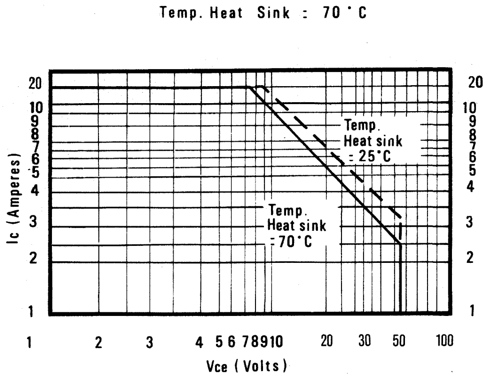
I M D vs Power Output



Power Gain vs Frequency

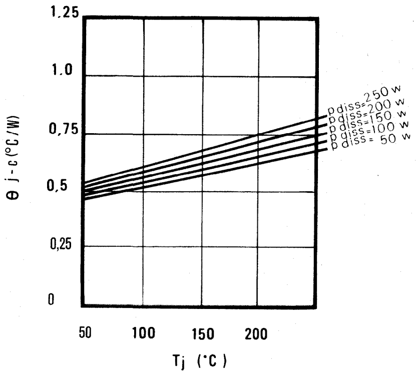


D.C. Safe Operating Area



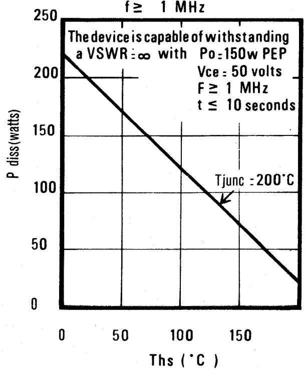
Thermal Resistance VS Junction Temperature

for Various p dissipated

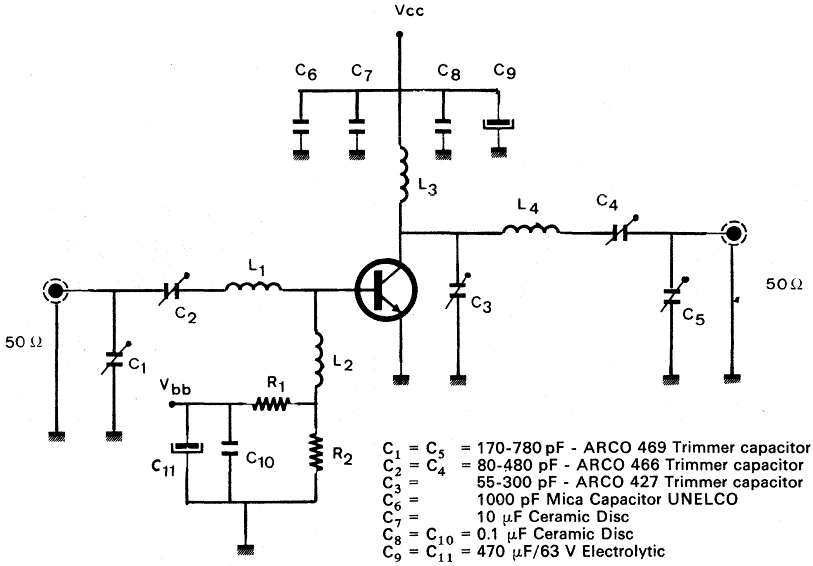


Power Dissipation vs Heatsink Temperature

Power Dissipation vs Heatsink Temperature
Vce : 50 V
f ≥ 1 MHz



28 MHz TEST CIRCUIT

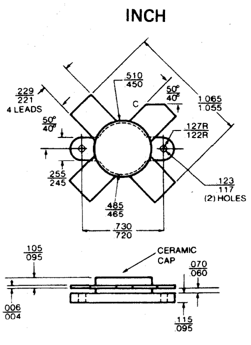


C_1 = C_5 = 170-780 pF - ARCO 469 Trimmer capacitor
C_2 = C_4 = 80-480 pF - ARCO 466 Trimmer capacitor
C_3 = 55-300 pF - ARCO 427 Trimmer capacitor
C_6 = 1000 pF Mica Capacitor UNELCO
C_7 = 10 μF Ceramic Disc
C_8 = C_{10} = 0.1 μF Ceramic Disc
C_9 = C_{11} = 470 μF/63 V Electrolytic

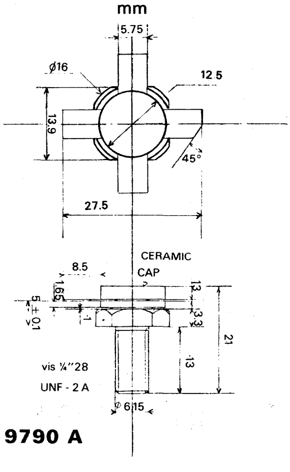
L_1 = 5 turns 15/10 mm Silvered wire - 10 mm I.D. - 25 mm length
L_2 = 10 turns 8/10 mm Enamelled wire - 10 mm I.D.
L_3 = 4 turns 12/10 mm Enamelled wire - 10 mm I.D. - 10 mm length
L_4 = 7 turns 15/10 mm Enamelled wire - 10 mm I.D. - 20 mm length

R_1 = 1 Ω - 2 W
R_2 = 2.7 Ω - 2 W

PACKAGE OUTLINE

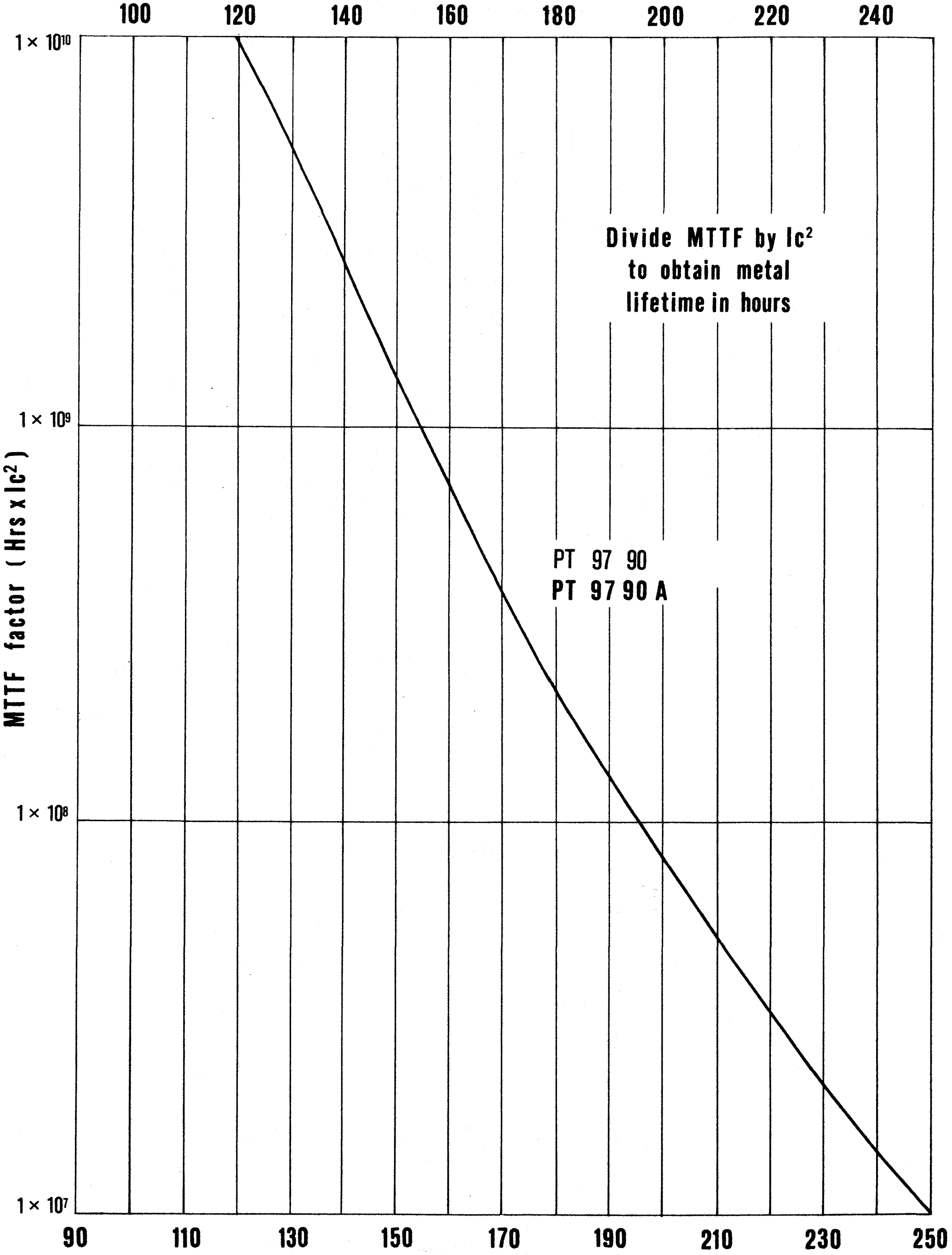


PT 9790



PT 9790 A

MTTF Factor vs junction température



MOBILE

MOBILE

PRODUCT SUMMARY

P/N	FREQUENCY (MHz)	POWER OUTPUT (W)	GAIN (dB)	VOLTAGE (V)	PACKAGE	PAGE
TP 210	88	0.05		7.5	T-PACK	**97**
TP 212	88	5.0		7.5	280 SOE	**101**
2 N 4427	91	0.5	17	8	TO-39	**55**
TP 1045	88	1.5	11.8	9.5	280 SOE Studless	**125**
TP 2312	88	3	15.7	12.5	TO-39 GE	**145**
TP 8706	88	3.5	15.5	12	380 SOE	**177**
TP 2314	88	4	16	12.5	TO-39 GE	**149**
TP 1028	88	5	10	12.5	380 SOE	**121**
TP 5695	88	10	9.2	12.5	380 SOE	**173**
TP 2320	88	20	11.2	12.5	380 SOE	**153**
ML 20	68-88	20	21.2	12.5	MVM	**75**
TP 1010	88	22	10.9	12.5	380 SOE	**117**
TP 2304	88	40	7	12.5	380 SOE	**137**
TP 2180	88	80	7.0	12.5	J-ZERO-C	**129**
TP 1045	175	1.5	11.7	9.5	280 SOE Studless	**125**
TP 2503	175	5	11	9.5	280 SOE Studless	**169**
TP 2500	175	0.9	12.5	12.5	TO-46	**165**
2 N 4427	175	1	10	12.5	TO-39	**55**
PT 8740	175	1.8	12.5	12.5	TO-39	**85**
TP 2310	175	2.5	12	12.5	TO-39	**141**
TP 2312	175	2.75	15.3	12.5	TO-39 GE	**145**
TP 2301	175	3	15	12.5	TO-131	**133**
2 N 5589	175	3	8.2	13.6	380 SOE	**59**
TP 2314	175	4	12	12.5	TO-39 GE	**149**
2 N 6080	175	4	12	12.5	380 SOE	**63**
PT 8828	175	9	11.1	12.5	380 SOE	**93**
2 N 5590	175	10	5.2	13.6	380 SOE	**59**
2 N 6081	175	15	6.4	12.5	380 SOE	**63**
PT 8811	175	15.0	10.0	12.5	280 SOE	**89**
TP 2320	175	17.0	8.2	12.5	380 SOE	**153**
JO 4020	175	20	9	12.5	J-ZERO-C	**69**
MVB 6	140-175	6	26	10.5	MVM	**81**
MV 20	140-175	20	20	12.5	MVM	**77**
2 N 5591	175	25	4.4	13.6	380 SOE	**59**
2 N 6082	175	25	6.2	12.5	380 SOE	**63**
2 N 6083	175	30	5.7	12.5	380 SOE	**63**
TP 2303	175	30	6	12.5	380 SOE	**133**
MV 30	150-160	30	21.7	13.5	MVM	**77**
JO 4030	175	30	7.8	12.5	J-ZERO-C	**69**
2 N 6084	175	40	4.6	12.5	380 SOE	**63**

MOBILE
PRODUCT SUMMARY

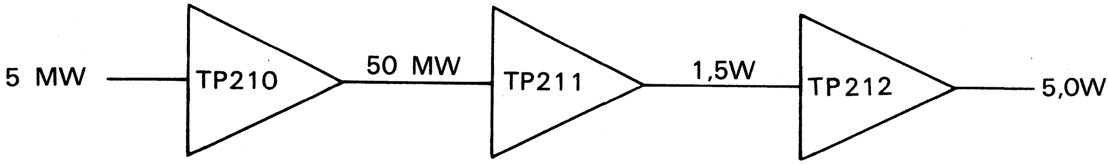
P/N	FREQUENCY (MHz)	POWER OUTPUT (W)	GAIN (dB)	VOLTAGE (V)	PACKAGE	PAGE
TP 2304	175	40	5.2	12.5	380 SOE	**137**
JO 4040	175	40	7.3	12.5	J-ZERO-C	**69**
JO 4045	175	45	6.5	12.5	J-ZERO-C	**73**
JO 4070	175	70	5.9	12.5	J-ZERO-C	**73**
2 N 3866	175	1	11.2	28	39-TO	**51**
PT 9730	175	4	13	28	380 SOE	**201**
PT 9732	175	8	12	28	380 SOE	**201**
PT 9734	175	15	11.5	28	380 SOE	**201**
PT 9731	175	25	10	28	380 SOE	**201**
PT 9733	175	50	7.9	28	380 SOE	**201**
TP 2404	175	50	7.9	28	500 SOE	**157**
TP 2405	175	90	5.5	27	500 SOE	**161**
JO 1006	175	100	7	28	J-ZERO-C	**185**
PT 9782 (A)	175	100 (PK)	7	28	380 SOE	—
TP 250	470	0.01	10	7.5	T-PACK	**105**
TP 251	470	0.175	12.4	7.5	200 SOE Studless	**109**
TP 252	470	1.50	10	7.5	280 SOE	**113**
TP 2500	470	0.35	8.5	12.5	TO-46	**165**
TP 1045	470	2	10	12.5	280 SOE Studless	**125**
PT 8809	470	2	10	12.5	280 SOE	**89**
TP 2503	470	5	8.5	12.5	280 SOE Studless	**169**
PT 8810	470	5	8.5	12.5	280 SOE	**89**
MX 7.5	400-512	7.5	18.0	12.5	MXM	**83**
PT 8811	470	10	6	12.5	280 SOE	**89**
MX 12	400-512	12.0	19.0	12.5	MXM	**83**
MX 15	400-470	15.0	19.0	12.5	MXM	**83**
JO 3025	470	25	4	12.5	J-ZERO-C	**67**
JO 3055	470	55	4.4	12.5	J-ZERO-C	**67**
2 N 3866	400	1	10	28	TO-39	**51**
PT 9700	400	1.5	11	28	280 SOE	**193**
PT 9701	400	4	9	28	280 SOE	**193**
PT 9703	400	10	9	28	280 SOE	**193**
PT 9702	400	20	7	28	280 SOE	**193**
PT 9704	400	30	6.3	28	280 SOE	**193**
PT 9704 A	400	30	7.8	28	280 SOE	**193**
JO 2015 A	400	70	8.4	28	J-ZERO-C	**189**

MOBILE

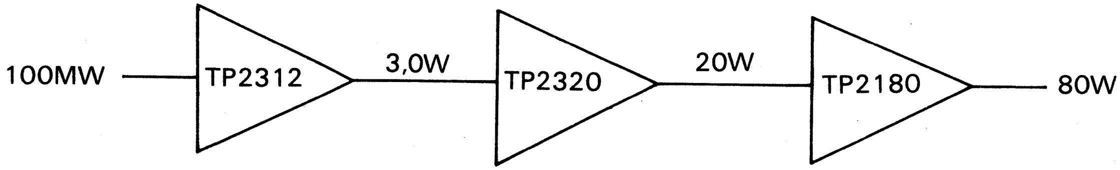
LINE-UP SUGGESTIONS

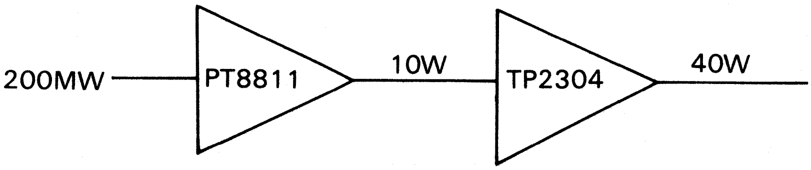
88 MHz

7.5V POCKETPHONES



12,5V POWER AMPLIFIER



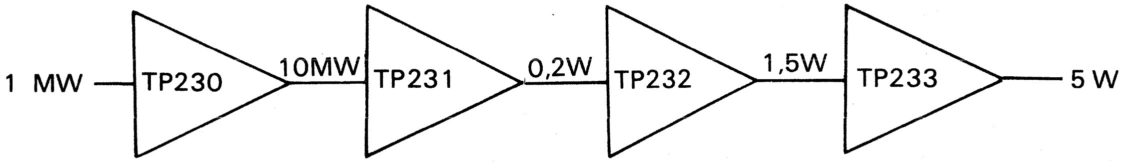


MOBILE

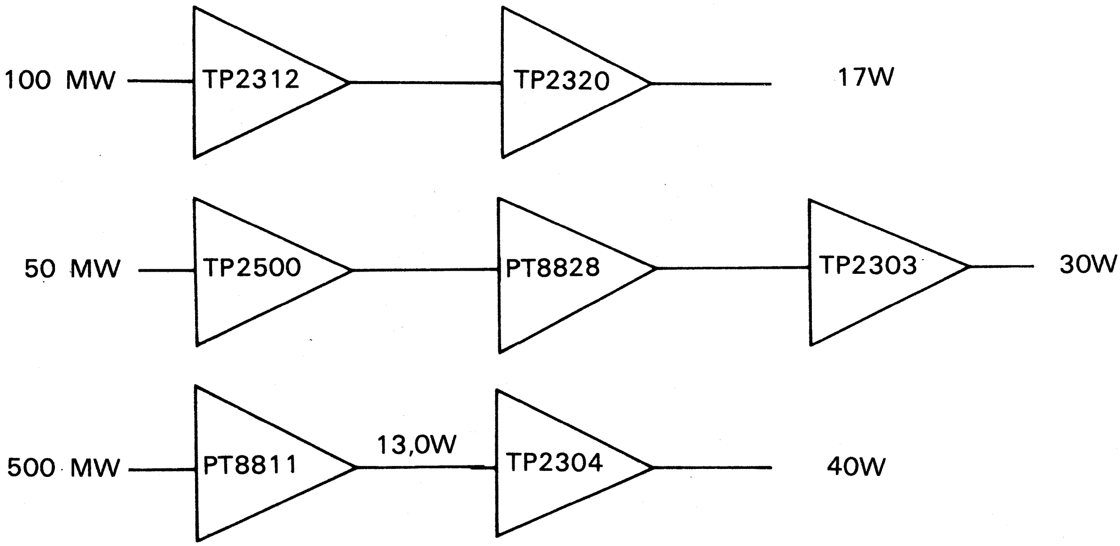
LINE-UP SUGGESTIONS

175 MHz

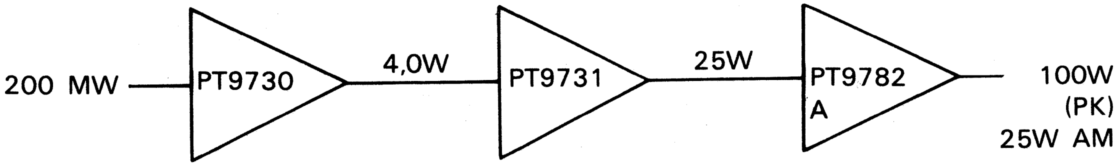
7,5V POCKETPHONES



12,5V POWER APLIFIERS



28V AM/FM POWER AMPLIFIER

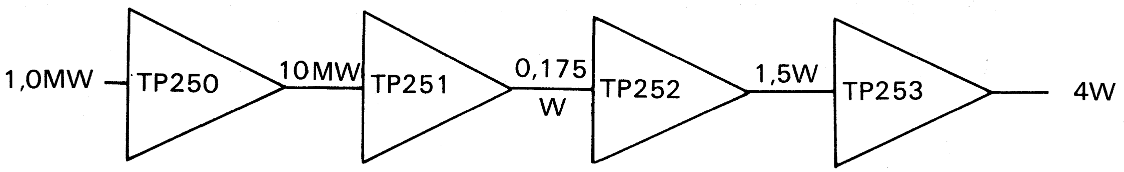


MOBILE

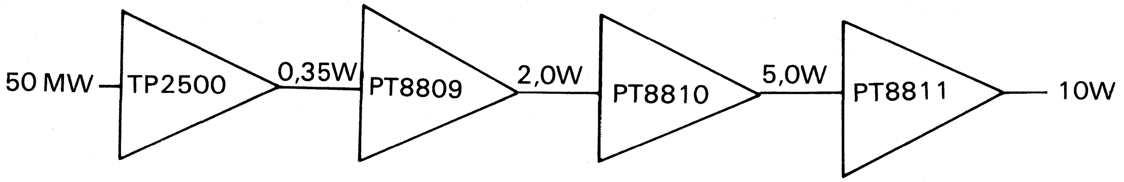
LINE-UP SUGGESTIONS

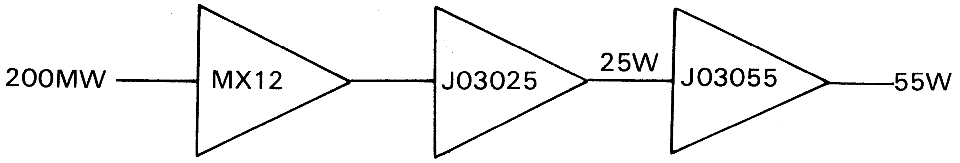
470 MHz

7,5V POCKETPHONES

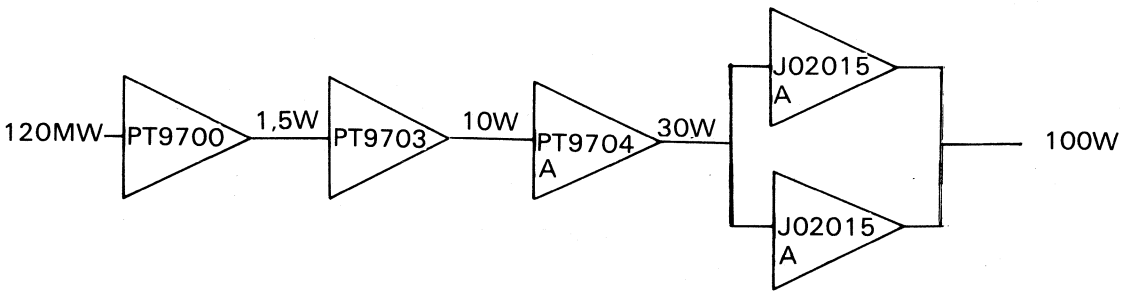


12,5V POWER AMPLIFIERS





28V POWER AMPLIFIER



TRW® SEMICONDUCTORS

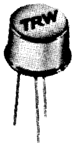
2N3866

RF Power Transistor

1 Watt at 400 MHz,
10 dB Gain, 28 V.

Intended for class A, B or C VHF/UHF military and industrial communications.

Mobile - Aircraft - CATV/MATV - Sonobuoy - Radio Sonde - Fuse - Telemetry.



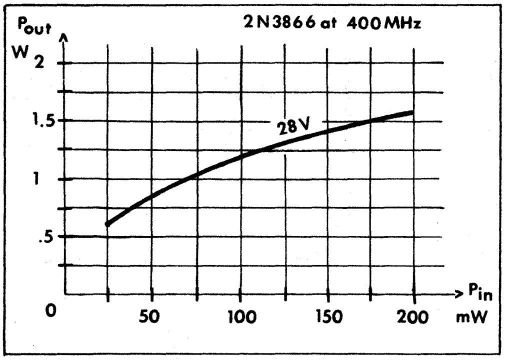
TO 39

Electrical Characteristics (T_{flange} = 25 °C)

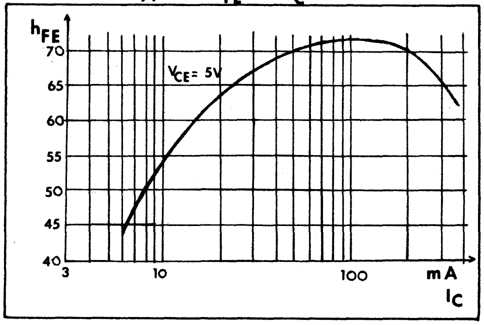
	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC Test	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 0.1 mA I_C = 0	3.5			V
	BV_{CEO}	Collector - Emitter Breakdown Voltage	I_C = 5 mA I_B = 0	30			V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 0.1 mA I_E = 0	55			V
	I_{CEO}	Collector Cutoff Current	V_{CB} = 28 V I_E = 0			0.02	mA
	H_{FE}	D.C Current Gain	V_{CE} = 5 V I_C = 50 mA	20			—
RF Test	P_{GAIN}	Power Gain	V_{CE} = 28 V P_{in} = 0.1 W F = 400 MHz	1			W
	η	Efficiency	V_{CB} = 28 V P_{out} = 1 W F = 400 MHz	45			%
	h_{fe}	R.F Current Gain	V_{CE} = 15 V F = 200 MHz I_C= 50 mA		4		—
	C_{OB}	Collector - Base Capacitance	V_{CB} = 30 V F = 1 MHz		3		pF
Operating	I_C	Continous Collector Current				0.5	A
	θ_{j-c}	Thermal Resistance	T_C = 25 °C			35	°C/W
	T_{STG}	Storage Temperature and Junction Temperature		— 65°		200 °	°C
	P_D	Power Dissipation	T_C = 25 °C			5	W

TYPICAL P_{out} vs P_{in}.

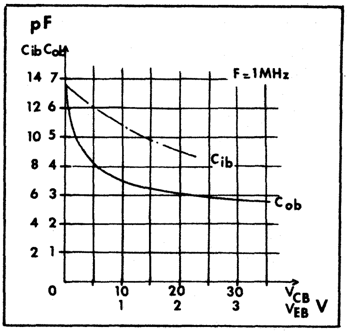
TYPICAL VALUES



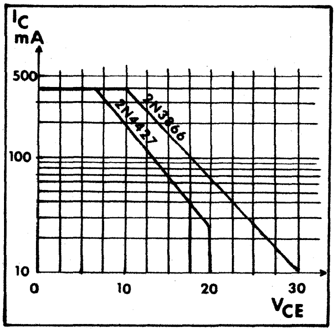
Typical h_{FE} vs I_C.



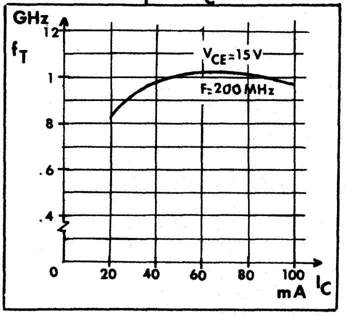
C_{ob}, C_{ib} vs V_{CB},V_{EB}.



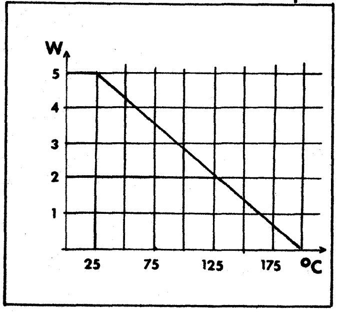
DC Safe Operating Area



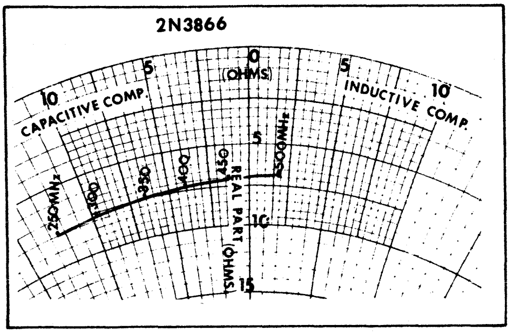
f_T vs I_C



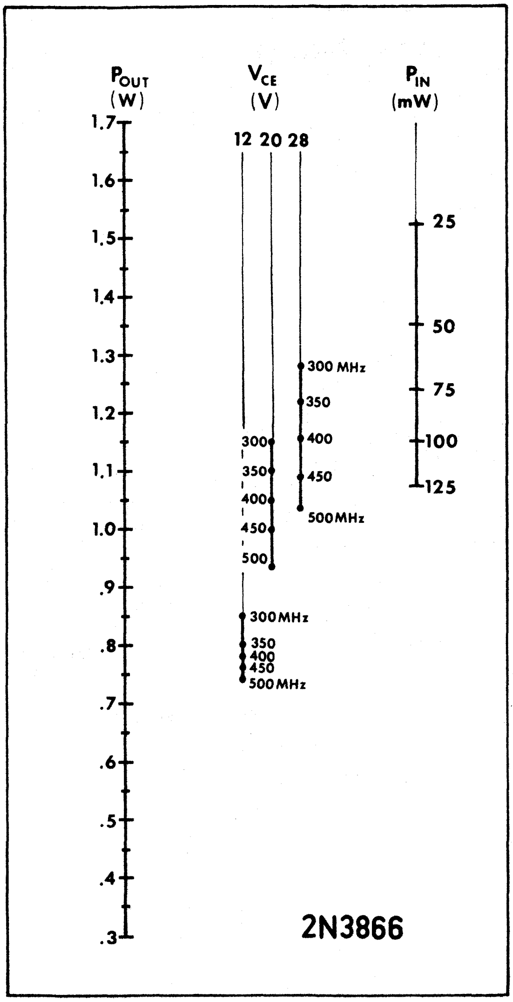
Maximum Power vs Case Temp.



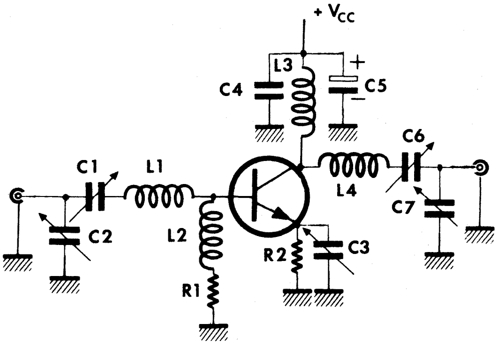
TYPICAL Z_{IN} vs F.



TYPICAL P_{OUT} vs P_{IN}, V_{CE}, F.

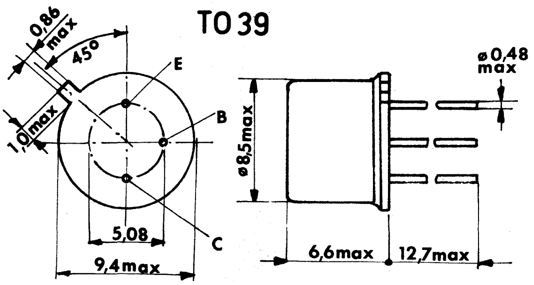


RF POWER TEST CIRCUIT



C1	7 - 60 pF
C2	4 - 40 pF
C3	7 - 60 pF
C4	1000 pF
C5	50 pF
C6	0,9 - 7 pF
C7	1,5 - 20 pF
R1	3,9 Ω
R2	5 Ω

TO 39



DIMENTIONS IN mm.

TRW® SEMICONDUCTORS

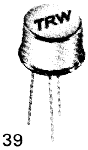
2N4427

RF Power Transistor

1 Watt at 175 MHz,
10 dB Gain, 12 V.

Intended for class A, B or C VHF/UHF military and industrial communications.

Mobile - Aircraft - CATV/MATV - Sonobuoy - Radio Sonde - Fuse - Telemetry.

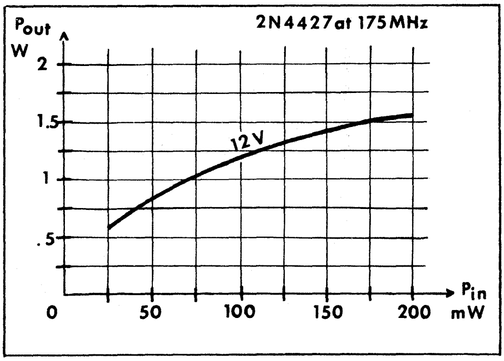


TO 39

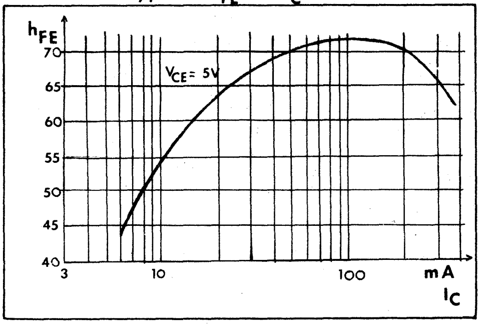
Electrical Characteristics (T_{flange} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC Test	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 0.1 mA I_C = 0	2			V
	BV_{CEO}	Collector - Emitter Breakdown Voltage	I_C = 5 mA I_B = 0	20			V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 0.1 mA I_E = 0	40			V
	I_{CEO}	Collector Cutoff Current	V_{CB} = 12 V I_E = 0			0.02	mA
	H_{FE}	D.C Current Gain	V_{CE} = 5 V I_C = 100 mA	20			—
RF Test	P_{GAIN}	Power Gain	V_{CE} = 12 V P_{in} = 0.1 W F = 175 MHz	1			W
	η	Efficiency	V_{CE} = 12 V P_{out} = 1 W F = 175 MHz	50			%
	h_{fe}	R.F Current Gain	V_{CE} = 15 V I_C = 50 mA F = 200 MHz		2.5		—
	C_{OB}	Collector - Base Capacitance	V_{CB} = 12 V F = 1 MHz		4		pF
Operating	I_C	Continous Collector Current				0.5	A
	θ_{j-C}	Thermal Resistance	T_C = 25 °C			35	°C/W
	T_{STG}	Storage Temperature and Junction Temperature		— 65°		200°	°C
	P_D	Power Dissipation	T_C = 25 °C			5	W

TYPICAL P_{out} vs P_{in}.

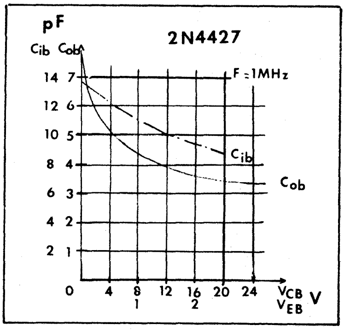


Typical h_{FE} vs I_C.

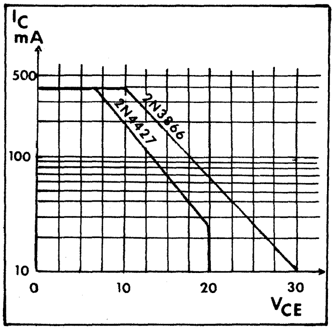


TYPICAL VALUES

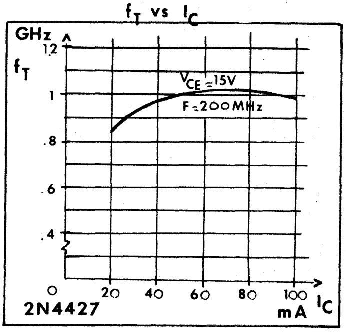
C_{ob}, C_{ib} vs V_{CB}, V_{EB}



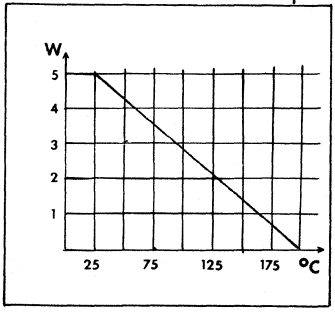
DC Safe Operating Area



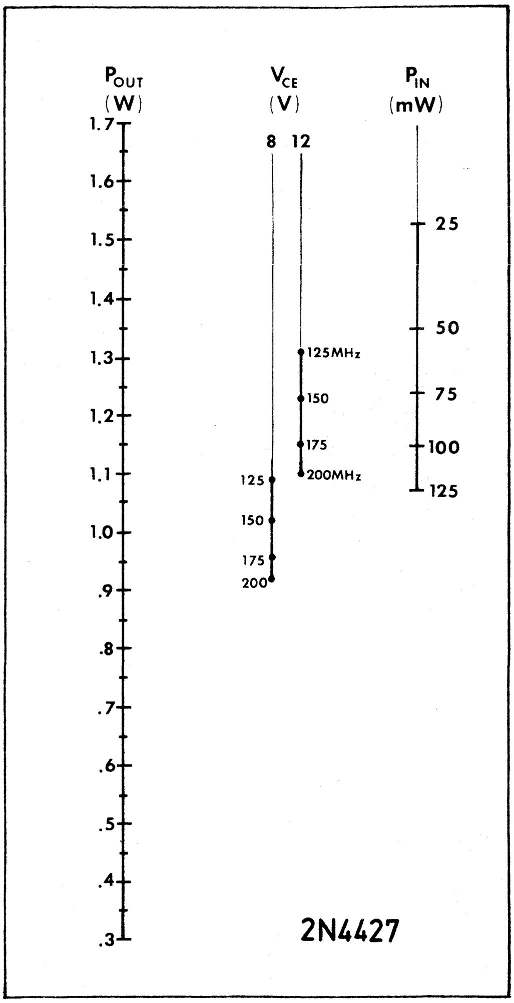
f_T vs I_C



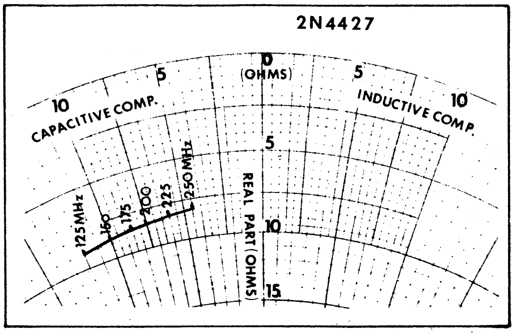
Maximum Power vs Case Temp.



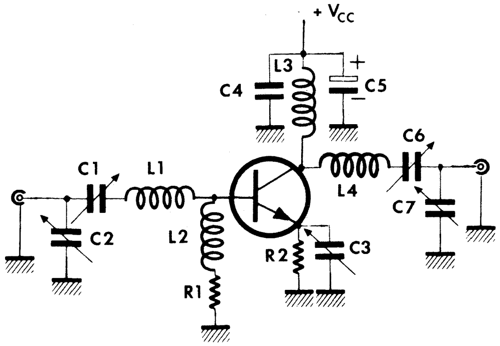
TYPICAL Z_{IN} vs F.



TYPICAL P_{OUT} vs P_{IN}, V_{CE}, F.

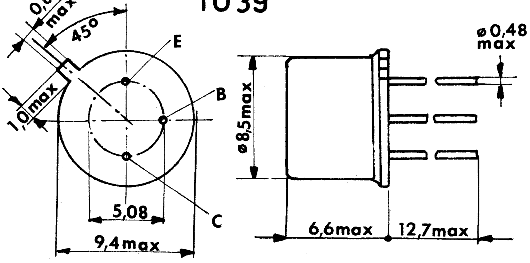


RF POWER TEST CIRCUIT



2N4427
7 - 60 pF
7 - 60 pF
—
1000 pF
50 µF
4 - 40 pF
1,5 - 20 pF
3,9 Ω
0

TO 39



DIMENTIONS IN mm.

TRW® SEMICONDUCTORS

2N 5589
2N 5590
2N 5591

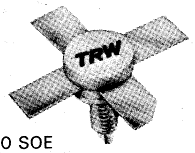
RF Power Transistors

3 W 10 W 25 W

175 MHz 13,6 V

The 2 N 5589... series is intended for use in 13.6 volts VHF amplifier applications.

These low cost rugged devices have an excellent performance and can achieve in excess of 25 W with as little as 350 mW drive power.

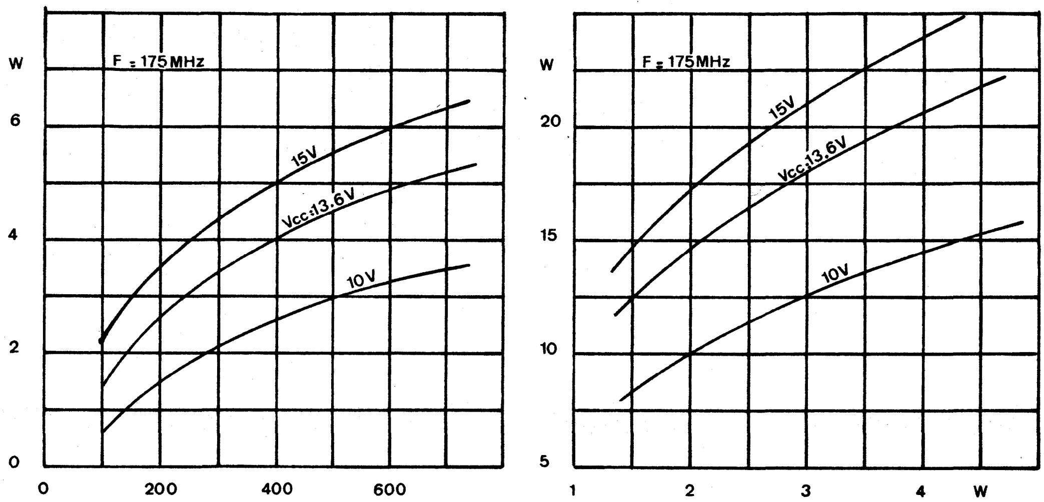


380 SOE

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	2N 5589	2N 5590	2N 5591	UNIT
DC Test	BV_{EBO}	Min Emitter - Base Breakdown Voltage	$I_E = 1$ mA $I_C = 0$ $I_E = 5$ mA $I_C = 0$	4	4	4	V
	BV_{CEO}	Min Collector - Emitter Breakdown Voltage	$I_C = 50$ mA $I_B = 0$ $I_C = 100$ mA $I_B = 0$ $I_C = 200$ mA $I_B = 0$	18	18	18	V
	BV_{CBO}	Min Collector - Base Breakdown Voltage	$I_C = 50$ mA $I_E = 0$ $I_C = 100$ mA $I_E = 0$ $I_C = 100$ mA $I_E = 0$	36	36	36	V
	I_{CBO}	Max Collector Cutoff Current	$V_{CB} = 15$ V $I_E = 0$	1	1	1	mA
	H_{FE}	Min D.C Current Gain	$V_{CE} = 5$ V $I_C = 100$ mA $V_{CE} = 5$ V $I_C = 250$ mA $V_{CE} = 5$ V $I_C = 500$ mA	5	5	5	—
RF Test	P_{GAIN}	Min Power Gain	$V_{CE} = 13.6$ V $P_{in} = 0.35$ W $P_{in} = 3$ W $F = 175$ MHz $P_{in} = 9$ W	3	10	25	W
	η	Min Efficiency	$V_{CE} = 13.6$ V $P_{out} = 3$ W $P_{out} = 10$ W $F = 175$ MHz $P_{out} = 25$ W	50	50	50	%
	Z_{in}	Common Emitter Amplifier Typ Input Impedance	$V_{CE} = 13.6$ V $P_{in} = 0.35$ W $P_{in} = 3$ W $F = 175$ MHz $P_{in} = 9$ W	3.8 + j 1.8	2.3 + j 1.8	0.86 + j 1.13	Ω
	Z_{Load}	Common Emitter Amplifier Typ Load Impedance	$V_{CE} = 13.6$ V $P_{out} = 3$ W $F = 175$ MHz $P_{out} = 10$ W $P_{out} = 25$ W	21.9 + j 13.9	5.1 + j 1.2	3.45 + j 0.09	Ω
	C_{OB}	Max Collector - Base Capacitance	$V_{CB} = 15$ V $F = 1$ MHz $I_E = 0$	30	70	120	pF
Operating	I_C	Continous Collector Current		0.6	2	7	A
	θ_{j-C}	Thermal Resistance	$T_C = 25$ °C	12	8	2.5	°C/W
	T_{STG}	Storage Temperature and Junction Temperature		← 65° to + 200 °C →			°C
	P_D	Power Dissipation	$T_C = 25$ °C	15	30	70	W

TYPICAL CHARACTERISTICS

Output Power vs Input Power and Voltage Supply

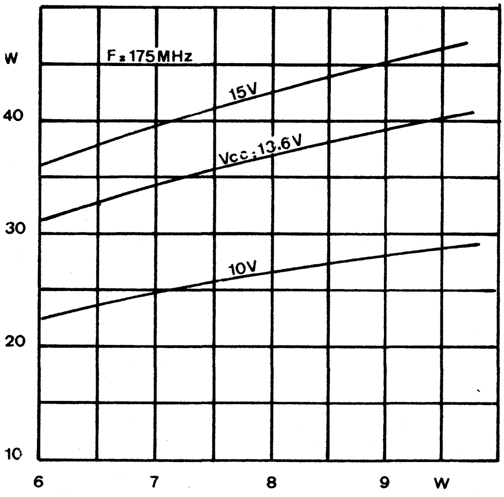


2 N 5589

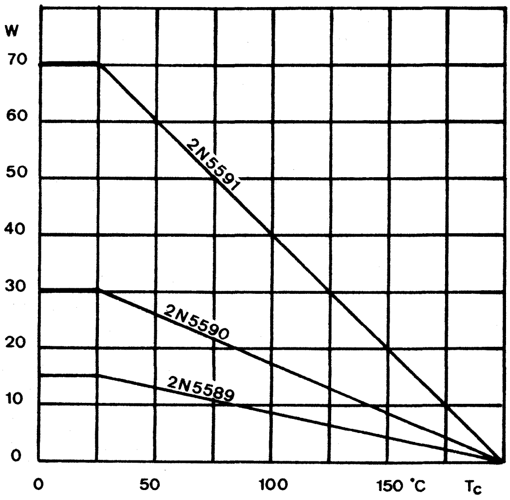
2 N 5590

Output Power vs Input Power and Voltage Supply

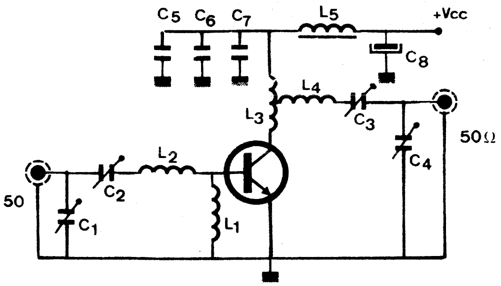
2 N 5591



Power - Temperature Derating Curve



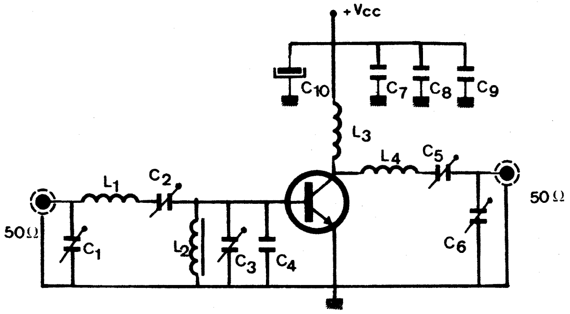
2 N 5589 TEST CIRCUIT



$C_1 = C_2 = C_3 = C_4$ = 3-70 pF trimmer capacitor ARCO 404
C_5 = 1400 pF mica capacitor UNELCO J101
C_6 = 10 nF ceramic disc
C_7 = 0.1 μF ceramic disc
C_8 = 47 μF/63 electrolytic

L_1 = 0.15 μH molded coil
L_2 = 3 turns 10/10 mm silvered wire 6 mm I.D.
L_3 = 3 turns 10/10 mm silvered wire 10 mm I.D.
L_4 = 3 turns 10/10 mm silvered wire 6 mm I.D.
L_5 = 2 turns on ferrite core

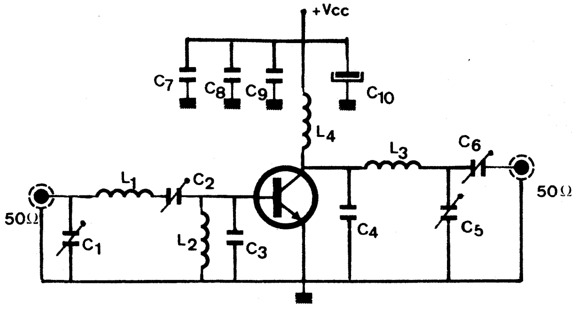
2 N 5590 TEST CIRCUIT



$C_1 = C_2 = C_5 = C_6$ = 7-100 pF trimmer capacitor ARCO 423
C_3 = 4-40 pF trimmer capacitor ARCO 403
C_4 = 100 pF mica capacitor UNELCO J101
C_7 = 1000 pF mica capacitor UNELCO J101
C_8 = 1000 pF ceramic disc
C_9 = 10 nF ceramic disc
C_{10} = 47 μF/63 V electrolytic

$L_1 = L_4$ = 2 turns - 12/10 mm silvered wire - 10 mm I.D.
L_2 = VK 200 - RTC
L_3 = 4 turns - 10/10 mm silvered wire - 10 mm I.D.

2 N 5591 TEST CIRCUIT

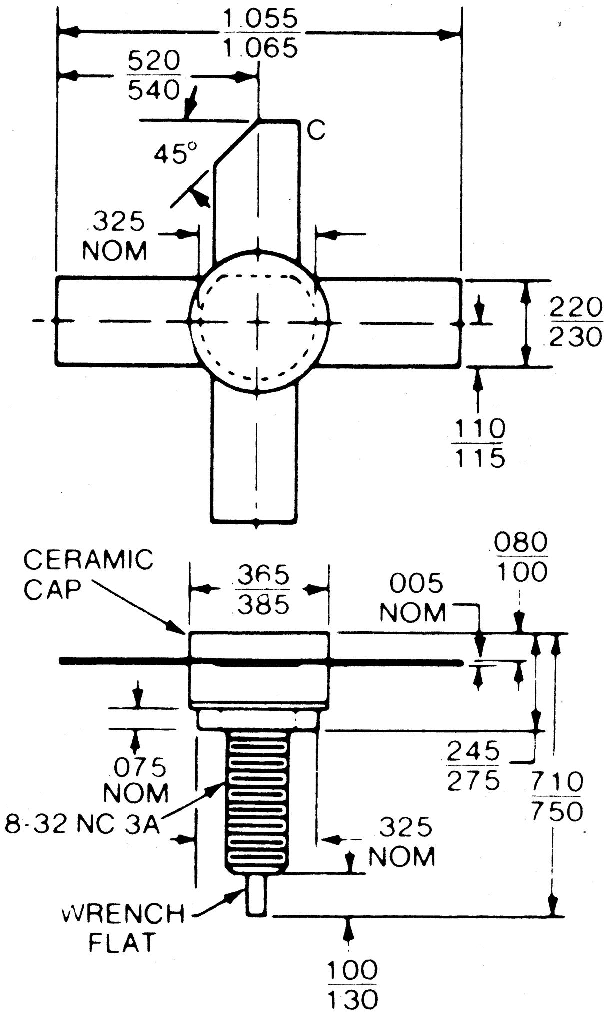


$C_1 = C_2 = C_5 = C_6$ = 7-100 pF trimmer capacitor ARCO 423
C_3 = 150 pF mica capacitor UNELCO J101
C_4 = 100 pF mica capacitor UNELCO J101
C_7 = 1000 pF mica capacitor UNELCO J101
C_8 = 10 nF ceramic disc
C_9 = 0.1 μF ceramic disc
C_{10} = 47 μF/63 V electrolytic

$L_1 = L_4$ = 3 turns 15/10 mm silvered wire 4 mm I.D.
L_2 = 0.47 μF molded coil
L_3 = 2 turns 15/10 mm silvered wire 4 mm I.D.

PACKAGE OUTLINE

.380 SOE



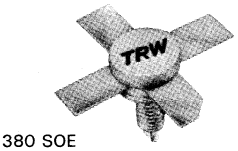
TRW® SEMICONDUCTORS

RF Power Transistor

2N 6080 4 W
2N 6081 15 W
2N 6082 25 W
2N 6083 30 W
2N 6084 40 W

175 MHz - 12.5 V

The 2 N 6080... series is intented for use in 12.5 volts VHF amplifier applications.
These low cost rugged devices have an excellent performance and can achieve in excess of 40 W with as little as 250 mW drive power.

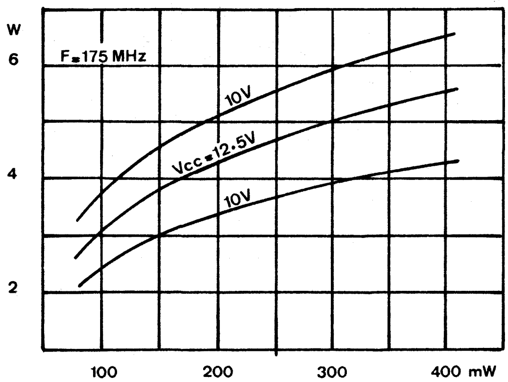


380 SOE

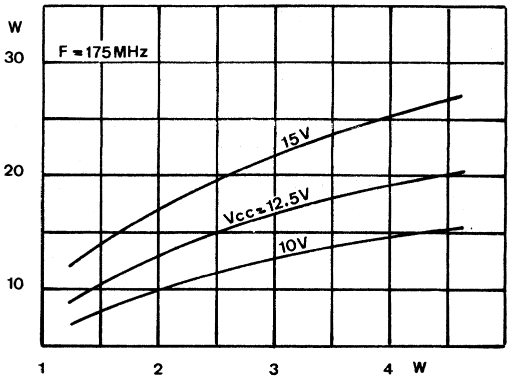
	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	2N 6080	2N 6081	2N 6082	2N 6083	2N 6084	UNIT
DC Test	BV_{EBO}	Min. Emitter - Base Breakdown Voltage	I_E = 1 mA I_C = 0 I_E = 2 mA I_C = 0 I_E = 5 mA I_C = 0 I_E = 10 mA I_C = 0	4	4	4	4	4	V
	BV_{CEO}	Min. Collector - Emitter Breakdown Voltage	I_C = 10 mA I_B = 0 I_C = 20 mA I_B = 0 I_C = 100 mA I_B = 0	18	18	18	18	18	V
	BV_{CBO}	Min. Collector - Base Breakdown Voltage	I_C = 5 mA I_E = 0 I_C = 10 mA I_E = 0 I_C = 15 mA I_E = 0 I_C = 20 mA I_E = 0	36	36	36	36	36	V
	I_{CBO}	Max. Collector Cutoff Current	V_{CB} = 15 V I_E = 0	0.25	0.5	1	1	2.5	mA
RF Test	H_{FE}	Min. DC Current Gain	V_{CE} = 5 V I_C = 0.25 A V_{CE} = 5 V I_C = 0.5 A V_{CE} = 5 V I_C = 1 A	5	5	5	5	5	—
	P_{GAIN}	Min. Power Gain	V_{CE} = 12.5 V P_{in} = 0.25 W P_{in} = 3.5 W F = 175 MHz P_{in} = 6 W P_{in} = 8 W P_{in} = 14 W	4	15	25	30	40	W
	η	Min. Efficiency	V_{CE} = 12.5 V P_{out} = 4 W P_{in} = 15 W P_{in} = 25 W F = 175 MHz P_{in} = 30 W P_{in} = 40 W	60	50	50	50	50	%
	C_{OB}	Max. Collector - Base Capacitance	V_{CB} = 15 V F = 1 MHz I_E = 0	20	85	130	130	200	pF
Operating	I_C	Continous Collector Current		1	2.5	5	7	8	A
	θ_{j-c}	Thermal Resistance	T_C = 25 °C	14.5	5.6	3.5	2.5	2.3	°C/W
	T_{STG}	Storage Temperature and Junction Temperature		— 65 °C to + 200 °C					°C
	P_D	Power Dissipation	T_C = 25 °C	12	31	50	70	75	W

Output Power vs Input Power and Voltage Supply

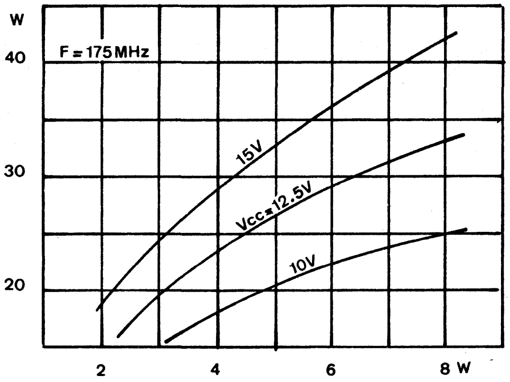
2 N 6080



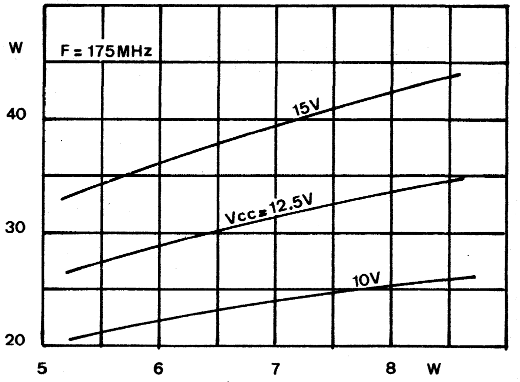
2 N 6081



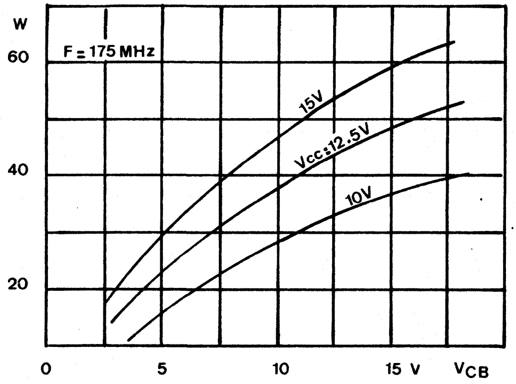
2 N 6082



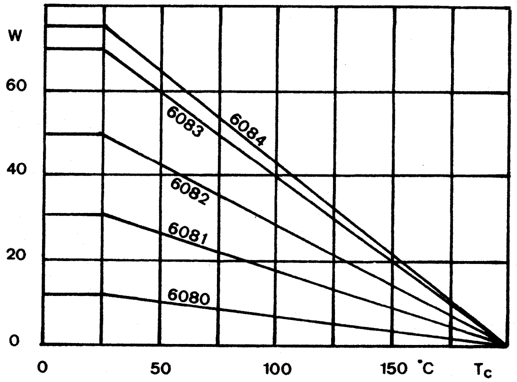
2 N 6083



2 N 6084

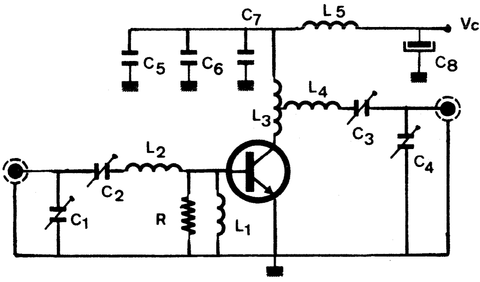


Power - Temperature Derating Curve



175 MHz TEST CIRCUIT

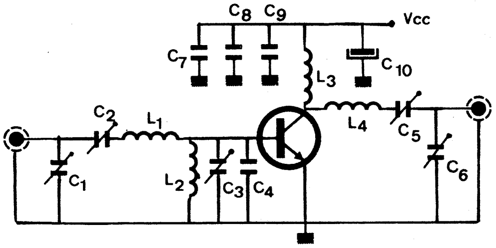
2 N 6080



$C_1 = C_2 = C_3 = C_4$ = 3-60 pF ARCO 404
C_5 = 1000 pF mica capacitor UNELCO J101
C_6 = 10 nF ceramic disc
C_7 = 0.1 µF ceramic disc
C_8 = 47 µF/63 V electrolytic

L_1 = 0.15 µH molded coil
L_2 = 3 turns 10/10 mm wire 6 mm I.D. 10 mm length
L_3 = 3 turns 10/10 mm wire 10 mm I.D. 12 mm length
L_4 = 3 turns 10/10 mm wire 6 mm I.D. 10 mm length
L_5 = 2 turns on ferrite core

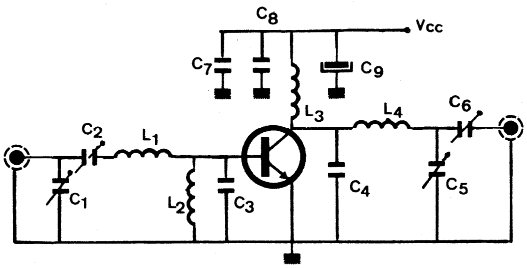
2 N 6081



$C_1 = C_2 = C_5 = C_6$ = 7-100 pF ARCO 423
C_3 = 4-40 pF ARCO 403
C_4 = 100 pF mica capacitor UNELCO J101
C_7 = 1000 pF mica capacitor UNELCO J101
C_8 = 1000 pF ceramic disc
C_9 = 10 nF ceramic disc
C_{10} = 47 µF/63 V electrolytic

$L_1 = L_4$ = 2 turns 12/10 mm wire 10 mm I.D.
L_2 = VK 200 RTC
L_3 = 4 turns 10/10 mm wire 10 mm I.D.

2 N 6082 - 2 N 6083 - 2 N 6084



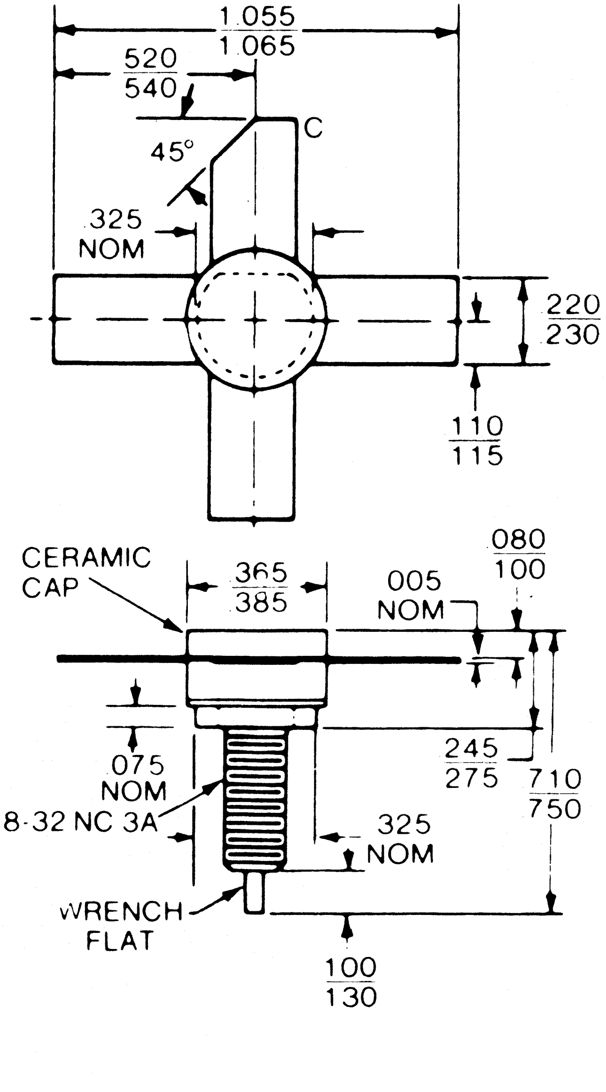
C_1 = 4-40 pF ARCO 403
$C_2 = C_5$ = 7-100 pF ARCO 423
C_3 = 200 pF mica capacitor UNELCO J101
C_4 = 150 pF mica capacitor UNELCO J101
C_6 = 7-200 pF ARCO 425
C_7 = 1000 pF mica capacitor UNELCO J101
C_8 = 0.1 µF ceramic disc
C_9 = 47 µF/63 V electrolytic

L_1 = 3 turns 15/10 mm silvered wire 6 mm I.D.
L_2 = 0.47 µH molded coil
L_3 = 6 turns 10/10 mm enameled wire wound on R_1
L_4 = 1 turn 15/10 mm silvered wire 6 mm I.D.

R_1 = 380 ohms 2 W carbon composition

PACKAGE OUTLINE

.380 SOE



TRW® **SEMICONDUCTORS**

JO 3025
JO 3037
JO 3055

RF Power Transistors

25 WATTS

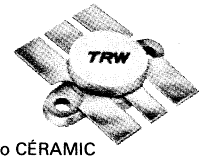
37 WATTS

55 WATTS

470 MHz - 12,5 V

The JO 3025, JO 3037 and JO 3055 are an internally matched NPN silicon UHF transistors they are inherently more reliable than conventional transistors.

They offer the greatest combination of gain, bandwidth and power output available in the industry.



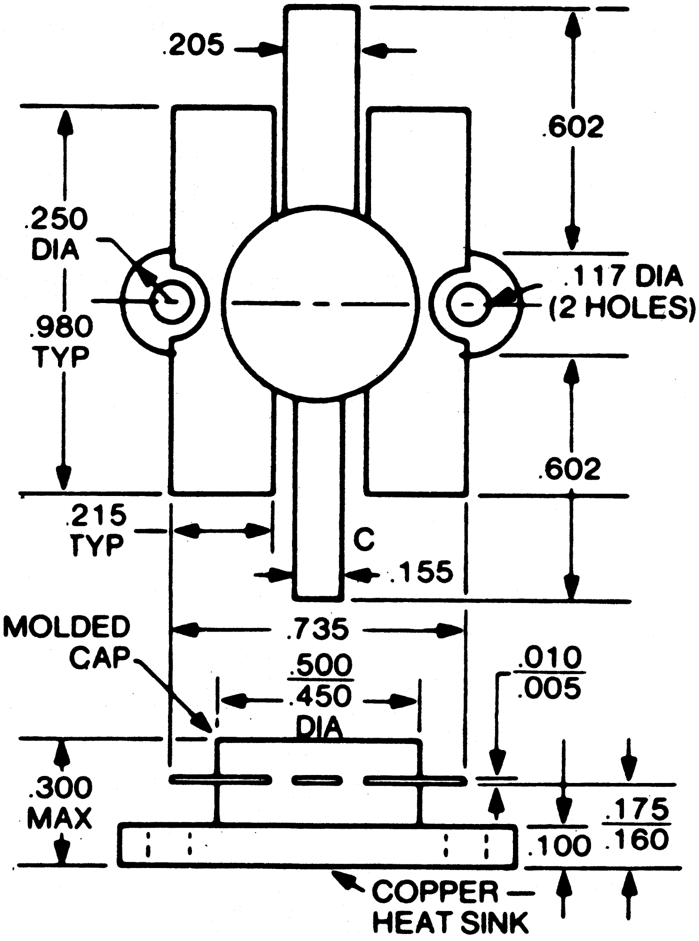
J zéro CÉRAMIC

Electrical Characteristics (T_{flange} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	JO 3025	JO 3037	JO 3055	UNIT
D C Test	BV_{EBO}	Min Emitter - Base Breakdown Voltage	I_E = 5 mA I_C = 0 I_E = 10 mA	4	4	4.5	V
	BV_{CEO}	Min Collector - Emitter Breakdown Voltage	I_C = 20 mA I_B = 0	16	16	17	V
	BV_{CBO}	Min Collector - Base Breakdown Voltage	I_C = 25 mA I_E = 0 I_C = 50 mA	36	36	38	V
	I_{CBO}	Max Collector Cutoff Current	V_{CB} = 20 V I_E = 0	2	5	5	mA
	H_{FE}	Min D.C Current Gain	V_{CE} = 5 V I_C = 1000 mA	20	20	20	—
R F Test	P_{GAIN}	Min Power Gain	V_{CE} = 12.5 V P_{in} = 8 W F = 470 MHz P_{in} = 13 W P_{in} = 20 W	25	37	55	W
	η	Min Efficiency	V_{CE} = 12.5 V Rated Output Power F = 470 MHz	50	50	50	%
	Load VSWR	Mismatch Tolerance	V_{CE} = 12.5 V Rated Output Power F = 470 MHz	∞ : 1	∞ : 1	∞ : 1	
	Z_{in}	Typ Common Emitter Amplifier Input Impedance	F = 470 MHz Rated Input Power V_{CE} = 12.5 V	1.9 + j 4	1.75 + j 5.1	2.2 + j 2.7	Ω
	Z_{Load}	Typ Common Emitter Amplifier Load Impedance	F = 470 MHz Rated Output Power V_{CE} = 12.5 V	2.5—j 2.6	1.7 + j 4.5	1.4—j 2.5	Ω
	C_{OB}	Max Collector - Base Capacitance	V_{CB} = 20 V F = 1 MHz	80	100	160	pF
Operating	I_C	Continous Collector Current		5	5	10	A
	θ_{j-C}	Thermal Resistance	T_C = 25 °C	2.9	2.1	1.75	°C/W
	T_{STG}	Storage Temperature and Junction Temperature		— 65 °C to + 200 °C	— 65 °C to + 200 °C	— 65 °C to + 200 °C	°C
	P_D	Power Dissipation	T_C = 25 °C	60	83	100	W

PACKAGE OUTLINE

J-Zero



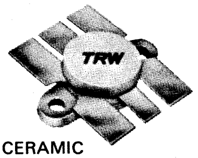
TRW **SEMICONDUCTORS**

RF Power Transistors

JO 4020 20 Watts
JO 4030 30 Watts
JO 4040 40 Watts

136-175 MHz ∞ VSWR

The JO 4020, 4030 and 4040 offer the greatest combination of gain, bandwidth and power output available in the industry. They are inherently more reliable than conventional transistors. They use internal impedance matching elements to improve performance in the following areas : Broadband performance without tuning ; increased stability ; high input-output isolation ; increased reliability and more cost effective designs.



J zéro CERAMIC

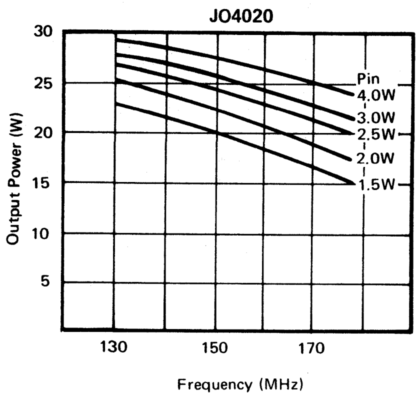
Electrical Characteristics (T_{flange} = 25 °C)

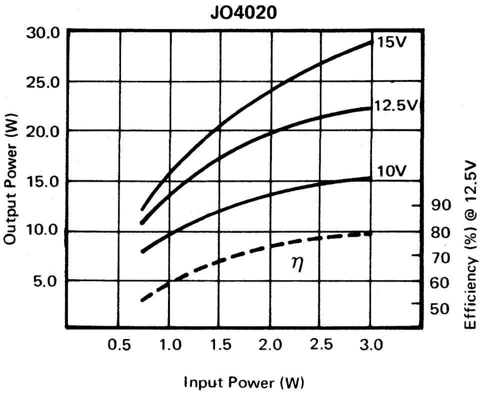
	SYMBOL	CHARACTERISTICS	TEST CONDITIONS		JO 4020	JO 4030	JO 4040	UNIT
DC Test	BV_{EBO}	Min. Emitter - Base Breakdown Voltage	$I_E = 5$ mA	$I_C = 0$	4	4	4	V
	BV_{CEO}	Min. Collector - Emitter Breakdown Voltage	$I_C = 50$ mA	$I_B = 0$	18	18	18	V
	BV_{CBO}	Min. Collector - Base Breakdown Voltage	$I_C = 50$ mA	$I_E = 0$	40	40	40	V
	I_{CBO}	Max. Collector Cutoff Current	$V_{CB} = 15$ V	$I_E = 0$	2	2	2	mA
	H_{FE}	Min. D.C Current Gain	$V_{CE} = 5$ V	$I_C = 500$ mA $I_C = 1000$ mA	25	25	25	—
RF Test	P_{GAIN}	Min. Power Gain	$V_{CE} = 12.5$ V F = 175 MHz	$P_{in} = 2.7$ W $P_{in} = 5$ W $P_{in} = 8$ W	20	30	40	W
	Load VSWR	Mismatch Tolerance	$V_{CE} = 15.5$ V F = 175 MHz	Rated Output Power	∞ : 1	∞ : 1	∞ : 1	
	Z_{in}	Common Emitter Amplifier Input Impedance	$V_{CE} = 12.5$ V F = 175 MHz	Rated Input Power	2.9 + j 1.75	2.5 + j 0.9	1.65 + j 2.7	Ω
	Z_{Load}	Common Emitter Amplifier Load Impedance	$V_{CE} = 12.5$ V F = 175 MHz	Rated Output Power	4 + j 1.25	2.5 — j 0.1	1.85 — j 0.1	Ω
	C_{OB}	Max. Collector - Base Capacitance	$V_{CB} = 15$ V	F = 1 MHz	70	100	180	PF
Operating	I_C	Continous Collector Current			4.8	5.6	8	A
	θ_{j-c}	Thermal Resistance	$T_C = 25$ °C		2.9	2.5	1.75	°C/W
	T_{STG}	Storage Temperature and Junction Temperature			— 65°		200°	°C
	P_D	Power Dissipation	$T_C = 25$ °C		60	70	100	W

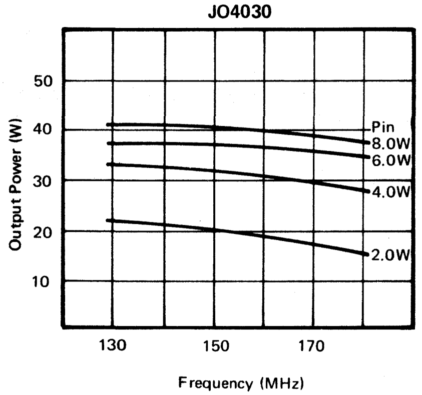
TYPICAL POWER GAIN PERFORMANCE WITH OPTIMUM MATCHING

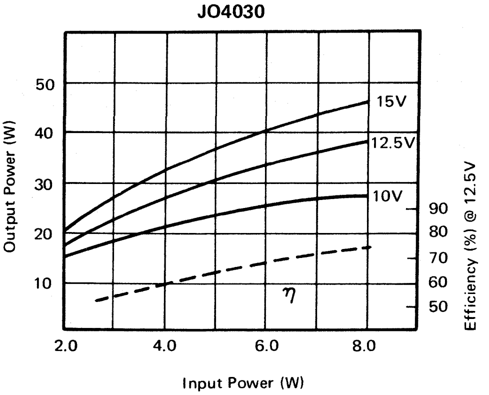
Power Output vs Frequency
V_{CE} = 12.5V

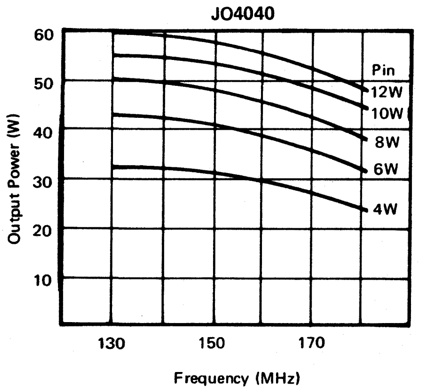
Power Output vs Power Input
f = 175 MHz

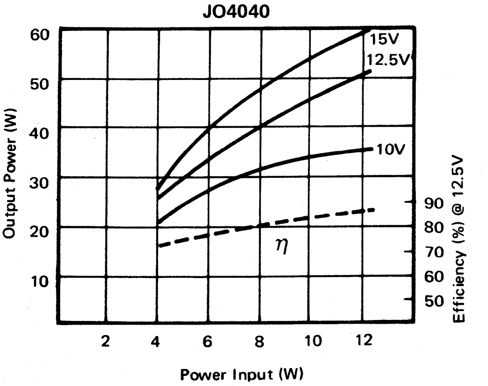








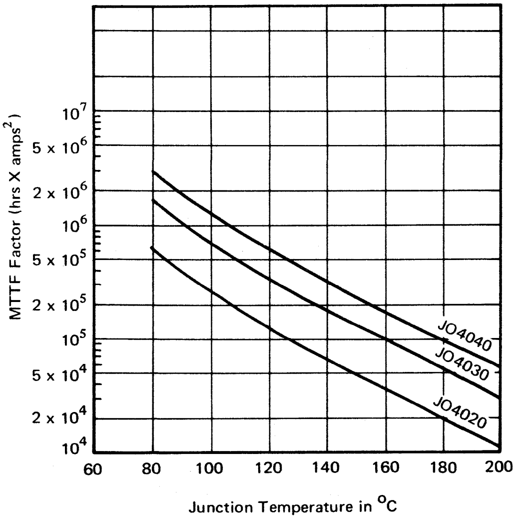




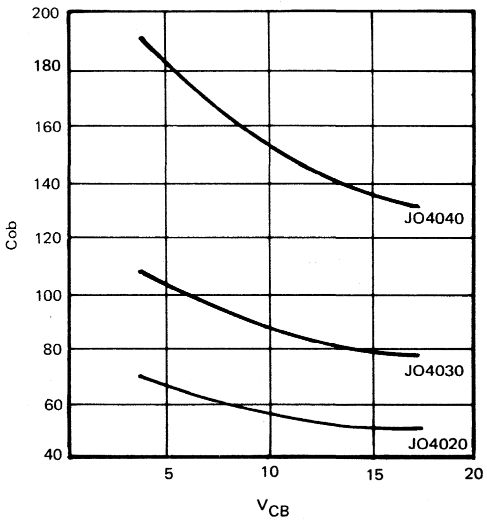
DEVICE IMPEDANCE PARAMETERS AT 12.5V AND RATED INPUT POWER

DEVICE	FREQUENCY (MHz)	Zin (Ω)	Z_{out} (Ω)
JO4020	136	1.60 + j2.25	5.40 – j1.4
	150	2.00 + j2.20	4.65 – j1.7
	165	2.40 + j2.10	4.10 – j1.75
	175	2.90 + j1.75	4.00 – j1.25
JO4030	136	1.40 + j1.50	3.60 + j0.65
	150	1.75 + j1.45	3.30 –j0
	165	2.15 + j1.20	2.75 –j0.25
	175	2.50 + j0.9	2.50 + j0.1
JO4040	136	1.05 + j2.05	2.45 + j0.35
	150	1.25 + j2.20	2.20 + j0.25
	165	1.50 + j2.45	1.93 + j0.15
	175	1.65 + j2.70	1.85 + j0.10

MTTF Factor



Collector Base Capacitance (pf) @ 1 MHz



MTTF factor is derived from calculations based on metal migration theory. The following example will serve to demonstrate the use of the MTTF factor chart shown above. Consider the JO4040 operating at normal conditions.

P_O = 40W
V_C = 12.5V
Pin = 8W
η = 80%

From this we calculate I_C = 4.0A. Therefore, the total power dissipation is 18W.

The junction temperature can then be calculated from

$$T_j = T_{stud} + P_d X \theta_{jc}.$$

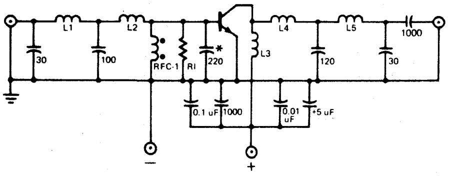
In this example $P_d X \theta_{jc}$ is 32°C.

For a stud temperature of 80°C, T_j is 112°C. From the chart above, we find the JO4040 has an MTTF factor of 1.0 X 10^6 hours amps² at 112°C. We calculate MTTF as follows:

$$\text{MTTF} = \frac{1.0 \text{ X } 10^6 \text{ hrs. amp}^2}{(4.0 \text{ amp})^2}$$

$$= 62{,}500 \text{ hrs.}$$

JO4020 TEST CIRCUIT
BROADBAND (136-175 MHz)



PARTS LIST

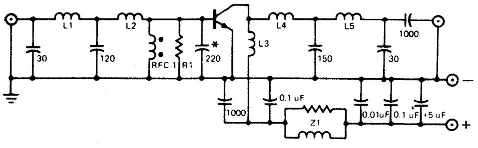
All capacitors in pF unless otherwise indicated.

All capacitors in pF are Underwood capacitors; others are disc-ceramic.

L1	2 turns #18AWG, 0.16" I.D., 1/4" spacing
L2	5/8" length #18AWG, shaped: ∩
L3	1-1/2" length #16AWG, straight wire
L4	1/2" length #18AWG, shaped: ∩
L5	3 turns #18AWG, 0.16" I.D., 1/8" spacing
R1	470Ω, 1/2 watt, carbon
RFC-1	2-1/2 turns #22AWG on Ferroxcube VK211/07-3B

*220pF consists of one 100pF and one 120pF. They are soldered as close as possible to the transistor, symmetrically, one on each side of the base lead.

JO4030 TEST CIRCUIT
BROADBAND (136-175 MHz)



PARTS LIST

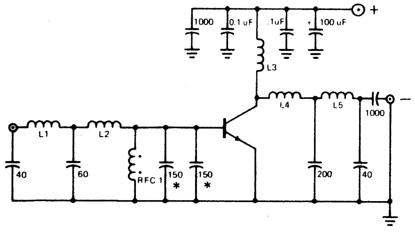
All capacitors in pF unless otherwise indicated.

All capacitors in pF are Underwood capacitors; others are disc-ceramic.

L1, L3	2 turns #18AWG, 0.16" I.D., 1/8" spacing
L2	1/2" length #18AWG, shaped: ∩
L4	3 mil. copper strap, 1/2"L x 5/32"W shaped: ∩
L5	3 turns #18AWG, 0.16" I.D., 1/8" spacing
R1	51Ω, 1/2 watt, carbon
RFC-1	2-1/2 turns #22AWG on Ferroxcube VK211/07-3B
Z1	11 turns #24AWG enameled, wound on 10Ω, 1/2 watt, carbon resistor

*220pF consists of one 100pF and one 120pF. They are soldered as close as possible to the transistor, symmetrically, one on each side of the base lead.

JO4040 TEST CIRCUIT
BROADBAND (136-175 MHz)



PARTS LIST

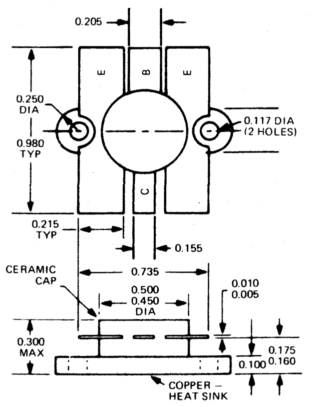
All capacitors in pF unless otherwise indicated.

All capacitors in pF are Underwood capacitors; others are disc-ceramic.

L1	1 turn #18AWG, 0.16" I.D.
L2	5/8" length #18AWG, shape: ∩
L3	1-1/2" length #18AWG
L4	3 mil. copper strap, 9/16"L x 5/32"W, shape: ∩
L5	2 turns #18AWG, 0.19" I.D., 0.15" spacing
RFC-1	2-1/2 turns #22AWG on Ferroxcube VK211/07-3B

*150pF capacitors are soldered as close as possible to the transistor, symmetrically, one on each side of the base lead.

CASE OUTLINE – JO PACKAGE



RF Power Transistors

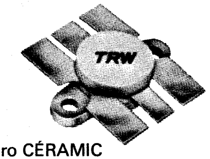
JO 4045 45 WATTS
JO 4070 70 WATTS
175 MHz - 12,5 V

The JO 4045 and JO 4070 use internal impedance matching elements to improve performance in the following areas :

Broadband performance without tuning increased stability.

High input output isolation.

Increased reliability and more cost effective designs.



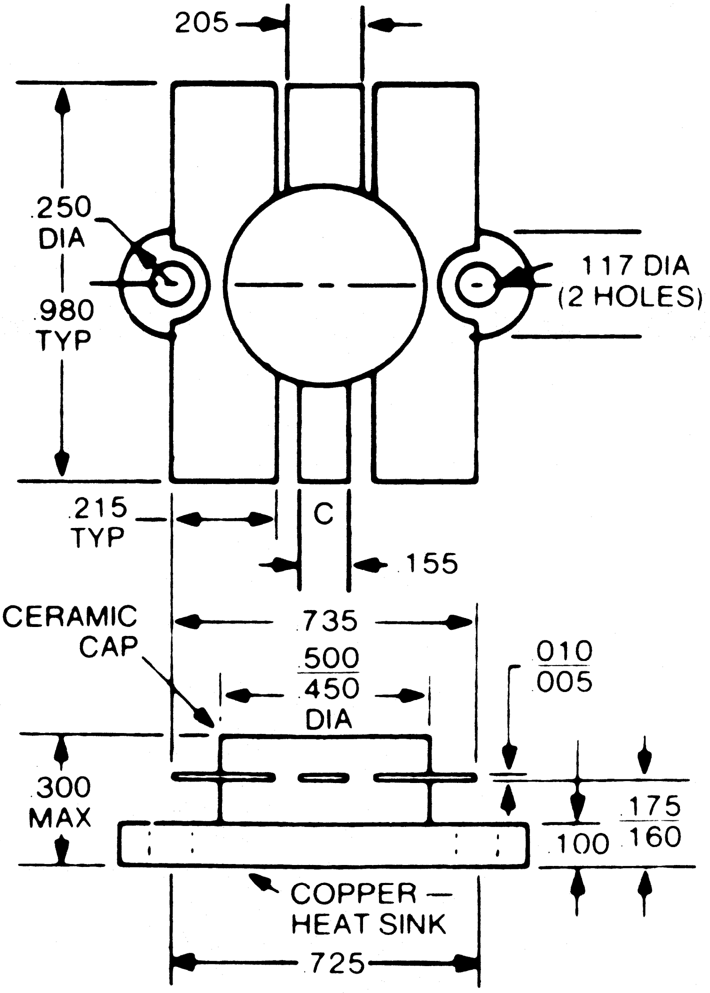
J zéro CÉRAMIC

Electrical Characteristics (T_{flange} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	JO 4045	JO 4070	UNIT
D C Test	BV_{EBO}	Min Emitter - Base Breakdown Voltage	I_E = 5 mA I_C = 0	4	4	V
	BV_{CEO}	Min Collector - Emitter Breakdown Voltage	I_C = 50 mA I_B = 0	18	18	V
	BV_{CBO}	Min Collector - Base Breakdown Voltage	I_C = 50 mA I_E = 0	40	40	V
	I_{CBO}	Max Collector Cutoff Current	V_{CB} = 15 V I_E = 0	2	5	mA
	H_{FE}	Min D.C Current Gain	V_{CE} = 5 V I_C = 1000 mA	10	10	—
R F Test	P_{GAIN}	Min Power Gain	V_{CE} = 12.5 V P_{in} = 9 W F = 175 MHz P_{in} = 18 W	45	70	W
	η	Min Efficiency	V_{CE} = 12.5 V Rated Output Power F = 175 MHz	60	60	%
	Load VSWR	Mismatch Tolerance	V_{CE} = 12.5 V Rated Output Power F = 175 MHz	∞ : 1	∞ : 1	
	Z_{in}	Typ Common Emitter Amplifier Input Impedance	V_{CE} = 12.5 V Rated Input Power F = 175 MHz	1.4 + j 0.9	1.8 + j 1.25	Ω
	Z_{Load}	Typ Common Emitter Amplifier Load Impedance	V_{CE} = 12.5 V Rated Output Power F = 175 MHz	1.9 + j 0	1.25 — j 0.6	Ω
	C_{OB}	Max Collector - Base Capacitance	V_{CB} = 20 V F = 1 MHz	100	180	pF
Operating	I_C	Continous Collector Current		8	12	A
	θ_{j-C}	Thermal Resistance	T_C = 25 °C	2.2	1.25	°C/W
	T_{STG}	Storage Temperature and Junction Temperature		— 65 °C to + 200 °C	— 65 °C to + 200 °C	°C
	P_D	Power Dissipation	T_C = 25 °C	80	140	W

PACKAGE OUTLINE

J-Zero-C



TRW COMPOSANTS ELECTRONIQUES S.A.

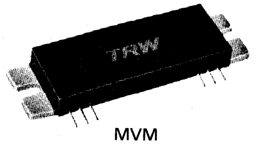
RF Power Module

68 - 88 MHz

20 W - 12,5 V

The ML modules are rugged power amplifier functions designed for battery powered mobile and marine applications in the 68-88 MHz band. The modules feature 50 Ω input and output impedances, highly repeatable broadband gain, and will withstand infinite load VSWR at 16 volts with overdrive and uncontrolled output power.

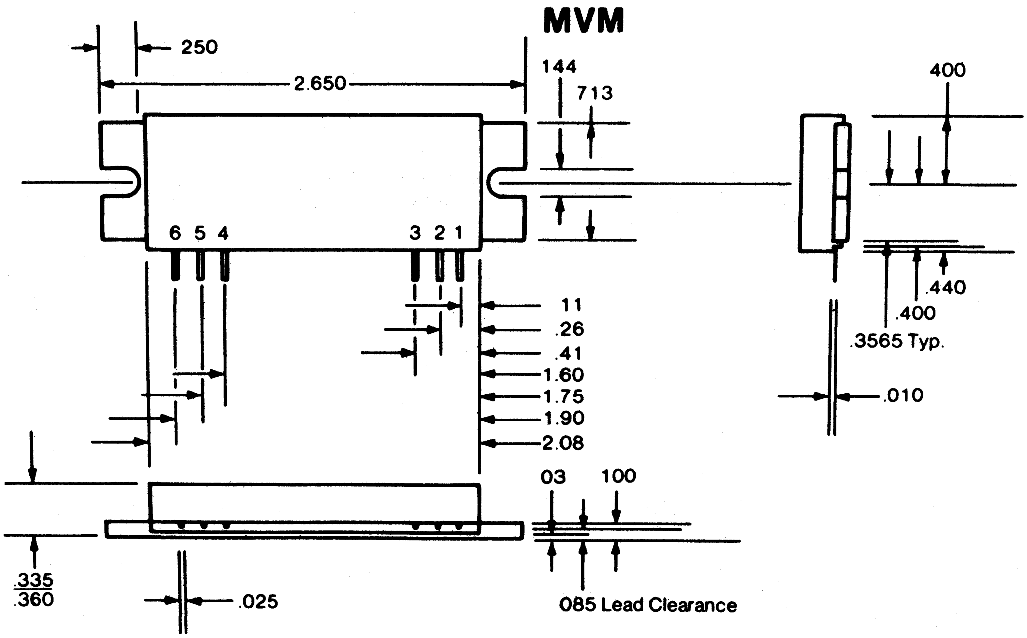
Compared to discrete components, these modules offer significant savings in size as well as cost of design, production and repair.


MVM

SPECIFICATIONS (T_{flange} = 25 °C, unless otherwise noted)

Characteristic	Test Conditions	ML 20	Units/Limit
Frequency Range		68-88	MHz
Supply Voltage, V_{CC}		12.5	Vdc, Nom.
Power Output	Rated V_{CC} Any In-Band Frequency $P_{in} \leqslant 0.15$ watts	20	W, Min.
Efficiency	Rated P_o, V_{CC}	40	%, Min.
Harmonic Outputs	Rated P_o, V_{CC}	— 30	dB, Max.
Input Return Loss	$Z_o = 50\ \Omega$	— 10	dB, Max.
Output Impedance		50	Ω, Nom.
Quiescent Current	$V_{CC} = 16$ V, $P_{in} = 0$ W	0.1	Adc, Max.
Power Slump	Rated P_o, V_{CC} 25 °C — 30 °C to + 80 °C	1	dB, Max.
Load VSWR, 0-360° (Degradation)	$V_{CC} = 16$ V, $P_{in} = 0.3$ W Lowest Frequency	50 : 1	No Degradation
Load VSWR, 0-360° (Stability)	$10\ V \leqslant V_{CC} \leqslant 16\ V$ $0 < P_{in} \leqslant 0.3$ W Any In-Band Frequency	3 : 1	Min. Typ.
Temperature Range	Operating, T_{FLANGE}	— 30 + 100	°C Min. °C Max.

PACKAGE OUTLINE



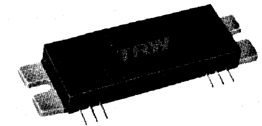
TRW® SEMICONDUCTORS **MV 20 - MV 30**

RF Power Modules

140 - 175 MHz
∞ VSWR @ 16 V

The MV modules are rugged power amplifier functions designed for battery powered mobile and marine applications in the 140-175 MHz band. The modules feature 50 Ω input and output impedances, highly repeatable broadband gain, and will withstand infinite load VSWR at 16 volts with overdrive and uncontrolled output power (typically more than 40 watts).

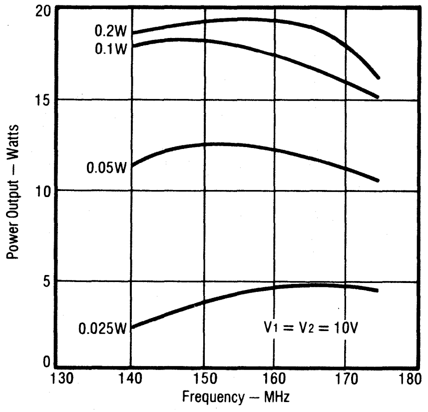
Compared to discrete components, these modules offer significant savings in size as well as cost of design, production and repair.

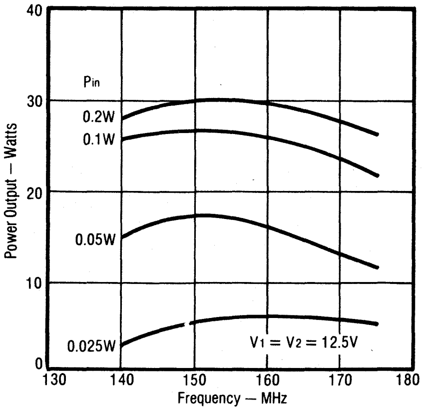

MVM

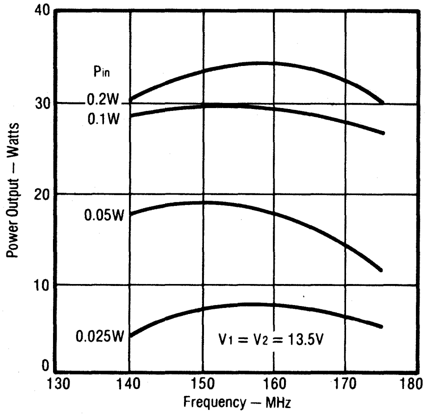
Electrical Characteristics (T_{flange} = 25 °C)

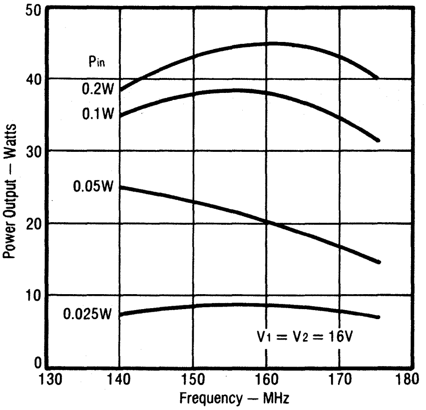
Characteristic	Test Conditions	MV20	MV30	Units/Limit
Frequency Range		140-175	150-160	MHz
Supply Voltage, V_{CC}		12.5	13.5	Vdc, Nom.
Power Output	Rated V_{CC} Any In-Band Frequency $P_{in} \leqslant 0.2$ Watts	20	30	W, Min.
Efficiency	Rated P_0, V_{CC}	40	50	%, Min.
Harmonic Outputs	Rated P_0, V_{CC}	— 35	— 40	dB, Max.
Input Return Loss	$Z_0 = 50\ \Omega$	— 10	— 10	dB, Max.
Output Impedance		50	50	Ω, Nom.
Quiescent Current	$V_{CC} = 16$ V, $P_{in} = 0$ W	0.1	0.1	Adc, Max.
Power Slump	Rated P_0, V_{CC} 25 °C — 30 °C to + 80 °C	1.0	1.0	dB, Max.
Load VSWR, 0-360° (Degradation)	$V_{CC} = 16$ V, $P_{in} = 0.3$ W Lowest Frequency	20 : 1	20 : 1	No Degradation
Load VSWR, 0-360° (Stability)	$10\text{ V} \leqslant V_{CC} \leqslant 16\text{ V}$ $0 < P_{in} \leqslant 0.3$ W Any In-Band Frequency	3 : 1 5 : 1	3 : 1 5 : 1	Min. Typ.
Temperature Range	Operating, T_{FLANGE}	— 30 + 100	— 30 + 100	°C Min. °C Max.

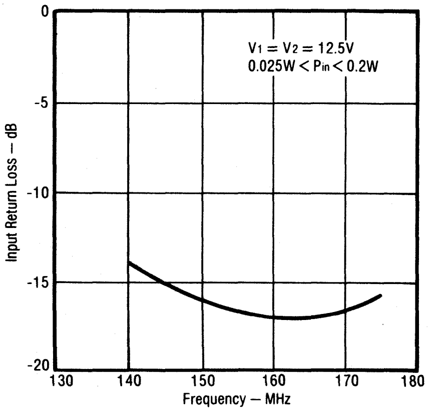
TYPICAL CHARACTERISTICS

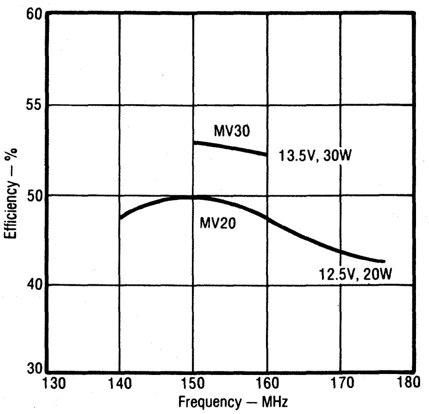


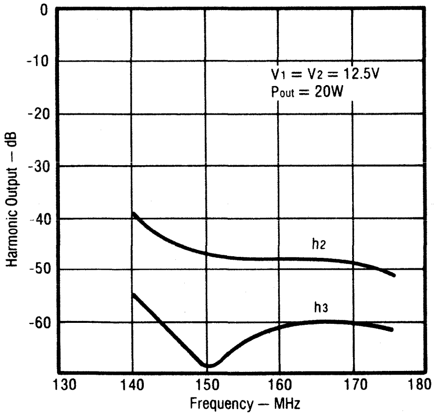


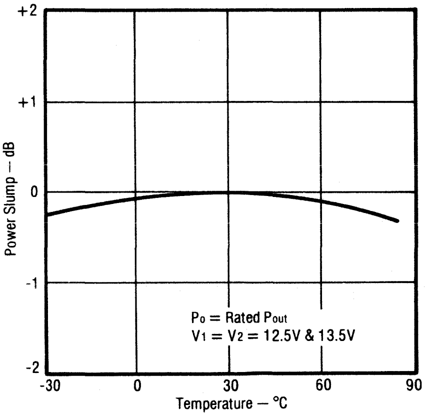


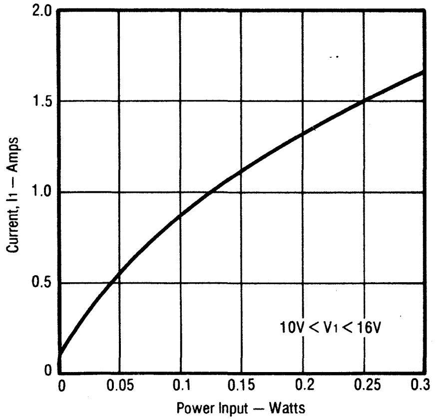


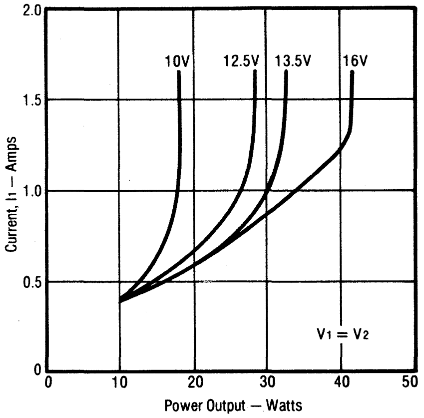


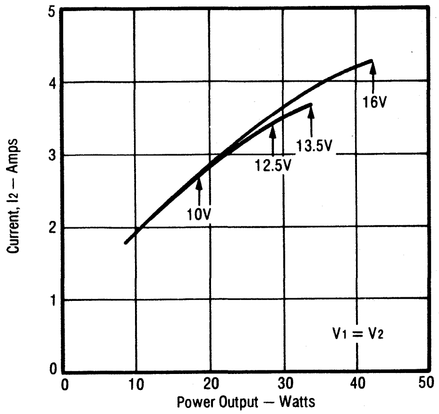


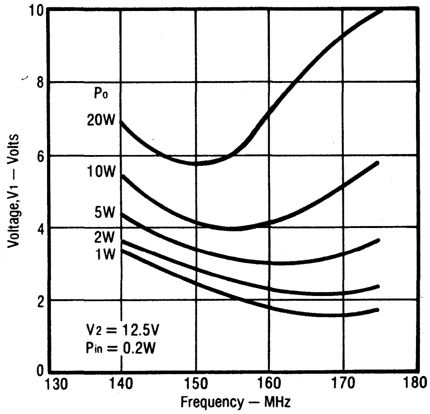

0
-10
-20
-30
-40
-50
-60
Harmonic Output — dB
$V_1 = V_2 = 12.5V$
$P_{out} = 20W$
h2
h3
130
140
150
160
170
180
Frequency — MHz


+2
+1
0
-1
-2
Power Slump — dB
P_o = Rated P_{out}
$V_1 = V_2 = 12.5V$ & 13.5V
-30
0
30
60
90
Temperature — °C

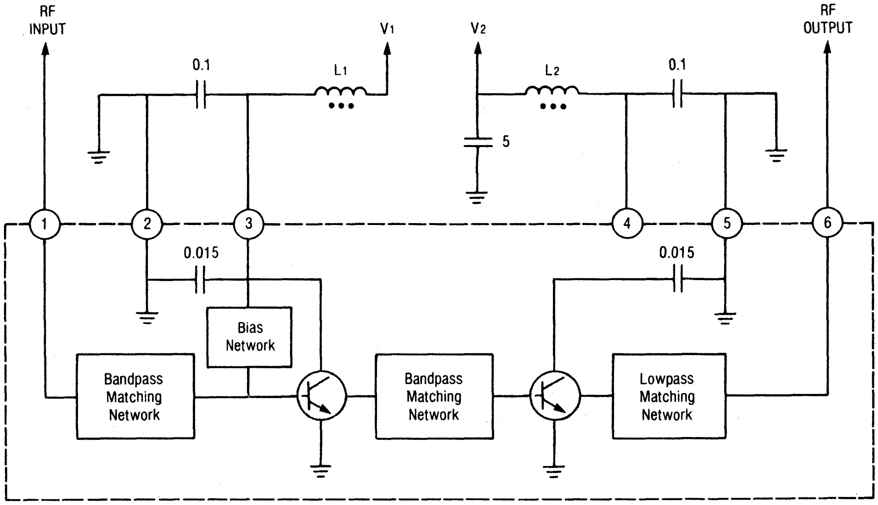

2.0
1.5
1.0
0.5
0
Current, I_1 — Amps
$10V < V_1 < 16V$
0
0.05
0.1
0.15
0.2
0.25
0.3
Power Input — Watts


2.0
1.5
1.0
0.5
0
Current, I_1 — Amps
10V
12.5V
13.5V
16V
$V_1 = V_2$
0
10
20
30
40
50
Power Output — Watts


5
4
3
2
1
0
Current, I_2 — Amps
16V
13.5V
12.5V
10V
$V_1 = V_2$
0
10
20
30
40
50
Power Output — Watts

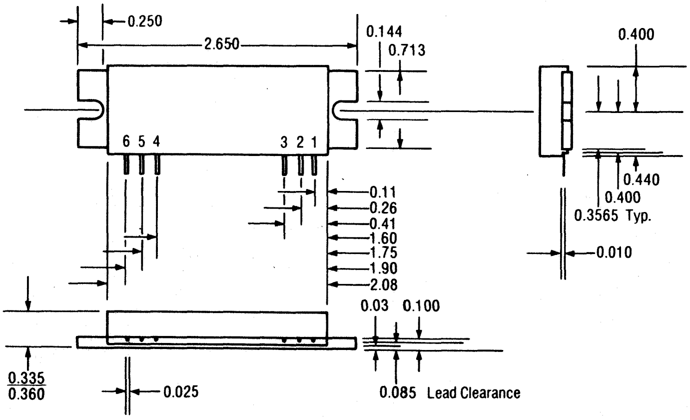

10
8
6
4
2
0
Voltage, V_1 — Volts
P_o
20W
10W
5W
2W
1W
$V_2 = 12.5V$
$P_{in} = 0.2W$
130
140
150
160
170
180
Frequency — MHz

CIRCUIT DIAGRAM FOR MV 20 AND MV 30



L1, L2: Ferroxcube VK211173B, 2½ turns
All capacitor values in μF

MVM PACKAGE OUTLINE



TRW® SEMICONDUCTORS **MVB 6**

RF Power Module

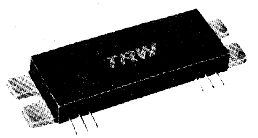
140 - 175 MHz

6 W - 10 V

The MVB 6 module is a rugged power amplifier function designed for battery powered mobile and marine applications in the 140-175 MHz.

The module features 50 Ω input and output impedance and will withstand infinite load VSWR at 10 V with overdrive and uncontrolled output power.

The module is suitable for use as a PA for lower powered mobile radios or as a driver stage for higher power amplifiers.



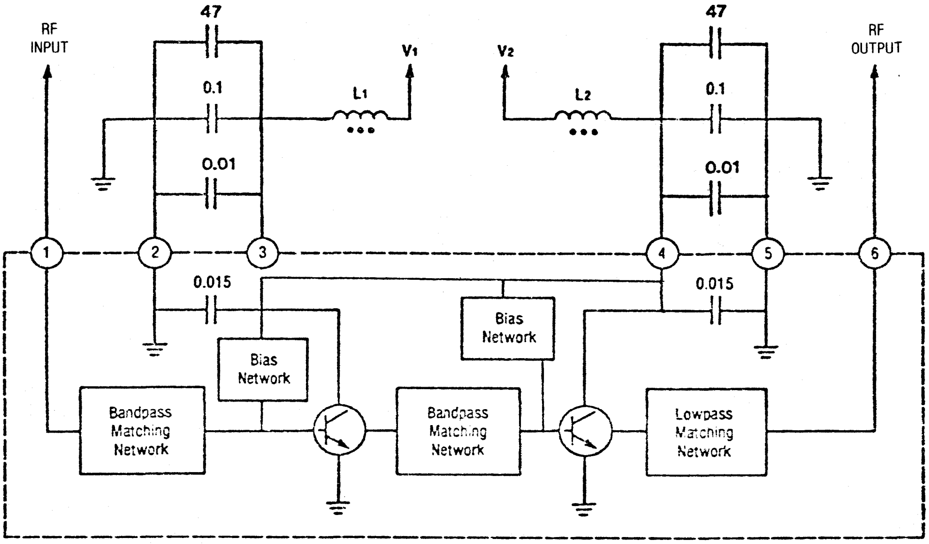
MVM

PRELIMINARY SPECIFICATION

Electrical Characteristics (T_{case} = 25 °C)

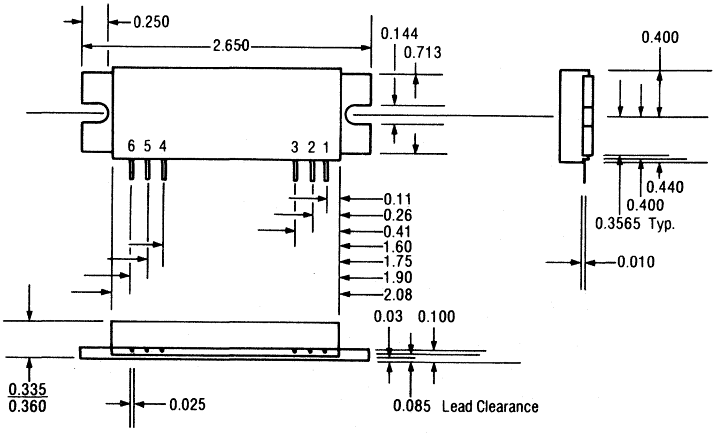
CHARACTERISTICS	TEST CONDITIONS	MVB 6	Units/Limit
Frequency range		140 - 175	MHz
Supply Voltage V_{CC}		10	Vdc Nom.
Power Output	Rated V_{CC} Any in Band Frequency $P_{in} \leqslant 50$ mW	6	W-Min
Efficiency	Rated P_{out} — V_{CC}	40	%-Min
Harmonic Outputs	Rated P_{out} — V_{CC}	— 25	dB-Max
Input Return Loss	Rated P_{out} — $Z_O = 50$ Ω	— 10	dB-Max
Output Impedance		50	Ω-Nom
Quiescent Current	$V_{CC} = 10$ V $P_{in} = 0$ W	0.1	Adc-Max
Power Slump	Rated P_{out} — V_{CC} 25 °C — 30 °C to + 80 °C	2	dB-Max
Load VSWR 0-360° (Degradation)	$V_{CC} = 10$ V $P_{in} = 100$ mW Lowest Frequency	20 : 1	No degradation
Load VSWR 0-360° (Stability)	$0 \leqslant P_{in} \leqslant 100$ mW $5 \leqslant V_{CC} \leqslant 10$ W Any in band frequency	3 : 1 5 : 1	Min Typ
Temperature range	Operating, T_{Flange}	— 30 + 100	°C Min °C Max

CIRCUIT DIAGRAM FOR MVB 6



L1, L2 Ferroxcube VK211173B, 2½ turns
All capacitor values in µF

MVM PACKAGE OUTLINE



TRW COMPOSANTS ELECTRONIQUES S.A.

TRW® SEMICONDUCTORS

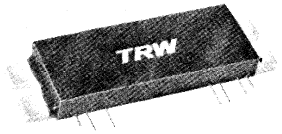
MX 7.5
MX 12
MX 15

RF Power Modules

TRW's MX modules are rugged power amplifier functions designed for 12 volt broadband UHF applications. The modules feature 50 Ω input and output impedances, broadband gain, and can withstand infinite VSWR at 14 volts. They are stable under all operating conditions and provide excellent harmonic rejection. Using simple and inexpensive external circuitry, the modules also feature gain control capability, providing insensitivity to severe overdrive, surge voltages, and excessive currents induced by high VSWR levels.

Compared to discrete components, these modules offer significant savings in size as well as in design, production, and repair costs.

POWER OUTPUT
16 W ∞ VSWR



MXM

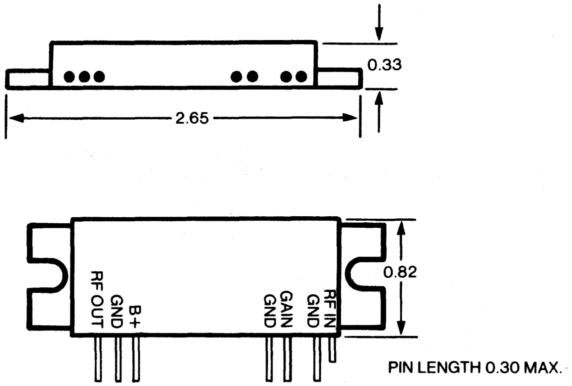
Electrical Characteristics (T_{flange} = 25 °C)

Characteristics	Test Conditions	MX 7.5	MX 12	MX 15	Unit
Frequency Ranges		400-430 430-470 470-512	400-430 430-470 470-512	400-430 430-470 —	MHz
Supply Voltage		12.5	12.5	12.5	Vdc nominal
Power Gain	$P_{in} \leqslant 125$ mW $P_{in} \leqslant 150$ mW $P_{in} \leqslant 200$ mW	7.5	12	15	W
Efficiency	Rated P_0	33	35	35	% min.
Harmonic Content	Rated P_0	— 30	— 30	— 30	dB min.
Load VSWR	14 V, 10 W, low frequency 14 V, 14 W, low frequency 14 V, 16 W, low frequency	∞ : 1	∞ : 1	∞ : 1	
Power Derating	— 30 °C to + 70 °C	2	2	2	dB max.
Stability	Any frequency	0-16 0-200 10	0-16 0-250 14	0-16 0-300 16	Vdc mW W max.
Input Impedance Return Loss		50 — 10	50 — 10	50 — 10	Ω nominal dB max.
Output Impedance		50	50	50	Ω nominal
φ JF		4	4	4	°C/W Typical
Operating Mode		C	C	C	Class
Temperature Range	Operating	— 30 + 100	— 30 + 100	— 30 + 100	°C min. °C max.
Gain Control Range	Operating	10	10	10	dB min.

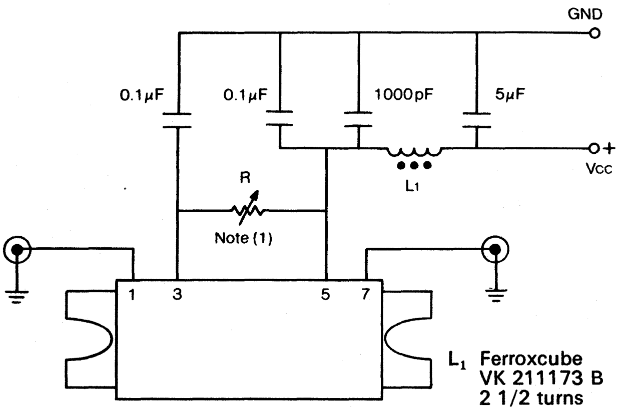
Absolute Maximum Rating (T_{flange} = 25 °C)

Characteristics	MX 7.5	MX 12	MX 15
Power Output	10 W	14 W	16 W
Power Input	200 mW	250 mW	300 mW
Supply Voltage	16 V	16 V	16 V
Total Current	3 A	4 A	4.5 A
Storage Temperature	—30° C to + 100 °C	—30 °C to + 100 °C	—30 °C to + 100 °C

MX 7.5, MX 12 AND MX 15 MODULE PACKAGES



APPLICATION OF TRW AMPLIFIER MODULES



Notes

1. Adjust R for rated P_0 at V_{CC} = 12.5 V R value will be 0-100 ohms. P_{in} should be set at rated value.
2. When adjusted as in Note 1, the MX series can be operated at up to 16 volts when the output is terminated in a nominal load of 50 ohms (3 : 1 max. VSWR) or up to 14 volts when the output is terminated in an " infinite " VSWR, any phase angle.

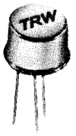
TRW® **SEMICONDUCTORS**

PT 8740

RF Power Transistor

2 W - 470 MHz
12.5 V

The PT 8740 is designed for use in 12.5 V UHF and VHF applications and is ideally suited for use in the predriver or driver stage of a power amplifier.

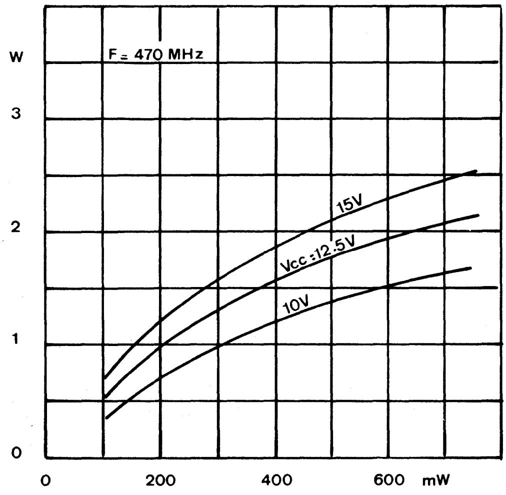

TO 39

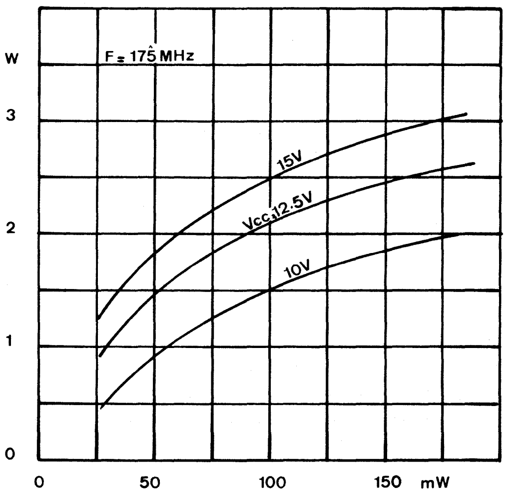
Electrical Characteristics (T_{case} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC Test	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 1 mA I_C = 0	4			V
	BV_{CEO}	Collector - Emitter Breakdown Voltage	I_C = 50 mA I_B = 0	18			V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 10 mA I_E = 0	40			V
	I_{CBO}	Collector Cutoff Current	V_{CB} = 15 V I_E = 0			1	mA
	H_{FE}	D.C Current Gain	V_{CE} = 10 V I_C = 100 mA	15		150	—
RF Test	P_{GAIN}	Power Gain	V_{CE} = 12.5 V F = 470 MHz P_{in} = 0.7 W V_{CE} = 12.5 V F = 175 MHz P_{in} = 0.1 W	2 1.8			W
	η	Efficiency	V_{CE} = 12.5 V F = 470 MHz P_{out} = 2 W	60			%
	Load VSWR	Mismatch Tolerance	All Phases Angles V_{CE} = 12.5 V F = 470 MHz P_{out} = 2 W		∞ : 1		
	Z_{in}	Common Emitter Amplifier Input Impedance	V_{CE} = 12.5 V F = 470 MHz P_{in} = 0.7 W V_{CE} = 12.5 V F = 175 MHz P_{in} = 0.1 W		4.31 — j 1.88 5.06 — j 9.62		Ω
	Z_{Load}	Common Emitter Amplifier Load Impedance	V_{CE} = 12.5 V F = 470 MHz V_{CE} = 12.5 V F = 175 MHz P_{out} = 1.8 W		21.1 + j 7.39 22.3 + j 31.36		Ω
	C_{OB}	Collector - Base Capacitance	V_{CB} = 20 V F = 1 MHz			12	pF
Operating	I_C	Continous Collector Current				0.5	A
	θ_{j-C}	Thermal Resistance	T_C = 25 °C			50	°C/W
	T_{STG}	Storage Temperature and Junction Temperature		— 65°		200°	°C
	P_D	Power Dissipation	T_C = 25 °C			3.5	W

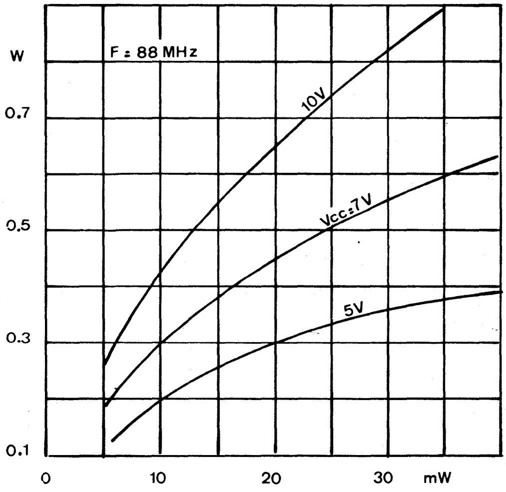
TYPICAL CHARACTERISTICS

Power Output vs Input Power and Voltage Supply

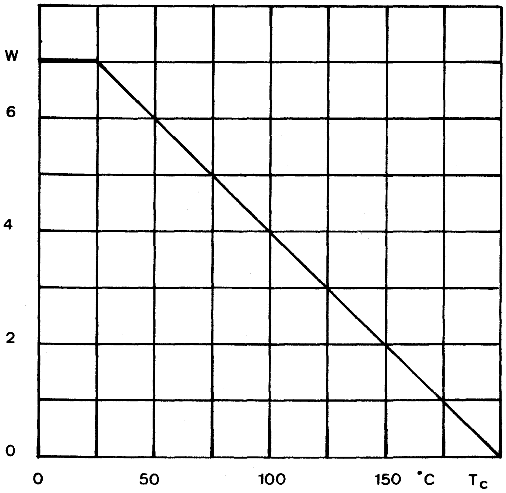




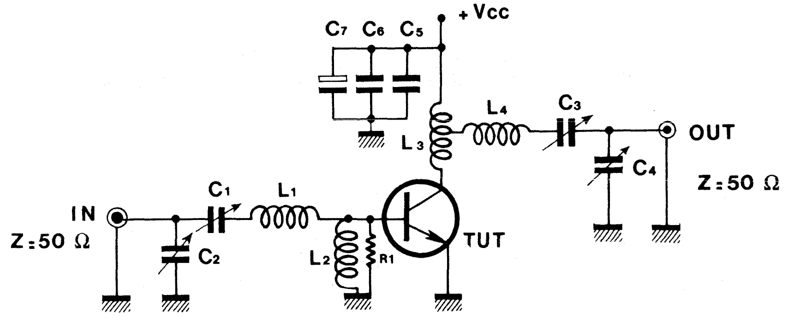
Power Output vs Input Power and Voltage Supply



Power - Temperature Derating Curve

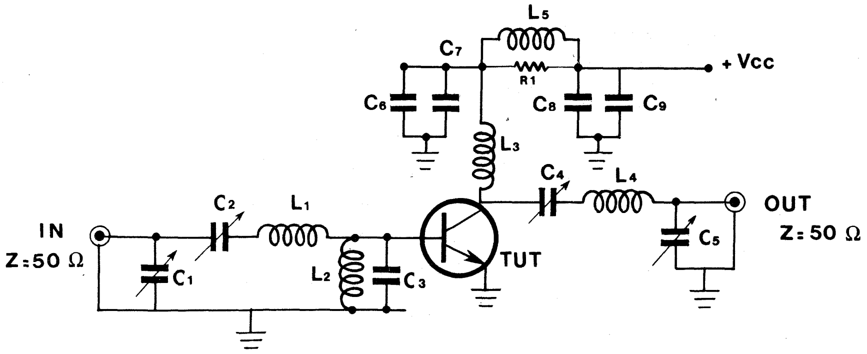


175 MHz AMPLIFIER-POWER OUTPUT TEST CIRCUIT



C_1-C_2-C_3-C_4 = 7.60 pF trimmer capacitor ARCO 404
C_5 = 1000 pF ceramic disc
C_6 = 10 nF ceramic disc
C_7 = 47 μF electrolytic
L_1 = 2 1/2 turns 10/10 mm wire - 1 cm I.D. - 1 cm length
L_2 = 1 μH molded coil
L_3 = 3 turns 10/10 mm wire - 1 cm I.D. - 1,5 cm length center tapped
L_4 = 2 1/2 turns 10/10 mm wire - 1 cm I.D. - 1 cm length
R_1 = 47 ohms 1/2 W carbon composition

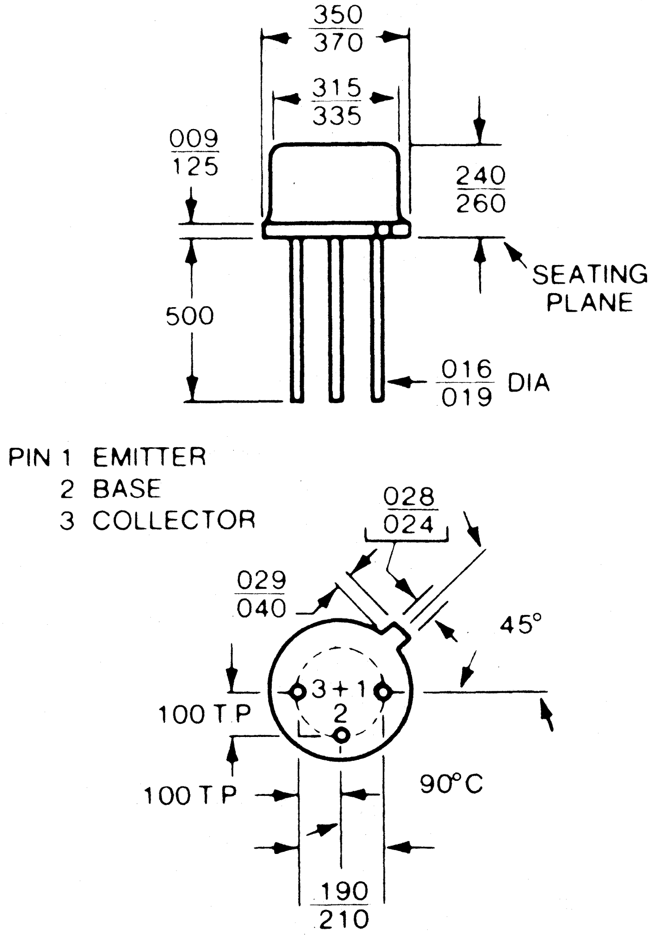
470 MHz AMPLIFIER-POWER OUTPUT TEST CIRCUIT



C_1 = 1,5-20 pF trimmer capacitor ARCO 402
C_2-C_4 = 7-60 pF trimmer capacitor ARCO 404
C_5 = 4-40 pF trimmer capacitor ARCO 403
C_3 = 20 pF ceramic disc
C_6-C_8 = 1000 pF silver mica capacitor
C_7-C_9 = 10 nF ceramic disc
L_1 = 3 mm × 12 mm copper strip
L_2 = 0.15 μH molded coil
L_3 = 2 turns 4/10 mm wire - 3 mm I.D.
L_4 = 5 mm × 15 mm copper strip
L_5 = 10 turns 4/10 mm wire on R1
R_1 = Resistor 20 ohms 1/2 W carbon composition

PACKAGE OUTLINE

TO-39



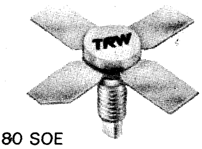
TRW® SEMICONDUCTORS

RF Power Transistors

PT 8809 2 W
PT 8810 5 W
PT 8811 10 W

470 MHz - 12.5 V

The PT 8809, 10 and 11 are designed for 12.5 volt, UHF applications. Power output is usable to the top of their ratings and they are able to withstand infinite VSWR at all phase angles at rated output power.



280 SOE

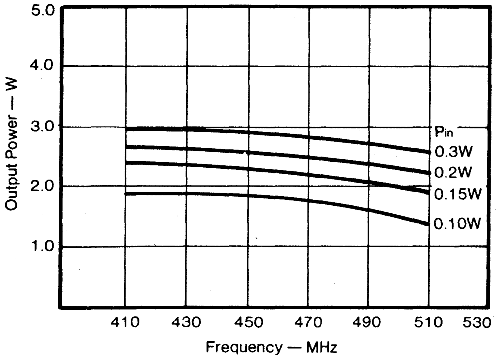
Electrical Characteristics (T_{CASE} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	PT 8809	PT 8810	PT 8811	UNIT
DC Test	BV_{EBO}	Min. Emitter - Base Breakdown	I_E = 1 mA I_C = 0 I_E = 2 mA I_C = 0 I_E = 5 mA I_C = 0	4	4	4	V
	BV_{CES}	Min. Collector - Emitter Breakdown	I_C = 5 mA V_{BE} = 0 I_C = 10 mA V_{BE} = 0 I_C = 20 mA V_{BE} = 0	36	36	36	V
	BV_{CEO}	Min. Collector - Emitter Breakdown	I_C = 25 mA I_B = 0 I_C = 50 mA I_B = 0	16	16	16	V
	I_{CBO}	Max. Collector Cutoff Current	V_{CB} = 15 V I_E = 0	1	1	2	mA
	H_{FE}	Min. D.C Current Gain	V_{CE} = 5 V I_C = 100 mA V_{CE} = 5 V I_C = 200 mA V_{CE} = 5 V I_C = 500 mA	20	20	20	—
RF Test	P_{GAIN}	Min. Power Gain	V_{CE} = 12.5 V P_{in} = 0.2 W P_{in} = 0.7 W F = 470 MHz P_{in} = 2.5 W	2	5	10	W
	η	Min. Collector Efficiency	V_{CE} = 12.5 V P_{out} = 2 W F = 470 MHz P_{out} = 5 W P_{out} = 10 W	60	55	55	%
	VSWR	Mismatch Tolerance	P_{out} = 2 W V_{CE} = 12.5 V P_{out} = 5 W F = 470 MHz P_{out} = 10 W	∞ : 1	∞ : 1	∞ : 1	
	C_{OB}	Max. Collector - Base Capacitance	V_{CB} = 15 V F = 1 MHz I_E = 0	8	17	30	pF
Operating	I_C	Continous Collector Current		0.75	1.7	3.4	A
	θ_{j-C}	Thermal Resistance	T_C = 25 °C	10	5	3.5	°C/W
	T_{STG}	Storage Temperature and Junction Temperature		— 65° to + 200°			°C
	P_D	Power Dissipation	T_C = 25 °C	17.5	35	50	W

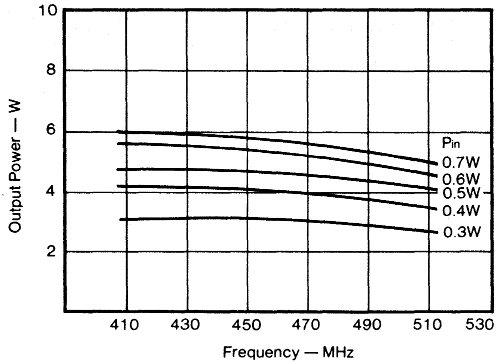
TYPICAL POWER GAIN PERFORMANCE IN BROADBND CIRCUIT

Power Output Frequency
V_{CE} = 12.5 V

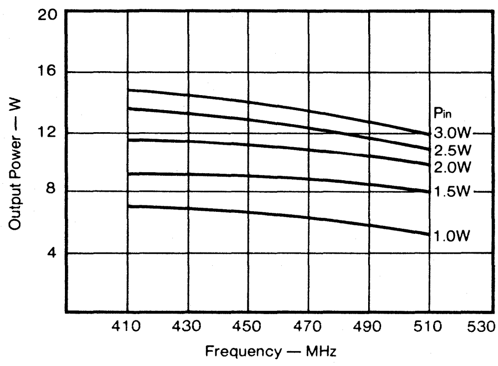
PT 8809



PT 8810

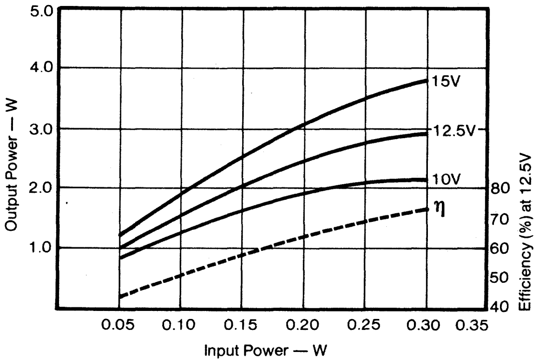


PT 8811

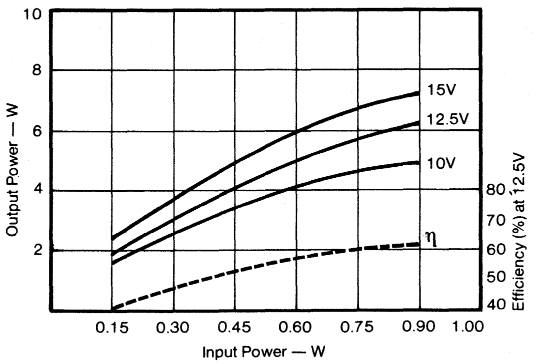


Power Output vs Power Input
f = 470 MHz

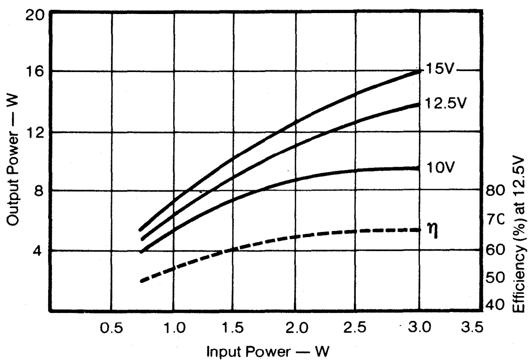
PT 8809



PT 8810

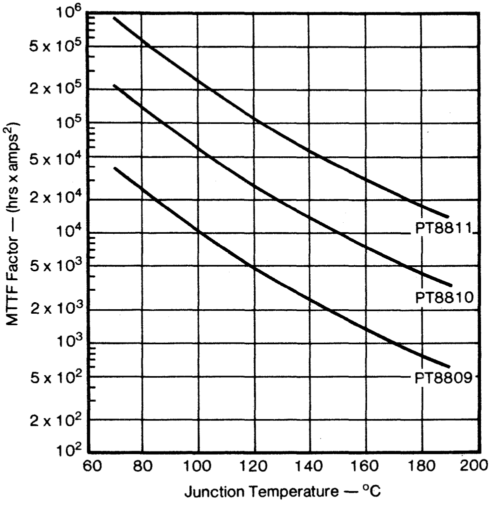


PT 8811

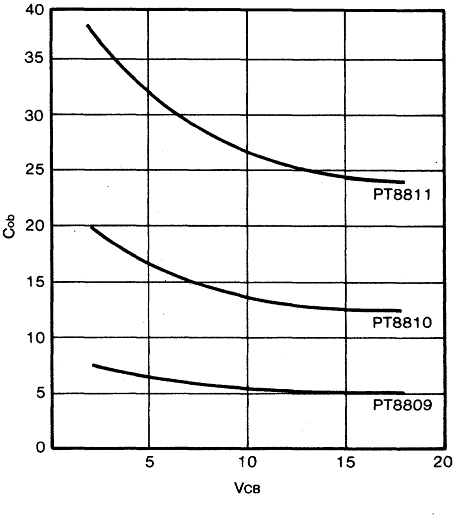


DEVICE IMPEDANCE PARAMETERS AT 12.5 V AND RATED INPUT POWER

DEVICE	FREQUENCY (MHz)	Z_n (Ω)	Z_{out} (Ω)
PT 8809	410	1.70 + j 1.92	15.7 — j 20.4
	430	1.79 + j 2.09	15.5 — j 19.7
	450	1.87 + j 2.26	15.4 — j 18.9
	470	1.96 + j 2.44	15.2 — j 18.2
	490	2.03 + j 2.61	15.1 — j 17.5
	510	2.11 + j 2.77	14.9 — j 16.7
PT 8810	410	1.49 + j 2.60	9.95 — j 6.20
	430	1.52 + j 2.90	9.80 — j 6.05
	450	1.56 + j 3.20	9.65 — j 5.90
	470	1.60 + j 3.50	9.55 — j 5.75
	490	1.63 + j 3.80	9.40 — j 5.60
	510	1.67 + j 4.10	9.30 — j 5.45
PT 8811	410	1.25 + j 2.65	6.00 — j 1.70
	430	1.24 + j 2.77	5.85 — j 1.64
	450	1.23 + j 2.89	5.70 — j 1.58
	470	1.22 + j 3.00	5.55 — j 1.62
	490	1.21 + j 3.12	5.40 — j 1.46
	510	1.20 + j 3.24	5.25 — j 1.40



MTTF Factor



Collector Base Capacitance (pF) at 1 MHz

MTTF factor is derived from calculations based on metal migration theory. The following example will serve to demonstrate the use of the MTTF factor charts shown above. Consider the PT 8810 operating at 470 MHz under normal conditions.

$P_0 = 5$ W
$V_C = 12.5$ V
$P_{in} = 0.6$ W
$\eta = 60\,\%$

From this we calculate $I_C = 0.67$ A; therefore, the total power dissipated is 4 watts.

The junction temperature can then be calculated from :

$$T_j = T_{stud} + Pd \times \theta_{jC}$$

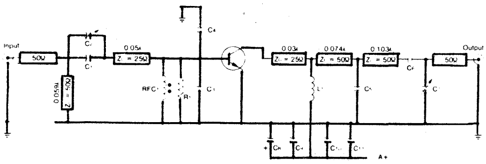
In this example $P_d \times \theta_{jC}$ is 20 °C.

For a stud temperature of 100 °C, T_j is 120 °C. From the chart above, we find the PT 8810 has an MTTF factor of 2.75×10^4 hours amps^2 at 120 °C. We calculate MTTF as follows :

$$\text{MTTF} = \frac{2.75 \times 10^4 \text{ hrs.amps}^2}{(0.67 \text{ amps})^2}$$

MTTF = 61,300 hours

PT 8809 TEST CIRCUIT BROADBAND (450-510 MHz)



COMPONENT AND MATERIAL LIST

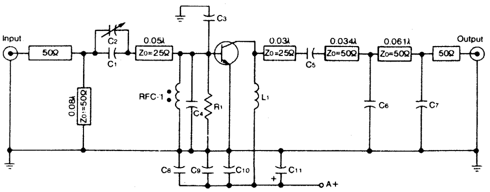
- C_1 3.9 pF, ceramic chip
- $C_{2,7}$ 0.8-10 pF, Voltronics AP 10, variable
- $C_{3,4}$ 27 pF, ceramic chip
- C_5 15 pF, ceramic chip
- C_6 470 pF, ceramic chip
- C_8 5 μF, electrolytic
- C_9 1000 pF, Underwood
- C_{10} 0.1 μF, disc-ceramic
- C_{11} 0.1 μF, disc-ceramic

- L_1 2 turns # 22 enameled, 0.1″ I.D.

- R_1 270 Ω, 1/2 watt, carbon
- RFC_1 2 1/2 turns # 22 AWG on Ferroxcube VK 211/17-4 B

All transmission lines reference at 480 MHz

PT 8810 TEST CIRCUIT BROADBAND (450-510 MHz)

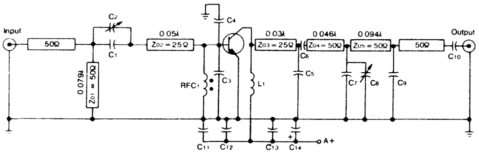


COMPONENT AND MATERIAL LIST

- C_1 3.9 pF, ceramic chip
- C_2 0.8-10 pF, Voltronics AP 10, variable
- $C_{3,4}$ 25 pF, ceramic chip
- C_5 1500 pF, ceramic chip
- C_6 10 pF, Underwood
- C_7 5 pF, Underwood
- C_8 0.01 μF, disc-ceramic
- C_9 0.10 μF, disc-ceramic
- C_{10} 1000 pF, Underwood
- C_{11} 5 μF, electrolytic
- L_1 4 turns, # 22 enameled, 0.1″ I.D.
- R_1 750 Ω, 1/2 watt, carbon
- RFC_1 2 1/2 turns # 22 AWG on Ferroxcube VK 211/17-4 B

All transmission lines reference at 480 MHz

PT 8811 TEST CIRCUIT BROADBAND (450-510 MHz)

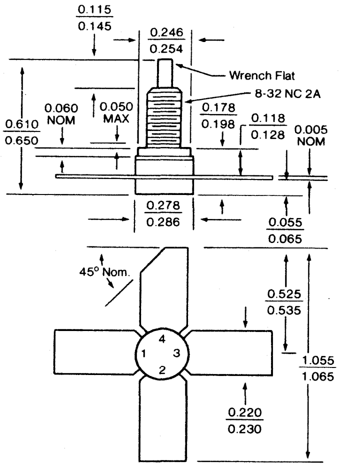


COMPONENT AND MATERIAL LIST

- C_1 3.9 pF, ceramic chip
- $C_{2,8}$ 0.8-10 pF, Voltronics AP 10, variable
- $C_{3,4}$ 27 pF, ceramic chip
- C_5 20 pF, Underwood
- C_6 81 pF, ceramic chip
- C_7 10 pF, Underwood
- C_9 5 pF, Underwood
- C_{10} 470 pF, ceramic chip
- C_{11} 1000 pF, Underwood
- C_{12} 0.1 μF, disc-ceramic
- C_{13} 0.01 μF, disc-ceramic
- C_{14} 5 μF, electrolytic
- L_1 4 turns, # 22 enameled, 0.1″ I.D.
- RFC_1 2 1/2 turns # 22 AWG on Ferroxcube VK 211/17-4 B

All transmission lines reference at 480 MHz

CASE OUTLINE



To convert inches to millimeters multiply by 25.4

STYLE 1:
PIN 1. EMITTER
2. BASE
3. EMITTER
4. COLLECTOR

TRW® **SEMICONDUCTORS**

PT 8828 (F)

RF TRANSISTOR

10 W - 175 MHz
12,5 V

NPN SILICON

Designed for 12.5 V VHF amplifiers. Class B or C operation.

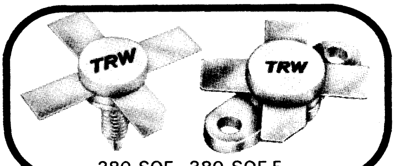
12.5 V characteristics :

Output power 175 MHz - 9 W min.

Minimum gain at 175 MHz - 11 dB.

Available in either stud or flange package.

Power output useable to the top ratings and capable of whithstanding infinite VSWR at all phase angles at rated output power.

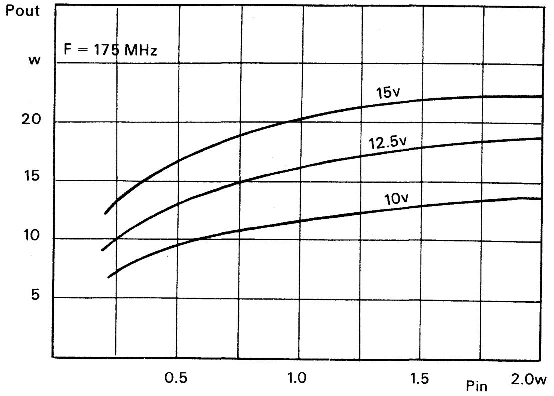


380 SOE 380 SOE F

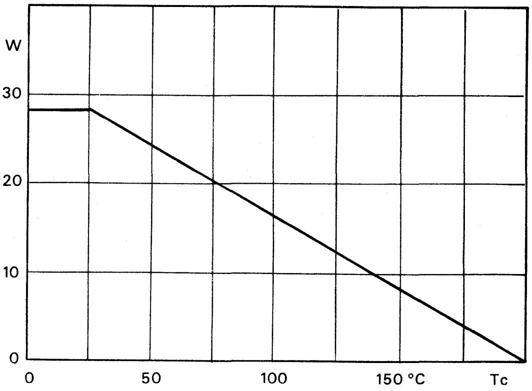
Electrical Characteristics (T_{flange} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC Test	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 5 mA I_C = 0	4			V
	BV_{CEO}	Collector - Emitter Breakdown Voltage	I_C = 50 mA I_B = 0	16			V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 20 mA I_E = 0	36			V
	I_{CBO}	Collector Cutoff Current	V_{CB} = 15 V I_E = 0			2	mA
	H_{FE}	D.C Current Gain	V_{CE} = 5 V I_C = 500 mA	20			—
RF Test	P_{GAIN}	Power Gain	V_{CE} = 12.5 V P_{in} = 0.7 W F = 175 MHz	9			W
	η	Efficiency	V_{CE} = 12.5 V P_{out} = 9 W F = 175 MHz	60			%
	Load VSWR	Mismatch Tolerance	V_{CE} = 12.5 V P_{out} = 9 W F = 175 MHz		∞ : 1		
	Z_{in}	Common Emitter Amplifier Input Impedance	V_{CE} = 12.5 V P_{in} = 0.7 W F = 175 MHz		1.8 – j 0.1		Ω
	Z_{Load}	Common Emitter Amplifier Load Impedance	V_{CE} = 12.5 V P_{out} = 9 W F = 175 MHz		8.29 + j 2.55		Ω
	C_{OB}	Collector - Base Capacitance	V_{CB} = 15 V F = 1 MHz			30	pF
Operating	I_C	Continous Collector Current				3.4	A
	θ_{j-c}	Thermal Resistance	T_C = 25 °C			3.5	°C/W
	T_{STG}	Storage Temperature and Junction Temperature		— 65°		200°	°C
	P_D	Power Dissipation	T_C = 25 °C			50	W

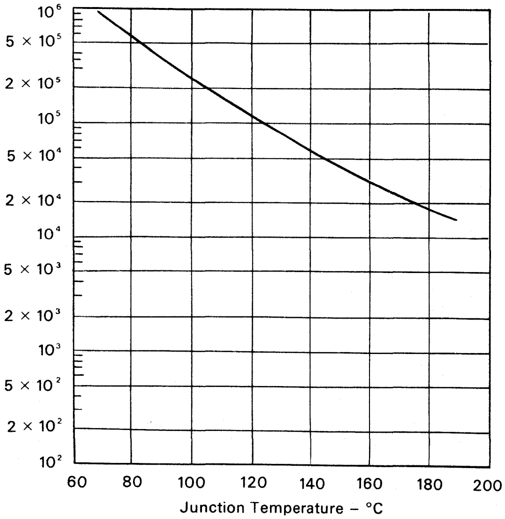
Typical characteristics



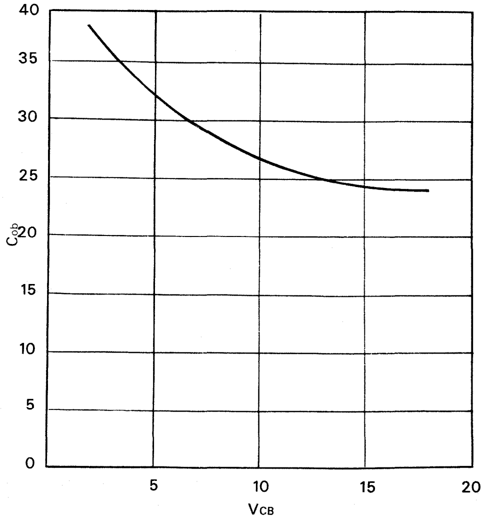
Power - Temperature Derating Curve



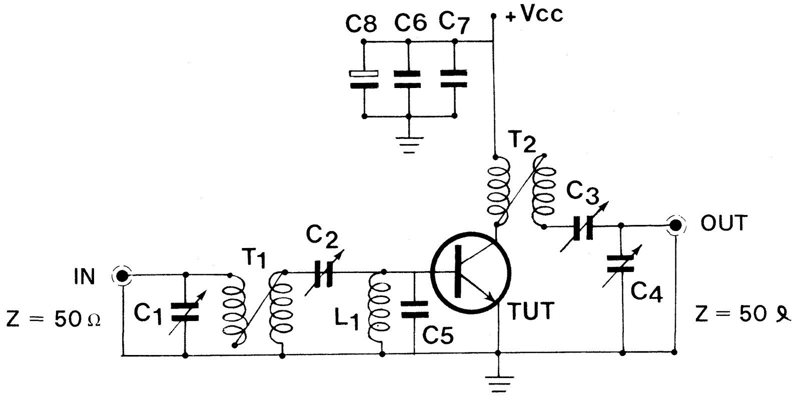
MTTF Factor



Collector Base Capacitance (pF) at 1 MHz



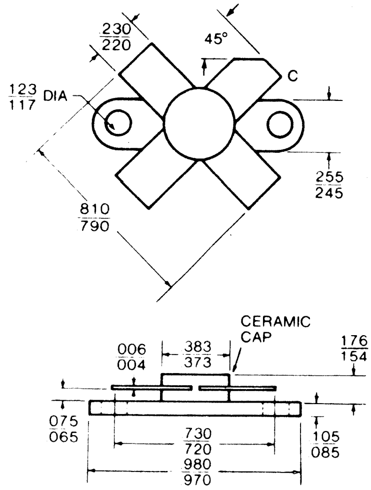
175 MHz - POWER OUTPUT TEST CIRCUIT



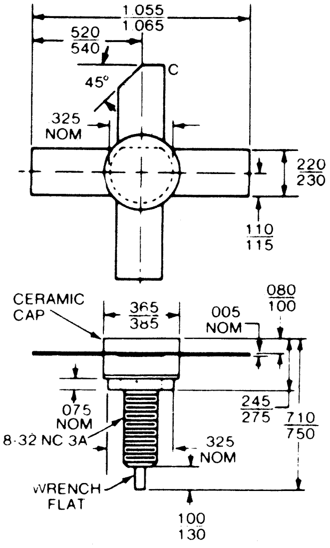
C_1-C_2-C_4 = 7-100 pF Trimmer Capacitor ARCO 423
C_3 = 24-200 pF Trimmer Capacitor ARCO 425
C_5 = 150 pF Silvered Mica Capacitor. Low Inductance
C_6 = 1000 pF Silvered Mica Capacitor
C_7 = 1000 pF Ceramic Disc
C_8 = 47 μF/63 V Electrolytic
L_1 = 10 μH Molded Coil
T_1-T_2 = Transmission Line Transformers 2 wires 8/10 mm Twisted - 5 cm length

PACKAGE OUTLINE

.380 SOE F



.380 SOE



TRW® **SEMICONDUCTORS**

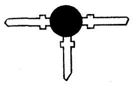
TP 210

7.5 Volts Transistor

88 MHz

19 dB GAIN

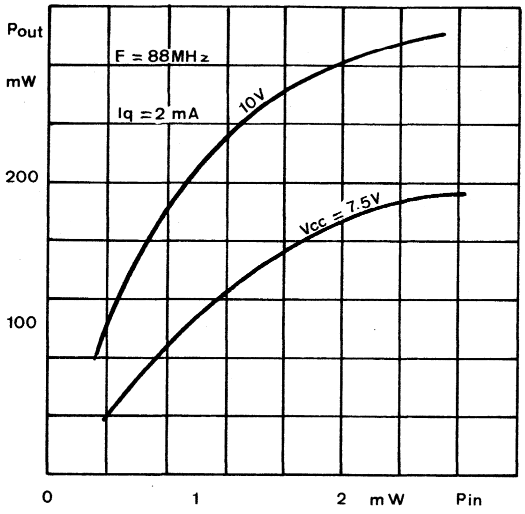
Using the most recent TRW technology, this T-Pack transistor has been specifically designed and characterized as a high gain 7.5 V VHF device. It is ideally suited for use in pocketphone applications where low battery voltage is used.


T - PACK

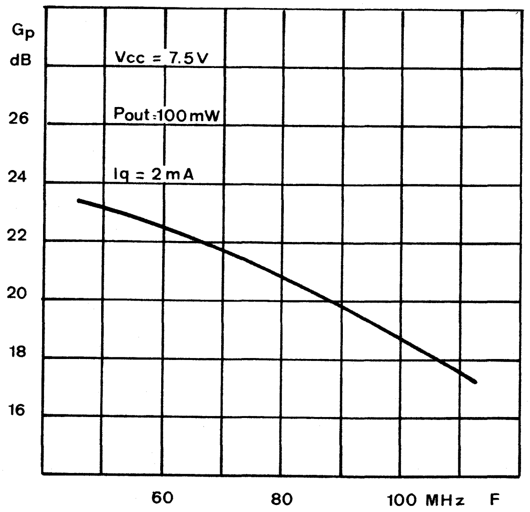
Preliminary

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC TEST	BV_{EBO}	Emitter Base Breakdown Voltage	$I_E = 0.1$ mA $I_C = 0$	3			V
	BV_{CEO}	Collector Emitter Breakdown Voltage	$I_C = 10$ mA $I_B = 0$	20			V
	BV_{CER}	Collector Emitter Breakdown Voltage	$I_C = 10$ mA $R_{BE} = 10\ \Omega$	25			V
	BV_{CEO}	Collector Base Breakdown Voltage	$I_C = 1$ mA $I_E = 0$	30			V
	H_{FE}	DC Current Gain	$V_{CE} = 10$ V $I_C = 40$ mA	15			—
RF TEST	P_{GAIN}	Power Gain	$V_{CE} = 7.5$ V $P_{in} = 1$ mW $I_C = 2$ mA $F = 88$ MHz	80			mW
	F_T	Cutoff Frequency	$V_{CE} = 10$ V $F = 100$ MHz $I_C = 40$ mA		2		GHz
	G_{Umax}	Maximum unilaterilized Gain	$V_{CE} = 10$ V $F = 100$ MHz $I_C = 40$ mA		26		dB
	S_{21}	Forward Gain 50 Ω/50 Ω	$V_{CE} = 10$ V $F = 100$ MHz $I_C = 40$ mA		24		dB
	C_{ob}	Collector Base Capacitance	$V_{CB} = 10$ V $F = 1$ MHz		2.5		pF
OPERATING THERMAL	I_{Cmax}	Maximum Collector Current				200	mA
	P_T	Dissipated Power	$T_{case} = 50$ °C			0.6	W
	T_{STG}	Storage Temperature		— 65°		+ 200	°C
	T_J	Junction Temperature					

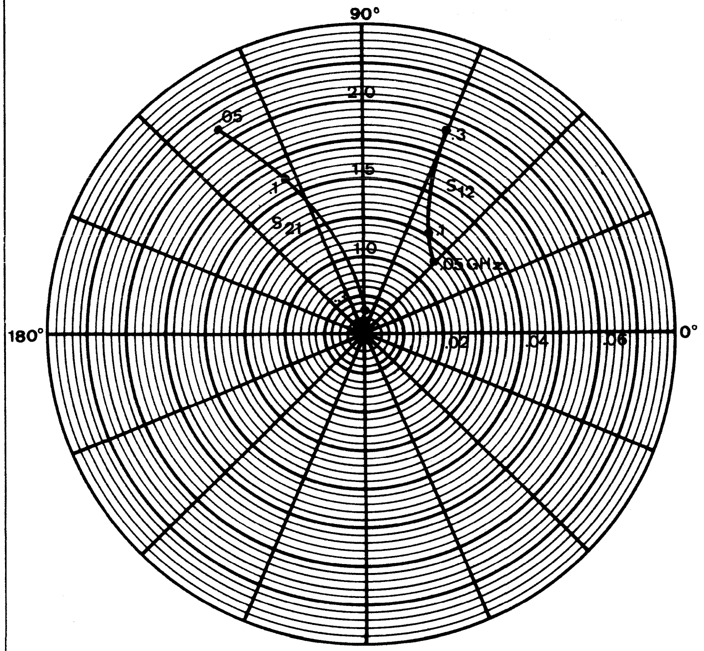
Output Power vs Frequency and Voltage Supply



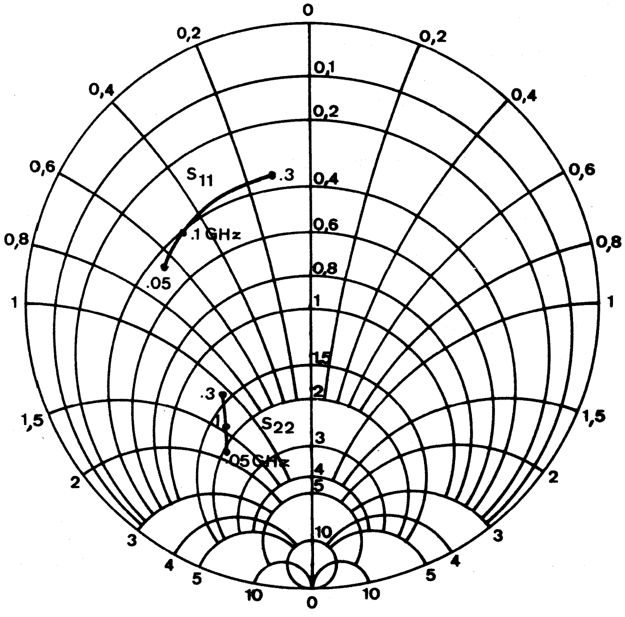
Power Gain vs Frequency



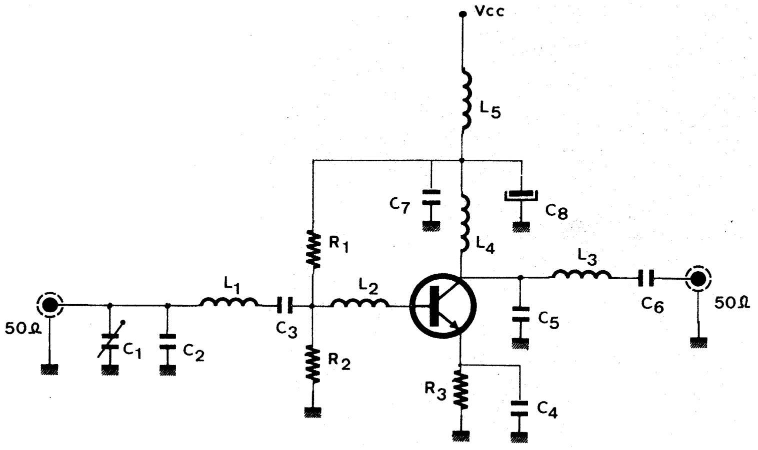
S21 - S12 Parameters vs Frequency
V_{CE} = 10 V - I_C = 40 mA



S11 - S22 Parameters vs Frequency
V_{CE} = 10 V - I_C = 40 mA



88 MHz Test Circuit

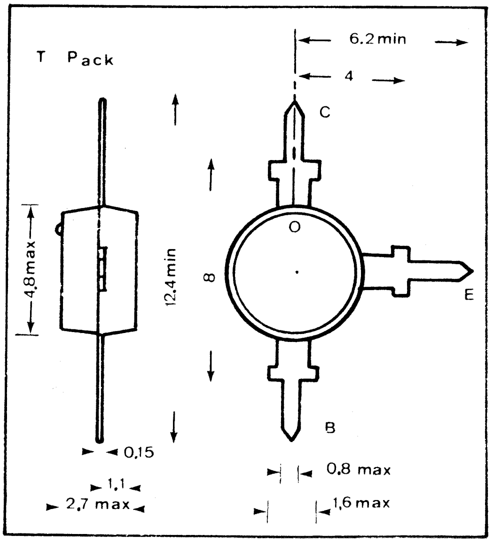


C_1 = 6-60 pF Trimmer Capacitor
C_2 = 22 pF Ceramic
C_3 = 180 pF Ceramic
C_4 = C_7 = 1 nF Ceramic
C_5 = 18 pF
C_6 = 220 pF
C_8 = 1 μF Electrolytic

L_1 = L_2 = 0.1 μH Molded Coil
L_3 = 0.18 μH Molded Coil
L_4 = 0.22 μH Molded Coil
L_5 = 1.2 μH Molded Coil

R_1 = 680 Ω Carbon composition
R_2 = 56 Ω Carbon composition
R_3 = 4.7 Ω Carbon composition

Package Outline



TRW® SEMICONDUCTORS

TP 212
TP 212 S

7.5 Volts Transistor

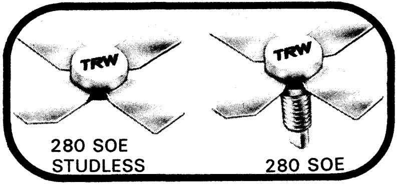
88 MHz

1.5 WATTS

13 dB GAIN

Using the latest in TRW technology, this device has been specifically designed and characterized for 7.5 V operation.

It is ideally suited for use in pocketphone where low battery voltage is used.



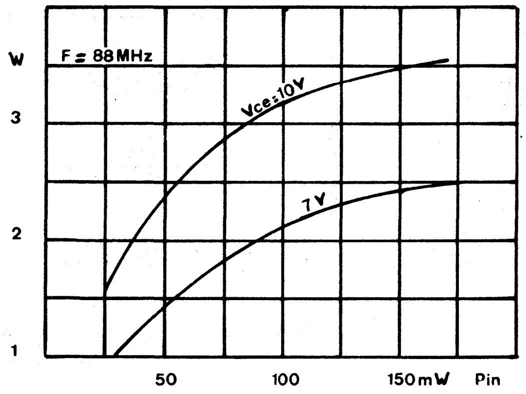
280 SOE STUDLESS

280 SOE

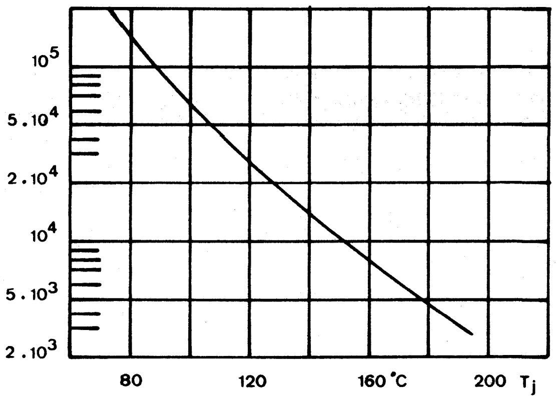
Preliminary Electrical Characteristics (T_{case} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC TEST	BV_{EBO}	Emitter Base Breakdown Voltage	I_E = 2 mA I_C = 0	4			V
	BV_{CEO}	Collector Emitter Breakdown Voltage	I_C = 50 mA I_B = 0	16			V
	BV_{CBO}	Collector Base Breakdown Voltage	I_C = 10 mA I_E = 0	36			V
	I_{CBO}	Collector Cutoff Current	V_{CB} = 15 V I_E = 0			1	mA
	H_{FE}	DC Current Gain	V_{CE} = 5 V I_C = 200 mA	20			—
RF TEST	P_{GAIN}	Power Gain	V_{CE} = 7.5 V F = 88 MHz P_{in} = 0.075 W	1.5			W
	η	Efficiency	V_{CE} = 7.5 V F = 88 MHz P_{out} = 1.5 W	50			%
	Load VSWR	Mismatch Tolerance	V_{CE} = 10 V F = 88 MHz P_{out} = 1.5 W		all phase angles : 1		
	Z_{in}	Common Emitter Amplifier Input Impedance	V_{CE} = 7.5 V F = 88 MHz P_{in} = 0.075 W		2.54 — j 3.5		Ω
	Z_{Load}	Common Emitter Amplifier Load Impedance	V_{CE} = 7.5 V F = 88 MHz P_{out} = 1.5 W		21.38 + j 10.3		Ω
	C_{OB}	Collector Base Capacitance	V_{CB} = 15 V F = 1 MHz		13	17	pF
OPERATING THERMAL	I_C	Continuous Collector Current				1.7	A
	$\theta_{j.C}$	Thermal Resistance	T_C = 25 °C			10	°C/W
	T_{STG}	Storage Temperature and Junction Temperature		— 65°		200°	°C
	P_D	Power Dissipation	T_C = 25 °C			17.5	W

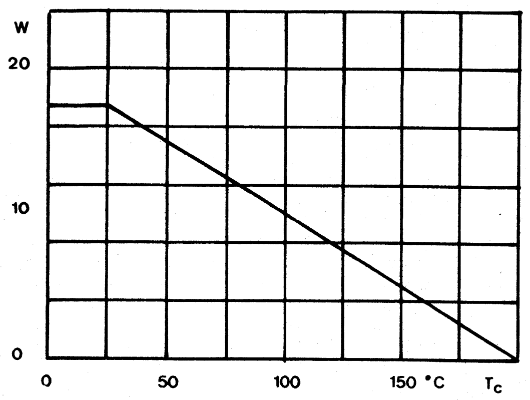
Output Power vs Input Power and Voltage Supply



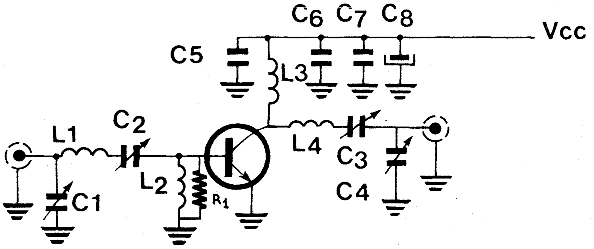
MTTF Factor vs Junction Temperature



Power - Temperature Operating Curve



88 MHz TEST CIRCUIT

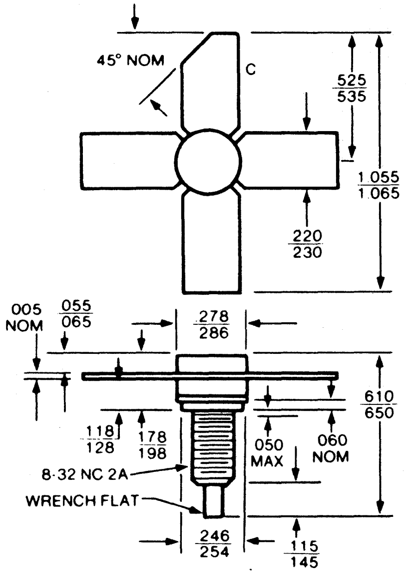


C_1 = C_2 = C_3 = 24-200 pF ARCO 425
C_4 = 7-100 pF ARCO 423
C_5 = 1000 pF mica capacitor UNELCO
C_6 = 10 nF ceramic disc
C_7 = 0.1 μF ceramic disc
C_8 = 100 μF/35 V electrolytic

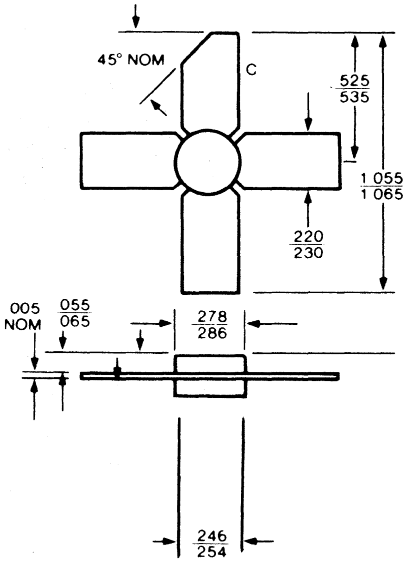
L_1 = L_4 = 4 turns 14 AWG 1/2″ I.D.
L_2 = 0.47 μH
L_3 = 6 turns 14 AWG 1/2″ I.D. Close Wound

R_1 = 47 ohms

PACKAGE OUTLINE



280 SOE



280 SOE STUDLESS

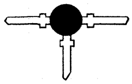
TRW® SEMICONDUCTORS **TP 250**

7.5 Volts Transistor

400 - 512 MHz

12 dB GAIN

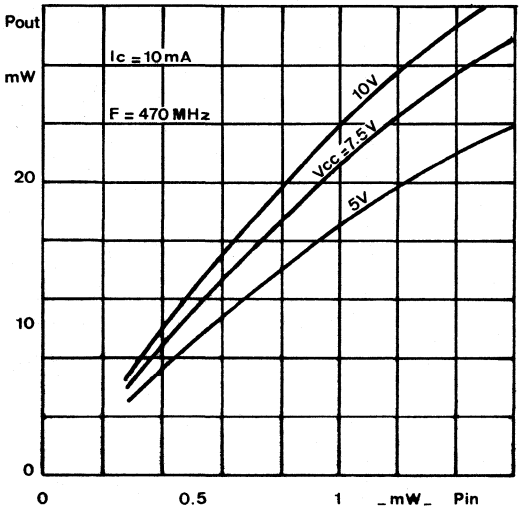
Using the most recent TRW technology, this T-Pack transistor has been specifically designed and characterized as a high gain 7.5 V VHF device. It is ideally suited for use in pocketphone applications where low battery voltage is used.


T - PACK

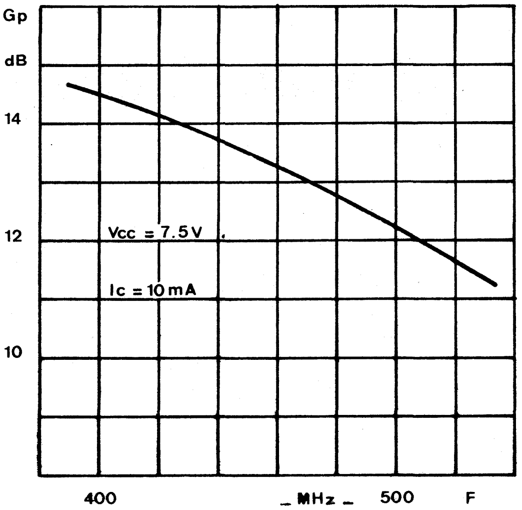
Preliminary

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC TEST	BV_{EBO}	Emitter Base Breakdown Voltage	$I_E = 0.1$ mA $I_C = 0$	3			V
	BV_{CEO}	Collector Emitter Breakdown Voltage	$I_C = 10$ mA $I_B = 0$	18			V
	BV_{CER}	Collector Emitter Breakdown Voltage	$I_C = 10$ mA $R_{BE} = 10\ \Omega$	30			V
	BV_{CBO}	Collector Base Breakdown Voltage	$I_C = 1$ mA $I_E = 0$	35			V
	H_{FE}	DC Current Gain	$V_{CE} = 10$ V $I_C = 40$ mA	15			—
RF TEST	P_{GAIN}	Power Gain	$V_{CE} = 7.5$ V $P_{in} = 1$ mW $I_C = 10$ mA F = 470 MHz	15			mW
	F_T	Cut-off Frequency	$V_{CE} = 10$ V F = 500 MHz $I_C = 40$ mA		2.5		GHz
	$G_{U\,max}$	Maximum Unilaterilized Gain	$V_{CE} = 10$ V F = 500 MHz $I_C = 40$ mA		14		dB
	S_{21}	Forward Gain 50 Ω/50 Ω	$V_{CE} = 10$ V F = 500 MHz $I_C = 40$ mA		12.5		dB
	C_{ob}	Collector Base Capacitance	$V_{CB} = 10$ V F = 1 MHz		2.5		pF
OPERATING	$I_{C\,max}$	Maximum Collector Current				200	mA
	P_T	Dissipated Power	$T_{case} = 50$ °C			0.6	W
	T_{STG}	Storage Temperature		— 65		+ 200	°C
	T_J	Junction Temperature					

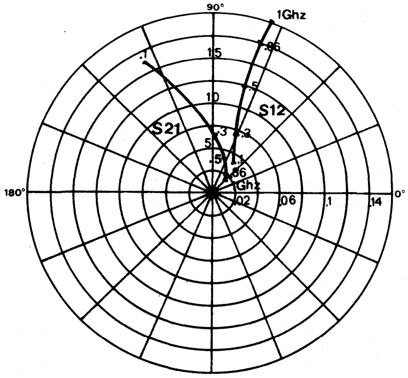
Output Power vs Input Power and Voltage Supply



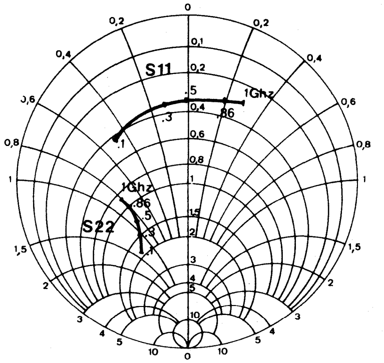
Power Gain vs Frequency



S21 - S12 Parameters vs Frequency
V_{CE} = 10 V - I_C = 40 mA

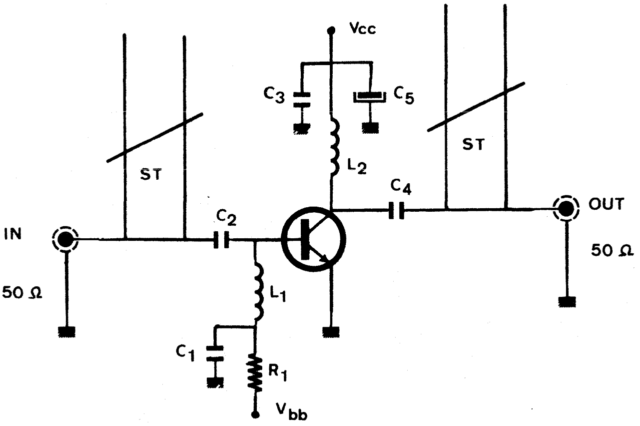


S11 - S22 Parameters vs Frequency
V_{CE} = 10 V - I_C = 40 mA



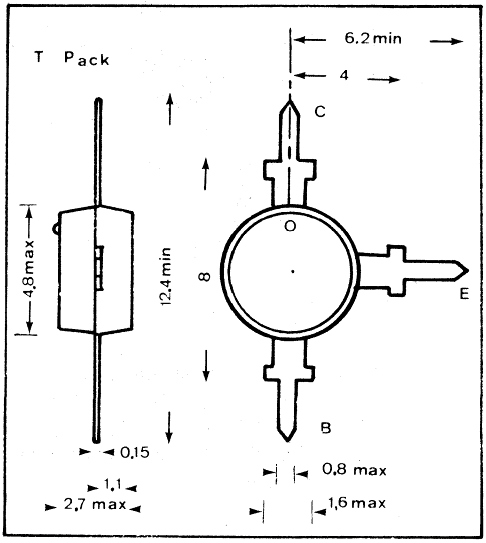
TYPICAL VALUE

Test Circuit 400-512 MHz



$L_1 = L_2 = 0.33$ μH Molded coil
$C_1 = C_2 = C_3 = C_4 = 1000$ pF Ceramic chip
$C_5 = 10$ μF/25 V Electrolytic
$R_1 = 10$ kΩ 1/2 W Carbon composition
ST = Stub tuner

Package Outline



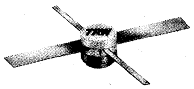
TRW® SEMICONDUCTORS

TP 251

7.5 Volts Transistor

400 - 512 MHz
0.2 Watts
13 dB Gain

The latest in the TRW RF transistor, this device has been specifically designed and characterized for 7.5 V operation. It is ideally suited for use in pocketphones where low battery voltage is used.

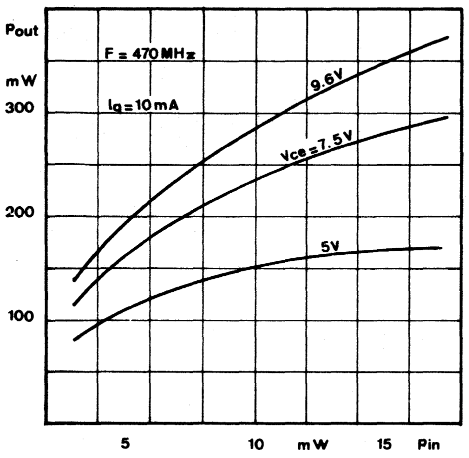


200 SOE STUDLESS

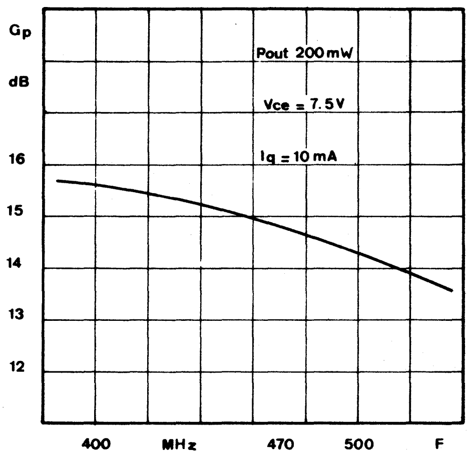
PRELIMINARY

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS		MIN.	TYP.	MAX.	UNIT
DC Test	BV_{EBO}	Emitter - Base Breakdown Voltage	$I_E = 1$ mA	$I_C = 0$	4			V
	BV_{CEO}	Collector - Emitter Breakdown Voltage	$I_C = 5$ mA	$I_B = 0$	18			V
	BV_{CBO}	Collector - Base Breakdown Voltage	$I_C = 2$ mA	$I_E = 0$	40			V
	I_{CBO}	Collector Cutoff Current	$V_{CB} = 15$ V	$I_E = 0$			0.5	mA
	H_{FE}	D.C Current Gain	$V_{CE} = 5$ V	$I_C = 50$ mA	20			—
RF Test	P_{GAIN}	Power Gain	F = 470 MHz $V_{CE} = 7.5$ V $V_{CE} = 9.6$ V	Iq = 10 mA $P_{in} = 10$ mW $P_{in} = 10$ mW	0.175 0.200	0.230 0.290		W
	η	Efficiency	F = 470 MHz $V_{CE} = 7.5$ V	Iq = 10 mA Rated Output Power	35	40		%
	Z_{in}	Common Emitter Amplifier Input Impedance	F = 470 MHz $V_{CE} = 7.5$ V	AB Class $P_{in} = 10$ mW		5 + j 0.5		Ω
	Z_{Load}	Common Emitter Amplifier Load Impedance	F = 470 MHz $V_{CE} = 7.5$ V	AB Class $P_{out} = 0.2$ W		47 + j 45		Ω
	C_{OB}	Collector - Base Capacitance	$V_{CB} = 10$ V	F = 1 MHz		1.6	2.5	pF
Operating	I_C	Continous Collector Current					0.2	A
	θ_{j-C}	Thermal Resistance	$T_C = 25$ °C				175	°C/W
	T_{STG}	Storage Temperature and Junction Temperature			— 65°		200°	°C
	P_D	Power Dissipation	$T_C = 25$ °C				1	W

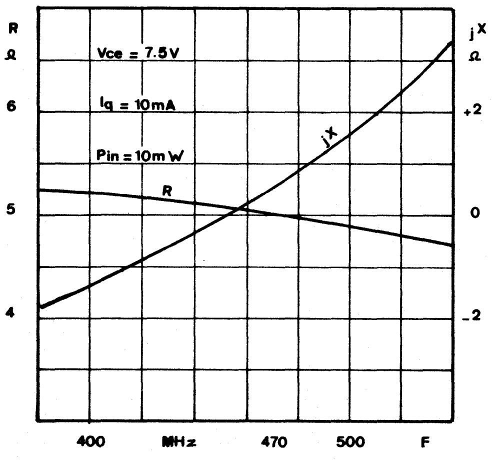
Output Power vs Input Power and V_{CE}



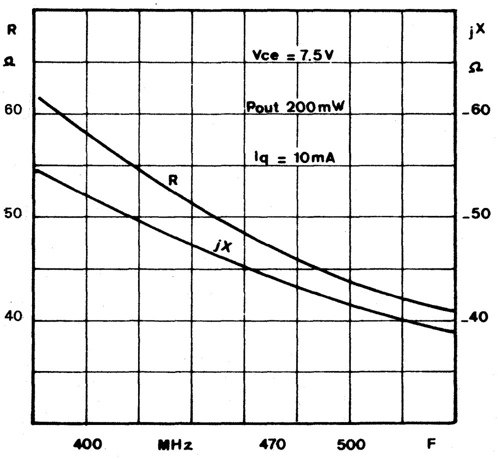
Power Gain vs Frequency



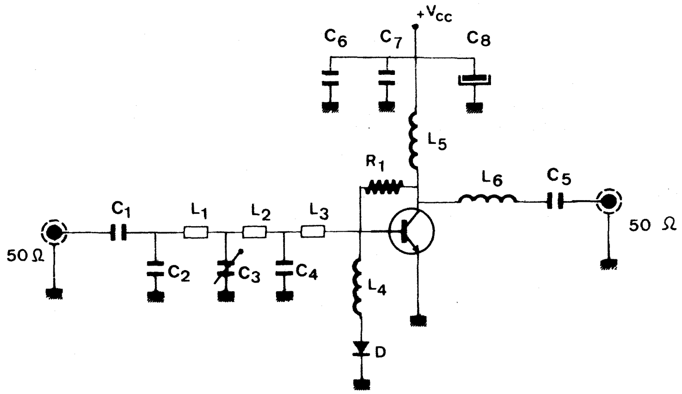
Input Impedance vs Frequency



Output Impedance vs Frequency



400-512 MHz TEST CIRCUIT

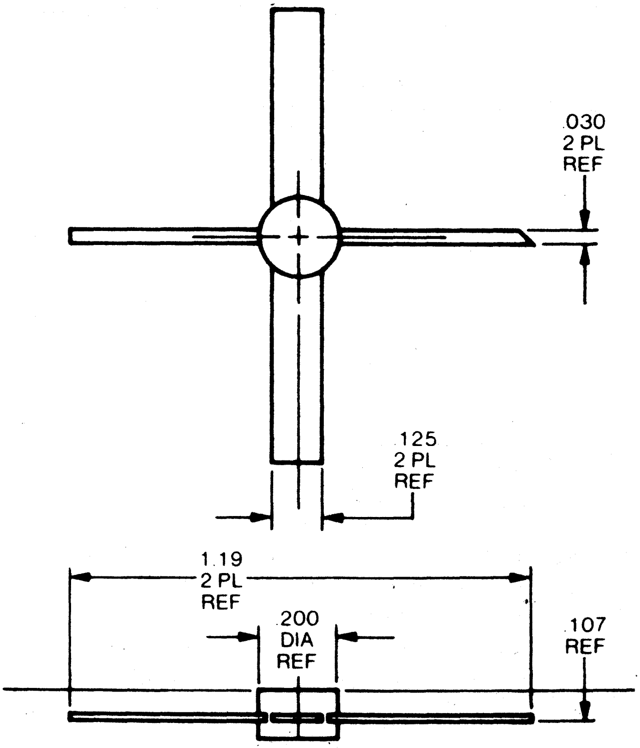


C_1 = 27 pF Ceramic 632 RTC
C_2 = 8.2 pF Ceramic 632 RTC
C_3 = 3-20 pF Trimmer Capacitor
C_4 = 22 pF Ceramic 632 RTC
C_5 = C_6 = 1000 pF Ceramic 629 RTC
C_7 = 10 nF Ceramic 629 RTC
C_8 = 10 μF/25 V Electrolytic

L_1 = Stripline Z_0 = 70 ohms l = 0.061 λ
L_2 = Stripline Z_0 = 70 ohms l = 0.026 λ } F_{REF} = 480 MHz
L_3 = Stripline Z_0 = 50 ohms l = 0.031 λ
L_4 = L_5 = 0.15 μH Molded Coil
L_6 = 3 turns - Silvered Wire 6/10 mm - 4 mm I.D - 8 mm length

R_1 = 5 10 Ω Carbon Composition 1/4 W

PACKAGE
.200 SOE STUDLESS



TRW® SEMICONDUCTORS

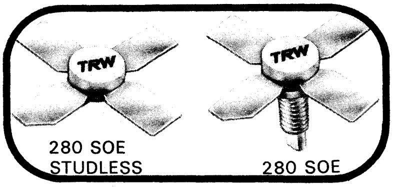
TP 252 (S)

7.5 Volts Transistor

400 - 512 MHz
1.5 Watts
10 dB Gain

The latest in the TRW RF transistor, this device has been specifically designed and characterized for 7.5 V operation.

It is ideally suited for use in pocketphone where low battery voltage is used.



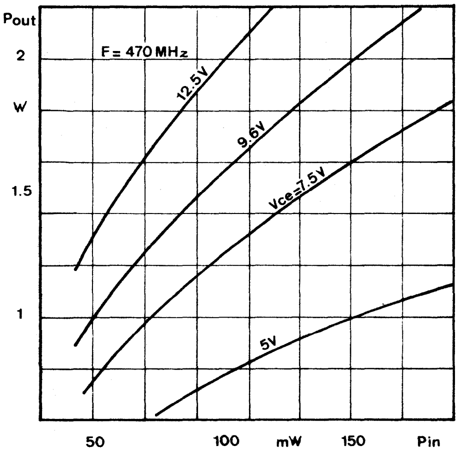
280 SOE STUDLESS

280 SOE

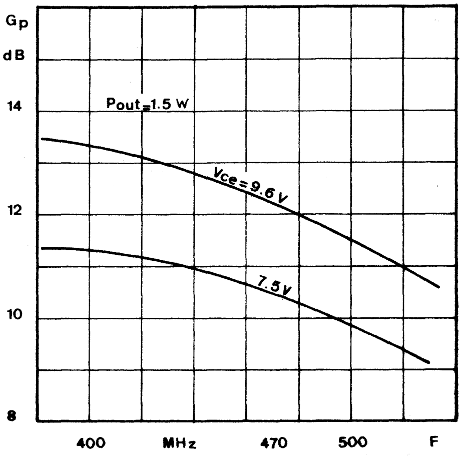
PRELIMINARY

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC Test	BV_{EBO}	Emitter - Base Breakdown Voltage	$I_E = 1$ mA $I_C = 0$	4			V
	BV_{CEO}	Collector - Emitter Breakdown Voltage	$I_C = 10$ mA $I_B = 0$	14			V
	BV_{CBO}	Collector - Base Breakdown Voltage	$I_C = 5$ mA $I_E = 0$	30			V
	I_{CBO}	Collector Cutoff Current	$V_{CB} = 15$ V $I_E = 0$			0.5	mA
	H_{FE}	D.C Current Gain	$V_{CE} = 5$ V $I_C = 100$ mA	20			—
R F Test	P_{GAIN}	Power Gain	F = 470 MHz $V_{CE} = 7.5$ V $P_{in} = 175$ mW $V_{CE} = 9.6$ V $P_{in} = 150$ mW	1.5 1.5	1.8 2		W
	η	Efficiency	F = 470 MHz $V_{CE} = 7.5$ V $P_{out} = 1.5$ W	50	60		%
	Load VSWR	Mismatch Tolerance	F = 470 MHz $V_{CE} = 10$ V $P_{out} = 1.5$ W		∞ : 1 All phases		
	Z_{in}	Common Emitter Amplifier Input Impedance	F = 470 MHz $V_{CE} = 7.5$ V $P_{in} = 150$ mW		1.8 + j 3.5		Ω
	Z_{Load}	Common Emitter Amplifier Load Impedance	F = 470 MHz $V_{CE} = 7.5$ V $P_{out} = 1.5$ W		11 + j 6		Ω
	C_{OB}	Collector - Base Capacitance	$V_{CB} = 10$ V F = 1 MHz		5.5	7	pF
Operating	I_C	Continous Collector Current				1	A
	θ_{j-c}	Thermal Resistance	$T_C = 25$ °C			10	°C/W
	T_{STG}	Storage Temperature and Junction Temperature		— 65°		200°	°C
	P_D	Power Dissipation	$T_C = 25$ °C			17.5	W

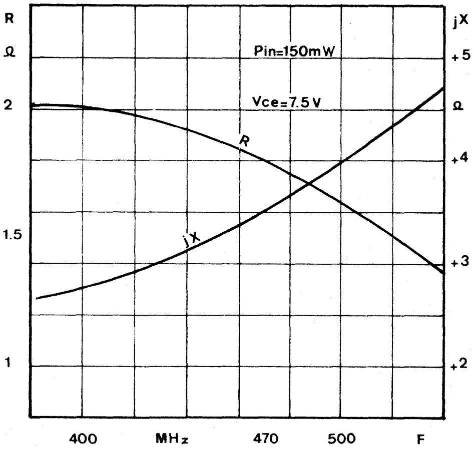
Output Power vs Input Power and V_{CE}



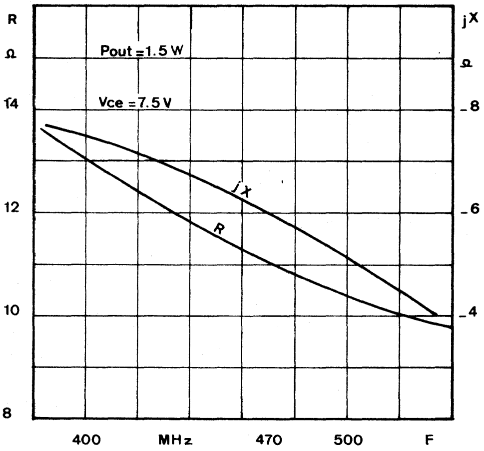
Power Gain vs Frequency and V_{CE}



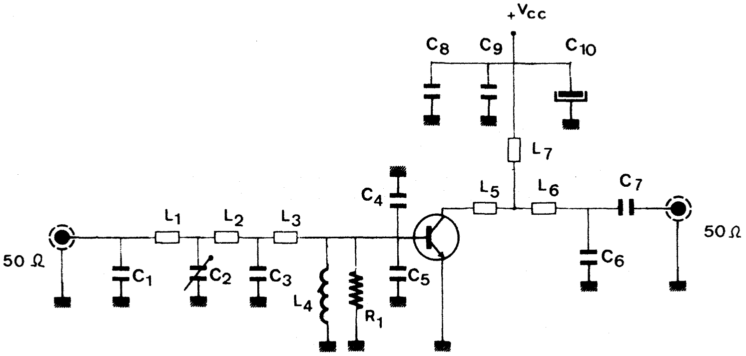
Input Impedance vs Frequency



Output Impedance vs Frequency



400-512 MHz TEST CIRCUIT



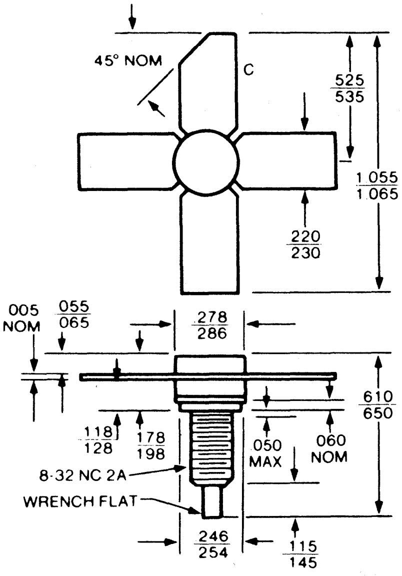
C_1 = 4.7 pF Ceramic 632 RTC
C_2 = 2-10 pF Trimmer Capacitor
C_3 = 15 pF Ceramic 632 RTC
$C_4 = C_5$ = 39 pF Ceramic Chip ATC
C_6 = 10 pF Ceramic Chip ATC
$C_7 = C_8$ = 1000 pF Ceramic 629 RTC
C_9 = 10 nF Ceramic 629 RTC
C_{10} = 10 µF/25 V Electrolytic

L_1 = Stripline Z_0 = 70 ohms l = 0.032 λ
L_2 = Stripline Z_0 = 70 ohms l = 0.029 λ
L_3 = Stripline Z_0 = 25 ohms l = 0.031 λ
L_5 = Stripline Z_0 = 25 ohms l = 0.006 λ
L_6 = Stripline Z_0 = 70 ohms l = 0.052 λ
L_7 = Stripline Z_0 = 70 ohms l = 0.064 λ
F_{REF} = 480 MHz

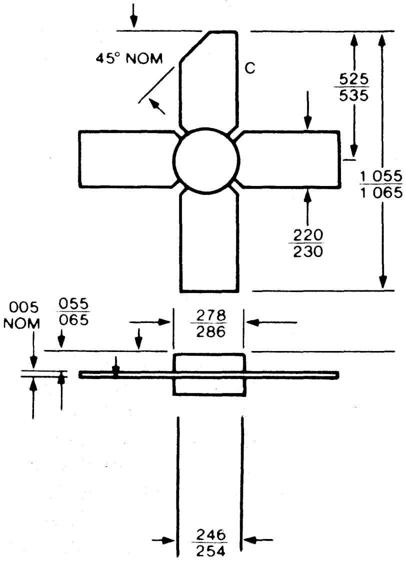
L_4 = 0.15 µH Molded Coil

R_1 = 47 ohms Carbon Composition - 1/4 W

PACKAGE OUTLINE



280 SOE



280 SOE STUDLESS

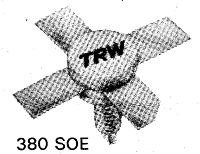
TP 1010

RF Power Transistor

25 W - 12.5 V
88 MHz

The TP 1010 as been designed for use in 12.5 V - 88 MHz amplifiers.

Its features which include high gain and capability of withstanding VSWR at all phases angles make it ideally suited as a rugged output device for mobile radio applications.



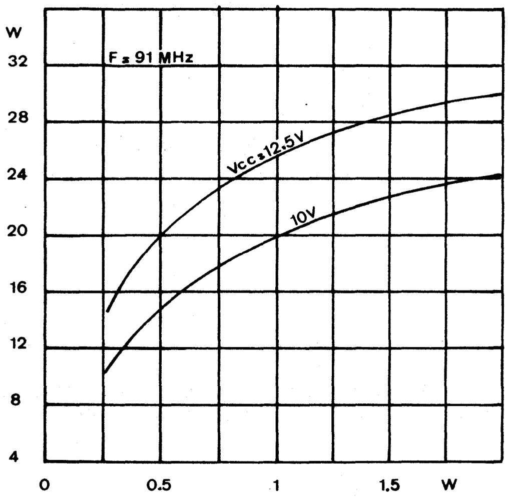
380 SOE

Electrical Characteristics (T_{case} = 25 °C)

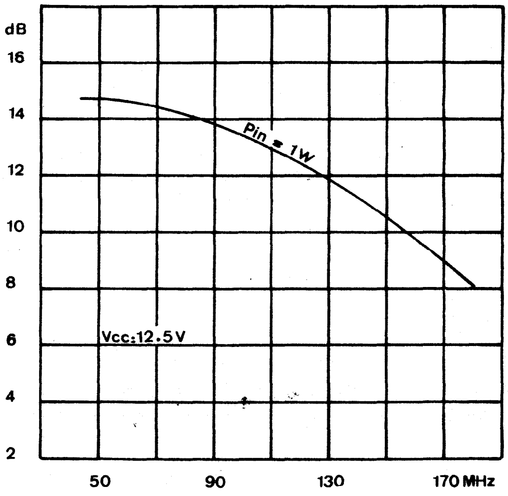
	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC Test	BV_{EBO}	Emitter - Base Breakdown Voltage	$I_E = 1$ mA $I_C = 0$	4			V
	BV_{CEO}	Collector - Emitter Breakdown Voltage	$I_C = 50$ mA $I_B = 0$	18			V
	BV_{CBO}	Collector - Base Breakdown Voltage	$I_C = 5$ mA $I_E = 0$	40			V
	I_{CBO}	Collector Cutoff Current	$V_{CB} = 15$ V $I_E = 0$			2	mA
	H_{FE}	D.C Current Gain	$V_{CE} = 10$ V $I_C = 100$ mA	15		200	—
RF Test	P_{GAIN}	Power Gain	$V_{CE} = 11$ V F = 91 MHz $P_{in} = 1.8$ W	22			W
	η	Efficiency	$V_{CE} = 11$ V F = 91 MHz $P_{out} = 22$ W	50			%
	Load VSWR	Mismatch Tolerance	All Phases Angles $V_{CE} = 11$ V F = 91 MHz $P_{out} = 22$ W		∞ : 1		
	Z_{in}	Common Emitter Amplifier Input Impedance	$V_{CE} = 11$ V F = 91 MHz $P_{in} = 1.8$ W		0.86 − j 0.44		Ω
	Z_{Load}	Common Emitter Amplifier Load Impedance	$V_{CE} = 11$ V F = 91 MHz $P_{out} = 22$ W		2.3 + j 1.18		Ω
	C_{OB}	Collector - Base Capacitance	$V_{CB} = 15$ V F = 1 MHz		80	90	pF
Operating	I_C	Continous Collector Current				4	A
	θ_{j-C}	Thermal Resistance	$T_C = 25$ °C			2.4	°C/W
	T_{STG}	Storage Temperature ano Junction Temperature		— 65°		200°	°C
	P_D	Power Dissipation	$T_C = 25$ °C			70	W

TYPICAL CHARACTERISTICS

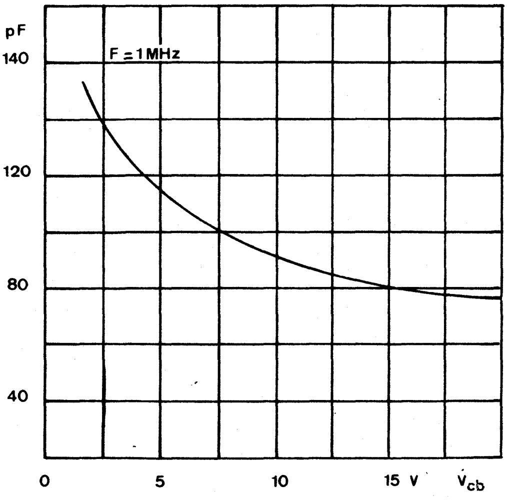
Output Power vs Input Power and Voltage Supply



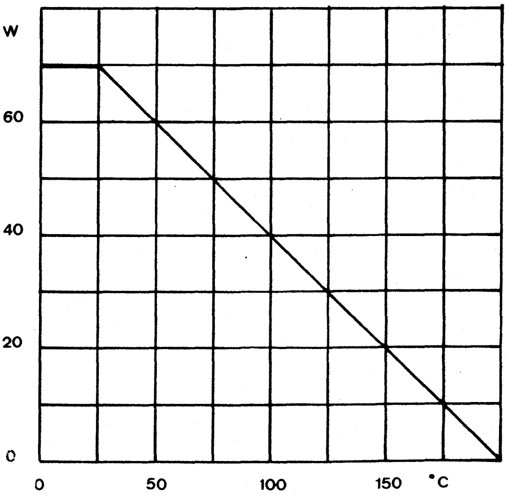
Power Gain vs Frequency



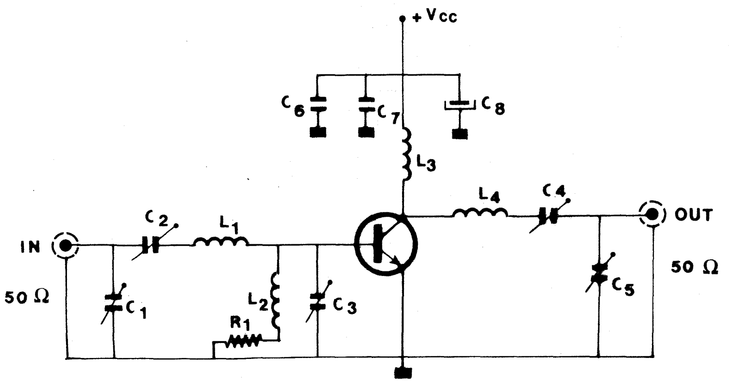
Collector Base Capacitance



Power - Temperature Derating Curve



88 MHz TEST CIRCUIT

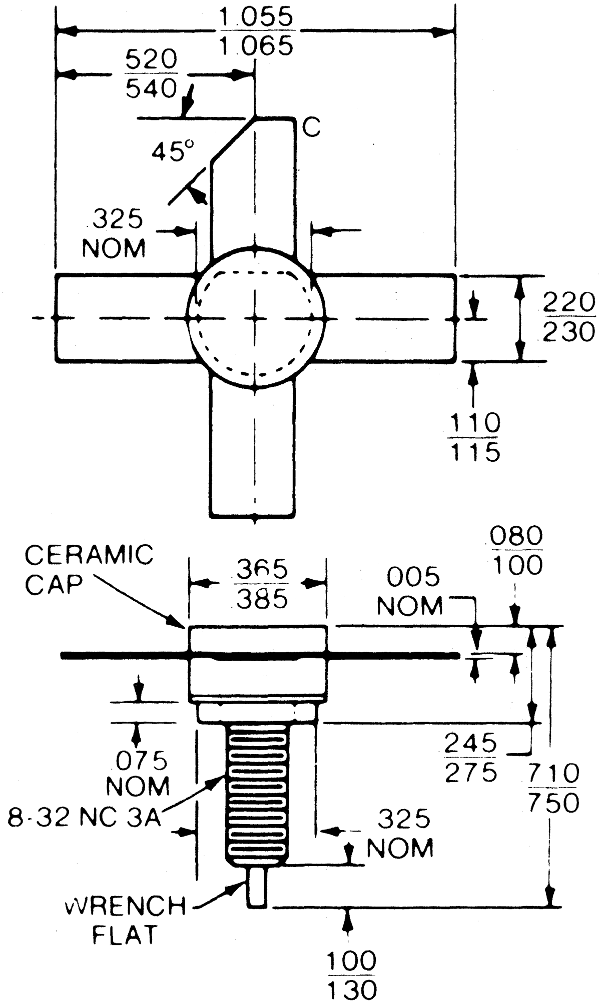


C_1 = C_4 = ARCO 425 24-200 pF trimmer capacitor
C_2 = ARCO 423 7-100 pF trimmer capacitor
C_3 = C_5 = ARCO 427 55-300 pF trimmer capacitor
C_6 = 1000 pF mica capacitor
C_7 = 10 nF ceramic
C_8 = 100 µF/35 V electrolytic

L_1 = 5 turns # 14 AWG 3/8″ I.D.
L_2 = 1 µH
L_3 = 9 turns # 16 AWG 5/16″ I.D.
L_4 = 4 turns # 14 AWG 3/3″ I.D.
R_1 = 2.4 Ω

PACKAGE OUTLINE

.380 SOE



TRW® **SEMICONDUCTORS**

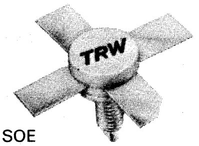
TP 1028

RF Power Transistor

5 W - 88 MHz
12.5 V

The TP 1028 as been designed for use in 12.5 V - 88 MHz amplifiers.

Its features which include high gain and capability of withstanding VSWR al all phases angles make it ideally suited for mobile radio applications.



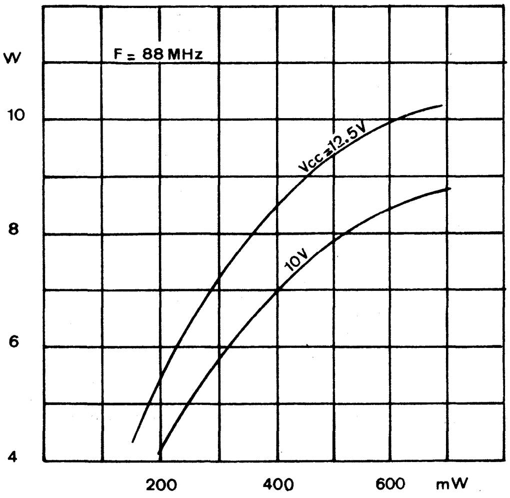
380 SOE

Electrical Characteristics (T_{case} = 25 °C)

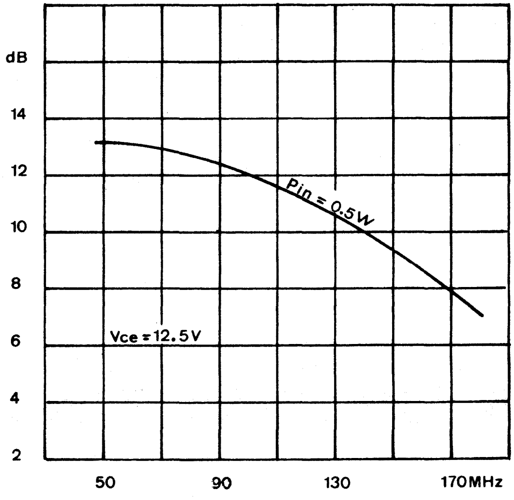
	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC Test	BV_{EBO}	Emitter - Base Breakdown Voltage	$I_E = 1$ mA $I_C = 0$	4			V
	BV_{CEO}	Collector - Emitter Breakdown Voltage	$I_C = 50$ mA $I_B = 0$	18			V
	BV_{CBO}	Collector - Base Breakdown Voltage	$I_C = 3$ mA $I_E = 0$	40			V
	I_{CBO}	Collector Cutoff Current	$V_{CB} = 15$ V $I_E = 0$			2	mA
	H_{FE}	D.C Current Gain	$V_{CE} = 10$ V $I_C = 100$ mA	15			—
RF Test	P_{GAIN}	Power Gain	$V_{CE} = 11$ V F = 91 MHz $P_{in} = 0.5$ W	5			W
	η	Efficiency	$V_{CE} = 11$ V F = 91 MHz $P_{out} = 5$ W	50			%
	Load VSWR	Mismatch Tolerance	All Phases Angles $V_{CE} = 11$ V F = 91 MHz $P_{out} = 5$ W		∞ : 1		
	Z_{in}	Common Emitter Amplifier Input Impedance	$V_{CE} = 11$ V F = 91 MHz $P_{in} = 0.5$ W		1.44 — j 0.26		Ω
	Z_{Load}	Common Emitter Amplifier Load Impedance	$V_{CE} = 11$ V F = 91 MHz $P_{out} = 5$ W		6.41 + j 6.48		Ω
	C_{OB}	Collector - Base Capacitance	$V_{CB} = 15$ V F = 1 MHz			50	pF
Operating	I_C	Continous Collector Current				2	A
	θ_{j-C}	Thermal Resistance	$T_C = 25$ °C			7	°C/W
	T_{STG}	Storage Temperature and Junction Temperature		— 65°		200°	°C
	P_D	Power Dissipation	$T_C = 25$ °C			25	W

TYPICAL CHARACTERISTICS

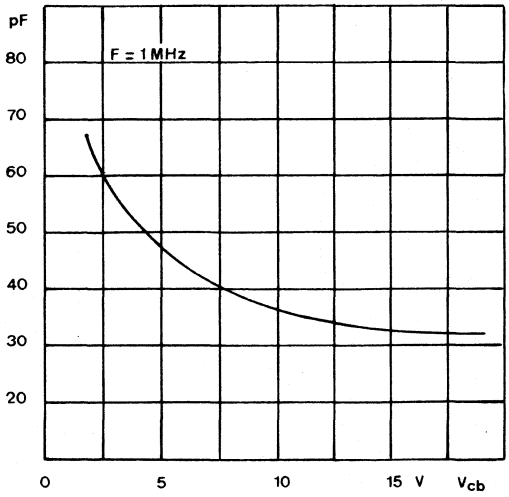
Output Power vs Input Power and Voltage Supply



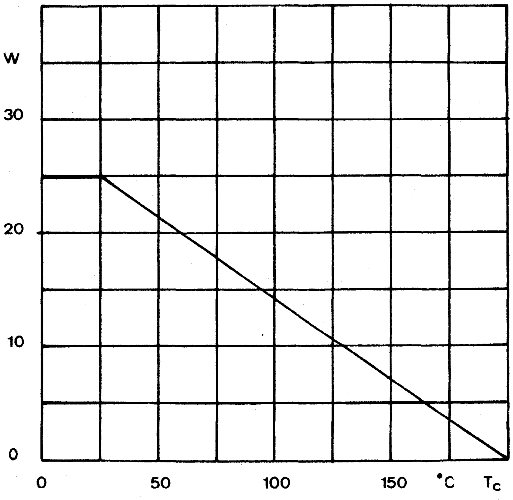
Power Gain vs Frequency



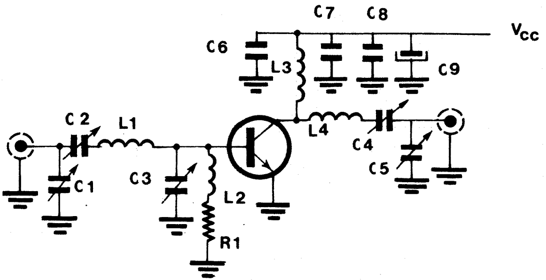
Collector Base capacitance



Power - Temperature Derating Curve



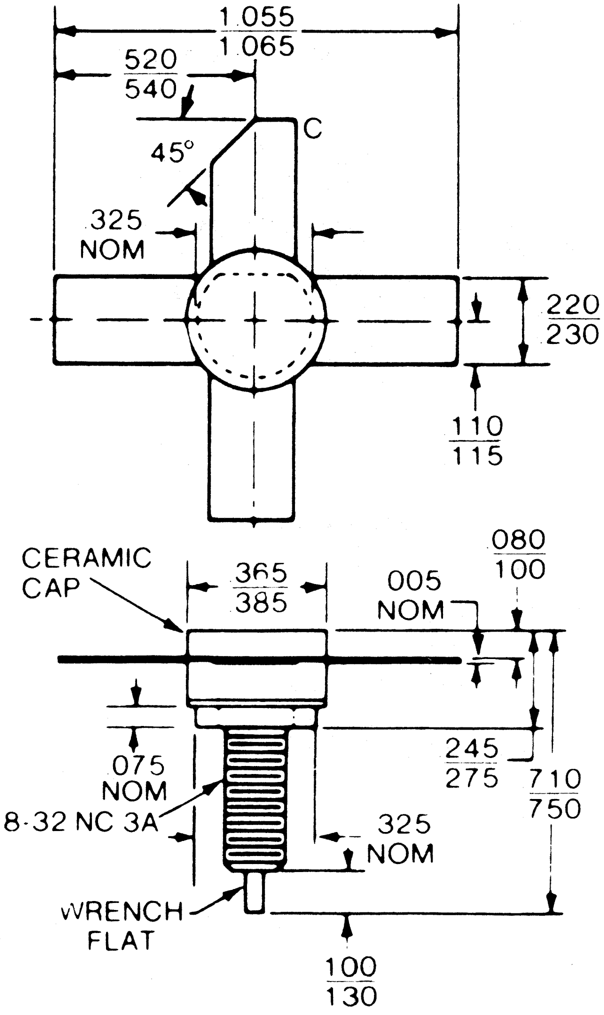
88 MHz TEST CIRCUIT



C_1-C_4	24/200 pF trimer capacitor
C_2	7/100 pF trimmer capacitor
C_3-C_5	55/300 pF trimmer capacitor
C_6	1000 pF
C_7	10000 pF
C_8	0.1 μF
C_9	100 μF/35 V
L_1	5 turns # 14 AWG 3/8″ I.D.
L_2	1 μH
L_3	9 turns # 16 AWG 5/16″ I.D.
L_4	4 turns # 14 AWG 3/8″ I.D.
R_1	2,4 Ω

PACKAGE OUTLINE

.380 SOE



TRW® **SEMICONDUCTORS**

TP 1045

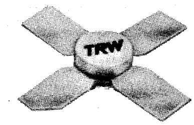
RF Power Transistor

2 W - 470 MHz
12.5 V

The TP 1045 is designed for 12.5 V VHF and UHF amplifiers.

Its high gain at reduced voltage and stripline package make it suitable for use in pocketphone applications.

The power output is useable to the top of its ratings and it is able to withstand an infinite VSWR at all phase angles at rated output power.

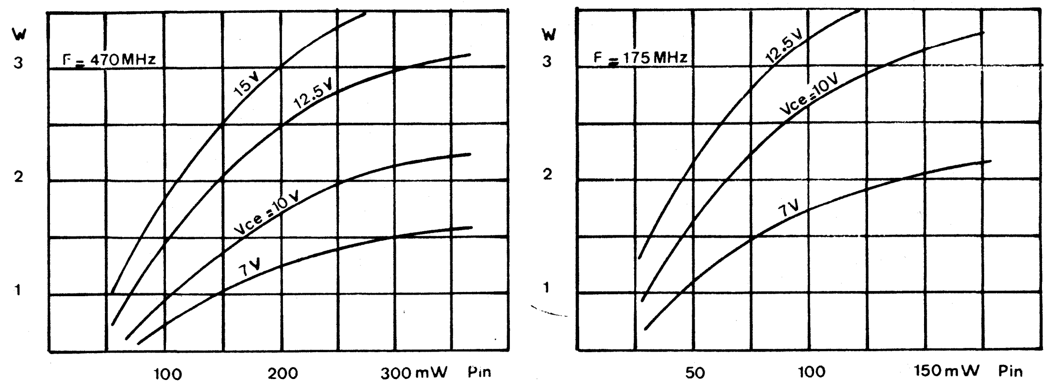


280 SOE STUDLESS

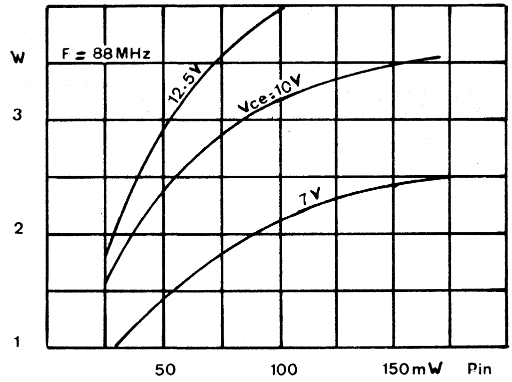
Electrical Characteristics (T_{case} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC Test	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 1 mA I_C = 0	4			V
	BV_{CEO}	Collector - Emitter Breakdown Voltage	I_C = 25 mA I_B = 0	16			V
	BV_{CBO}	Collector - Base Beakdown Voltage	I_C = 5 mA I_E = 0	36			V
	I_{CBO}	Collector Cutoff Current	V_{CB} = 15 V I_E = 0			1	mA
	H_{FE}	D.C Current Gain	V_{CE} = 5 V I_C = 100 mA	20			—
RF Test	P_{GAIN}	Power Gain	V_{CE} = 12.5 V F = 470 MHz P_{in} = 0.2 W V_{CE} = 9.5 V F = 175 MHz P_{in} = 0.1 W V_{CE} = 9.5 V F = 88 MHz P_{in} = 0.1 W	2 1.5 1.5	 2.2 2.9		W
	η	Efficiency	V_{CE} = 12.5 V F = 470 MHz P_{out} = 2 W	60			%
	Load VSWR	Mismatch Tolerance	All Phases Angles V_{CE} = 12.5 V F = 470 MHz P_{out} = 2 W		∞ : 1		
	Z_{in}	Common Emitter Amplifier Input Impedance	V_{CE} = 12.5 V F = 470 MHz P_{in} = 0.2 W		1.96 + j 2.44		Ω
	Z_{Load}	Common Emitter Amplifier Load Impedance	V_{CE} = 12.5 V F = 470 MHz P_{out} = 2 W		15.2 + j 18.2		Ω
	C_{OB}	Collector - Base Capacitance	V_{CB} = 15 V F = 1 MHz		5	8	pF
Operating	I_C	Continous Collector Current				0.75	A
	θ_{j-c}	Thermal Resistance	T_C = 25 °C			12	°C/W
	T_{STG}	Storage Temperature and Junction Temperature		— 65°		200°	°C
	P_D	Power Dissipation	T_C = 25 °C			14.5	W

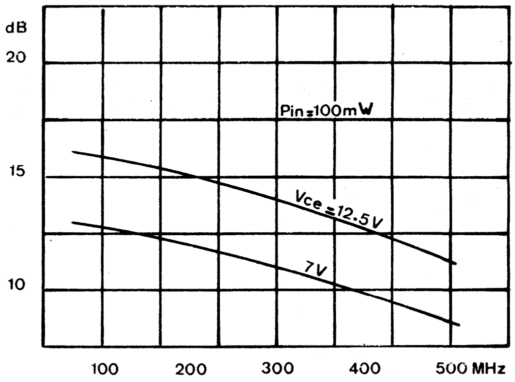
Output Power vs Input Power and Voltage Supply



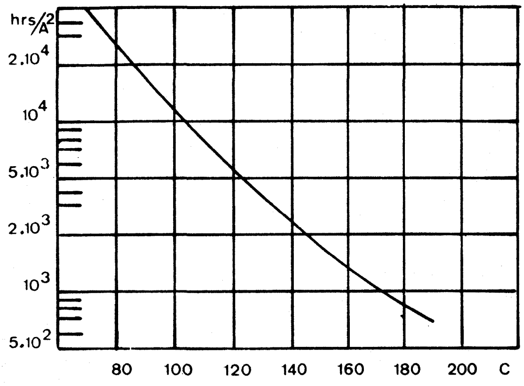
Output Power vs Input Power and Voltage Supply



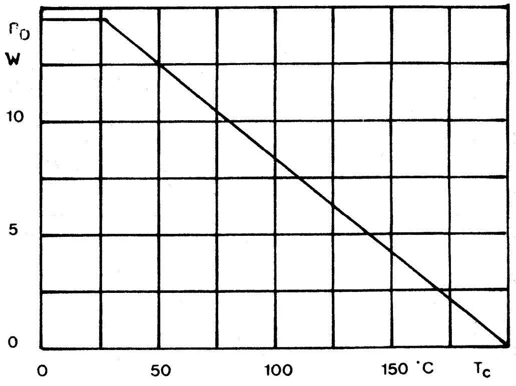
Power Gain vs Frequency and Voltage Supply



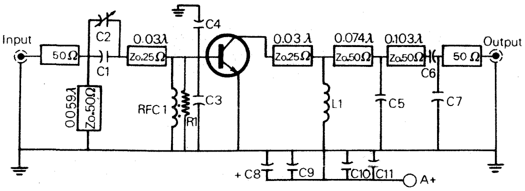
MTTF Factor vs Junction Temperature



Power - Temperature Derating Curve



TEST CIRCUIT
BROADBAND (450-510 MHz)

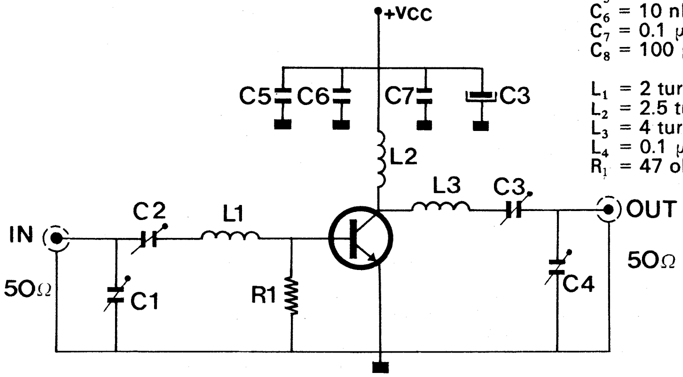


COMPONENT AND MATERIAL LIST

C_1	3.9 pF, ceramic chip
C_2, C_7	0.8-10 pF, Vol ronics AP 10, variable
C_3, C_4	27 pF, ceramic chip
C_5	15 pF, ceramic chip
C_6	470 pF, ceramic chip
C_8	5 μF, electrolytic
C_9	1000 pF, Underwood
C_{10}	0.1 μF, disc-ceramic
C_{11}	0.01 μF, disc-ceramic
L_1	2 turns # 22 enameled, 0.1" I.D.
R_1	270 Ω, ½ watt, carbon
RFC-1	2 ½ turns # 22 AWG on Ferroxcube VK211/17-4B

All transmission lines reference at 480 MHz

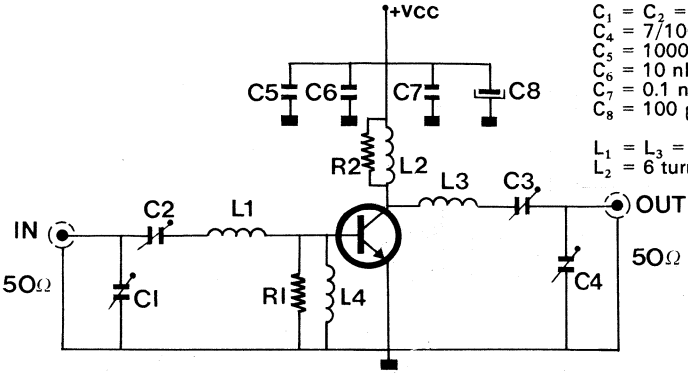
175 MHz TEST CIRCUIT



C_1 = 2-60 pF ARCO 404
C_2 = 24-200 pF ARCO 425
C_3 = 7-100 pF ARCO 425
C_4 = 4-40 pF ARCO 423
C_5 = 1000 pF UNELCO
C_6 = 10 nF ceramic disc
C_7 = 0.1 μF ceramic disc
C_8 = 100 μF/35 V electrolytic

L_1 = 2 turns - 8/10 mm wire - 4 mm I.D.
L_2 = 2.5 turns - 8/10 mm wire on ferrite core
L_3 = 4 turns - 8/10 mm wire - 4 mm I.D.
L_4 = 0.1 μH Molded Coil
R_1 = 47 ohms - 1/2 W carbon

88 MHz TEST CIRCUIT

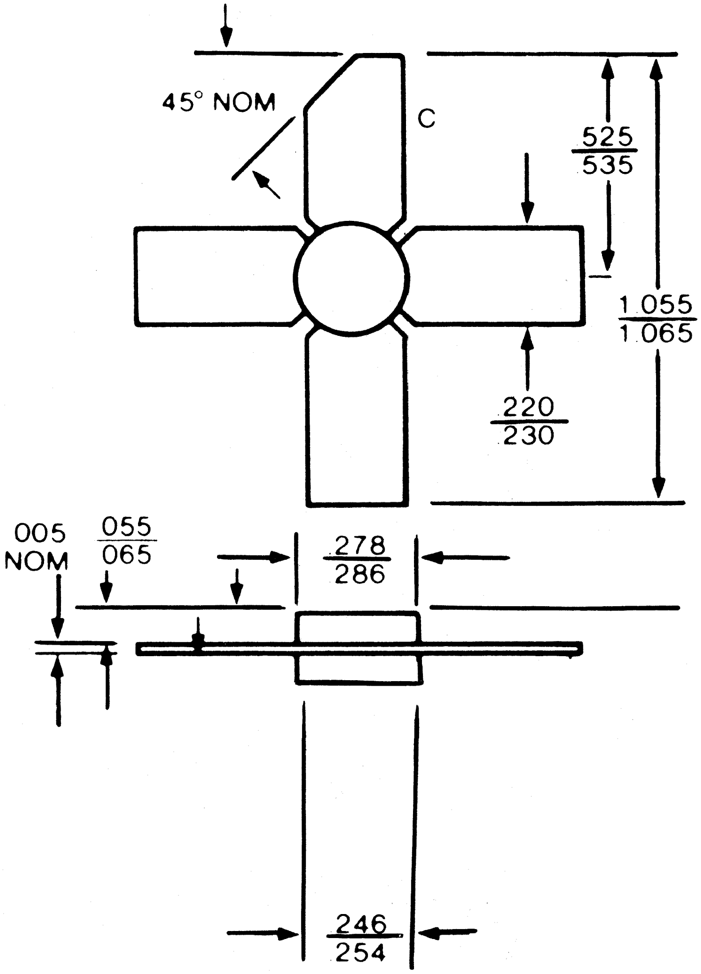


C_1 = C_2 = C_3 = 24/200 pF ARCO 425
C_4 = 7/100 pF ARCO 423
C_5 = 1000 pF UNELCO
C_6 = 10 nF ceramic disc
C_7 = 0.1 nF ceramic disc
C_8 = 100 μF/35 V electrolytic

L_1 = L_3 = 4 turns 14 AWG - 1/2" I.D.
L_2 = 6 turns - 14 AWG - 1/2" I.D. close wound

PACKAGE OUTLINE

280 SOE STUDLESS



TRW® SEMICONDUCTORS

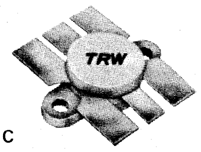
TP 2180

RF Power Transistor

80 W - 12.5 V
88 MHz

The TP 2180 is designed for use in 12.5 V VHF amplifiers operating under class A, B or C conditions.

Its construction which incorporates gold metalization and diffused ballast resistors for longer life, enables the part to be used at its maximum ratings and be able to withstand an infinite VSWR at all phase angles.



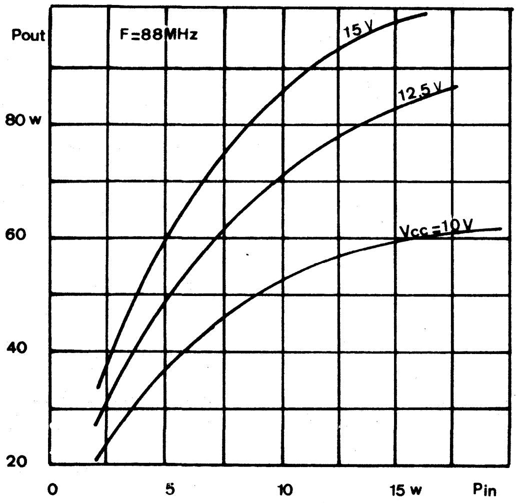
J zéro C

Electrical Characteristics (T_{case} = 25 °C)

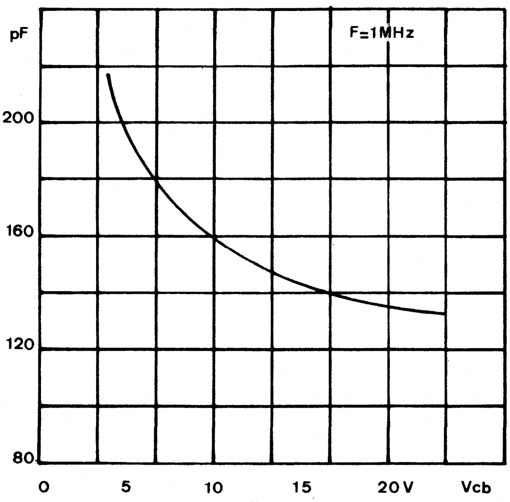
	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC Test	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 10 mA I_C = 0	4			V
	BV_{CEO}	Collector - Emitter Breakdown Voltage	I_C = 200 mA I_B = 0	18			V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 100 mA I_E = 0	40			V
	I_{CBO}	Collector Cutoff Current	V_{CB} = 20 V I_E = 0			5	mA
	H_{FE}	D.C Current Gain	V_{CE} = 5 V I_C = 1000 mA	10			—
RF Test	P_{GAIN}	Power Gain	V_{CE} = 12.5 V F = 88 MHz P_{in} = 16 W	80			W
	η	Efficiency	V_{CE} = 12.5 V F = 88 MHz P_{out} = 80 W	60	70		%
	Load VSWR	Mismatch Tolerance	All Phases Angles V_{CE} = 12.5 V F = 88 MHz P_{out} = 8 0W		∞ : 1		
	Z_{in}	Common Emitter Amplifier Input Impedance	V_{CE} = 12.5 V F = 88 MHz P_{in} = 16 W		0.3 — j 0.4		Ω
	Z_{Load}	Common Emitter Amplifier Load Impedance	V_{CE} = 12.5 V F = 88 MHz P_{out} = 80 W		0.6 + j 0.44		Ω
	C_{OB}	Collector - Base Capacitance	V_{CB} = 20 V F = 1 MHz			180	pF
Operating	I_C	Continous Collector Current				16	A
	θ_{j-c}	Thermal Resistance	T_C = 25 °C			1.25	°C/W
	T_{STG}	Storage Temperature and Junction Temperature		— 65°		200°	°C
	P_D	Power Dissipation	T_C = 25 °C			140	W

TYPICAL CHARACTERISTICS

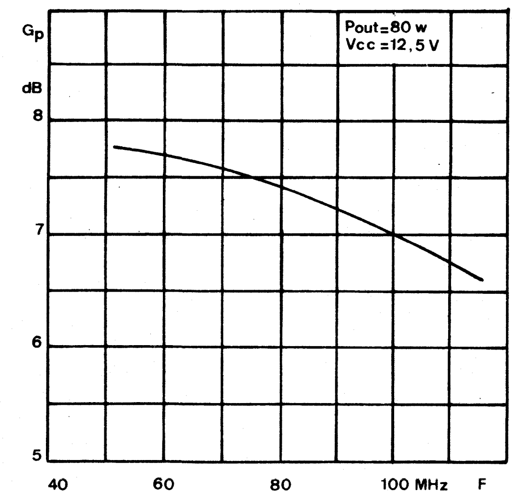
Output power vs input power and voltage supply



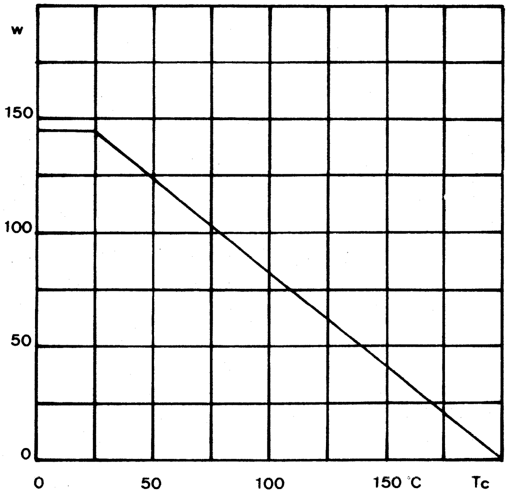
Collector base capacitance



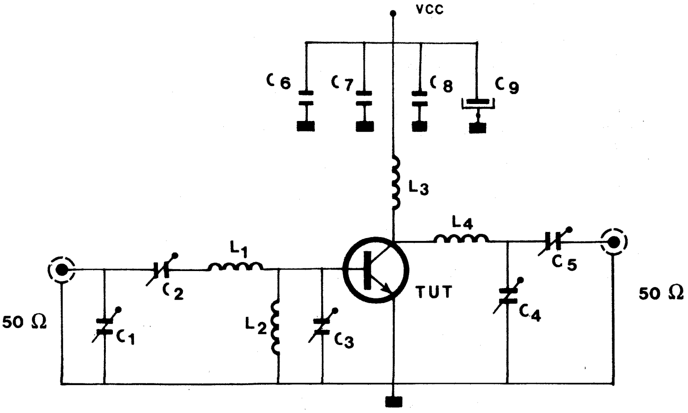
Power gain vs frequency



Power - Temperature operating curve



88 MHz TEST CIRCUIT

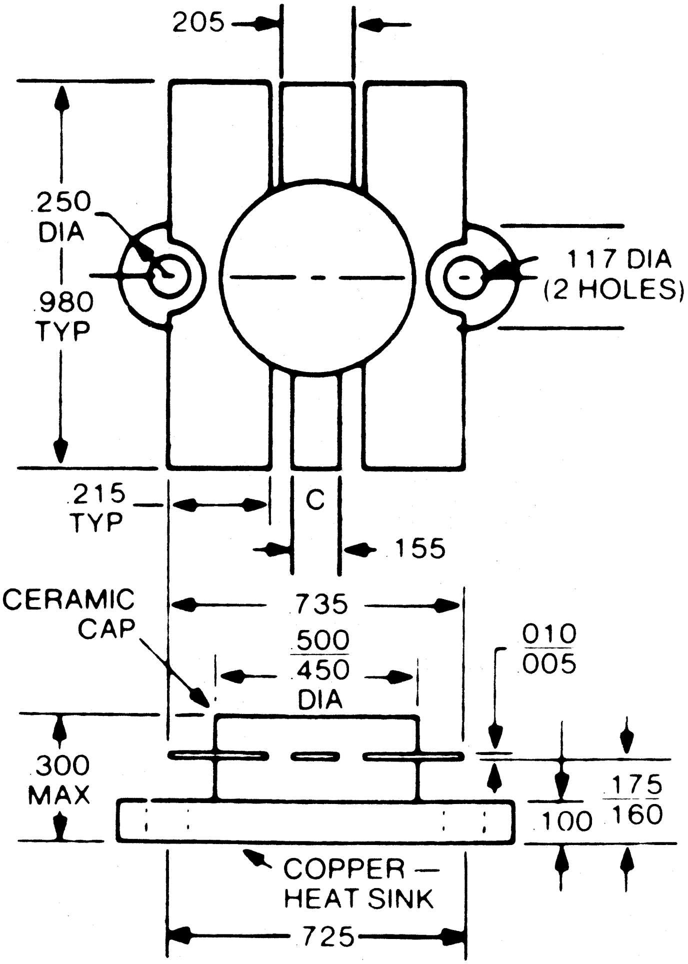


C_1 = C_4 = 24-200 pF trimmer capacitor ARCO 425
C_2 = C_3 = 55-300 pF trimmer capacitor ARCO 427
C_5 = 7-100 pF trimmer capacitor ARCO 423
C_6 = 1000 pF mica capacitor UNELCO
C_7 = 10 nF ceramic disc
C_8 = 0.1 µF ceramic disc
C_9 = 470 µF/40 V

L_1 = 3 turns - 12/10 mm silvered wire - 5 mm I.D.
L_2 = 0.68 µH molded coil
L_3 = 5 turns - 12/10 mm silvered wire - 12 mm I.D.
L_4 = 1 turn - 12/10 mm silvered wire - 6 mm I.D.

PACKAGE OUTLINE

J-Zero-C



TRW® **SEMICONDUCTORS**

TP 2301
TP 2302
TP 2303

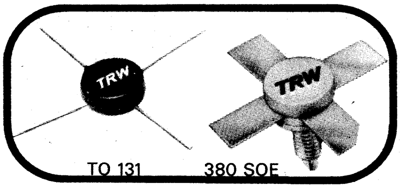
RF Power Transistors

3 W 10 W 30 W

175 MHz - 12.5 V

The TP 2301... series is intented for use in 12.5 volts VHF amplifier applications.

These low cost rugged devices have an excellent performance and can achieve in excess of 30 W with as little as 100 mW drive power.

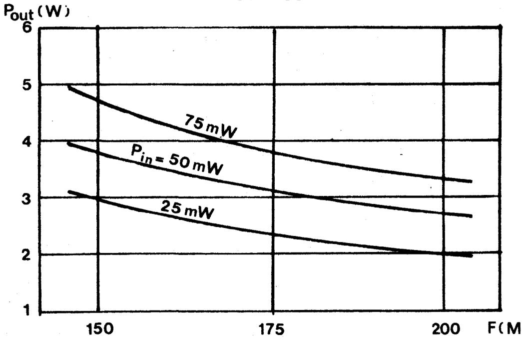


Electrical Characteristics (T_{case} = 25 °C)

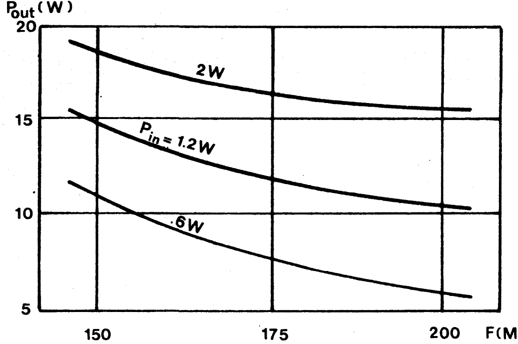
	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	TP 2301	TP 2302	TP 2303	UNIT
DC Test	BV_{EBO}	Min. Emitter - Base Breakdown Voltage	I_E = 1 mA I_C = 0 I_E = 5 mA I_C = 0	4	4	4	V
	BV_{CEO}	Min. Collector - Emitter Breakdown Voltage	I_C = 40 mA I_B = 0 I_C = 50 mA I_B = 0	18	18	18	V
	BV_{CBO}	Min. Collector - Base Breakdown Voltage	I_C = 10 mA I_E = 0 I_C = 20 mA I_E = 0 I_C = 50 mA I_E = 0	40	40	40	V
	I_{CBO}	Max. Collector Cutoff Current	V_{CB} = 15 V I_E = 0	1	1	2	mA
	H_{FE}	Min. D.C Current Gain	V_{CE} = 10 V I_C = 50 mA V_{CE} = 5 V I_C = 500 mA V_{CE} = 5 V I_C = 500 mA	15	20	15	—
RF Test	P_{GAIN}	Min. Power Gain	V_{CE} = 12.5 V P_{in} = 0.1 W P_{in} = 1.2 W F = 175 MHz P_{in} = 7.5 W	3	10	30	W
	η	Min. Efficiency	V_{CE} = 12.5 V P_{out} = 3 W P_{out} = 10 W F = 175 MHz P_{out} = 30 W	60	60	60	%
	Z_{in}	Common Emitter Amplifier Typ Input Impedance	V_{CE} = 12.5 V P_{in} = 0.1 W F = 175 MHz P_{in} = 1.2 W P_{in} = 7.5 W	2.7 — j 5	1.27 + j 0.96	1.18 + j 1	Ω
	Z_{LOAD}	Common Emitter Amplifier Typ Load Impedance	V_{CE} = 12.5 V P_{out} = 3 W P_{out} = 10 W F = 175 MHz P_{out} = 30 W	16.1 + j17	5.74 + j 1.38	2.7 + j 0.48	Ω
	C_{OB}	Max Collector - Base Capacitance	V_{CB} = 15 V F = 1 MHz I_E = 0	8.5	40	80	pF
Operating	I_C	Continous Collector Current		1	3	7	A
	θ_{j-C}	Thermal Resistance	T_C = 25 °C	22	5	2.5	°C/W
	T_{STG}	Storage Temperature and Junction Temperature		— 65 °C to + 200 °C			°C
	P_D	Power Dissipation	T_C = 25 °C	8	30	70	W

Output Power vs Frequency (V_{CC} = 12.5 V)

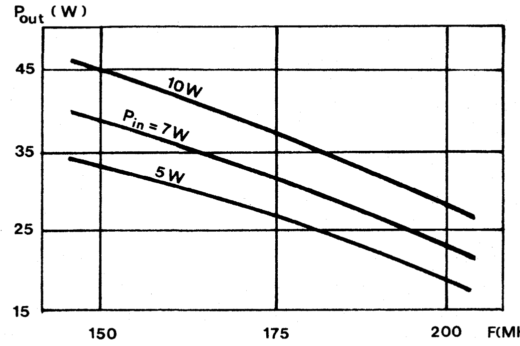
TP 2301



TP 2302

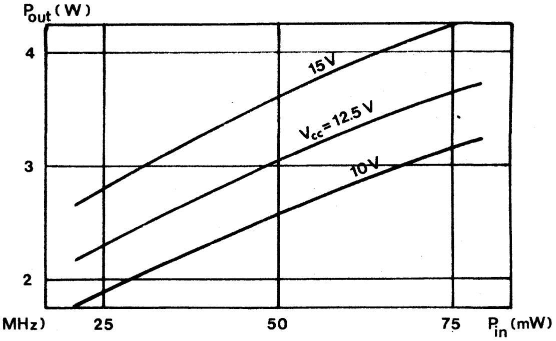


TP 2303

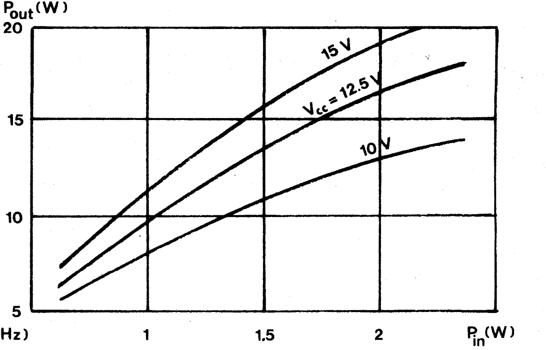


Output Power vs Input Power (F = 175 MHz)

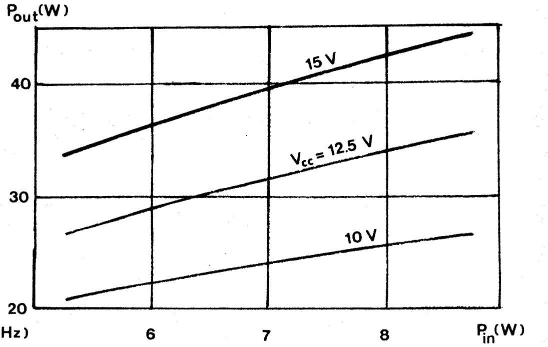
TP 2301



TP 2302

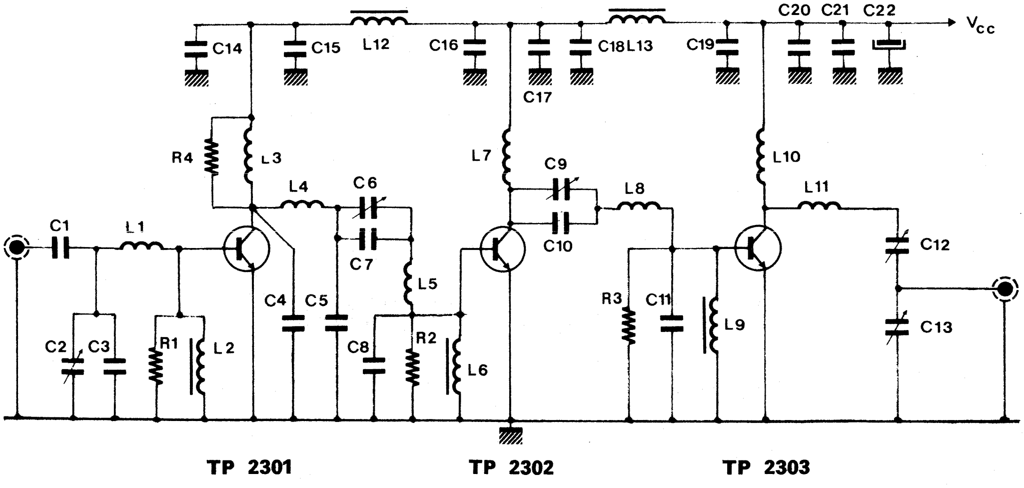


TP 2303



NOTA : Typical Characteristics

TYPICAL APPLICATION : 100 mW - 25 W, 12.5 V, 175 MHz Amplifier



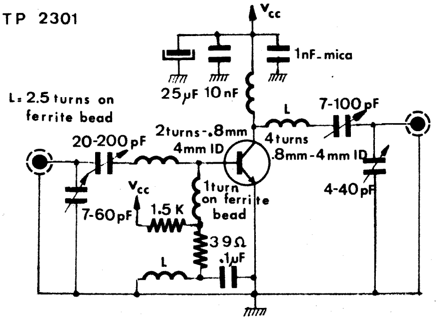
C_1	15 pF ceramic capacitor
$C_{2,6,9}$	2-18 pF trimmer capacitor
C_3	20 pF ceramic capacitor
C_4	10 pF ceramic capacitor
C_5	100 pF ceramic capacitor
C_7	22 pF ceramic capacitor
$C_{8,11}$	150 pF ceramic capacitor
C_{10}	33 pF ceramic capacitor
$C_{12,13}$	4-100 pF trimmer capacitor

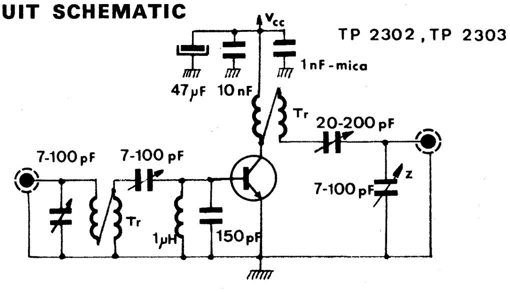
$C_{14,16,19}$	1000 pF ceramic capacitor
$C_{15,17,20}$	10000 pF ceramic capacitor
$C_{18,21}$	4700 pF ceramic capacitor
C_{22}	22 μF - 25 V
R_1	10 ohms 1/4 W
R_2	15 ohms 1/4 W
R_3	22 ohms 1 W
R_4	200 ohms 1/4 W

L_1	3 turns - 3 mm I.D. - 6/10 mm enamelled copper wire
$L_{2,9,13}$	0.1 μH molded inductance
L_3	0.39 μH molded inductance
$L_{4,8}$	2 turns - 3 mm I.D. - 6/10 mm enamelled copper wire
L_5	4 turns - 3 mm I.D. - 6/10 mm enamelled copper wire

L_6	0.15 μH molded inductance
L_7	4 turns - 6 mm I.D. - 8/10 mm enamelled copper wire
L_{10}	2 turns - 6 mm I.D. - 8/10 mm enamelled copper wire
L_{11}	1 turn - 8 mm I.D. - 8/10 mm enamelled copper wire
L_{12}	0.47 μH molded inductance

175 MHz TEST CIRCUIT SCHEMATIC

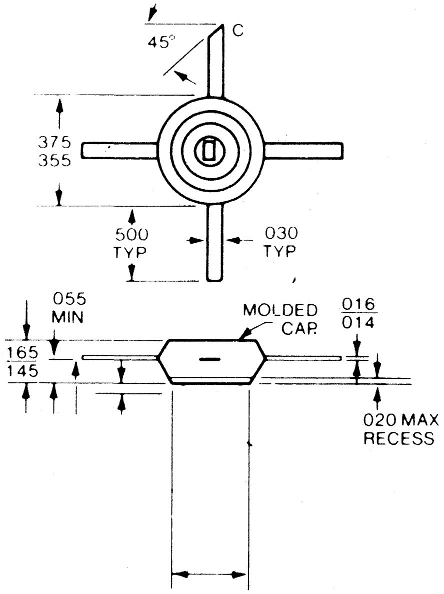




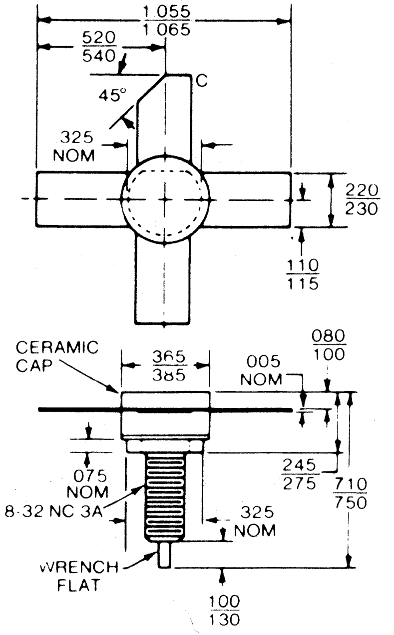
Tr = Twisted wires transformer - 2wires - .8mm - 5cm long

PACKAGE OUTLINE

TO-131



.380 SOE



TRW® SEMICONDUCTORS

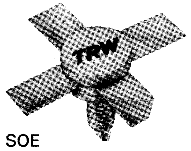
TP 2304

RF Power Transistor

40 W - 175 MHz
12.5 V

The TP 2304 is designed for use in 12.5 V VHF amplifiers operating under class A, B or C conditions.

Its construction which incorporates gold metalization and diffused ballast resistors for longer life, enables the part to be used at its maximum ratings and be able to withstand an infinite VSWR at all phase angles.



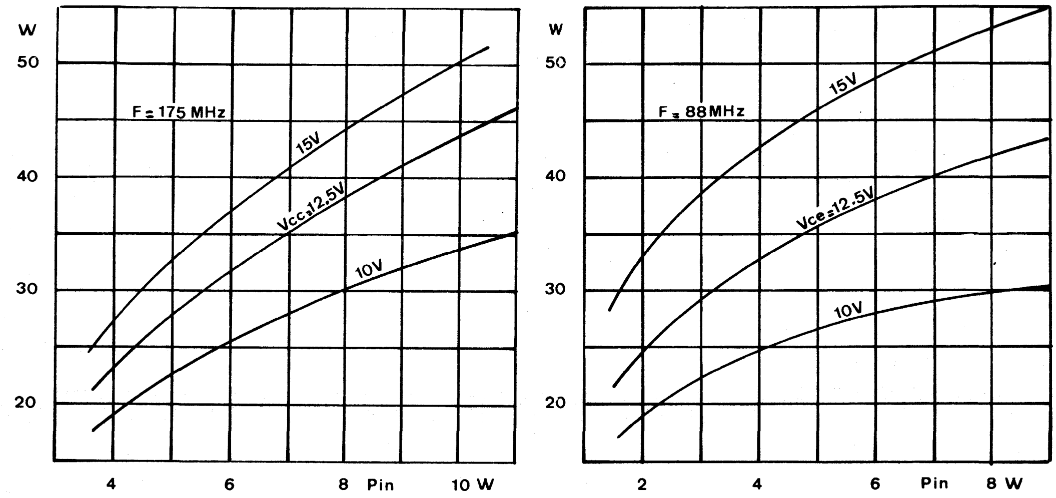
380 SOE

Electrical Characteristics (T_{flange} = 25 °C)

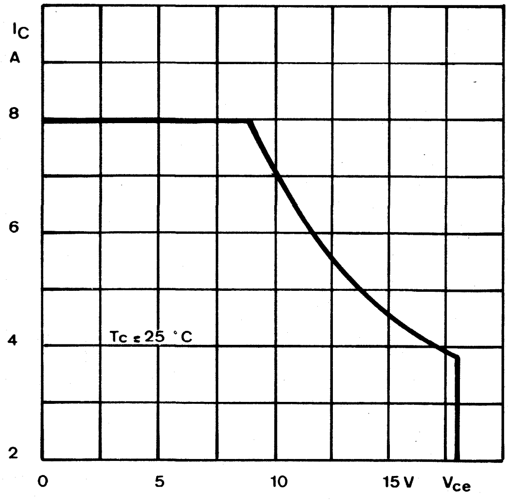
	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC Test	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 5 mA I_C = 0	4			V
	BV_{CEO}	Collector - Emitter Breakdown Voltage	I_C = 50 mA I_B = 0	18			V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 50 mA I_E = 0	40			V
	I_{CBO}	Collector Cutoff Current	V_{CB} = 15 V I_E = 0			2	mA
	H_{FE}	D.C Current Gain	V_{CE} = 5 V I_C = 1000 mA	10			—
RF Test	P_{GAIN}	Power Gain	V_{CE} = 12.5 V F = 175 MHz P_{in} = 12 W V_{CE} = 12.5 V F = 88 MHz P_{in} = 8 W	40 40			W
	η	Efficiency	V_{CE} = 12.5 V F = 175 MHz P_{out} = 40 W	60			%
	Load VSWR	Mismatch Tolerance	All Phases Angles V_{CE} = 12.5 V F = 175 MHz P_{out} = 40 W		∞ : 1		
	Z_{in}	Common Emitter Amplifier Input Impedance	V_{CE} = 12.5 V F = 175 MHz P_{in} = 10 W		1.5 + j 1.6		Ω
	Z_{Load}	Common Emitter Amplifier Load Impedance	V_{CE} = 12.5 V F = 175 MHz P_{out} = 40 W		2.25+j0.1		Ω
	C_{OB}	Collector - Base Capacitance	V_{CB} = 20 V F = 1 MHz		70	100	pF
Operating	I_C	Continous Collector Current				8	A
	θ_{j-C}	Thermal Resistance	T_C = 25 °C			2.2	°C/W
	T_{STG}	Storage Temperature and Junction Temperature		— 65°		200°	°C
	P_D	Power Dissipation	T_C = 25 °C			80	W

TYPICAL CHARACTERISTICS

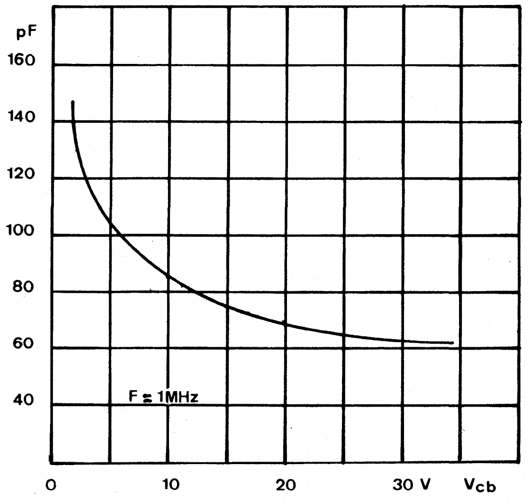
Output Power vs Input Power and Voltage Supply



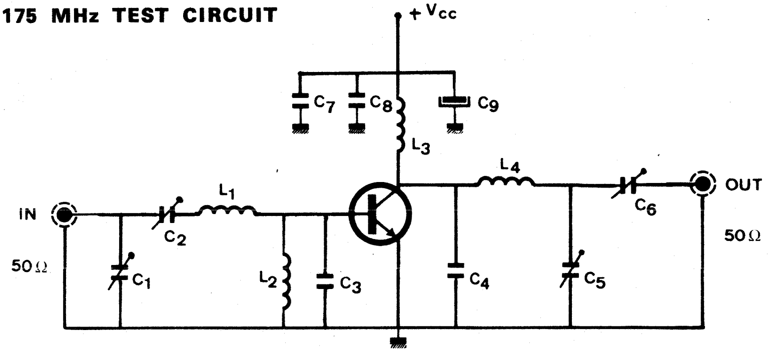
Safe Operating Area



Collector Base Capacitance



175 MHz TEST CIRCUIT



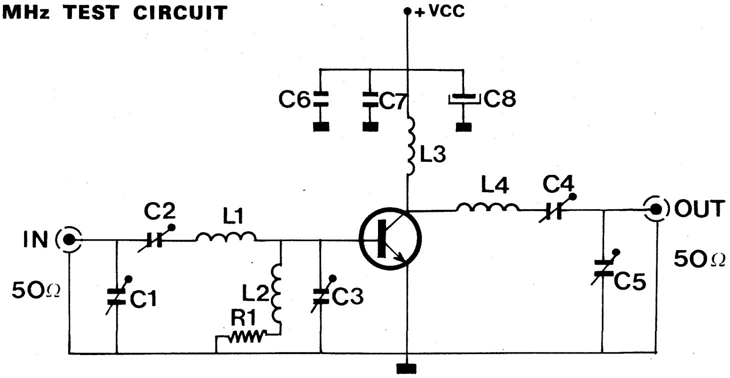
C_1 = ARCO 403 trimmer capacitor
C_2 = C_5 = ARCO 423 trimmer capacitor
C_3 = 200 pF mica capacitor UNELCO
C_4 = 150 pF mica capacitor UNELCO
C_6 = ARCO 425 trimmer capacitor
C_7 = 1000 pF mica capacitor UNELCO
C_8 = 0.1 μF ceramic disc
C_9 = 47 μF/63 V electrolytic

L_1 = 3 turns 15/10 mm silvered wire 6 mm I.D.
L_2 = 0.47 μH molded coil
L_3 = 6 turns 10/10 mm enameled wire wound on R_1

L_4 = 1 turns 15/10 mm silvered wire 6 mm I.D.

R_1 = 380 ohms 2 W carbon composition

88 MHz TEST CIRCUIT

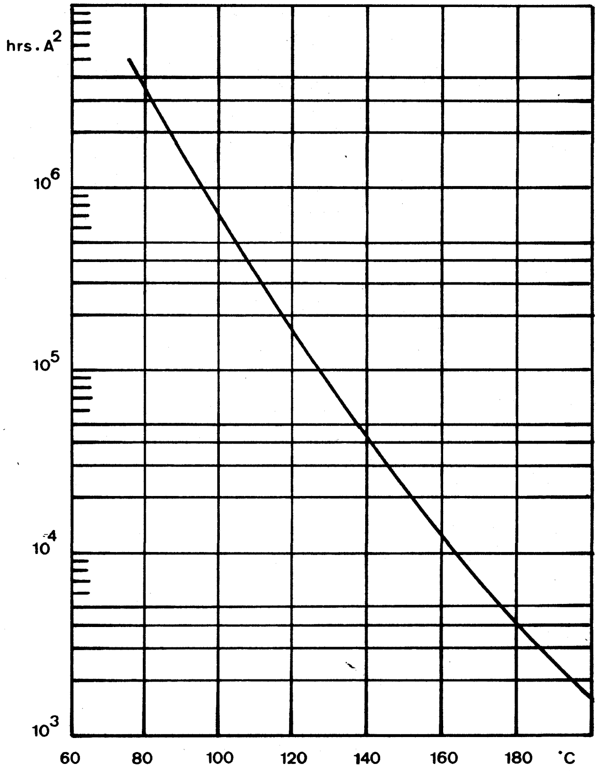


C_1 = C_4 = ARCO 425 24-200 pF trimmer capacitor
C_2 = ARCO 423 7-100 pF trimmer capacitor
C_3 = C_5 = ARCO 427 55-300 pF trimmer capacitor
C_6 = 1000 pF mica capacitor
C_7 = 10 nF ceramic
C_8 = 100 μF/35 V electrolytic

L_1 = 5 turns # 14 AWG 3/8″ I.D.
L_2 = 1 μH
L_3 = 9 turns # 16 AWG 5/16″ I.D.
L_4 = 4 turns # 14 AWG 3/8″ I.D.

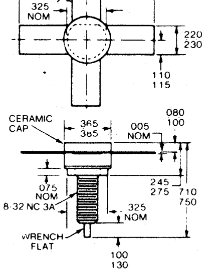
R_1 = 2.4 Ω

MTTF Factor vs Junction Temperature



PACKAGE OUTLINE

.380 SOE



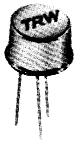
TRW® SEMICONDUCTORS

TP 2310

RF Power Transistor

2.5 W - 175 MHz
12.5 V

The TP 2310 is designed for use in 12.5 V VHF applications and is ideally suited for use in the predriver or driver stage of a power amplifier where high gain is required.



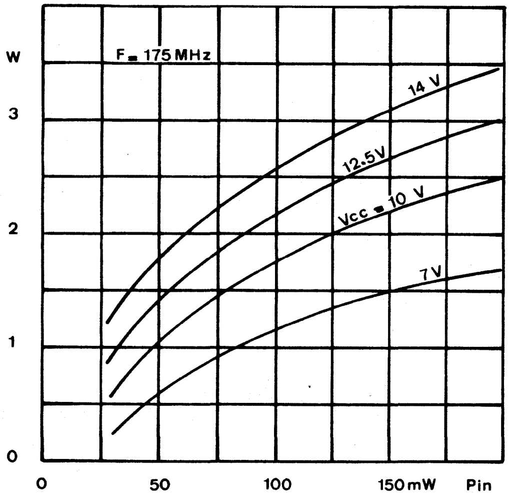
TO 39

Electrical Characteristics (T_{case} = 25 °C)

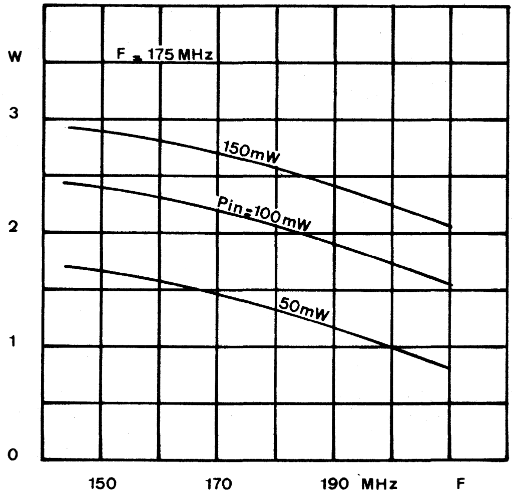
	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC Test	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 1 mA I_C = 0	4			V
	BV_{CEO}	Collector - Emitter Breakdown Voltage	I_C = 25 mA I_B = 0	16			V
	BV_{CBO}	Collector - Base Breakdwon Voltage	I_C = 5 mA I_E = 0	35			V
	I_{CBO}	Collector Cutoff Current	V_{CB} = 15 V I_E = 0			1	mA
	H_{FE}	D.C Current Gain	V_{CE} = 5 V I_C = 100 mA	20			—
RF Test	P_{GAIN}	Power Gain	V_{CE} = 12.5 V F = 175 MHz P_{in} = 150 mW	2.5			W
	η	Efficiency	V_{CE} = 12.5 V F = 175 MHz P_{out} = 25 W				%
	Z_{in}	Common Emitter Amplifier Input Impedance	V_{CE} = 12.5 V F = 175 MHz P_{in} = 150 mW		1.41 —j 10.62		Ω
	Z_{Load}	Common Emitter Amplifier Loac Impedance	V_{CE} = 12.5 V F = 175 MHz P_{out} = 2.5 W		38.3 + j 28.8		Ω
	C_{OB}	Collector - Base Capacitance	V_{CB} = 15 V F = 1 MHz		5	7	pF
Operating	I_C	Continous Collector Current				0.7	A
	θ_{j-c}	Thermal Resistance	T_C = 25 °C			23.5	°C/W
	T_{STG}	Storage Temperature and Junction Temperature		— 65°		200°	°C
	P_D	Power Dissipation	T_C = 25 °C			7.5	W

TYPICAL CHARACTERISTICS

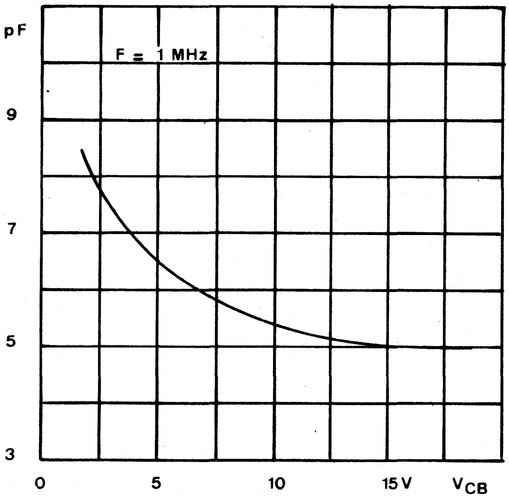
Output Power vs Input Power and Voltage Supply



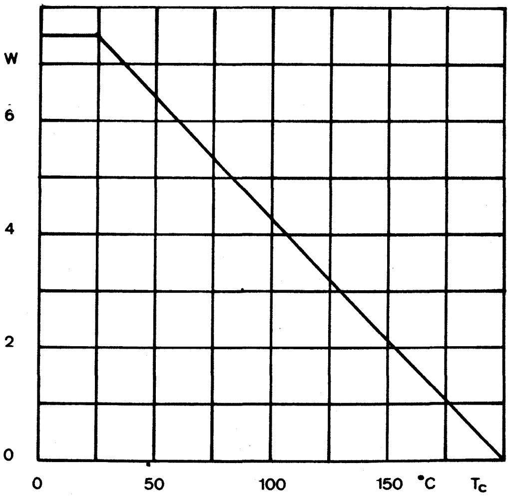
Output Power vs Frequency and Input Power



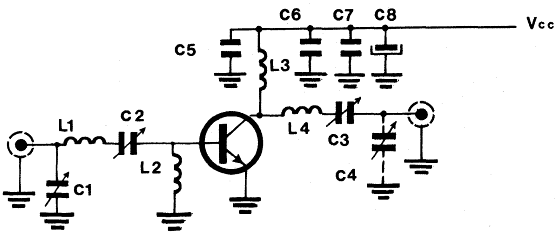
Collector Base Capacitance



Power - Temperature Derating Curve



POWER GAIN TEST CIRCUIT

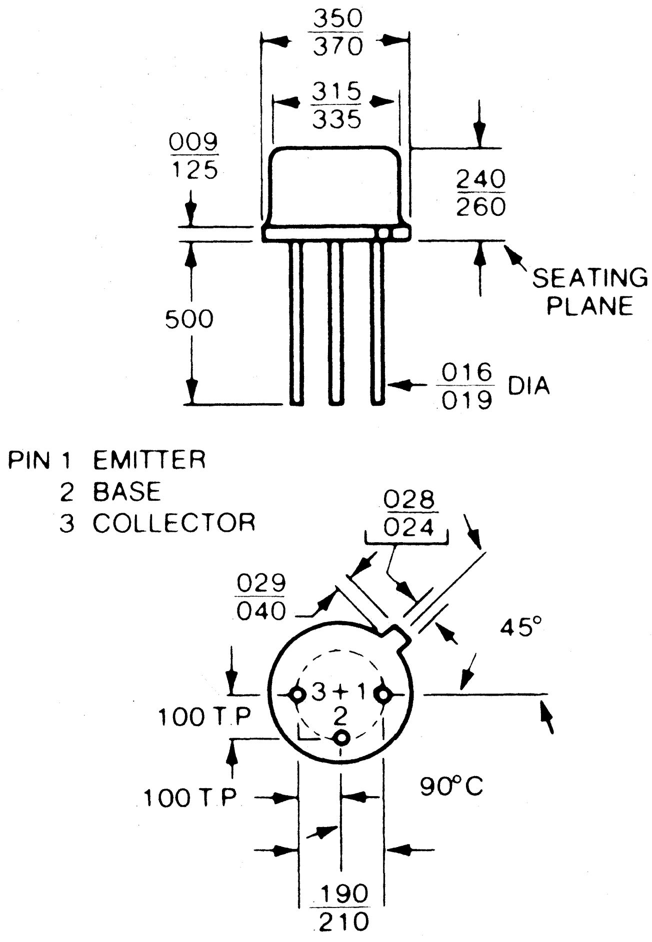


COMPONENTS

C_1-C_2-C_3	24/200 pF ≠ trimmer capacitor
C_4	7/100 pF trimmer capacitor
C_5	1000 pF
C_6	10000 pF
C_7	0.1 μF
C_8	100 μF/35 V
L_1-L_4	4 turns ≠ 14 AWG 1/2″ I.D.
L_2	0.47 μH
L_3	6 turns 14 AWG 1/2″ I.D. close wound

PACKAGE OUTLINE

TO-39



TRW® SEMICONDUCTORS **TP 2312**

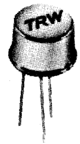
RF Power Transistor

3 W - 175 MHz
12.5 V

The TP 2312 is designed for 6 V to 12 V VHF applications and is intended for class A, B or C medium power amplifiers, frequency multioliers or oscillator circuits.

Its grounded emitter construction gives excellent thermal dissipation and the ability of providing further heatsinking where necessary the case also acts as a good RF screen.

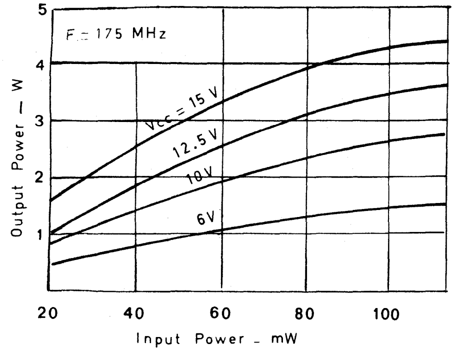
This device features high gain and an infinite VSWR rating at all phase angles at rated power output.

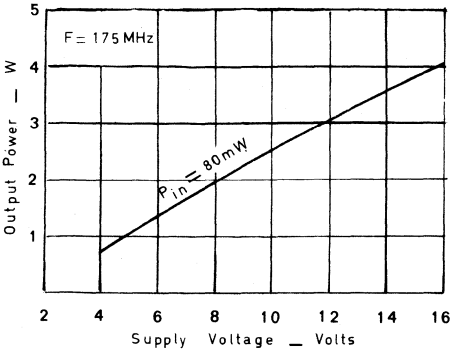


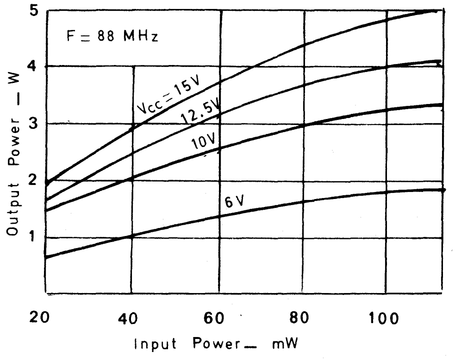
TO 39 GE

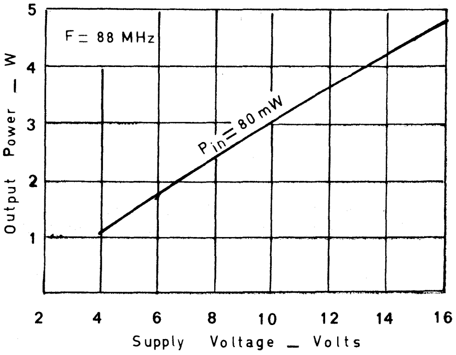
Electrical Characteristics (T_{case} = 25 °C)

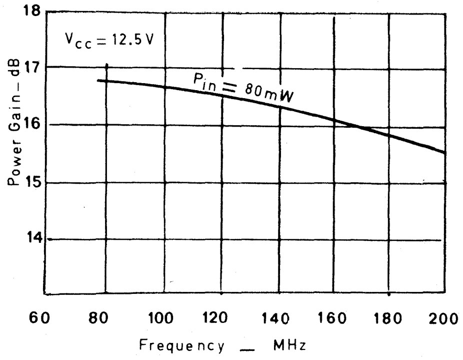
	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC Test	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 1 mA I_C = 0	4			V
	BV_{CEO}	Collector - Emitter Breakdown Voltage	I_C = 25 mA I_B = 0	16			V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 5 mA I_E = 0	35			V
	I_{CBO}	Collector Cutoff Current	V_{CB} = 15 V I_E = 0			1	mA
	H_{FE}	D.C Current Gain	V_{CE} = 5 V I_C = 100 mA	20	70		—
RF Test	P_{GAIN}	Power Gain	V_{CE} = 12.5 V F = 175 MHz P_{in} = 80 mW V_{CE} = 6 V F = 175 MHz P_{in} = 80 mW V_{CE} = 12.5 V F = 88 MHz P_{in} = 80 mW	2.75 1 3	3 1.3 3.5		W
	η	Efficiency	V_{CE} = 12.5 V F = 175 MHz P_{out} = 3 W	60	68		%
	Load VSWR	Mismatch Tolerance	All Phase Angles V_{CE} = 12.5 V F = 175 MHz P_{out} = 2.75 W		∞ : 1		
	Z_{in}	Common Emitter Amplifier Input Impedance	V_{CE} = 12.5 V F = 175 MHz P_{in} = 80 mW F = 88 MHz		2.9 + j 4.36 2.94 — j 7.67		Ω
	Z_{Load}	Common Emitter Amplifier Load Impedance	V_{CE} = 12.5 V F = 175 MHz P_{out} = 3 W F = 88 MHz		25.1 + j 10.2 29 + j 18.4		Ω
	C_{OB}	Collector - Base Capacitance	V_{CB} = 20 V F = 1 MHz		5.5	7	pF
Operating	I_C	Continous Collector Current				0.7	A
	θ_{j-C}	Thermal Resistance	T_C = 25 °C			25	°C/W
	T_{STG}	Storage Temperature and Junction Temperature	—	— 65°		200°	°C
	P_D	Power Dissipation	T_C = 25 °C			7	W

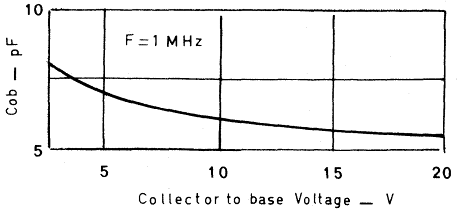


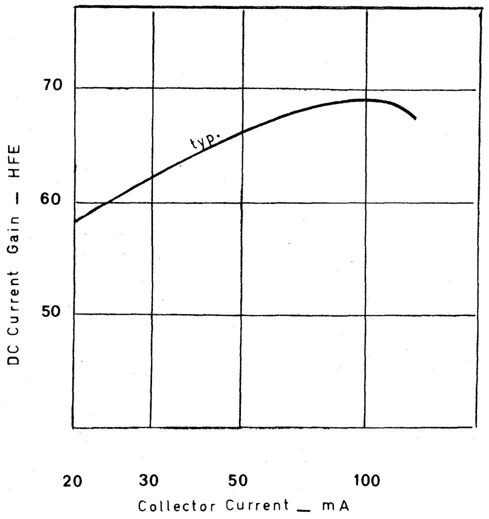






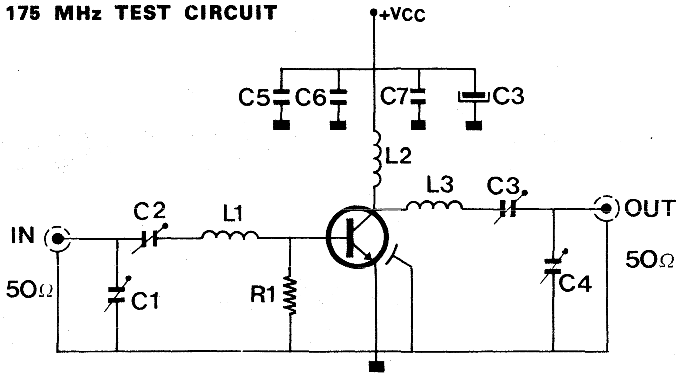






NOTA : TYPICAL CHARACTERISTICS

175 MHz TEST CIRCUIT



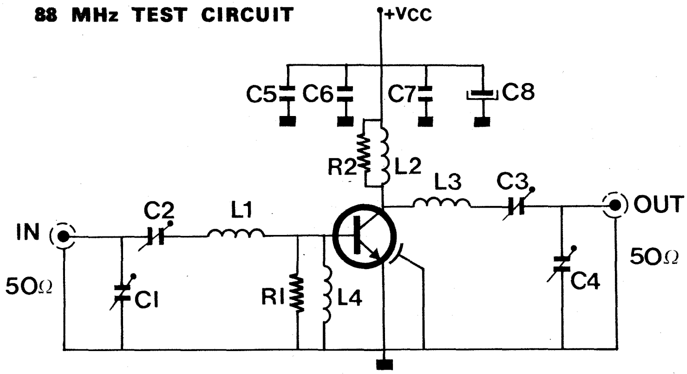
$C_1 = C_2 = C_3 = C_4$ = ARCO 404 7-60 pF trimmer capacitor
C_5 = 1000 pF mica capacitor
C_6 = 10 nF ceramic disc
C_7 = 0.1 μF ceramic disc
C_8 = 47 μF electrolytic

$L_1 = L_3$ = 2.5 turns - silvered wire ⌀ 1.5 mm - 10 mm I.D.
L_2 = 3 turns - silvered wire ⌀ 1.5 mm - 10 mm I.D.

R_1 = 47 ohms - 1/2 W - carbon composition

NOTA : CASE MUST BE GROUNDED

88 MHz TEST CIRCUIT



$C_1 = C_2 = C_3 = C_4$ = ARCO 404 7-60 pF trimmer capacitor
C_5 = 1000 pF mica capacitor
C_6 = 10 nF ceramic disc
C_7 = 0.1 μF ceramic disc
C_8 = 47 μF electrolytic

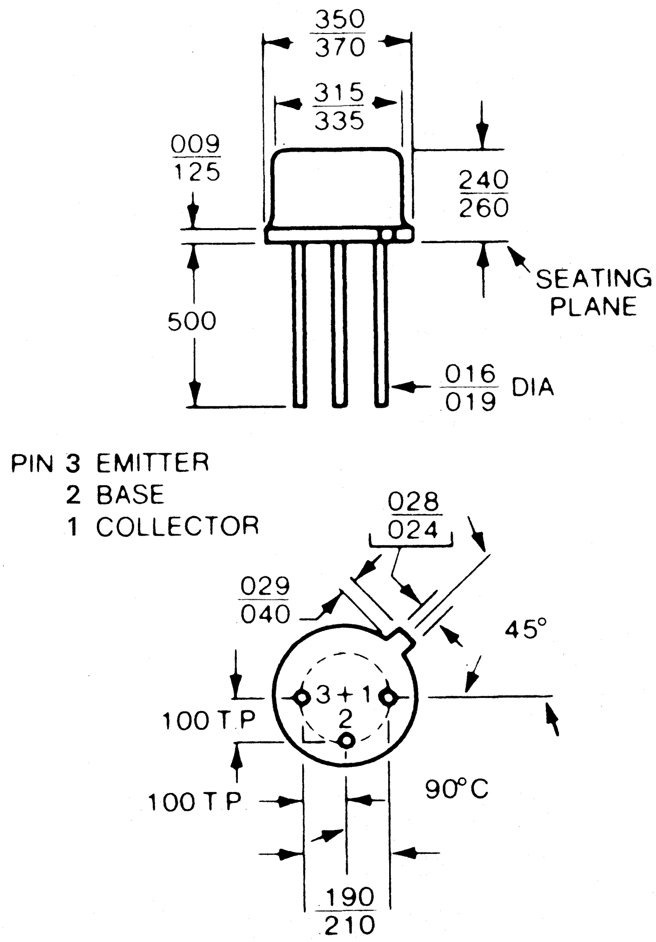
$L_1 = L_3$ = 2.5 turns - silvered wire ⌀ 1.5 mm - 10 mm I.D.
L_2 = 3 turns - silvered wire ⌀ 1.5 mm - 10 mm I.D.
L_4 = 0.45 μH - molded coil
R_1 = 47 ohms - 1/2 W

R_2 = 220 ohms - 1/2 W

NOTA : CASE MUST BE GROUNDED

PACKAGE OUTLINE

TO-39 GE



TRW® SEMICONDUCTORS

TP 2314

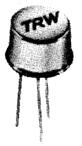
RF Power Transistor

4 W - 175 MHz
12.5 V

The TP 2314 is designed for 6 V to 12 V VHF applications and is intended for class A, B or C medium power amplifiers, frequency multipliers or oscillator circuits.

Its grounded emitter constructions gives excellent thermal dissipation and the ability of providing further heatsinking where necessary.

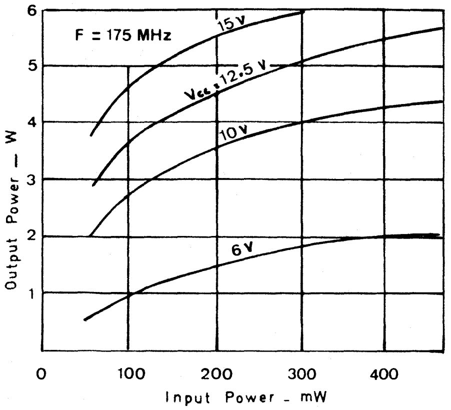
The case also acts as a good RF screen this device features high gain and an infinite VSWR rating at all phase angles at rated power output.

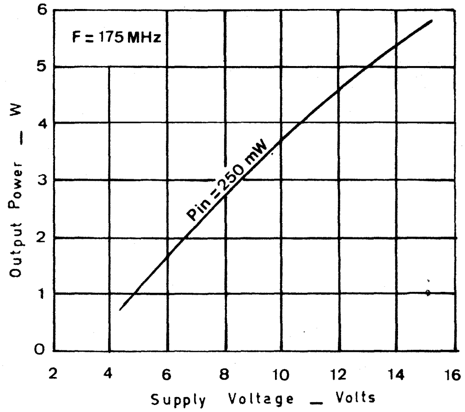


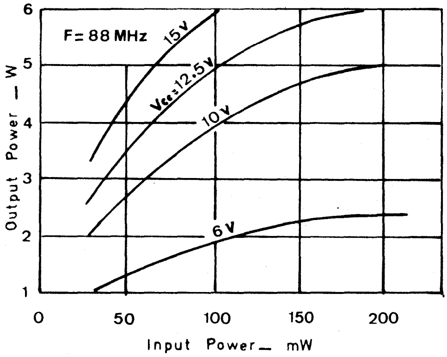
TO 39 GE

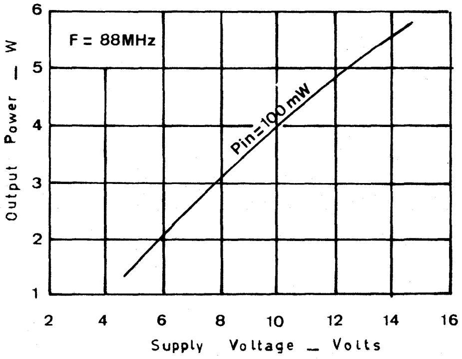
Electrical Characteristics (T_{case} = 25 °C)

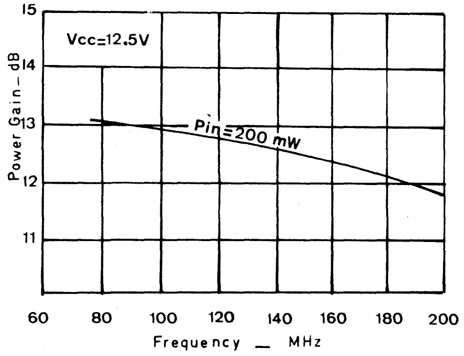
	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC Test	BV_{EBO}	Emitter - Base Breakdwon Voltage	I_E = 2 mA I_C = 0	4			V
	BV_{CEO}	Collector - Emitter Breakdown Voltage	I_C = 50 mA I_B = 0	16			V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 10 mA I_E = 0	36			V
	I_{CBO}	Collector Cutoff Current	V_{CB} = 15 V I_E = 0			1	mA
	H_{FE}	D.C Current Gain	V_{CE} = 5 V I_C = 200 mA	20	40		—
RF Test	P_{GAIN}	Power Gain	V_{CE} = 12.5 V F = 175 MHz P_{in} = 250 mW V_{CE} = 6 V F = 175 MHz P_{in} = 250 mW V_{CE} = 12.5 V F = 88 MHz P_{in} = 250 mW	4 1 4	4.8 1.6 4.8		W
	η	Efficiency	V_{CE} = 12.5 V F = 175 MHz P_{out} = 4 W	55	64		%
	Load VSWR	Mismatch Tolerance	All Phase Angles V_{CE} = 12.5 V F = 175 MHz P_{out} = 4 W		∞ : 1		
	Z_{in}	Common Emitter Amplifier Input Impedance	V_{CE} = 12.5 V F = 175 MHz P_{in} = 250 mW F = 88 MHz		4.33 — j 3.69 4.5 — j 4.8		Ω
	Z_{Load}	Common Emitter Amplifier Load Impedance	V_{CE} = 12.5 V F = 175 MHz P_{out} = 4 W F = 88 MHz		15.96 + j 4.13 18.74 + j 6.44		Ω
	C_{OB}	Collector - Base Capacitance	V_{CB} = 20 V F = 1 MHz		12	15	pF
Operating	I_C	Continous Collector Current				1	A
	θ_{j-C}	Thermal Resistance	T_C = 25 °C			20	°C/W
	T_{STG}	Storage Temperature and Junction Temperature		— 65°		200°	°C
	P_D	Power Dissipation	T_C = 25 °C			8	W

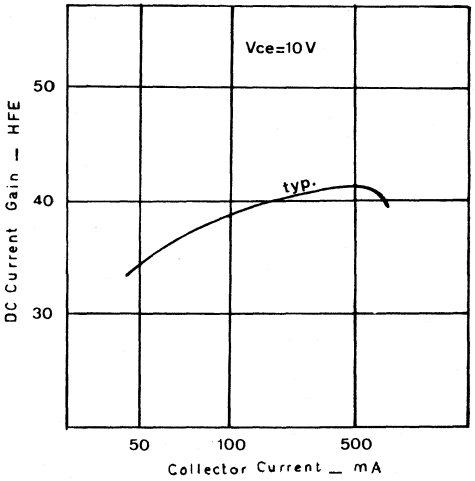


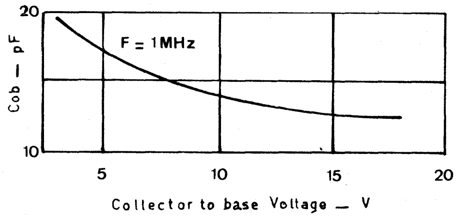






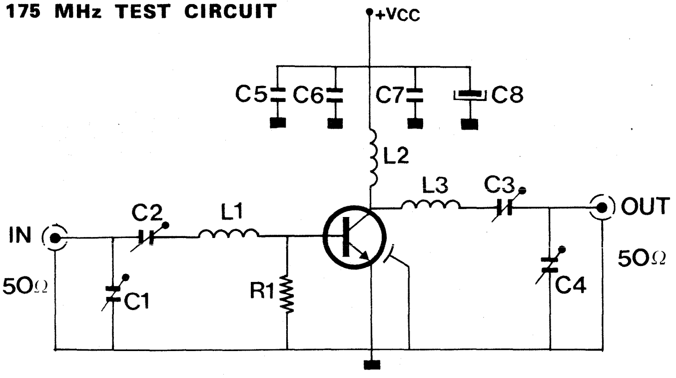






NOTA : TYPICAL CHARACTERISTICS

175 MHz TEST CIRCUIT



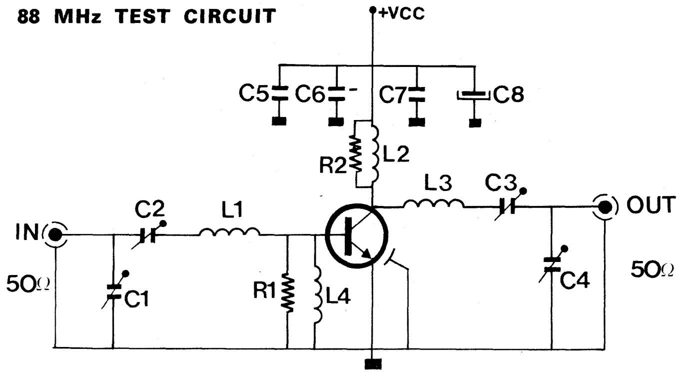
$C_1 = C_2 = C_3 = C_4$ = ARCO 404 7-60 pF trimmer capacitor
C_5 = 1000 pF mica capacitor
C_6 = 10 nF ceramic disc
C_7 = 0.1 μF ceramic disc
C_8 = 47 μF electrolytic

$L_1 = L_3$ = 2.5 turns - silvered wire ∅ 1.5 mm - 10 mm I.D.
L_2 = 3 turns - silvered wire ∅ 1.5 mm - 10 mm I.D.

R_1 = 47 ohms - 1/2 W - carbon composition

NOTA : CASE MUST BE GROUNDED

88 MHz TEST CIRCUIT

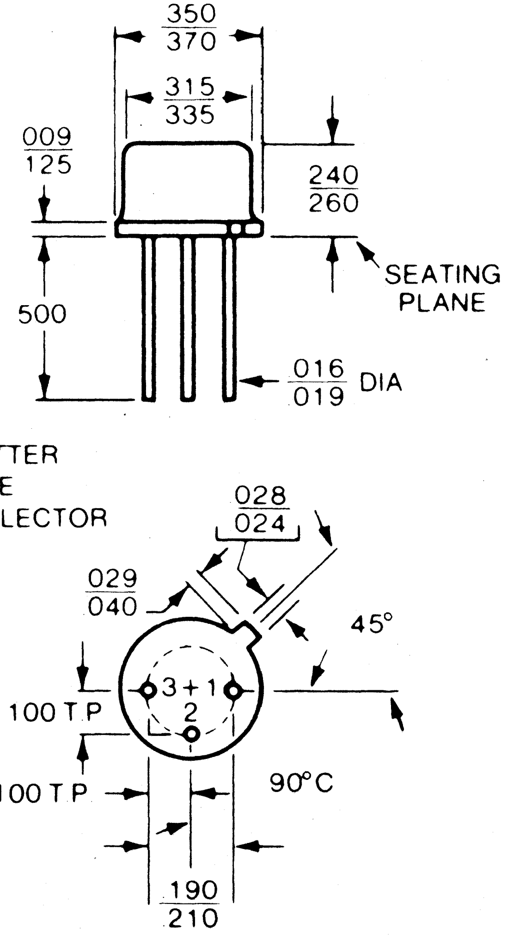


$C_1 = C_2 = C_3 = C_4$ = ARCO 404 7-60 pF trimmer capacitor
C_5 = 1000 pF mica capacitor
C_6 = 10 nF ceramic disc
C_7 = 0.1 μF ceramic disc
C_8 = 47 μF electrolytic
$L_1 = L_3$ = 2.5 turns - silvered wire ∅ 1.5 mm - 10 mm I.D.
L_2 = 3 turns - silvered wire ∅ 1.5 mm - 10 mm I.D.
L_4 = 0.47 μF - molded coil
R_1 = 47 ohms - 1/2 W
R_2 = 220 ohms - 1/2 W

NOTA : CASE MUST BE GROUNDED

PACKAGE OUTLINE

TO-39 GE



TRW® SEMICONDUCTORS

TP 2320

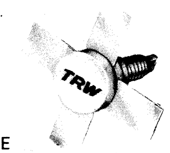
RF Power Transistor

20 W - 175 MHz

12.5 V

The TP 2320 is designed for use in 12.5 V VHF amplifiers operating under class A, B or C conditions.

Its construction which incorporates gold metalization and diffused ballast resistors for longer life, enables the part to be used at its maximum ratings and be able to withstand an infinite VSWR at all phase angles.



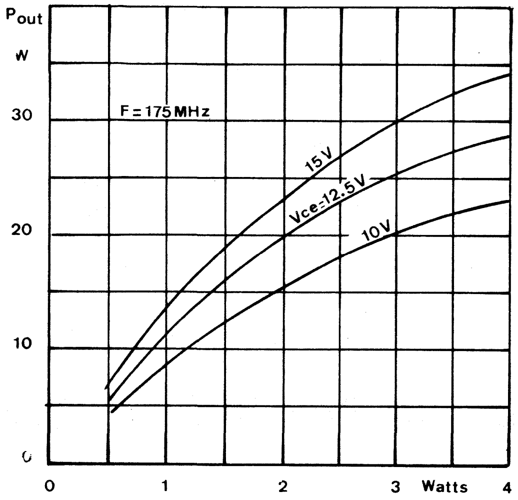
380 SOE

Electrical Characteristics (T_{CASE} = 25 °C)

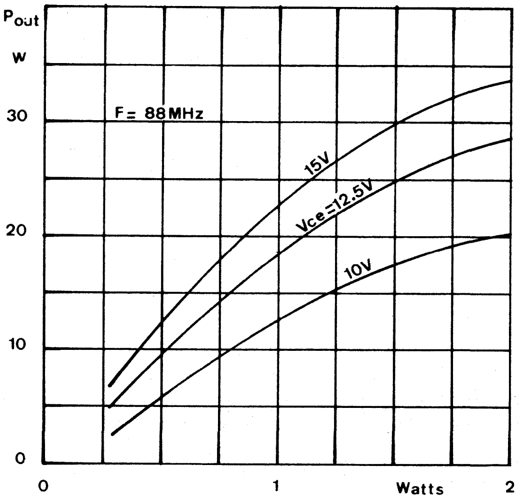
	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC Test	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 5 mA I_C = 0	4			V
	BV_{CEO}	Collector - Emitter Breakdown Voltage	I_C = 50 mA I_B = 0	18			V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 50 mA I_E = 0	40			V
	I_{CBO}	Collector Cutoff Current	V_{CB} = 15 V I_E = 0			2	mA
	H_{FE}	D.C Current Gain	V_{CE} = 5 V I_C = 500 mA	20			—
RF Test	P_{GAIN}	Power Gain	V_{CE} = 12.5 V F = 175 MHz P_{in} = 3 W V_{CE} = 12.5 V F = 88 MHz P_{in} = 1.5 W	17 17	20 20		W
	η	Efficiency	V_{CE} = 12.5 V F = 175 MHz P_{out} = 20 W	50			%
	Load VSWR	Mismatch Tolerance	All Phases Angles V_{CE} = 12.5 V F = 175 MHz P_{out} = 17 W		∞ : 1		
	Z_{in}	Common Emitter Amplifier Input Impedance	V_{CE} = 12.5 V F = 175 MHz P_{in} = 3 W		2 + j 1.5		Ω
	Z_{Load}	Common Emitter Amplifier Load Impedance	V_{CE} = 12.5 V F = 175 MHz P_{out} = 20 W		4.2 + j 0.7		Ω
	C_{OB}	Collector - Base Capacitance	V_{CE} = 20 V F = 1 MHz I_E = 0		55	70	pF
Operating	I_C	Continous Collector Current				6	A
	θ_{j-C}	Thermal Resistance	T_C = 25 °C			3.5	°C/W
	T_{STG}	Storage Temperature and Junction Temperature		— 65°		+200°	°C
	P_D	Power Dissipation	T_C = 25 °C			50	W

TYPICAL CHARACTERISTICS

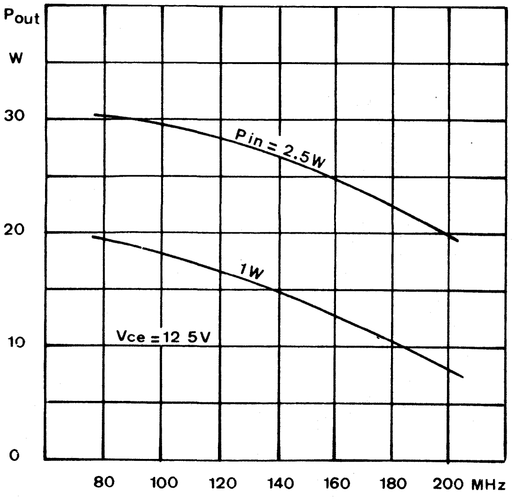
Output power vs input power and voltage supply



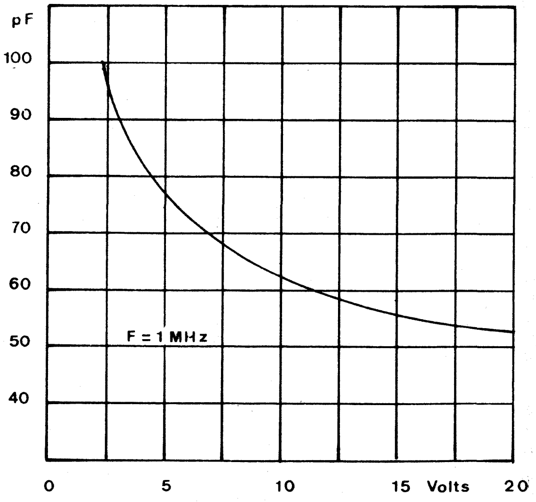
Output power vs input power and voltage supply



Output power vs frequency and input power

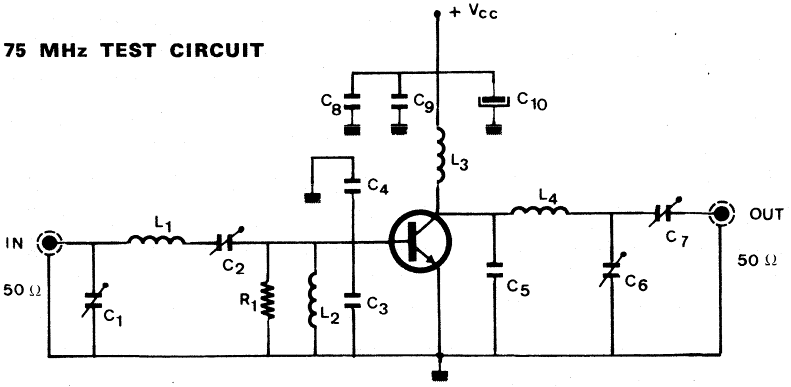


Coll. base capacitance



TRW COMPOSANTS ELECTRONIQUES S.A.

175 MHz TEST CIRCUIT



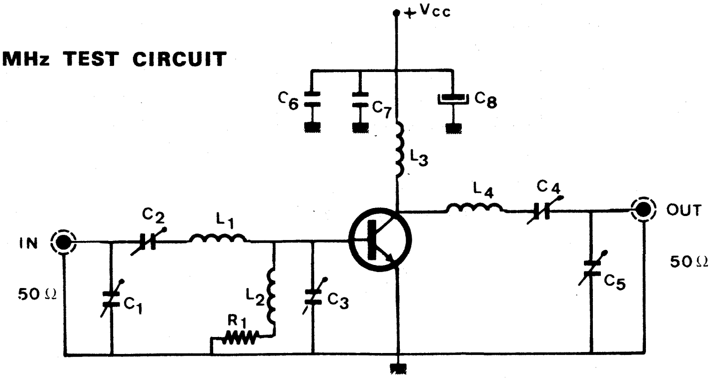
C_1 = ARCO 423 - 7-100 pF trimmer capacitor
C_2 = ARCO 423
C_3 = C_4 = 80 pF mica capacitor UNELCO
C_5 = 100 pF mica capacitor UNELCO
C_6 = C_7 = ARCO 423
C_8 = 1000 pF mica capacitor UNELCO
C_9 = 1000 pF ceramic disc
C_{10} = 47 µF electrolytic

L_1 = 3 turns 12/10 mm silvered wire - 6 mm I.D.

L_2 = 1 µH molded coil
L_3 = 3 turns 12/10 mm silvered wire - 6 mm I.D.
L_4 = 2 turns 12/10 mm silvered wire - 6 mm I.D.

R_1 = 150 ohms

88 MHz TEST CIRCUIT

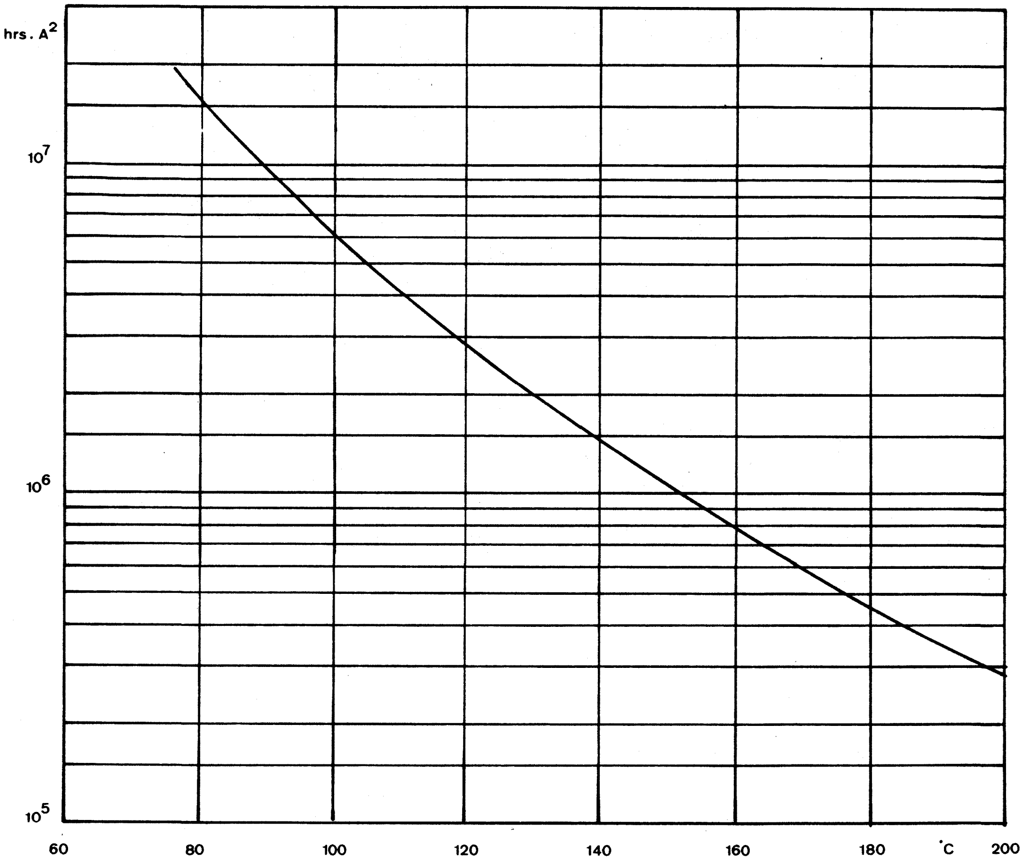


C_1 = C_4 = ARCO 425 24-200 pF trimmer capacitor
C_2 = ARCO 423 7-100 pF trimmer capacitor
C_3 = C_5 = ARCO 427 55-300 pF trimmer capacitor
C_6 = 1000 pF mica capacitor
C_7 = 10 nF ceramic
C_8 = 100 µF/35 V electrolytic

L_1 5 turns # 14 AWG 3/8″ ID
L_2 1 µH
L_3 9 turns # 16 AWG 5/16″ ID
L_4 4 turns # 14 AWG 3/8″ ID

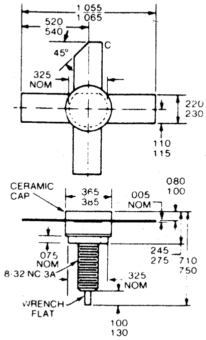
R_1 2.4 Ω

MTTF factor vs junction temperature



PACKAGE OUTLINE

.380 SOE



TRW® SEMICONDUCTORS

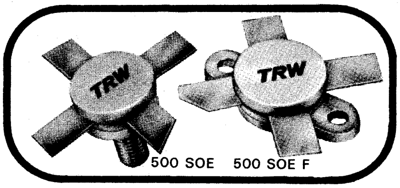
TP 2404

RF Power Transistor

50 W - 175 MHz
28 V

The TP 2404 is designed for use in 28 V FM or 12.5 V AM VHF amplifiers operating under class A, B or C conditions.

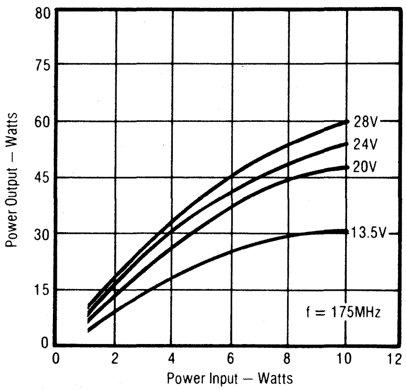
Its construction which incorporates gold metalization and diffused ballast resistors for longer life, enables the part to be used at its maximum ratings and be able to withstand an infinite VSWR at all phase angles.



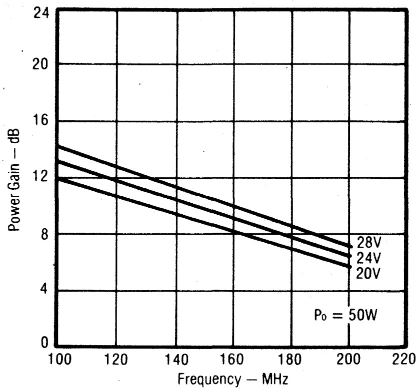
Electrical Characteristics (T_{case} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC Test	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 25 mA I_C = 0	4			V
	BV_{CEO}	Collector - Emitter Breakdown Voltage	I_C = 100 mA I_B = 0	35			V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 100 mA I_E = 0	65			V
	I_{CBO}	Collector Cutoff Current Voltage	V_{CB} = 30 V I_E = 0			2	mA
	H_{FE}	D.C Current Gain	V_{CE} = 5 V I_C = 1000 mA	10			—
RF Test	P_{GAIN}	Power Gain	V_{CE} = 28 V F = 175 MHz P_{in} = 9 W	50			W
	η	Efficiency	V_{CE} = 28 V F = 175 MHz P_{out} = 50 W	65	70		%
	Load VSWR	Mismatch Tolerance	All Phases Angles V_{CE} = 28 V F = 175 MHz P_{out} = 50 W		∞ : 1		
	Z_{in}	Common Emitter Amplifier Input Impedance	V_{CE} = 28 V F = 175 MHz P_{in} = 9 W		1 + j 1.3		Ω
	Z_{Load}	Common Emitter Amplifier Load Impedance	V_{CE} = 28 V F = 175 MHz P_{out} = 50 W		8 + j 3		Ω
	C_{OB}	Collector - Base Capacitance	V_{CB} = 30 V F = 1 MHz			90	pF
Operating	I_C	Continous Collector Current				8	A
	θ_{j-C}	Thermal Resistance	T_C = 25 °C			1.5	°C/W
	T_{STG}	Storage Temperature and Junction Temperature		— 65°		200°	°C
	P_D	Power Dissipation	T_C = 25 °C			115	W

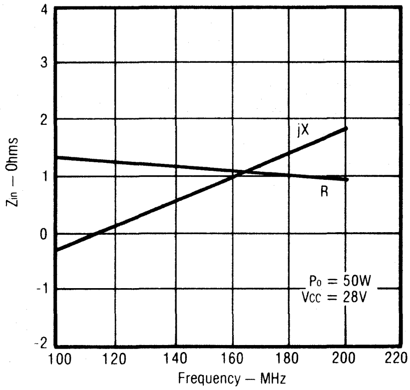
Power Output vs Power Input



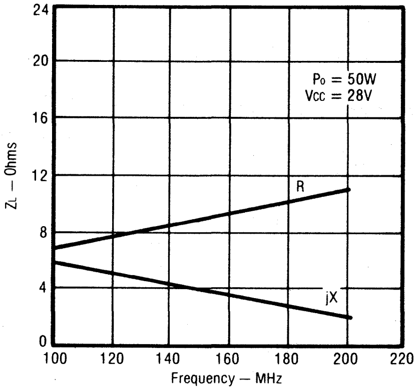
Power Gain vs Frequency



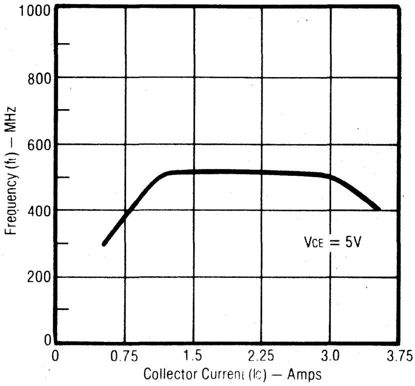
Series Input Impedance vs Frequency



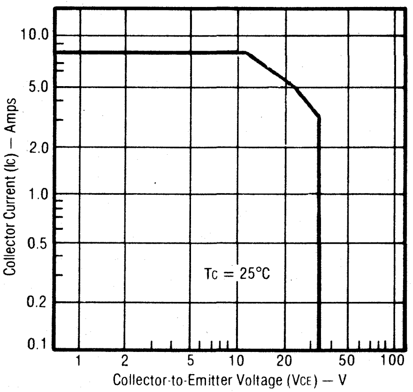
Series Load Impedance vs Frequency



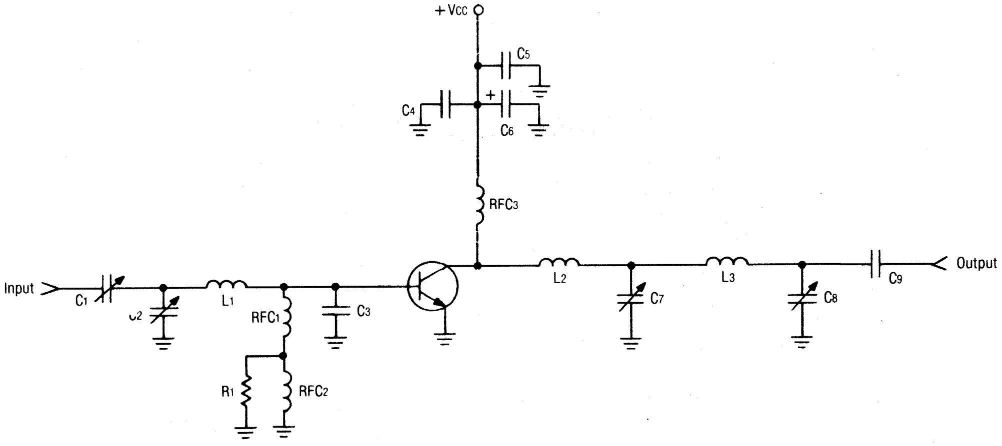
f_t vs I_C



Safe Operating Area



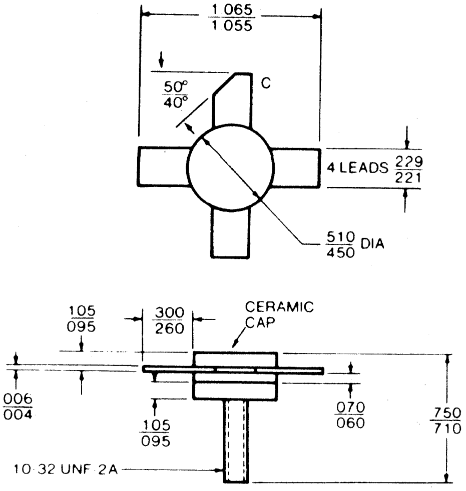
175 MHz TEST CIRCUIT



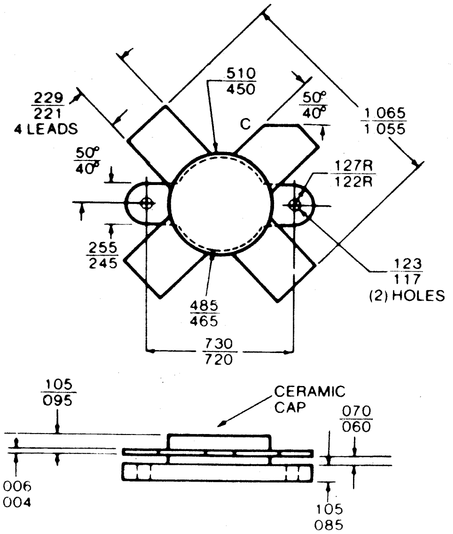
$C_{1,2,8}$	8-60 pF ARCO # 404
C_3	150 pF UNELCO
C_4	500 pF UNELCO
C_5	0.1 mF disc capacitor
C_6	5 mF 50 V electrolytic
C_7	5-80 pF ARCO # 462
C_9	0.001 mF disc capacitor
L_1	1 turn, 0.1″ wide by 0.02″ thick copper strip, 5/16″ I.D.
L_2	U-shaped copper strip, 0.1″ wide by 0.02″ wide thick 0.25″ high by 0.675″ long
L_3	1-1/2 turns, 0.1″ wide by 0.02″ thick copper strip, 5/16″ I.D.
R_1	10 ohms, 0.5 W carbon resistor
RFC_1	150 nH molded inductor
RFC_2	10.000 nH molded inductor
RFC_3	4 turns # 16 AWG, 5/16″ I.D.

PACKAGE OUTLINE

.500 SOE



.500 SOE F



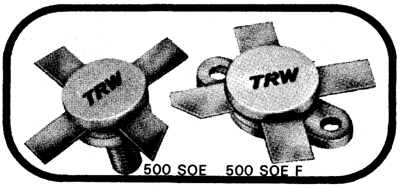
TRW® SEMICONDUCTORS **TP 2405**

RF Power Transistor

90 W - 175 MHz
27 V

The TP 2405 is designed for use in 28 V FM and 12.5 V AM VHF amplifiers operating under class A, B or C conditions.

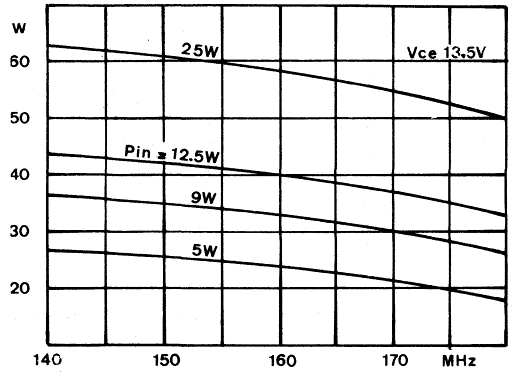
Its construction which incorporates gold metalization and diffused ballast resistors for longer life, enables the part to withstand an infinite VSWR at all phase angles.



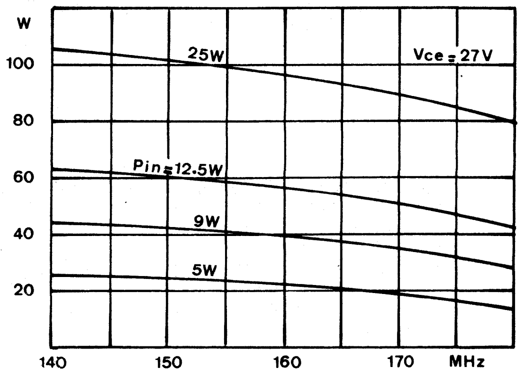
Electrical Characteristics (T_{case} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC Test	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 10 mA I_C = 0	4			V
	BV_{CEO}	Collector - Emitter Breakdown Voltage	I_C = 100 mA I_B = 0	35			V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 100 mA I_E = 0	65			V
	I_{CBO}	Collector Cutoff Current	V_{CB} = 30 V I_E = 0			2	mA
	H_{FE}	D.C Current Gain	V_{CE} = 5 V I_C = 3 A	10			—
RF Test	P_{GAIN}	Power Gain	V_{CE} = 27 V F = 150 MHz P_{in} = 25 W V_{CE} = 27 V F = 150 MHz P_{in} = 12.5 W V_{CE} = 13.5 V F = 150 MHz P_{in} = 9 W	90 45 22.5	100 50 25		W
	η	Efficiency	V_{CE} = 27 V F = 150 MHz P_{out} = 100 W	60			%
	Load VSWR	Mismatch Tolerance	V_{CE} = 27 V P_{out} = 75 W All Phases F = 150 MHz P_{out} = 100 W		∞ : 1 10 : 1		
	Z_{in}	Common Emitter Amplifier Input Impedance	V_{CE} = 27 V F = 150 MHz P_{in} = 25 W		1 + j 5		Ω
	Z_{Load}	Common Emitter Amplifier Load Impedance	V_{CE} = 27 V F = 150 MHz P_{out} = 100 W		3 + j 1		Ω
	C_{OB}	Collector - Base Capacitance	V_{CB} = 30 V F = 1 MHz		115	150	pF
Operating	I_C	Continous Collector Current				10	A
	θ_{j-C}	Thermal Resistance	T_C = 25 °C			1.25	°C/W
	T_{STG}	Storage Temperature and Junction Temperature		— 65°		200°	°C
	P_D	Power Dissipation	T_C = 25 °C			140	W

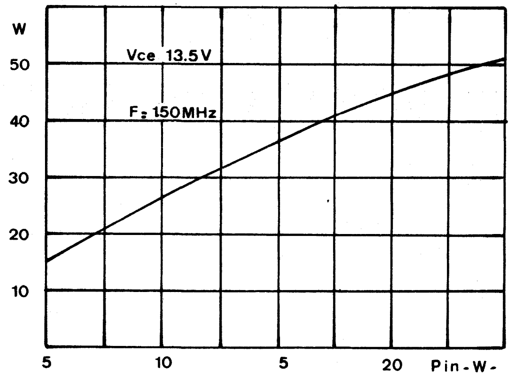
Output Power vs Frequency and Input Power



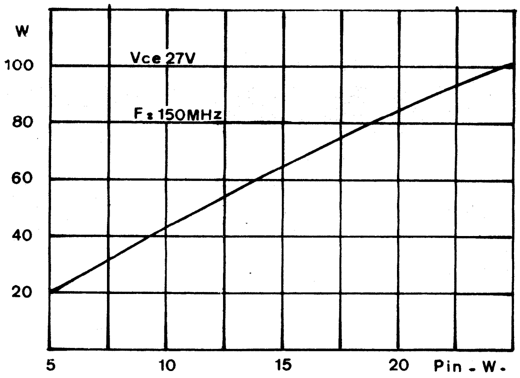
Output Power vs Frequency and Input Power



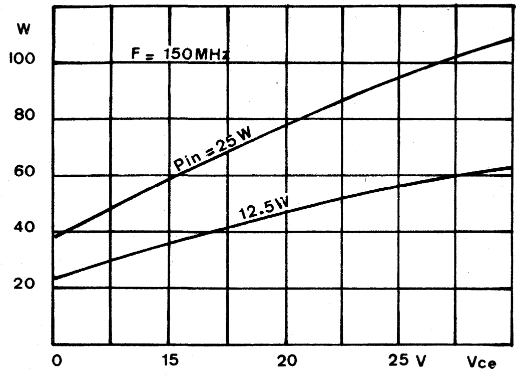
Output Power vs Input Power



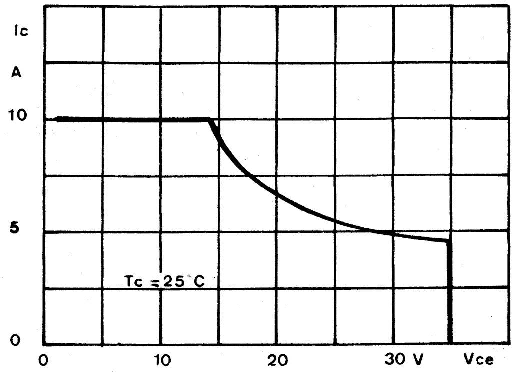
Output Power vs Input Power



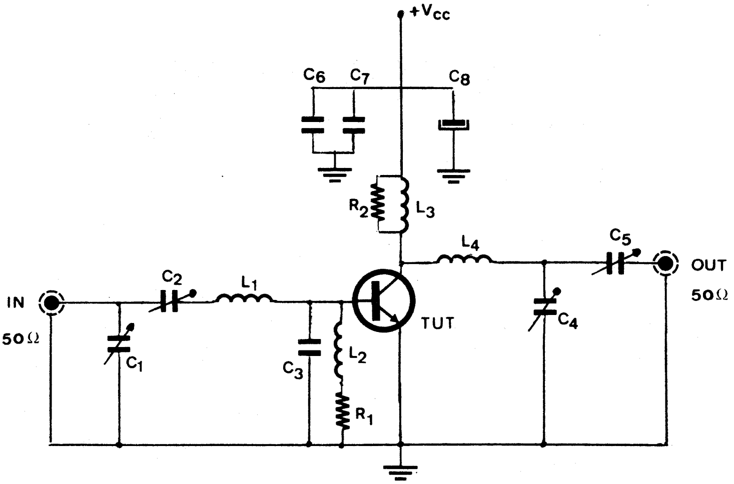
Output Power vs Voltage Supply and Input Power



Safe Operating Area



150 MHz TEST CIRCUIT SCHEMATIC



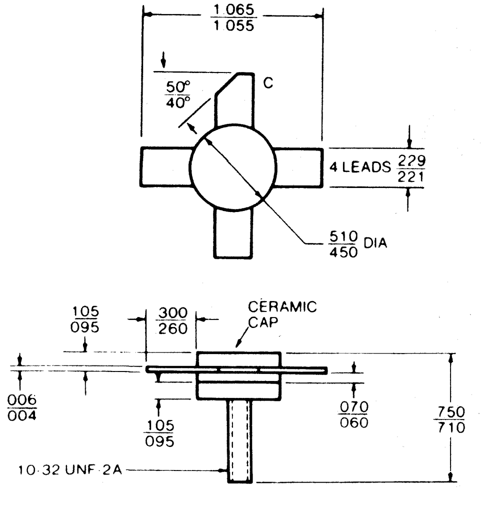
C_1 = C_4 = trimmer capacitor ARCO 423
C_2 = trimmer capacitor ARCO 425
C_3 = 250 pF mica capacitor UNELCO
C_5 = trimmer capacitor ARCO 404
C_6 = 1000 pF ceramic capacitor
C_7 = 10 nF ceramic capacitor
C_8 = 47 μF/63 V electrolytic

L_1 = 2 turns silvered wire 15/10 mm - 6 mm I.D.
L_2 = 0.15 μH molded coil
L_3 = 10 turns enameled wire 8/10 mm woud on R2
L_4 = copper strip 2 mm × 30 mm

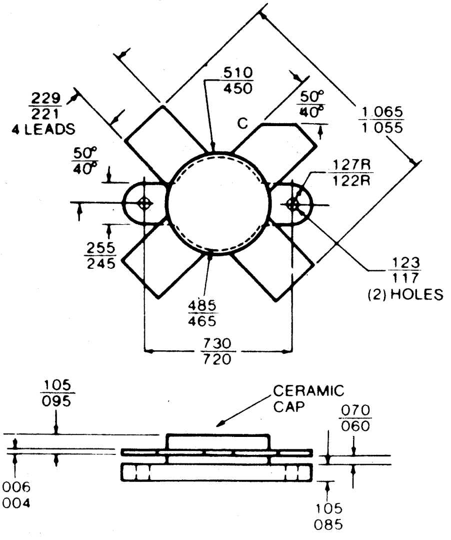
R_1 = 2.7 ohms 1/2 W carbon composition
R_2 = 1 K ohms 2 W carbon composition

PACKAGE OUTLINE

.500 SOE



.500 SOE F



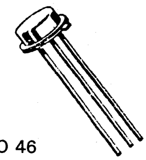
TRW® **SEMICONDUCTORS** **TP 2500**

RF Power Transistor

470 MHz - 12 V

The TP 2500 has been especially designed for use in 12,5 V VHF and UHF amplifiers where size is of prime importance.

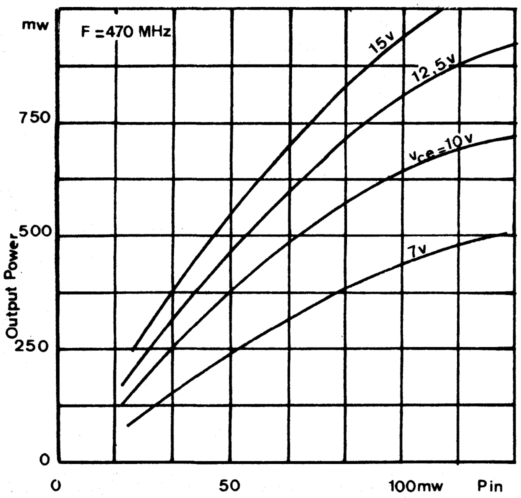
Its low profile TO 46 and high gain makes it ideally suited for use in pocketphone and portable instrument applications.


TO 46

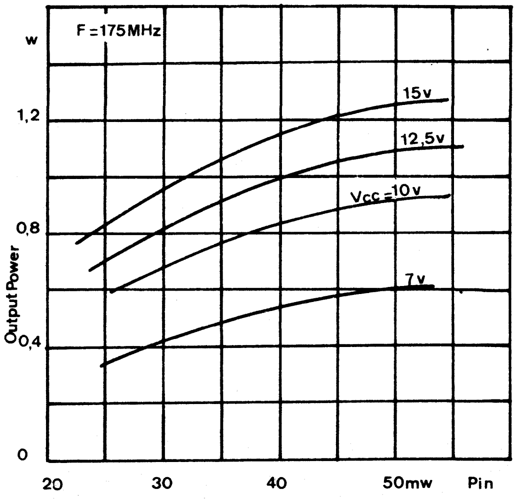
Electrical Characteristics (T_{case} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC Test	BV_{EBO}	Emitter - Base Breakdown Voltage	$I_E = 1$ mA $I_C = 0$	4			V
	BV_{CEO}	Collector - Emitter Breakdown Voltage	$I_C = 25$ mA $I_B = 0$	16			V
	BV_{CBO}	Collector - Base Breakdown	$I_C = 5$ mA $I_E = 0$	35			V
	I_{CBO}	Collector Cutoff Current	$V_{CB} = 15$ V $I_B = 0$			1	mA
	H_{FE}	D.C Current Gain	$V_{CE} = 5$ V $I_C = 100$ mA	20	70		—
RF Test	P_{GAIN}	Power Gain	$V_{CE} = 12.5$ V $P_{in} = 50$ mW F = 470 MHz F = 175 MHz	0.35 0.9			W
	η	Efficiency	$V_{CE} = 12.5$ V F = 470 MHz $P_{out} = 400$ mW	60	70		%
	Z_{in}	Common Emitter Amplifier Input Impedance	$V_{CE} = 12.5$ V $P_{in} = 50$ mW F = 470 MHz F = 175 MHz		4.35 + j 5.22 4.15 — j 3.76		Ω
	Z_{Load}	Common Emitter Amplifier Load Impedance	$V_{CE} = 12.5$ V $P_{out} = 400$ mW F = 470 MHz F = 175 MHz		26 + j 47.4 42.5 — j 68		Ω
	C_{OB}	Collector - Base Capacitance	$V_{CB} = 15$ V F = 1 MHz		5	7	pF
Operating	I_C	Continous Collector Current				0.7	A
	θ_{j-c}	Thermal Resistance	$T_C = 25$ °C			87.5	°C/W
	T_{STG}	Storage Temperature and Junction Temperature		— 65°		200°	°C
	P_D	Power Dissipation	$T_C = 25$ °C			2	W

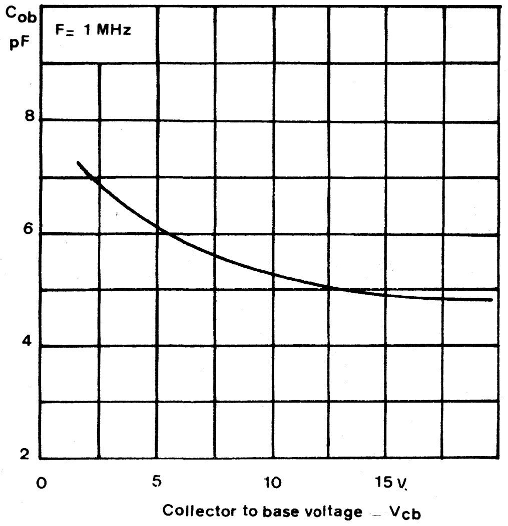
Output Power vs Input Power and Voltage Supply (AT 470 MHz)



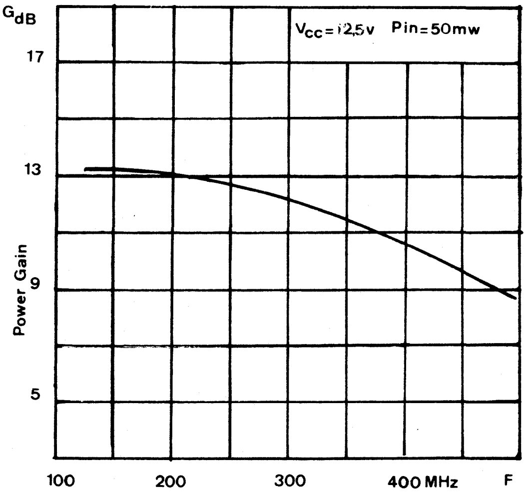
Output Power vs Input Power and Voltage Supply (AT 175 MHz)



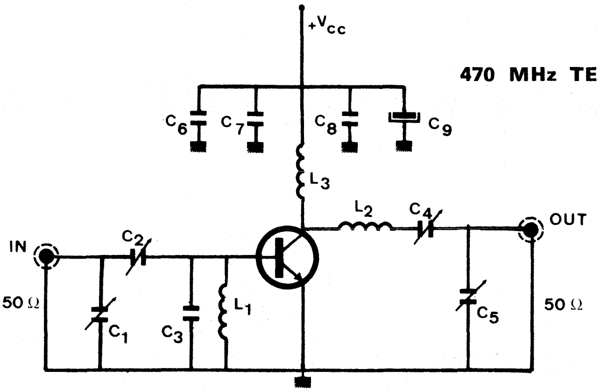
Collector Base Capacitance



Output Power vs Frequency

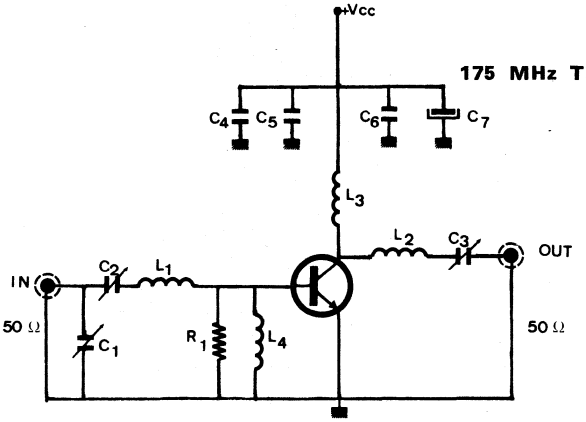


470 MHz TEST CIRCUIT



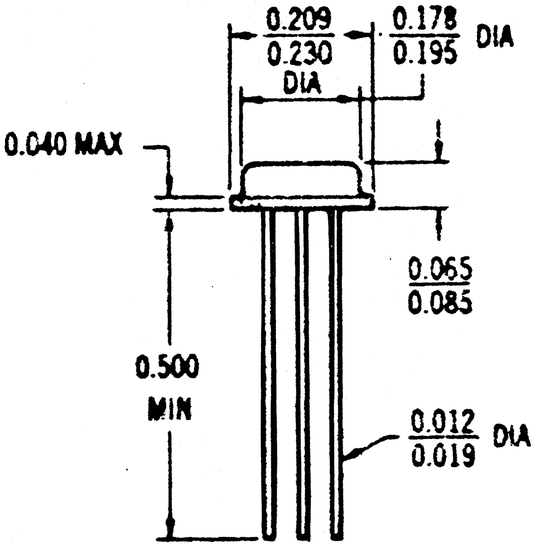
L_1 molded coil - 0,1 µH
L_2 = 1 turn silvered wire ⌀ 0.3 mm - 4 mm I.D.
L_3 = 2.5 turns silvered wire ⌀ 0.3 mm - 4 mm I.D.
C_1 = C_4 = ARCO 402 - 1.5-20 pF - trimmer capacitor
C_2 = ARCO 403 - 4-40 pF - trimmer capacitor
C_5 = ARCO 400 - 0.9-7 pF - trimmer capacitor
C_3 = Chip ATC - 39 pF
C_6 = 1000 pF - mica capacitor
C_7 = 680 nF - ceramic disc
C_8 = 0.1 µF - ceramic disc
C_9 = 10 µF - electrolytic

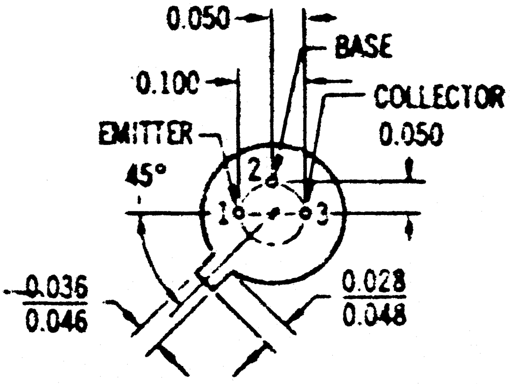
175 MHz TEST CIRCUIT



L_1 = 2 turns silvered wire - ⌀ 0.8 mm - 6 mm I.D.
L_2 = 4 turns silvered wire - ⌀ 0.8 mm - 6 mm I.D.
L_3 = 3 turns silvered wire - ⌀ 0.8 mm - 6 mm I.D.
L_4 = molded coil - 0.1 µH
R_1 = 22 ohms - 1/2 W - carbon composition
C_1 = C_2 = ARCO 425 - 24-200 pF - trimmer capacitor
C_3 = ARCO 427 - 55-300 pF - trimmer capacitor
C_4 = 1000 pF - mica capacitor
C_5 = 10 nF - ceramic disc
C_6 = 0.1 µF - ceramic disc
C_7 = 10 µF - electrolytic

PACKAGE OUTLINE





TRW® **SEMICONDUCTORS**

TP 2503

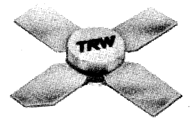
RF Power Transistor

5 W - 470 MHz
12.5 V

The TP 2503 is designed for 12.5 V VHF and UHF amplifiers.

Its high gain at reduced voltage and stripline package make it suitable for use in pocketphone applications.

The power output is useable to the top of its ratings and it is able to withstand an infinite VSWR at all phase angles at rated output power.

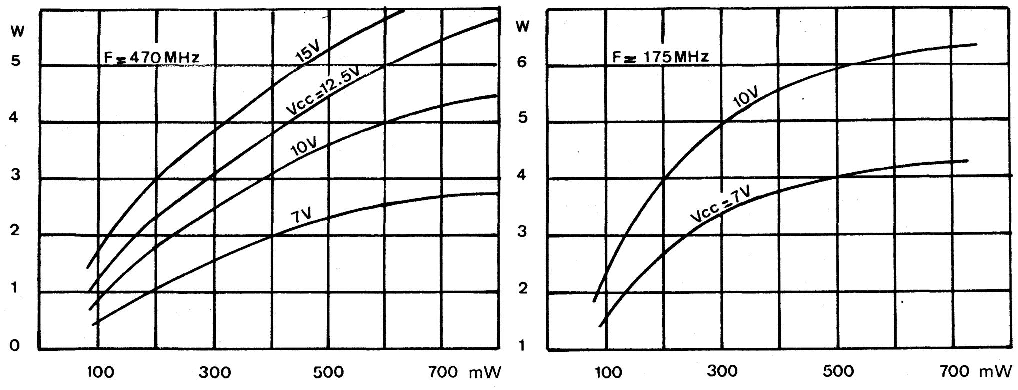


280 SOE STUDLESS

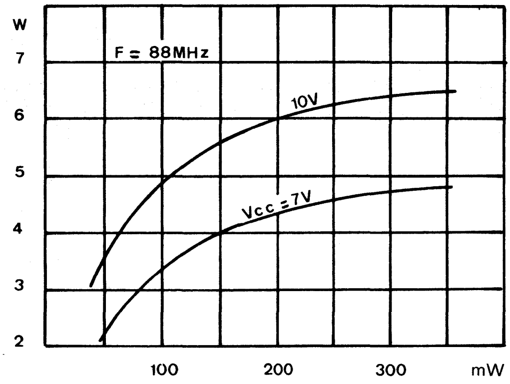
Electrical Characteristics (T_{case} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC Test	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 2 mA I_C = 0	4			V
	BV_{CEO}	Collector - Emitter Breakdown Voltage	I_C = 50 mA I_B = 0	16			V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 10 mA I_E = 0	36			V
	I_{CBO}	Collector Cutoff Current	V_{CB} = 15 V I_E = 0			1	mA
	H_{FE}	D.C Current Gain	V_{CE} = 5 V I_C = 200 mA	20			—
RF Test	P_{GAIN}	Power Gain	V_{CE} = 12.5 V F = 470 MHz P_{in} = 0.7 W V_{CE} = 9.5 V F = 175 MHz P_{in} = 0.4 W V_{CE} = 9.5 V F = 88 MHz P_{in} = 0.2 W	5 5 5	5.5 5.5 6		W
	η	Efficiency	V_{CE} = 12.5 V F = 470 MHz P_{out} = 2 W	55			%
	Load VSWR	Mismatch Tolerance	All Phases Angles V_{CE} = 12.5 V F = 470 MHz P_{out} = 5 W		∞ : 1		
	Z_{in}	Common Emitter Amplifier Input Impedance	V_{CE} = 12.5 V F = 470 MHz P_{in} = 0.7 W		1.6 + j 3.5		Ω
	Z_{Load}	Common Emitter Amplifier Load Impedance	V_{CE} = 12.5 V F = 470 MHz P_{out} = 5 W		9.55 + j 5.75		Ω
	C_{OB}	Collector - Base Capacitance	V_{CB} = 15 V F = 1 MHz		13	17	pF
Operating	I_C	Continous Collector Current				1.7	A
	θ_{j-C}	Thermal Resistance	T_C = 25 °C			10	°C/W
	T_{STG}	Storage Temperature and Junction Temperature		— 65°		200°	°C
	P_D	Power Dissipation	T_C = 25 °C			17.5	W

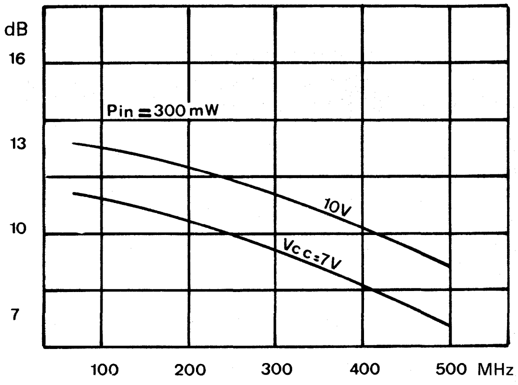
Output Power vs Input Power and Voltage Supply



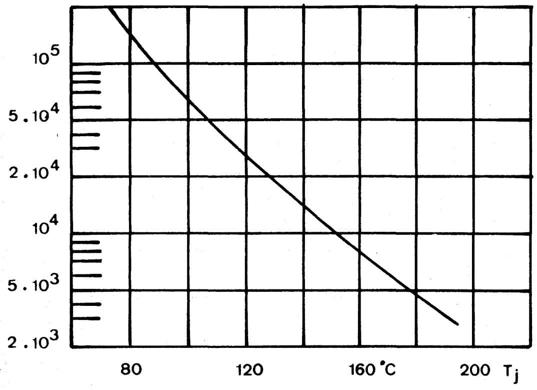
Output Power vs Input Power and Voltage Supply



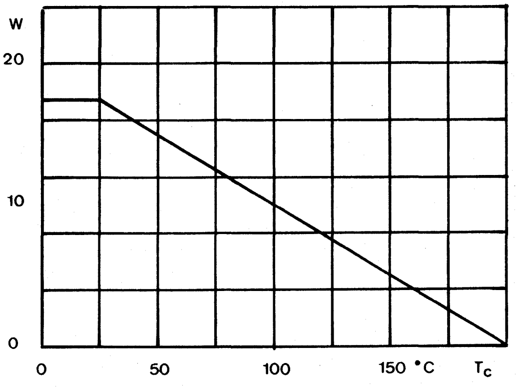
Power Gain vs Frequency and Voltage Supply



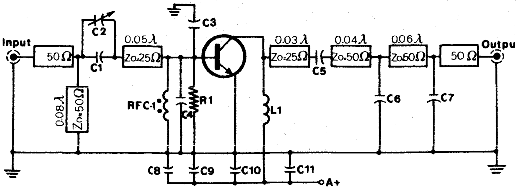
MTTF Factor vs Junction Temperature



Power - Temperature Operating Curve



TEST CIRCUIT BROADBAND (450-510 MHz)

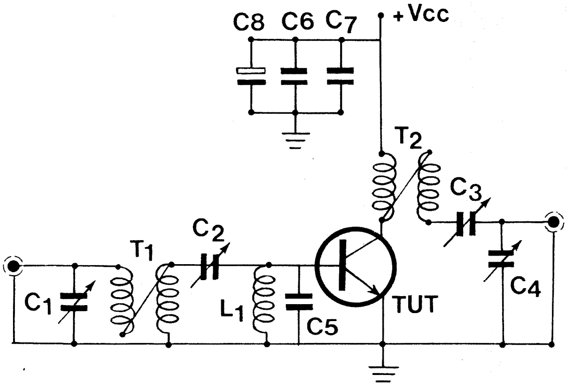


COMPONENT AND MATERIAL LIST

C_1	3,9 pF, ceramic chip
C_2	0.8-10 pF, Voltronics AP 10, variable
C_3, C_4	25 pF, ceramic chip
C_5	1500 pF, ceramic chip
C_6	10 pF, Underwood
C_7	5 pF, Underwood
C_8	0.01 μF, disc-ceramic
C_9	0.10 μF, disc-ceramic
C_{10}	1000 pF, Underwood
C_{11}	5 μF, electrolytic
L_1	4 turns, # 22 enameled, 0.1" I.D.
R_1	750 Ω, ½ watt, carbon
RFC-1	2½ turns # 22 AWG on Ferroxcube VK211/17-4B

All transmission lines reference at 480 MHz

175 MHz TEST CIRCUIT

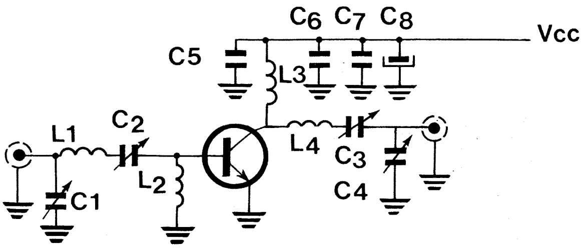


$C_1 = C_2 = C_4$ = 7-100 pF ARCO 423
C_3 = 24-200 pF ARCO 425
C_5 = 150 pF mica capacitor UNELCO
C_6 = 1000 pF mica capacitor UNELCO
C_7 = 10 nF ceramic disc
C_8 = 47 μF/63 V electrolytic

L_1 = 10 μH Molded Coil

$T_1 = T_2$ = Transmission Line Transformers 2 wires 8/10 mm twisted - 5 cm length

88 MHz TEST CIRCUIT

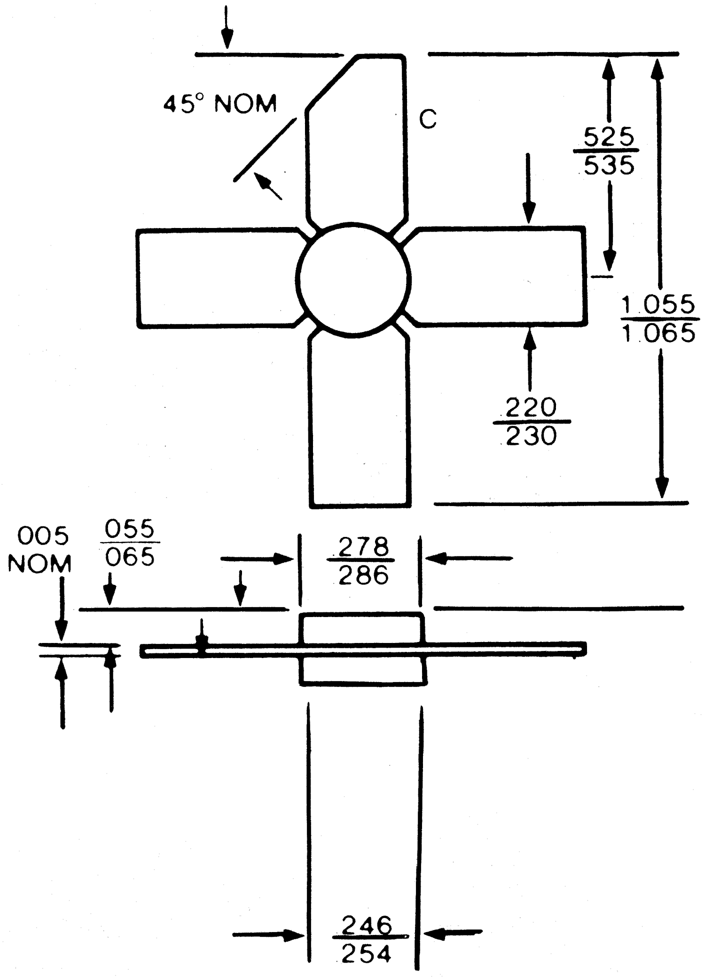


$C_1 = C_2 = C_3$ = 24-200 pF ARCO 425
C_4 = 7-100 pF ARCO 423
C_5 = 1000 pF mica capacitor UNELCO
C_6 = 10 nF ceramic disc
C_7 = 0.1 μF ceramic disc
C_8 = 100 μF/35 V electrolytic

$L_1 = L_4$ = 4 turns 14 AWG 1/2" I.D.
L_2 = 0.47 μH
L_3 = 6 turns 14 AWG 1/2" I.D. Close Wound

PACKAGE OUTLINE

280 SOE STUDLESS



TRW COMPOSANTS ELECTRONIQUES S.A.

TRW® SEMICONDUCTORS **TP 5695**

RF TRANSISTOR

10 W - 88 MHz - 12 V

NPN SILICON

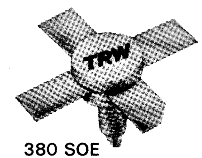
Designed for 12.5 V VHF amplifiers. Class B or C operation.

12.5 V characteristics :

Output power 88 MHz - 8 W min.

Minimum gain at 88 MHz - 10 dB.

Power output useable to the top ratings and capable of withstanding infinite VSWR at all phase angles.

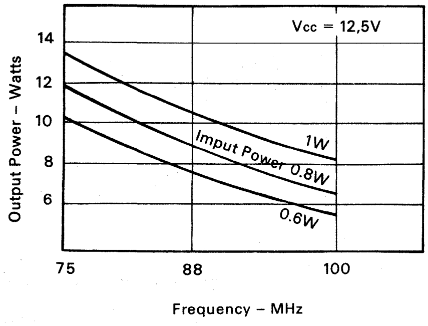


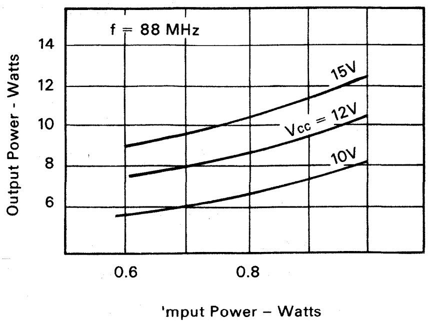
380 SOE

Electrical Characteristics (T_{flange} = 25 °C)

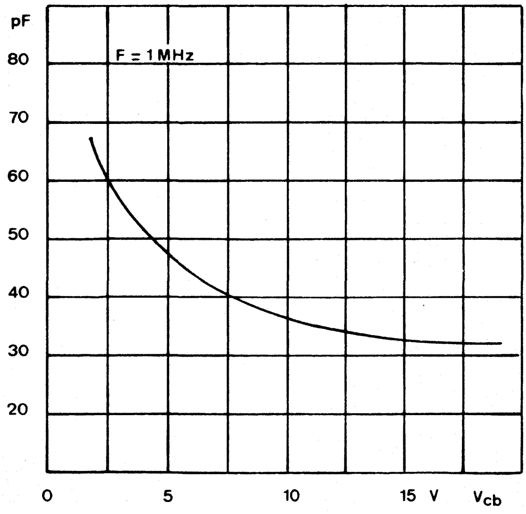
	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC Test	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 1 mA I_C = 0	4			V
	BV_{CEO}	Collector - Emitter Breakdown Voltage	I_C = 50 mA I_B = 0	20			V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 3 mA I_E = 0	40			V
	I_{CBO}	Collector Cutoff Current	V_{CB} = 15 V I_E = 0			2	mA
	H_{FE}	D.C Current Gain	V_{CE} = 10 V I_C = 100 mA	15			—
RF Test	P_{GAIN}	Power Gain	V_{CE} = 12.5 V P_{in} = 1.2 W F = 88 MHz	10			W
	η	Efficiency	V_{CE} = 12.5 V P_{out} = 20 W F = 88 MHz	60			%
	Load VSWR	Mismatch Tolerance	V_{CE} = 12.5 V P_{out} = 10 W F = 88 MHz		∞ : 1		
	Z_{in}	Common Emitter Amplifier Input Impedance	V_{CE} = 12.5 V P_{in} = 1.2 W F = 88 MHz		4 + j 1.5		Ω
	Z_{Load}	Common Emitter Amplifier Load Impedance	V_{CE} = 12.5 V P_{out} = 10 W F = 88 MHz		6.48 + j 0.88		Ω
	C_{OB}	Collector - Base Capacitance	V_{CB} = 15 V F = 1 MHz		35	50	pF
Operating	I_C	Continous Collector Current				2	A
	θ_{j-C}	Thermal Resistance	T_C = 25 °C			7	°C/W
	T_{STG}	Storage Temperature and Junction Temperature		— 65°		200°	°C
	P_D	Power Dissipation	T_C = 25 °C			25	W

Typical RF Characteristics

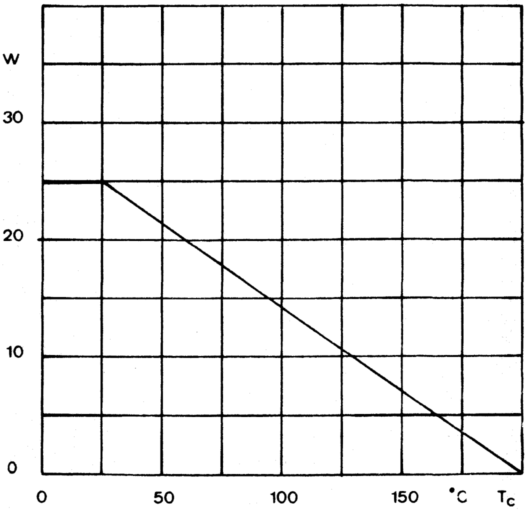




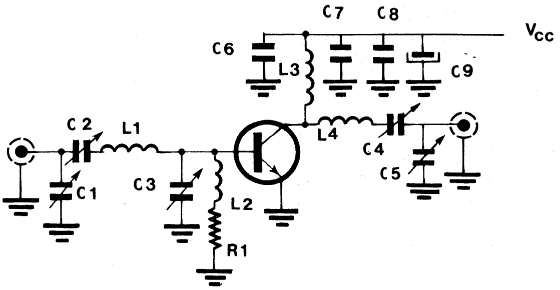
Collector Base capacitance



Power - Temperature Derating Curve



88 MHz TEST CIRCUIT



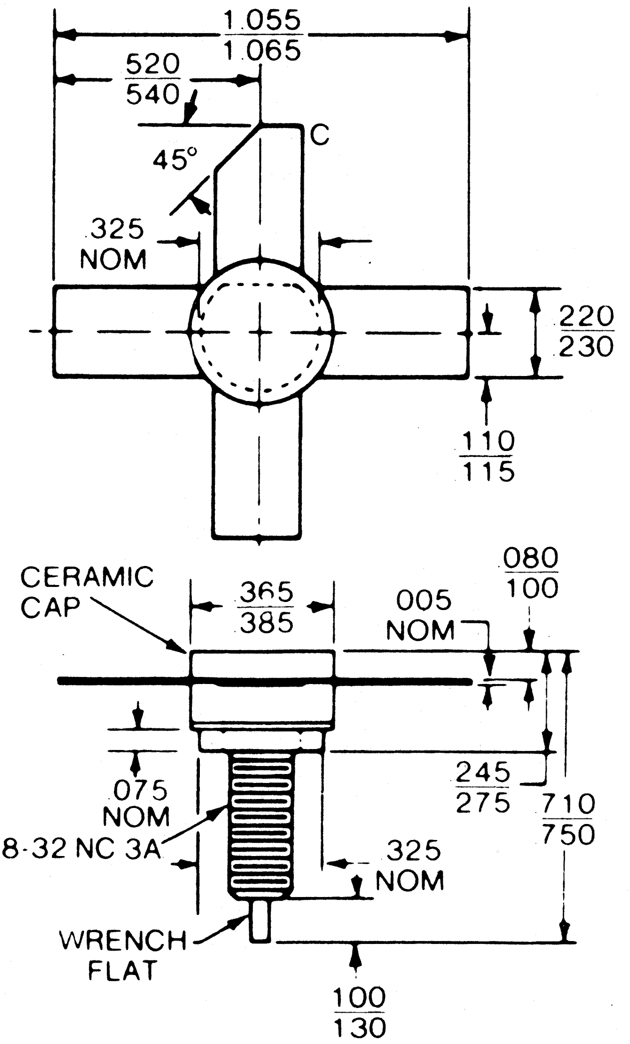
C_1-C_4 = 24/200 pF Trimmer capacitor
C_2 = 7/100 pF Trimmer capacitor
C_3-C_5 = 55/300 pF Trimmer capacitor
C_6 = 1000 pF
C_7 = 10000 pF
C_8 = 0,1 μF
C_9 = 100 μF/35 V

L_1 = 5 turns # 14 AWG 3/8" ID
L_2 = 1 μH
L_3 = 9 turns # 16 AWG 5/16" ID
L_4 = 4 turns # 14 AWG 3/8" ID

R_1 = 2,4 Ω

PACKAGE OUTLINE

.380 SOE



TRW COMPOSANTS ELECTRONIQUES S.A.

TRW® **SEMICONDUCTORS**

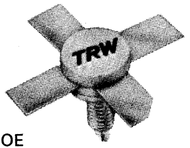
TP 8706

RF Power Transistor

7 W - 175 MHz
28 V

The TP 8706 is designed for use in 28 V FM or 12.5 V AM VHF amplifiers operating under class A, B or C conditions.

Its construction which incorporates gold metalization for longer life, enables the part to be used at its maximum ratings and be able to withstand and infinite VSWR at all phase angles.

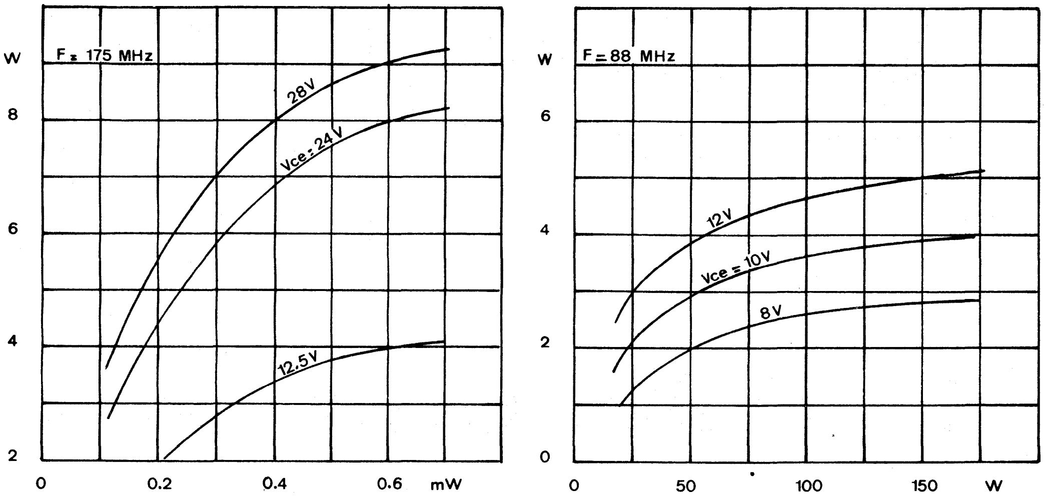

380 SOE

Electrical Characteristics (T_{case} = 25 °C)

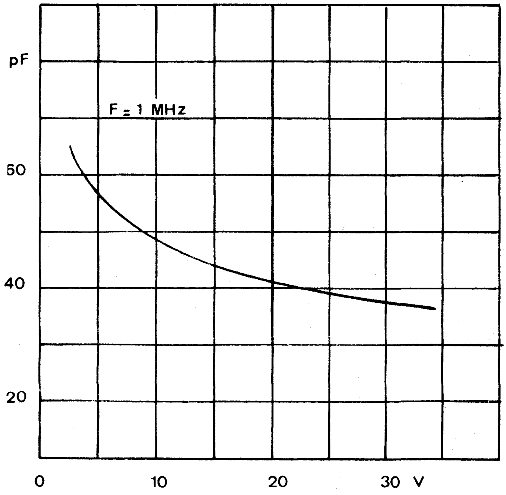
	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC Test	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 1 mA I_C = 0	4			V
	BV_{CEO}	Collector - Emitter Breakdown Voltage	I_C = 50 mA I_B = 0	36			V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 50 mA I_E = 0	60			V
	I_{CBO}	Collector Cutoff Current	V_{CB} = 25 V I_E = 0			1	mA
	H_{FE}	D.C Current Gain	V_{CE} = 10 V I_C = 100 mA	20		150	—
RF Test	P_{GAIN}	Power Gain	V_{CE} = 28 V F = 175 MHz P_{in} = 0.4 W V_{CE} = 12.5 V F = 88 MHz P_{in} = 0.1 W	7 3.5	7.8 4.5		W
	η	Efficiency	V_{CE} = 28 V F = 175 MHz P_{out} = 7 W	50			%
	Load VSWR	Mismatch Tolerance	All Phases Angles V_{CE} = 28 V F = 175 MHz P_{out} = 7 W		∞ : 1		
	Z_{in}	Common Emitter Amplifier Input Impedance	V_{CE} = 28 V F = 175 MHz P_{in} = 0.4 W		2.3 + j 0.7		Ω
	Z_{Load}	Common Emitter Amplifier Load Impedance	V_{CE} = 28 V F = 175 MHz P_{out} = 7 W		21.94 + j 26.17		Ω
	C_{OB}	Collector - Base Capacitance	V_{CB} = 30 V F = 1 MHz		37	50	pF
Operating	I_C	Continous Collector Current				1.5	A
	θ_{j-c}	Thermal Resistance	T_C = 25 °C			17.5	°C/W
	T_{STG}	Storage Temperature and Junction Temperature		— 65°		200°	°C
	P_D	Power Dissipation	T_C = 25 °C			10	W

TYPICAL CHARACTERISTICS

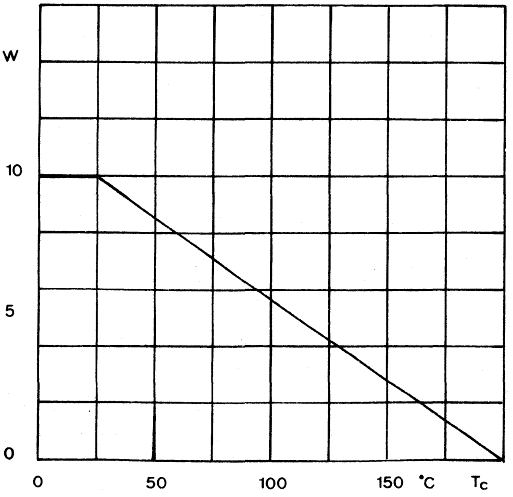
Output Power vs Input Power and Voltage Supply



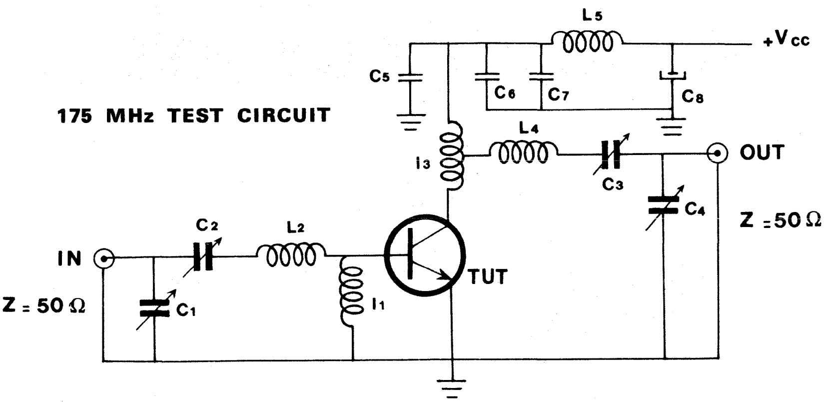
Coll. Base Capacitance



Power - Temperature Derating Curve

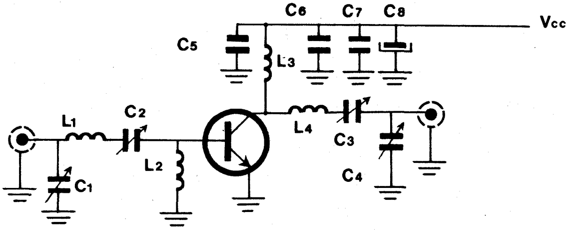


175 MHz TEST CIRCUIT



C_1-C_2-C_3-C_4	adjustable capacitor 3/70 pF
C_5	1000 pF disc capacitor
C_6	10000 pF disc capacitor
C_7	0.1 μF disc capacitor
C_8	50 μF electrolytic capacitor
L_1	0.15 μH choke
L_2	3 turns 1 mm wire 6 mm I.D. 10 mm length
L_3	3 turns 1 mm wire 10 mm I.D. 12 mm length
L_4	3 turns 1 mm wire 6 mm I.D. 10 mm length
L_5	2 turns on ferrite

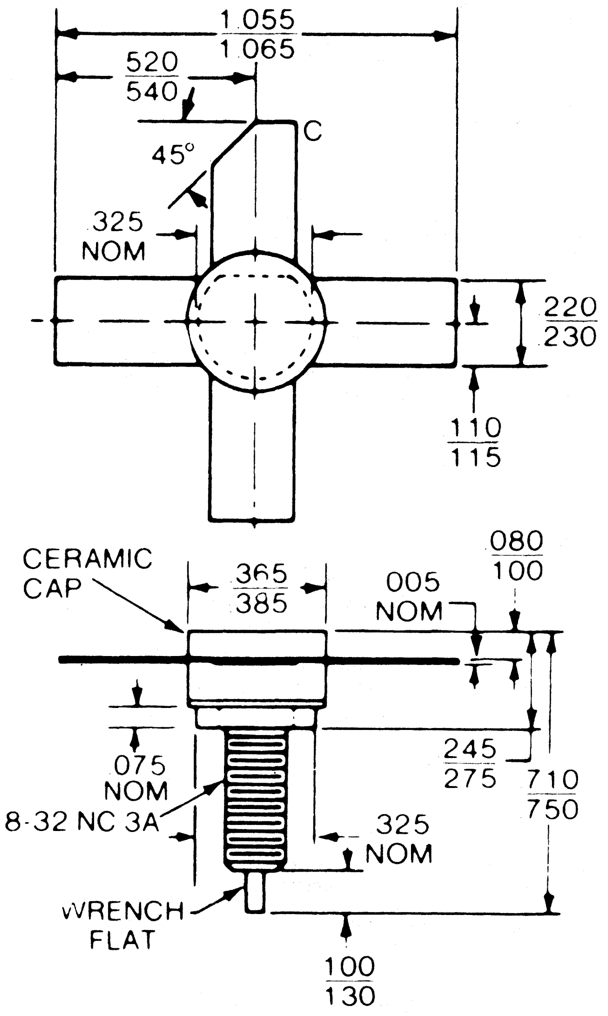
88 MHz TEST CIRCUIT



C_1-C_2-C_3	24/200 pF # trimmer capacitor
C_4	7/100 pF trimmer capacitor
C_5	1000 pF
C_6	10000 pF
C_7	0.1 μF
C_8	100 μF/35 V
L_1-L_4	4 turns # 14 AWG 1/2" I.D.
L_2	0.47 μH
L_3	6 turns 14 AWG 1/2" I.D. close wound

PACKAGE OUTLINE

.380 SOE



VHF/UHF BROADBAND

VHF AND UHF BROADBAND POWER TRANSISTORS

PRODUCT SUMMARY

VHF BROADBAND TRANSISTORS –28V –175 MHz

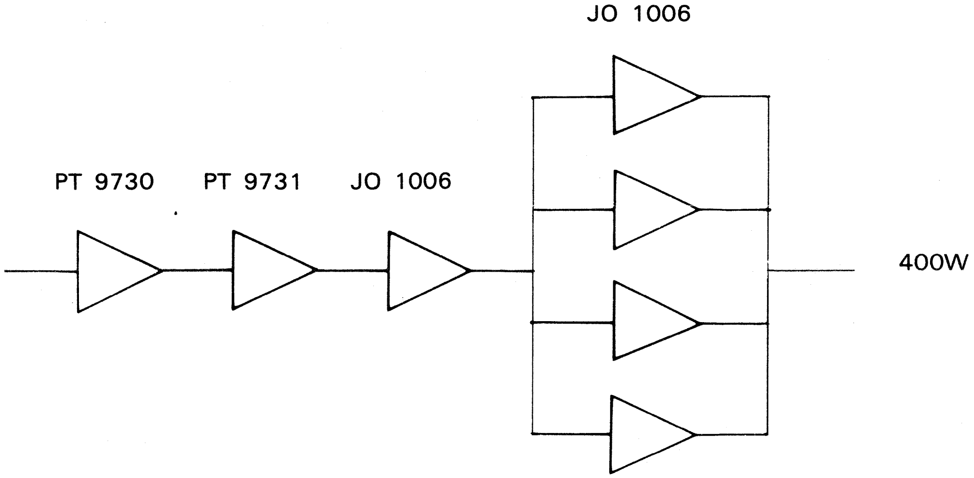
		PAGE
PT 9730	4 W	**201**
PT 9732	8 W	**201**
PT 9734	15 W	**201**
PT 9731	25 W	**201**
PT 9733	50 W	**201**
JO 1006	100 W	**185**

UHF BROADBAND TRANSISTORS –28V –400 MHz

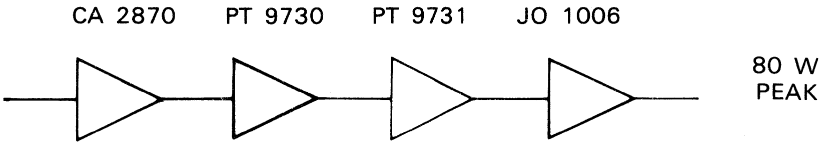
PT 9700	1.5 W	**193**
PT 9701	4 W	**193**
PT 9703	10 W	**193**
PT 9702	20 W	**193**
PT 9704A	30 W	**193**
TPM 401	1 W	**209**
TPM 405	5 W	**213**
TPM 425	25 W	**217**
JO 2015A	70 W	**189**

VHF - UHF
LINE-UP SUGGESTIONS

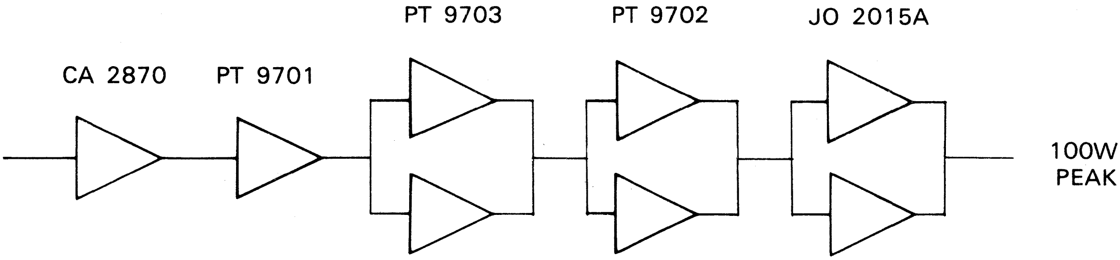
108-118 MHz - FM - 400W



118-156 MHz - AM - 80W PEAK - AIRCRAFT



225-400 MHz - AM - 100W PEAK - AIRCRAFT TACTICAL RADIO

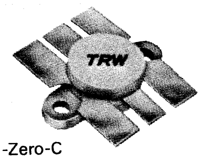


TRW® **SEMICONDUCTORS** **JO 1006**

VHF Power Transistors

100 - 180 MHz
100 W

The JO 1006 is an internally matched NPN silicon VHF transistor. Its computerized thermal, multicell design provides optimum heat dissipation and operating efficiency. Ruggedability and long-term reliability is guranteed by unique, diffused silicon ballasting resistors coupled with TRW's refractory-gold-passivated metalization system.

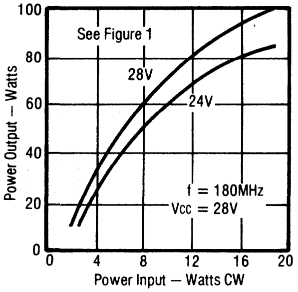


J-Zero-C

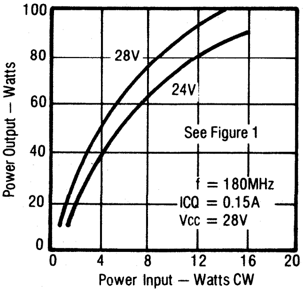
Electrical Characteristics (T_{flange} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC Test	BV_{EBO}	Emitter - Base Breakdown	I_E = 5 mA I_C = 0	4			V
	BV_{CES}	Collector - Emitter Breakdown	I_C = 100 mA V_{BE} = 0	60			V
	BV_{CEO}	Collector - Emitter Breakdown	I_C = 50 mA I_B = 0	35			V
	I_{CES}	Collector - Emitter Cutoff Current	V_{CE} = 25 V			10	mA
	H_{FE}	D.C Current Gain	I_C = 1 A V_{CE} = 10 V	20		150	—
RF Test	P_{GAIN}	Power Gain	V_{CE} = 28 V F = 175 MHz P_{in} = 20 W	100			W
	η	Collector Efficiency	V_{CE} = 28 V F = 175 MHz P_{out} = 100 W		60		%
	VSWR	Mismatch Tolerance	All Phase Angles V_{CE} = 28 V F = 175 MHz P_{out} = 100 W		∞ : 1		
	P_{SAT}	Saturated Power Output	V_{CE} = 28 V F = 175 MHz	125			W
	C_{OB}	Collector - Base Capacitance	V_{CB} = 28 V F = 1 MHz I_E = 0			200	pF
Operating	I_C	Continous Collector Current				12	A
	θ_{j-c}	Thermal Resistance	T_C = 25 °C			0.88	°C/W
	T_{STG}	Storage Temperature and Junction Temperature		— 65°		200	°C
	P_D	Power Dissipation	T_C = 25 °C	150			W

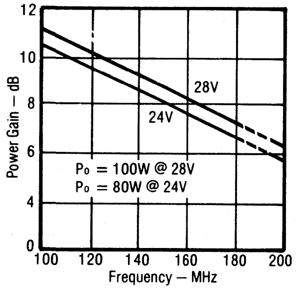
Class C Narrowband Power Input vs Power Output



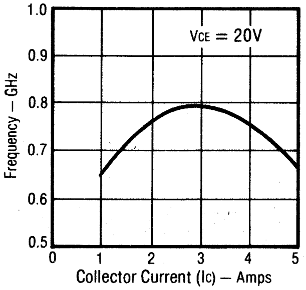
Class B Narrowband Power Input vs Power Output



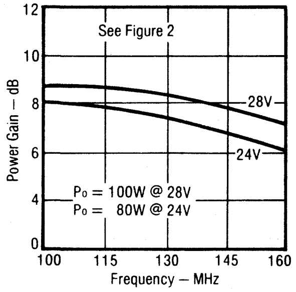
Class C Narrowband Power Gain vs Frequency



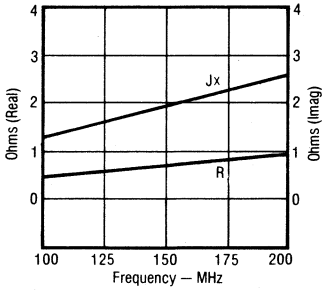
Narrowband f_t vs I_C



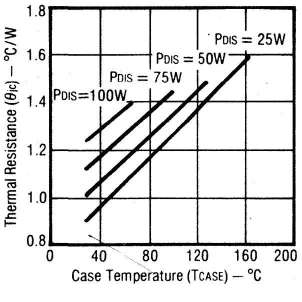
Broadband Power Gain vs Frequency



Series Input Impedance vs Frequency



Θ_{jC} vs T_{CASE}



DC Safe Operating Area

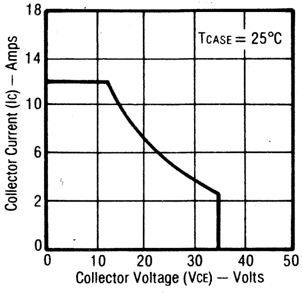
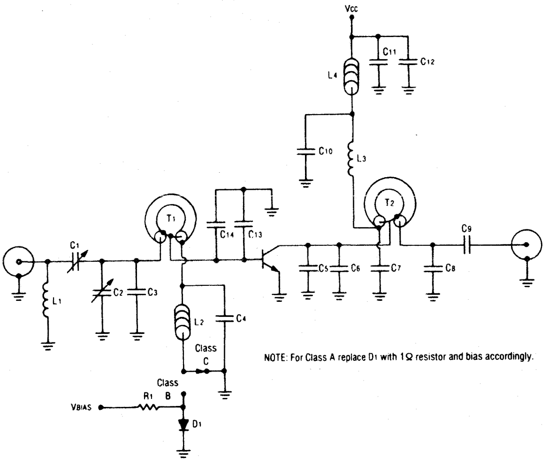


Figure 1. JO 1006 NARROWBAND TEST CIRCUIT (100-180 MHz)

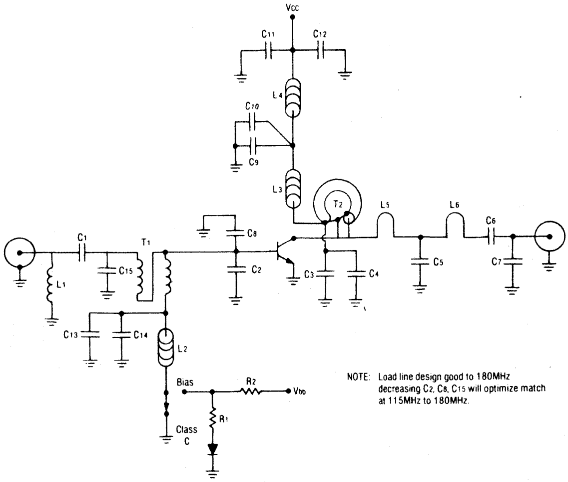


NOTE: For Class A replace D1 with 1Ω resistor and bias accordingly.

C_1	8-60 pF ARCO
C_2	3-35 pF ARCO
C_3	30 pF UNELCO
$C_{4,7,9,10,11}$	1000 pF UNELCO
C_5	110 pF UNELCO
C_6	120 pF UNELCO
C_8	40 pF UNELCO
C_{12}	25 μF Electrolytic

C_{13}	350 pF UNELCO
C_{14}	300 pF UNELCO
D_1	DSR 5050
L_1	5 turns, 0.125″ diameter # 22 AWG
$L_{2,4}$	3 Ferrite beads
R_1	12 Ω
T_1	0.075″ diameter semiridged 10 Ω co-ax
T_2	0.075″ diameter semiridged 25 Ω co-ax

Figure 2. JO 1006 BROADBAND TEST CIRCUIT (100-160 MHz)

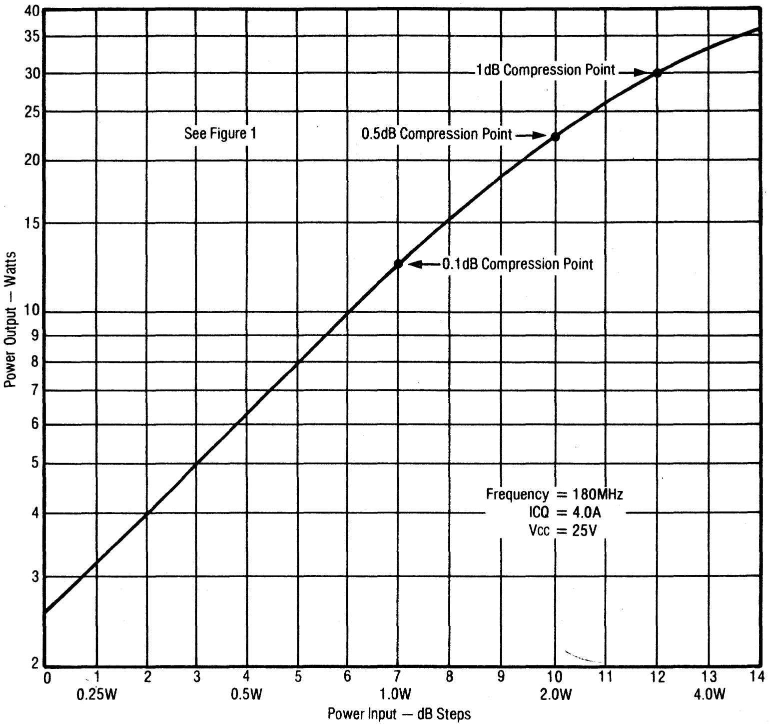


NOTE: Load line design good to 180MHz decreasing C2, C8, C15 will optimize match at 115MHz to 180MHz.

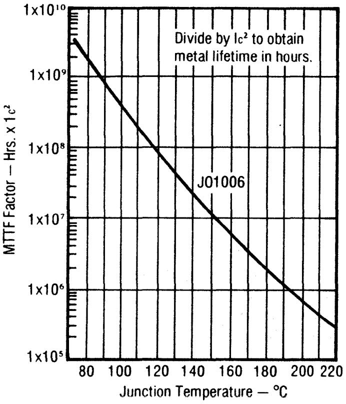
C_1	50 pF UNELCO
C_2	350 pF UNELCO
$C_{3,6,9,12,14}$	1000 pF UNELCO
$C_{4,10,13}$	0.1 μF disc
$C_{5,15}$	30 pF UNELCO
C_7	0-18 pF # 402 ARCO
C_8	300 pF UNELCO
C_{11}	100 μF Electrolytic
D_1	DSR 5050

L_1	4 turns, 0.125″ diameter # 22 AWG
$L_{2,3,4}$	3 Ferrite Beads on # 22 AWG
L_5	0.08″ wide ribbon, 0.25″ long
L_6	0.08″ wide ribbon, 0.125″ long
R_1	1 Ω
R_2	50 Ω
T_1	1″ long twisted pair # 22 AWG
T_2	0.075″ diameter semiridged 25 Ω co-ax, 2″ long (Balun transformer)

Class A Narrowband Power Input vs Power Output



MTTF Factor vs Junction Temperature



Where :

$P_0 = 100$ W

$\eta_C = 60$ %

$G_T = 7$ dB

$T_{CASE} = 45$ °C

$\theta_{jC} = 1.25$

$V_{CE} = 28$ V

$P_{DIS} = 87$ W

$T_j = 150$ °C

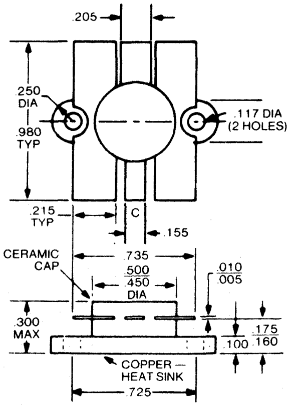
$$\text{MTTF Factor} = (1 \times 10^7 \text{ hrs})\ (\text{amp}^2)$$

$$\text{MTTF (hr)} = \frac{(1 \times 10^7 \text{ hrs})\ (\text{amp}^2)}{(5.95 \text{ amp})^2}$$

$$= 2.8 \times 10^5 \text{ hrs}$$

$$= 32 \text{ yrs}$$

J-Zero-C Package Outline

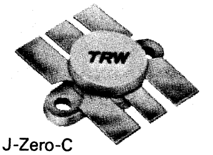


TRW® **SEMICONDUCTORS** **JO 2015 A**

UHF POWER TRANSISTOR

BROAD BAND
225 - 400 MHz
70 W - 28 V
∞ VSWR

The JO 2015 A is an internally matched NPN silicon UHF power transistor. Its multicell design allows optimum heat dissipation and operating efficiency. A slotted-grid finger structure assures uniform current injection. Ruggedability and long-term reliability is guaranteed by unique, diffused silicon ballasting resistors coupled with TRW's refractory-gold-passivated metalization system.

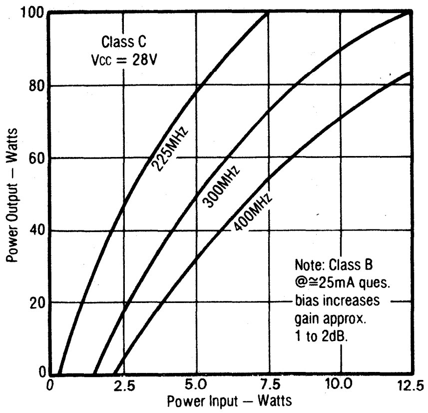


J-Zero-C

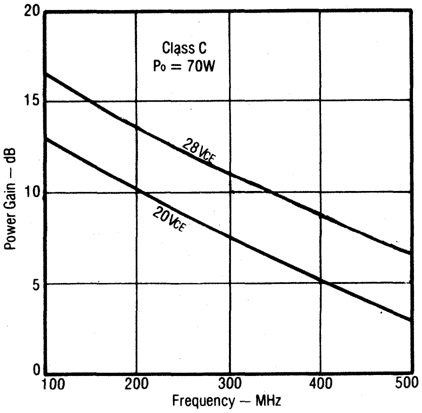
Electrical Characteristics (25 °C)

	Symbol	Characteristics	Condition	Value
D C Tests	BV_{CBO}	Collector-Base Breakdown Voltage	I_C = 100 mA	65 Vdc Min
	BV_{EBO}	Emitter-Base Breakdown Voltage	I_E = 5.0 mA	3.5 Vdc Min
	BV_{CEO}	Collector-Emitter Breakdown Voltage	I_C = 50 mA	30 Vdc Min
	VSWR	Mismatch Tolerance	V_{CE} = 28 V, f = 400 MHz, P_o = 70 W	∞ (All Angles)
	C_{ob}	Collector-Base Capacitance	V_{CB} = 28 V, f = 1 MHz	80 pF Max
	h_{FE}	DC Current Gain	V_{CE} = 10 V, I_C = 1 A	10-100
R F Tests	P_{gain}	Power Gain, CW Broadband	V_{CE} = 28 V, P_o = 70 W f = 225-400 MHz	8.4 dB Min
	P_{sat}	Saturated Power Output	V_{CE} = 28 V, f = 400 MHz	85 W Min
	η	Narrowband Collector Efficiency	V_{CE} = 28, f = 400 MHz, P_o = 70 W	55 % Min
Operating	T_{stg}	Max Storage Temperature		— 65 °C to + 200 °C
	θ_{jC}	Thermal Resistance	25 °C	1.25 °C/W
	I_C	Continuous Collector Current	V_{CE} = 10 V	10 A Max

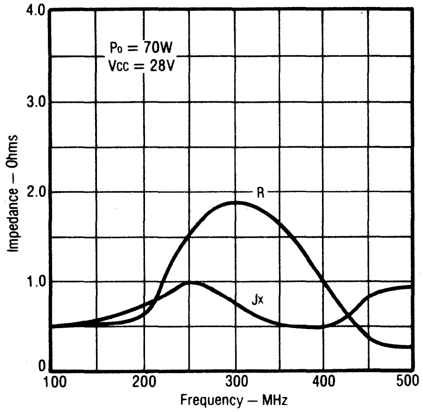
Power Output vs Power Input



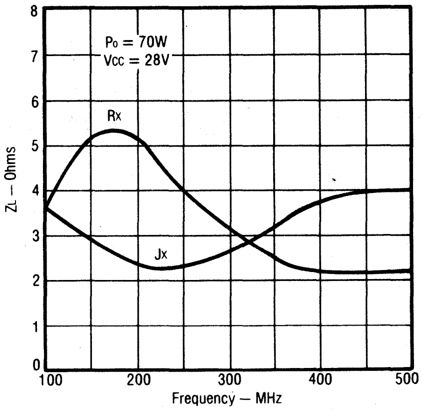
Power Gain vs Frequency



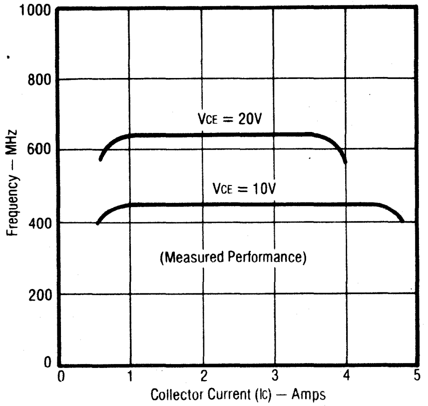
Series Input Impedance vs Frequency



Series Load Impedance vs Frequency



ft vs Ic



Safe Operating Area

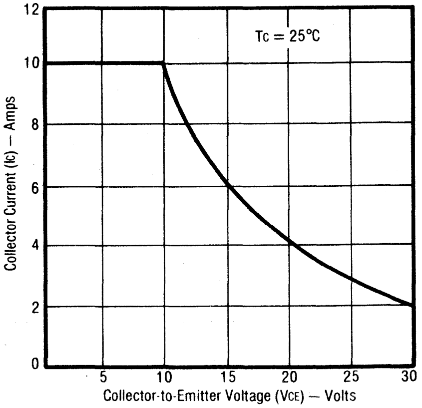
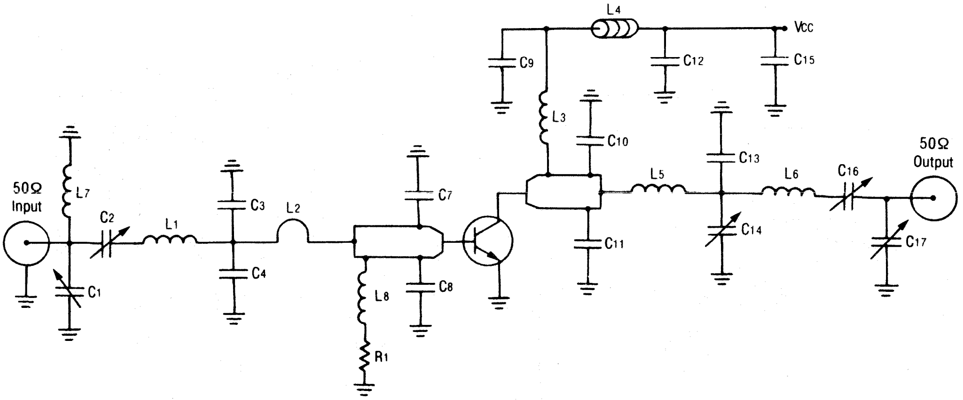
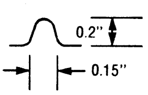


Figure 1. Narrowband Test Circuit



$C_{1,2,14,17}$	1.5-20pF ARCO #402	L_1	2 turns #22AWG, 0.1" form
$C_{3,4}$	10pF UNELCO	L_2	0.2" hairpin, 0.1" wide ribbon
$C_{7,8}$	60pF UNELCO	L_3	#22AWG, 1" diameter
$C_{10,11}$	40pF UNELCO	L_4	3 Ferrite beads on #22AWG
C_{13}	15pF UNELCO	L_5	#22AWG, 0.25" hairpin
$C_{9,12}$	1000pF UNELCO	L_6	1 turn #22AWG, 0.1" form
C_{15}	5μF electrolytic	L_7	6 turns #22AWG, 0.1" form
C_{16}	8-60pF ARCO #404	L_8	8 turns #22AWG, 0.1" form

L2



L5

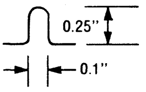
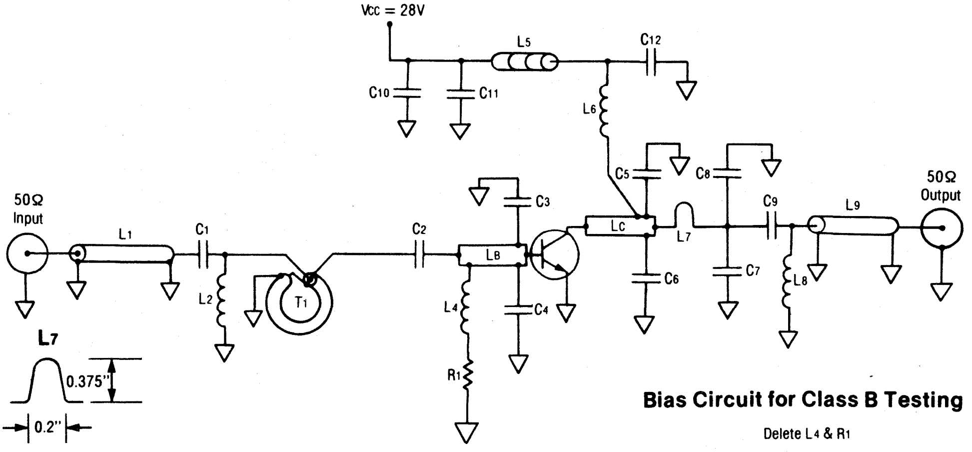
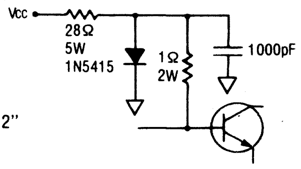


Figure 2. 70 Watt Broadband Test Circuit (225-400MHz)



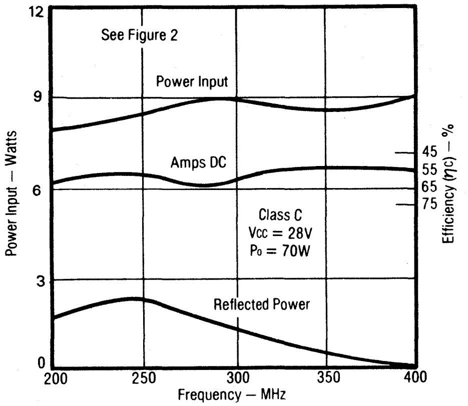
Bias Circuit for Class B Testing

Delete L_4 & R_1

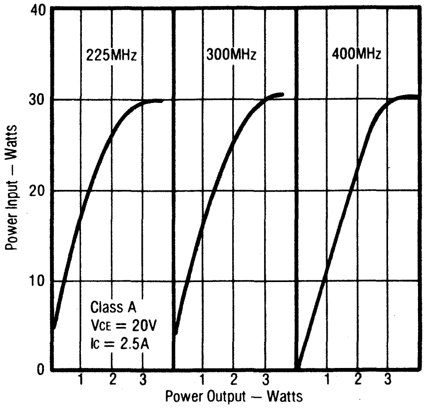


C_1	20pF JFD	$L_{2,4}$	4 turns #20AWG, 0.125" form
C_2	68pF JFD	L_5	3 Ferrite beads
$C_{3,4}$	60pF UNELCO	L_6	#20AWG, 1" diameter.
$C_{5,6}$	40pF UNELCO	L_7	3/8" hairpin
$C_{7,9}$	15pF UNELCO	L_8	3 turns #20AWG, 0.125" form
C_8	10pF UNELCO	L_B	Base Inductance Pad, 0.5" x 0.2"
C_{10}	5μF electrolytic	L_C	Collector Inductance Pad, 0.5" x 0.2"
$C_{11,12}$	1000pF UNELCO	R_1	0.5Ω, 1W
$L_{1,9}$	50Ω semirigid (length to suit circuit)	T_1	1", 25Ω semirigid coax

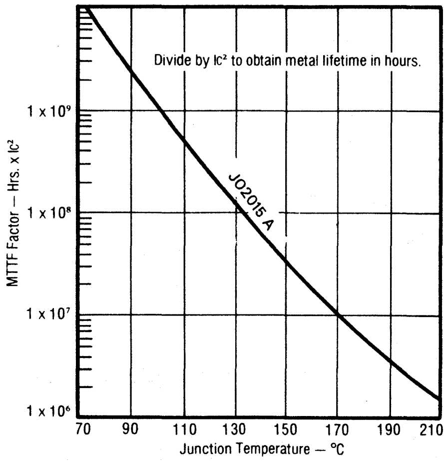
70W Broadband Performance



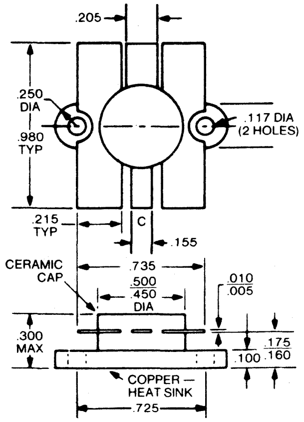
Typical Class A Linear Transfer Characteristics



MTTF Factor vs Tj



J-Zero-C Package Outline



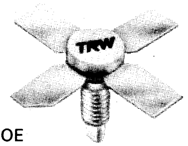
TRW® SEMICONDUCTORS

UHF Power Transistors

PT 9700	1.5 W
PT 9701	4 W
PT 9703	10 W
PT 9702	20 W
PT 9704	30 W
PT 9704 A	30 W

400 MHz - 28 V

The PT 9700 UHF Series features both high gain and high power, providing the desired power output with fewer devices. Microwave cellular geometries processed for UHF application provide both high performance and ruggedness. Diffused ballast resistors in the higher power units enable these devices to withstand infinite VSWR at all phase angles. Ballast resistor design enables operation at Class A, AB and C. These rugged units are suitable for both narrow band and broad band UHF communications and instrumentation service. All are gold metalized for long life and incorporate ceramic stripline packages.



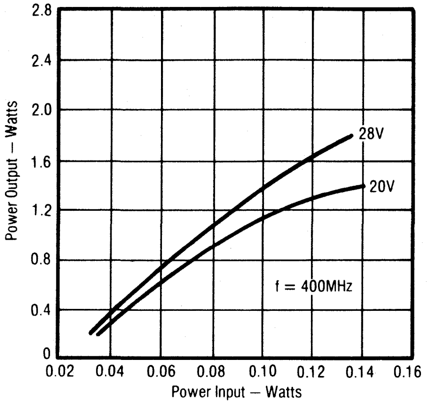
280 SOE

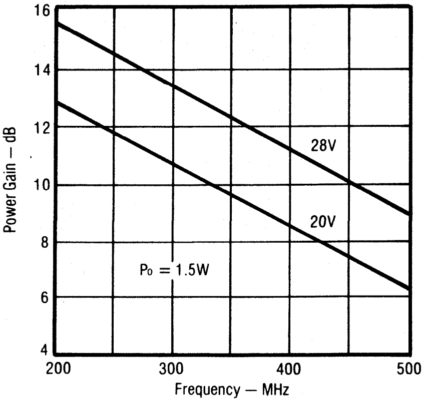
Electrical Characteristics (T_{flange} = 25 °C)

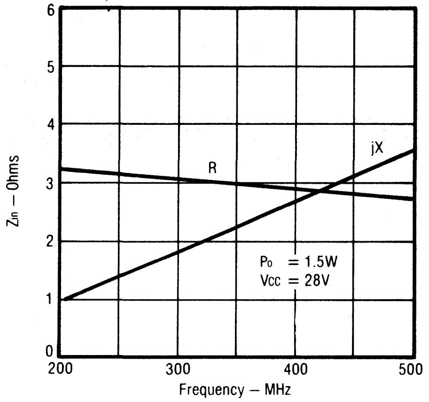
	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	PT 9700	PT 9701	PT 9703	PT 9702	PT 9704 PT 9704A	UNIT
DC Test	BV_{EBO}	Min. Emitter - Base Breakdown	I_E = 0.1 mA I_C = 0 I_E = 1 mA I_C = 0 I_E = 2 mA I_C = 0	3.5	4	4	4	4	V
	BV_{CES}	Min. Collector - Emitter Breakdown	I_C = 1 mA V_{BE} = 0 I_C = 10 mA V_{BE} = 0 I_C = 20 mA V_{BE} = 0	55	55	55	55	55	V
	BV_{CEO}	Min. Collector - Emitter Breakdown	I_C = 20 mA I_B = 0 I_C = 50 mA I_B = 0	35	30	30	30	30	V
	I_{CES}	Max. Collector - Emitter Cutoff Current	V_{CE} = 30 V	0.25	5	5	10	10	mA
	H_{FE}	Min. D.C Current Gain	I_C = 0.1 A V_{CE} = 5 V	20-150	10-150	10-150	10-150	10-150	—
RF Test	P_{GAIN}	Min. Power Gain	V_{CE} = 28 V P_{in} = 0.12 W P_{in} = 0.5 W P_{in} = 1.25 W F = 400 MHz P_{in} = 4 W P_{in} = 5 W	1.5	4	10	20	30*	W
	η	Min. Collector Efficiency	V_{CE} = 28 V Rated F = 400 MHz Output Power	55	55	60	60	60	%
	VSWR	Mismatch Tolerance	V_{CE} = 28 V Rated F = 400 MHz Output Power	∞	∞	∞	∞	∞	
	P_{SAT}	Min. Saturated Power Output	V_{CE} = 28 V F = 400 MHz	2	7	15	25	35	W
	C_{OB}	Max. Collector - Base Capacitance	V_{CB} = 28 V F = 1 MHz I_E = 0	3.5	14	14	22	35	pF
Operating	I_C	Continous Collector Current		0.5	0.75	1.25	2	5	A
	θ_{j-c}	Thermal Resistance	T_C = 25 °C	35	17.5	8.8	4.4	2.5	°C/W
	T_{STG}	Storage Temperature and Junction Temperature		— 65 to + 200					°C
	P_D	Power Dissipation	T_C = 25 °C	5	10	20	40	70	W

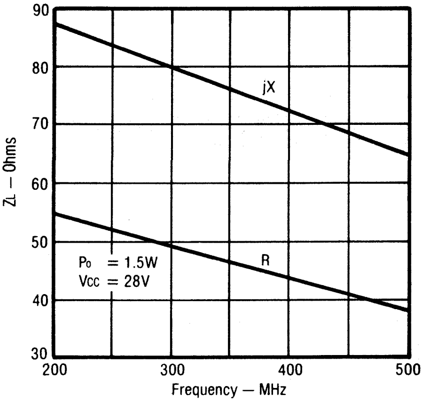
* PT 9704 Power Gain = 6.3 dB at 400 MHz - Power Out/Power in = 30 W/7 W

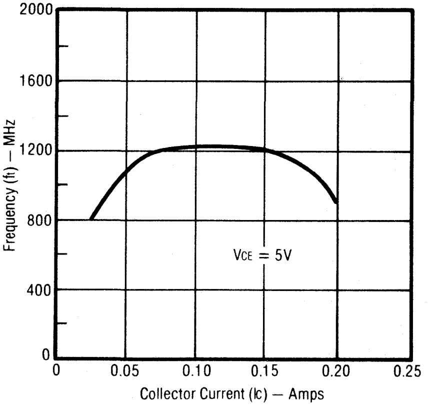
PT 9700 — 1.5 Watts

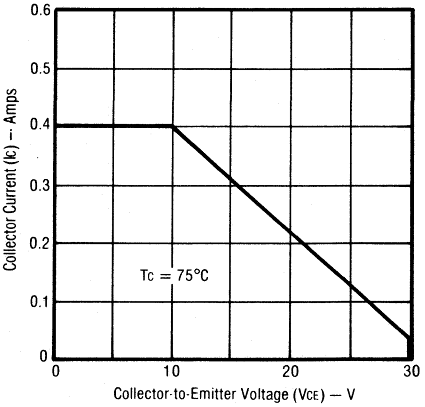

Power Output vs Power Input


Power Gain vs Frequency

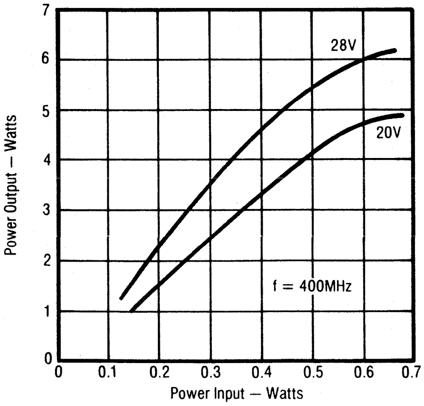

Series Input Impedance vs Frequency


Series Load Impedance vs Frequency

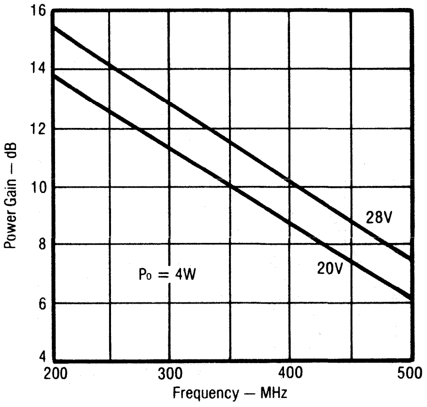

f_t vs I_C


Safe Operating Area

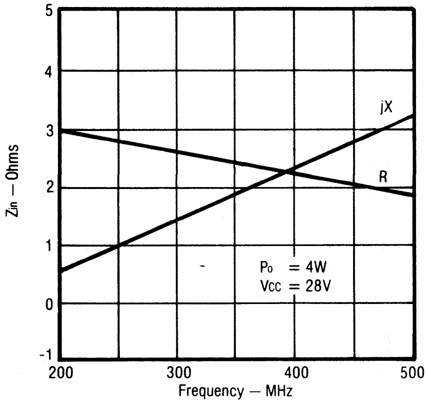
PT 9701 — 4 Watts



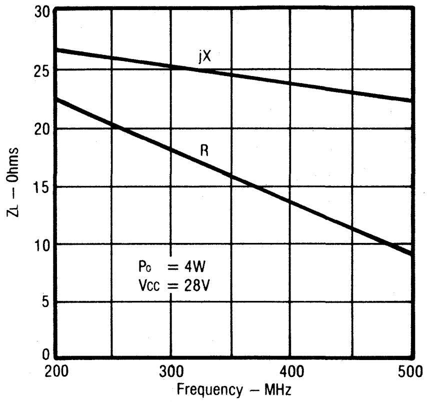
Power Output vs Power Input



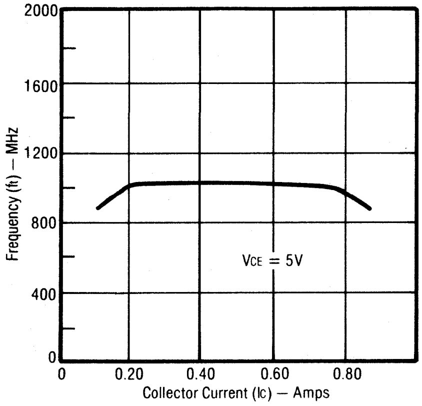
Power Gain vs Frequency



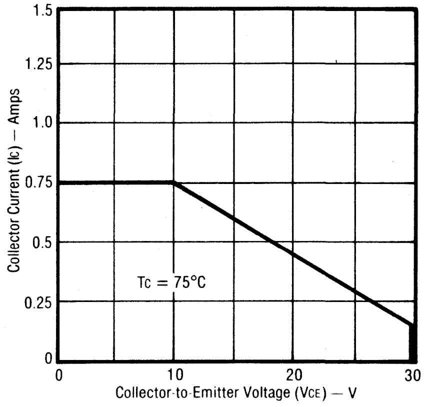
Series Input Impedance vs Frequency



Series Load Impedance vs Frequency

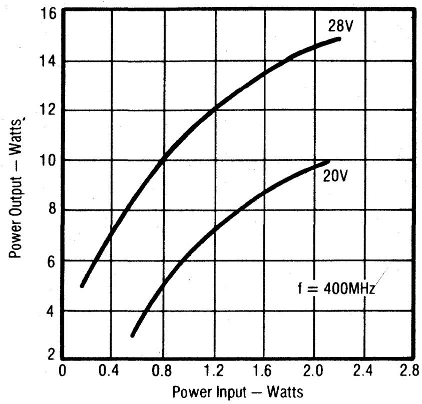


f_t vs I_C

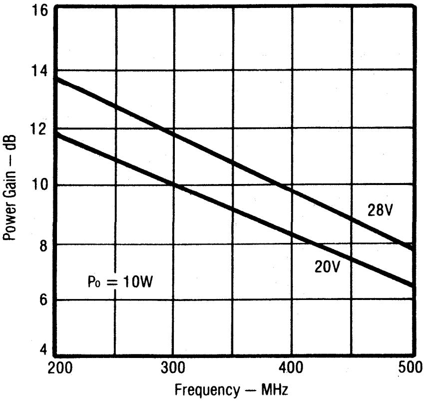


Safe Operating Area

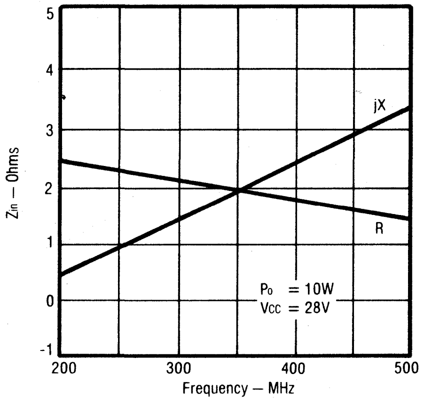
PT 9703 — 10 Watts



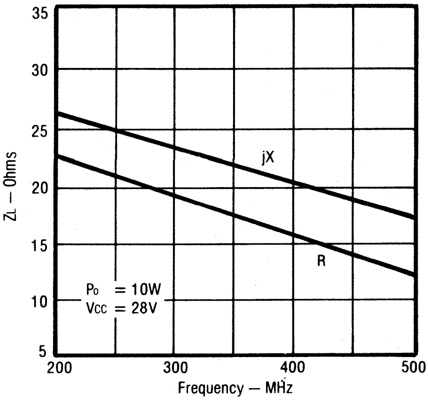
Power Output vs Power Input



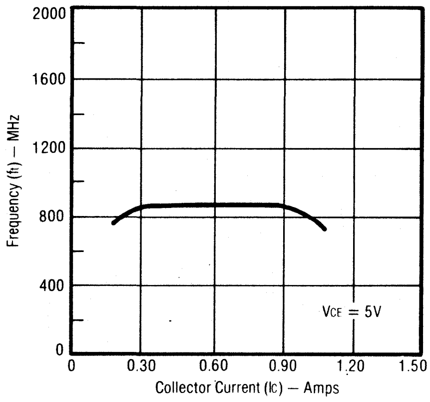
Power Gain vs Frequency



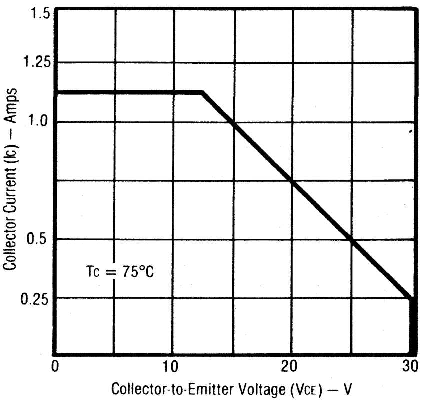
Series Input Impedance vs Frequency



Series Load Impedance vs Frequency



f_t vs I_C

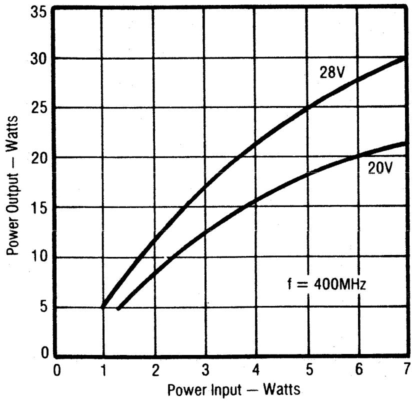


Safe Operating Area

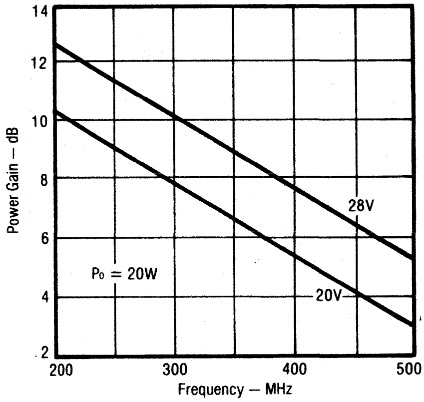
TRW COMPOSANTS ELECTRONIQUES S.A.

PT 9702 — 20 Watts

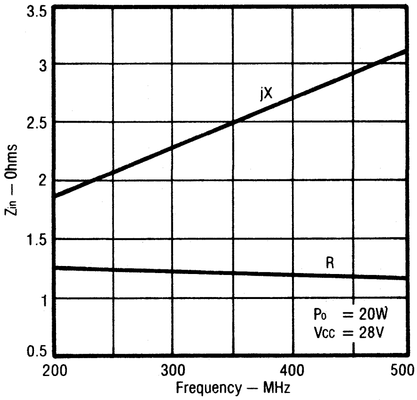
Power Output vs Power Input



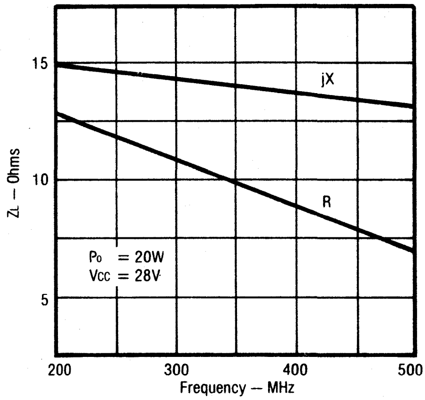
Power Gain vs Frequency



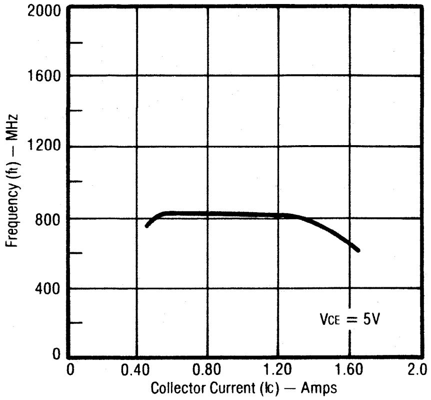
Series Input Impedance vs Frequency



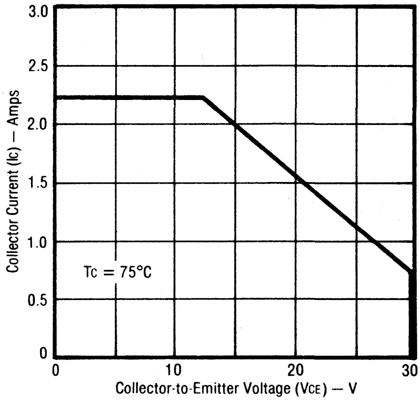
Series Load Impedance vs Frequency



f_t vs I_C

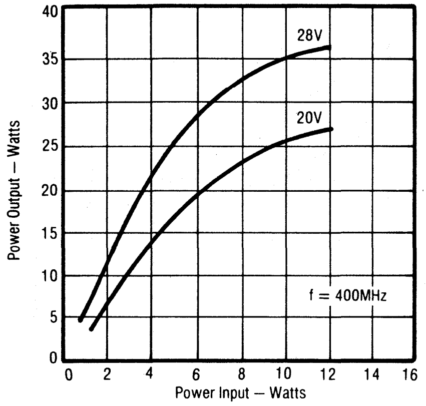


Safe Operating Area

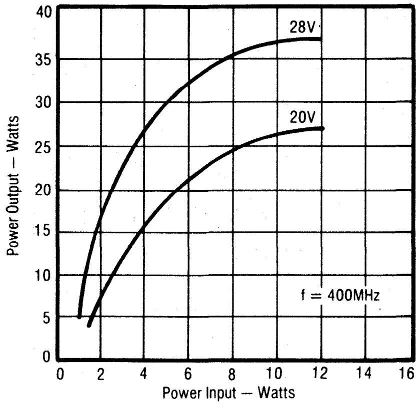


PT 9704 and PT 9704 A — 30 Watts

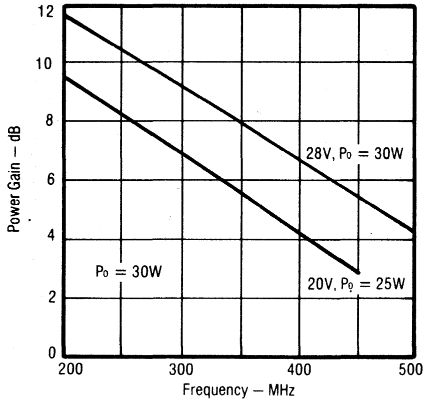
PT 9704 Power Output vs Power Input



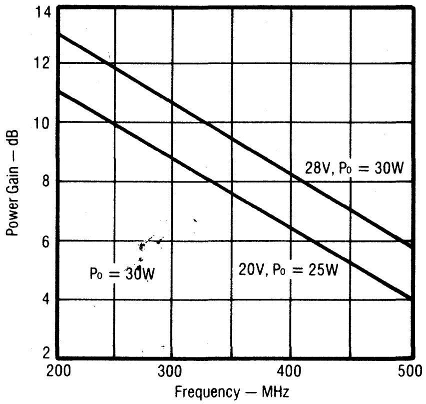
PT 9704 A Power Output vs Power Input



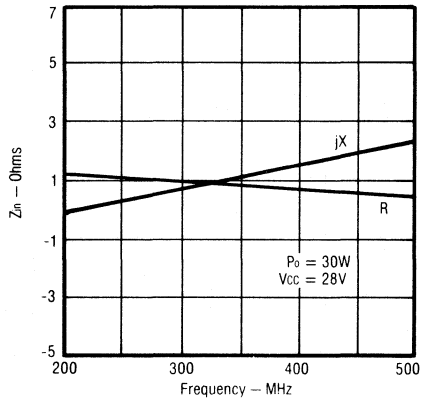
PT 9704 Power Gain vs Frequency



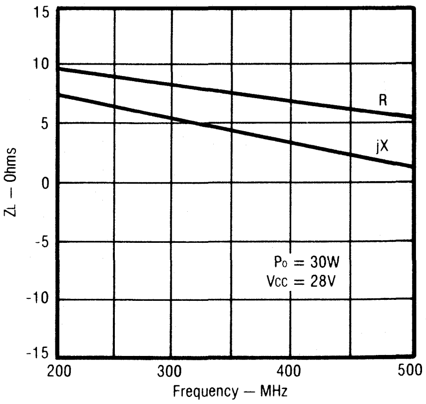
PT 9704 A Power Gain vs Frequency



PT 9704 and PT 9704 A Series Input Impedance vs Frequency

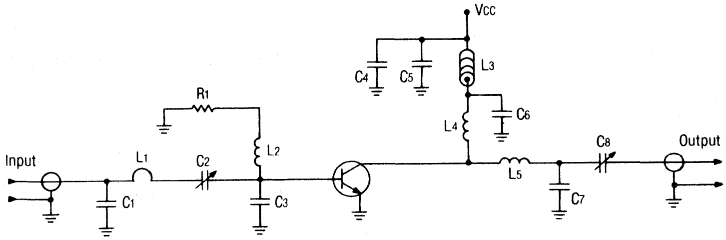


PT 9704 and PT 9704 A Series Load Impedance vs Frequency



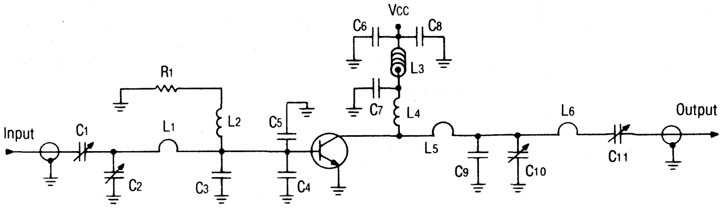
PT 9700, 400 MHz TEST CIRCUIT

$C_{1,7,8}$	0.9-7pF ARCO #400
C_2	3-35pF ARCO #403
C_3	30pF UNELCO
$C_{4,6}$	1000pF UNELCO
C_5	1000μF electrolytic
L_1	1 loop #22AWG, 3/4"
$L_{2,5}$	4 turns #22AWG, 0.1" I.D.
L_3	3 Ferrite beads
L_4	6 turns #22AWG, 0.1" I.D.
R_1	1 ohm, 1/4 watt carbon resistor



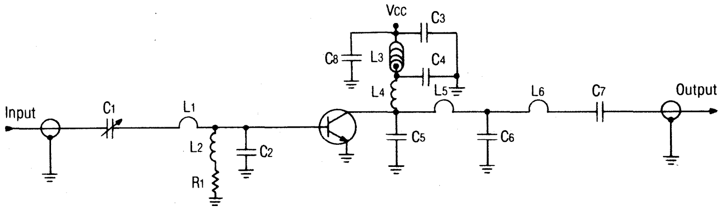
PT 9701 and PT 9703, 400 MHz TEST CIRCUIT

C_1	3-35pF ARCO #403
$C_{2,10}$	0.9-7pF ARCO #400
$C_{3,9}$	10pF UNELCO
$C_{4,5}$	30pF UNELCO
$C_{6,7}$	1000pF UNELCO
C_8	100μF electrolytic
C_{11}	0-18pF ARCO #402
L_1	#22AWG, 1/2"
L_2	4 turns #22AWG, 0.1" I.D.
L_3	3 Ferrite beads
L_4	2 turns #22AWG, 0.1" I.D.
L_5	#22AWG, 0.5" hairpin
L_6	3 turns #22AWG, 0.1" I.D.
R_1	1 ohm, 1/4 watt carbon resistor



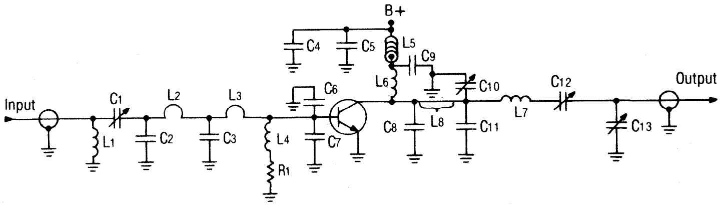
PT 9702, 400 MHz TEST CIRCUIT

C_1	1.5-20pF ARCO #402
C_2	40pF UNELCO
C_3	1000pF UNELCO
C_4	1000pF UNELCO
$C_{5,6}$	20pF UNELCO
C_7	30pF dipped mica
C_8	100μF electrolytic
L_1	#22AWG, 0.6"
L_2	4 turns #22AWG, 0.125 I.D.
L_3	3 Ferrite beads
L_4	3 turns #22AWG, 0.125 I.D.
L_5	#22AWG, 0.5" hairpin
L_6	#22AWG, 0.3" hairpin
R_1	1 ohm, 1/4 watt carbon resistor

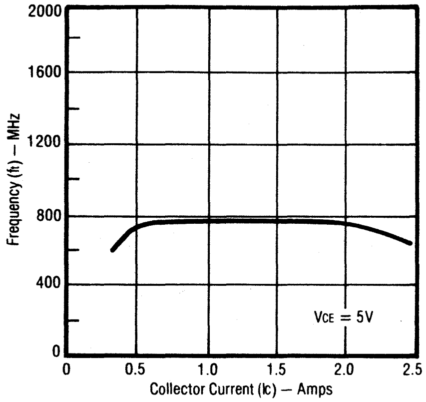


PT 9704 and PT 9704 A, 400 MHz TEST CIRCUIT

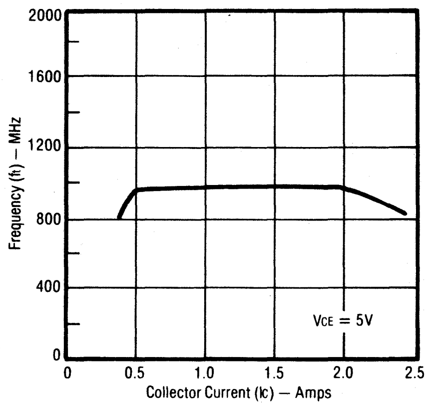
$C_{1,12}$	1.5-20pF ARCO #402
C_2	15pF UNELCO
$C_{3,6,7}$	30pF UNELCO
$C_{4,9}$	1000pF UNELCO
C_5	100μF electrolytic
C_8	35pF UNELCO
$C_{10,13}$	0.9-7pF ARCO #400
C_{11}	10pF UNELCO
L_1	6 turns #22AWG, 1/8" I.D.
L_2	#22AWG, 3/8" hairpin
L_3	1/8" by 1/4" strap
L_4	2 turns on resistor lead
L_5	3 Ferrite beads
$L_{6,7}$	2 turns #22AWG, 1/8" I.D.
L_8	#22AWG, 0.3"
R_1	1 ohm, 1/2 watt carbon resistor



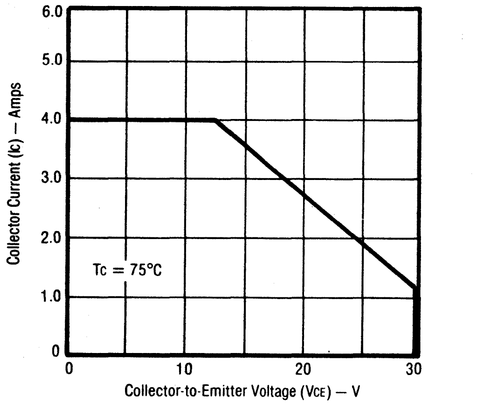
PT 9704 f_t vs I_C



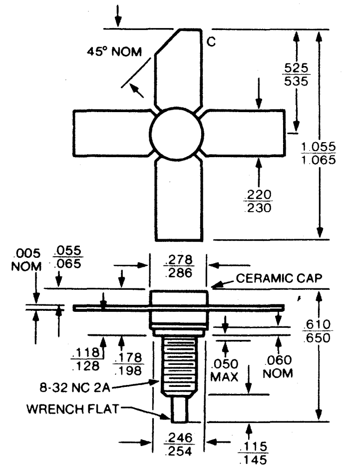
PT 9704 A f_t vs I_C



PT 9704 and PT 9704 A Safe Operating Area

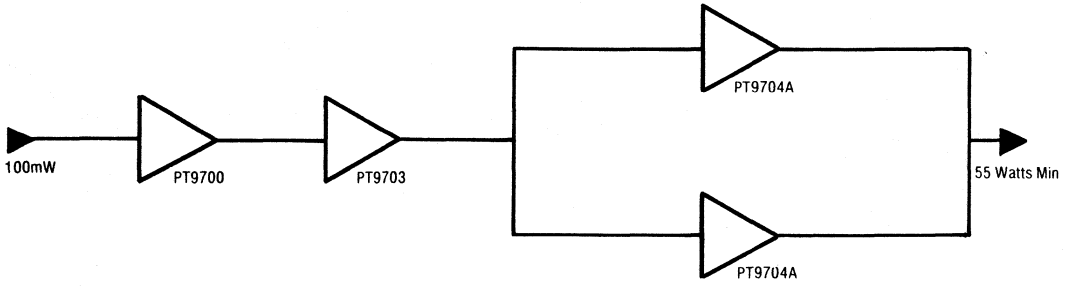


Package Outline



To convert inches to millimeters multiply by 2.54.

Typical Application
55 Watt UHF 28 V Power Amplifier
225-400 MHz



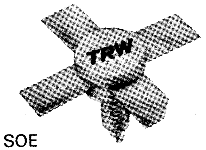
TRW® SEMICONDUCTORS

VHF Power Transistors

PT 9730 4 W
PT 9732 8 W
PT 9734 15 W
PT 9731 25 W
PT 9733 50 W

175 MHz - 28 V

The PT9730 VHF Series feature both high gain and high power, providing the desired power output with fewer devices. These power transistors are ballasted for ruggedness and will withstand infinite VSWR at all phase angles. A unique emitter structure provides high gain with wider emitter and base fingers resulting in high reliability. Ballast resistor design enables operation at Class A, AB, and C. These rugged units are suitable for both narrow band and broadband VHF communications and instrumentation service.

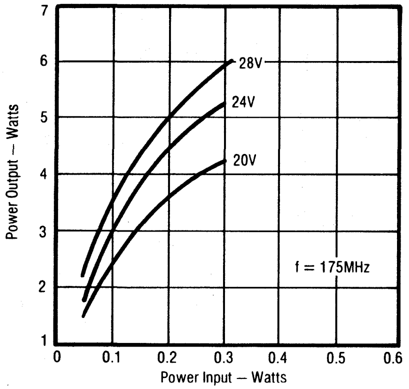


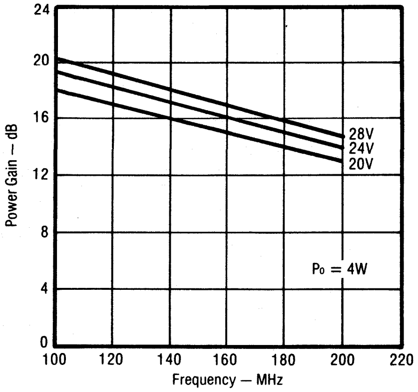
380 SOE

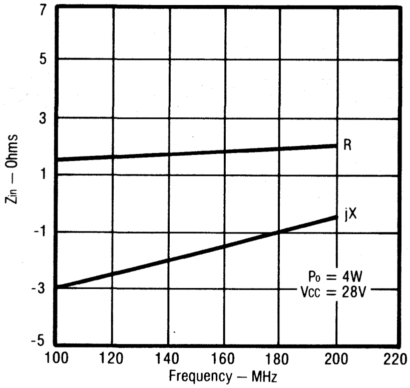
Electrical Characteristics (T_{flange} = 25 °C)

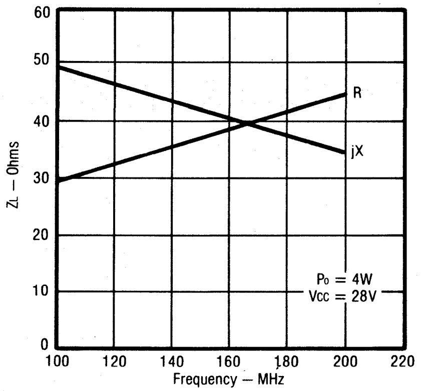
	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	PT 9730	PT 9732	PT 9734	PT 9731	PT 9733	UNIT
DC Test	BV_{EBO}	Min. Emitter - Base Breakdown	I_E = 1 mA I_C = 0	4	4	4	4	4	V
	BV_{CES}	Min. Collector - Emitter Breakdown	I_C = 50 mA V_{BE} = 0	60	60	60	60	60	V
	BV_{CEO}	Min. Collector - Emitter Breakdown	I_C = 25 mA I_B = 0	35	35	35	35	35	V
	I_{CES}	Max. Collector - Emitter Cutoff Current	V_{CE} = 25 V	0.5	0.5	0.75	1	2	mA
	H_{FE}	Min. D.C Current Gain	I_C = 500 mA V_{CE} = 10 V	20 to 150	20 to 150	20 to 150	20 to 150	20 to 150	—
RF Test	P_{GAIN}	Min. Power Gain	V_{CE} = 28 V F = 175 MHz P_{in} = 0.2 W P_{in} = 0.5 W P_{in} = 1 W P_{in} = 2.5 W P_{in} = 8 W	4	8	15	25	50	W
	η	Min. Collector Efficiency	V_{CE} = 28 V F = 175 MHz Rated Output Power	60	60	60	60	60	%
	VSWR	Mismatch Tolerance	V_{CE} = 28 V F = 175 MHz Rated Output Power	∞	∞	∞	∞	∞	
	P_{SAT}	Min. Saturated Power Output	V_{CE} = 28 V F = 175 MHz	6	10	18	30	60	W
	C_{OB}	Max. Collector - Base Capacitance	V_{CB} = 28 V F = 1 MHz I_E = 0	12	18	24	40	90	pF
Operating	I_C	Continous Collector Current		1	1.25	2.5	4	8	A
	θ_{j-c}	Thermal Resistance	T_C = 25 °C	17.5	8.8	5.8	3.9	2.1	°C/W
	T_{STG}	Storage Temperature and Junction Temperature		— 65 to + 200					°C
	P_D	Power Dissipation	T_C = 25 °C	10	20	30	45	85	W

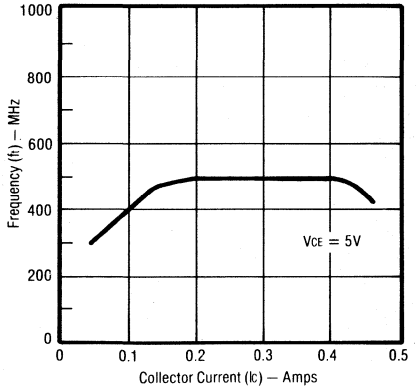
PT 9730 — 4 Watts

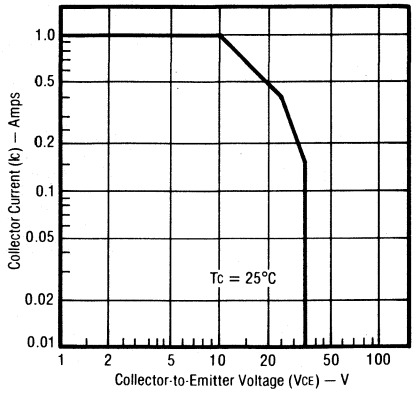

Power Output vs Power Input


Power Gain vs Frequency


Series Input Impedance vs Frequency

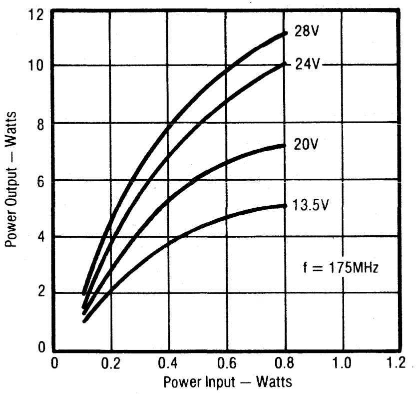

Series Load Impedance vs Frequency


f_t vs I_C

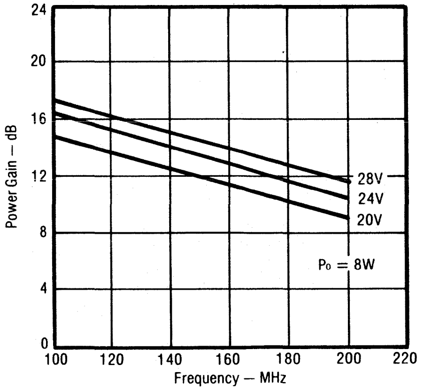

Safe Operating Area

PT 9732 — 8 Watts

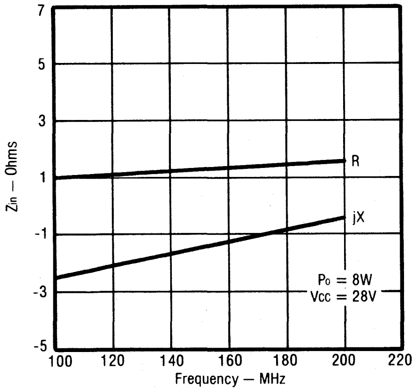
Power Output vs Power Input



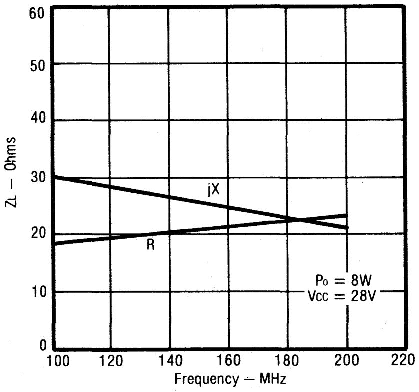
Power Gain vs Frequency



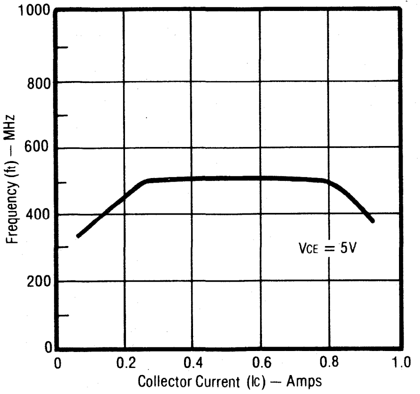
Series Input Impedance vs Frequency



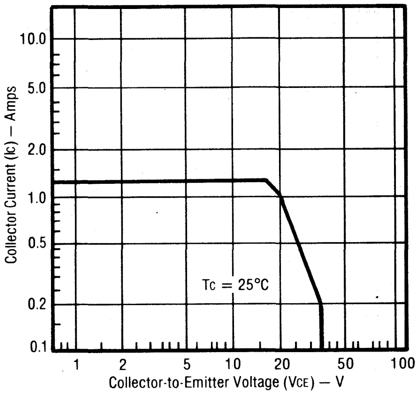
Series Load Impedance vs Frequency



f_t vs I_C

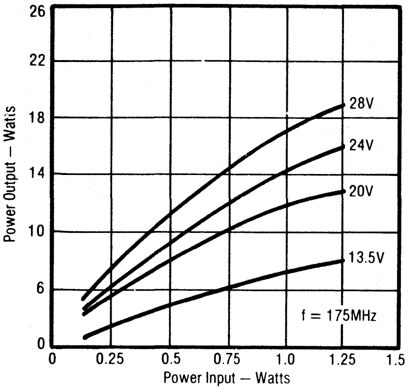


Safe Operating Area

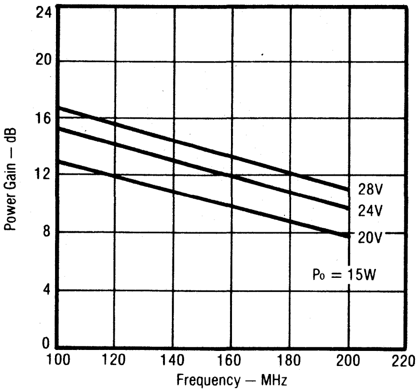


PT 9734 — 15 Watts

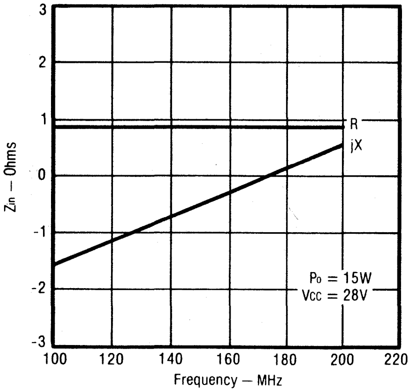
Power Output vs Power Input



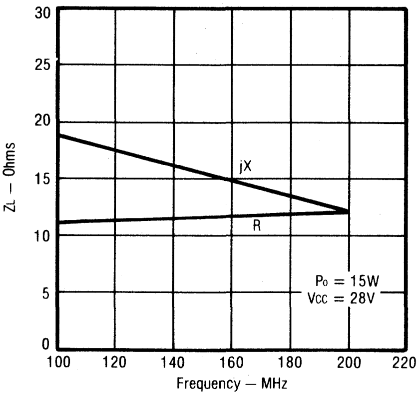
Power Gain vs Frequency



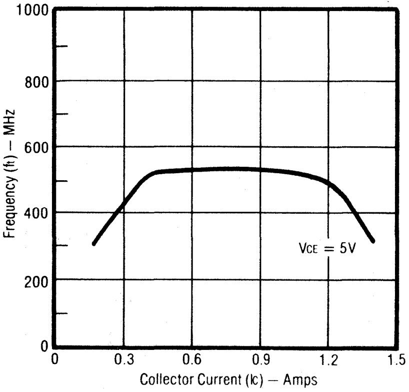
Series Input Impedance vs Frequency



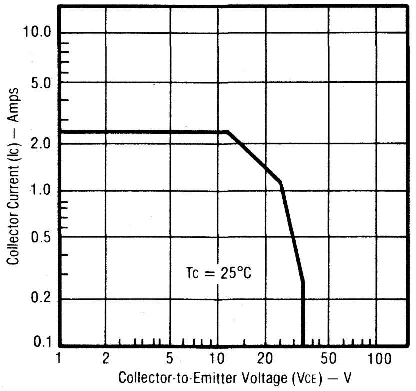
Series Load Impedance vs Frequency



f_t vs I_C

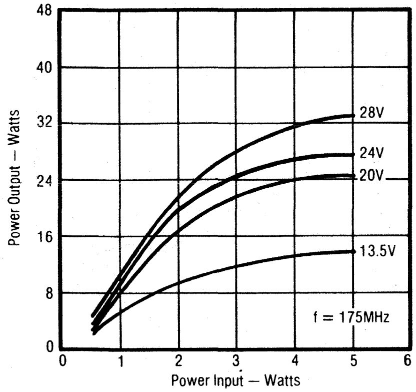


Safe Operating Area

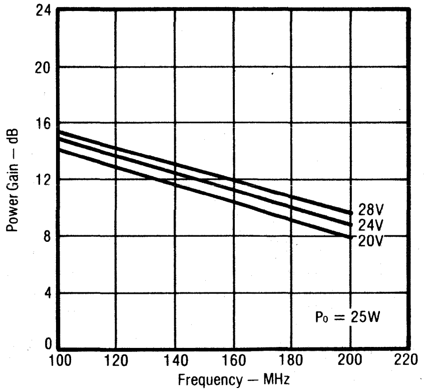


PT 9731 — 25 Watts

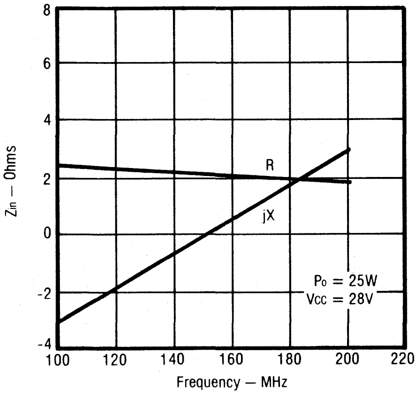
Power Output vs Power Input



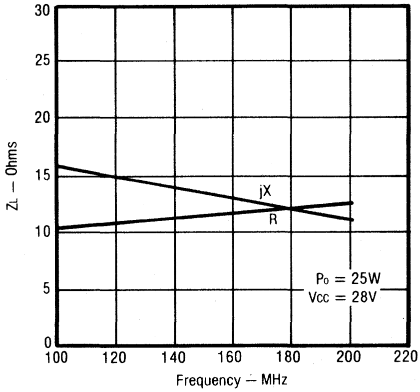
Power Gain vs Frequency



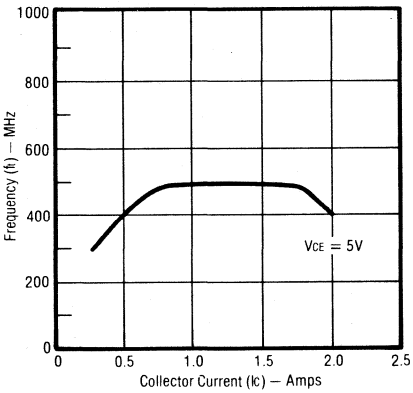
Series Input Impedance vs Frequency



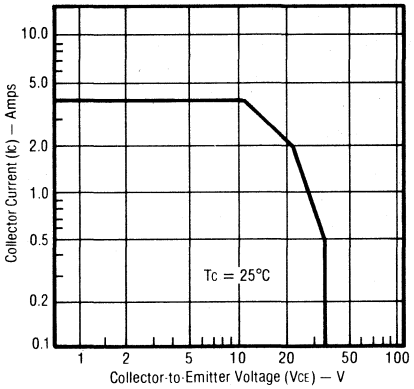
Series Load Impedance vs Frequency



f_t vs I_C

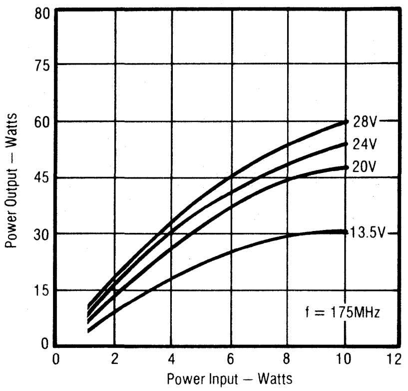


Safe Operating Area

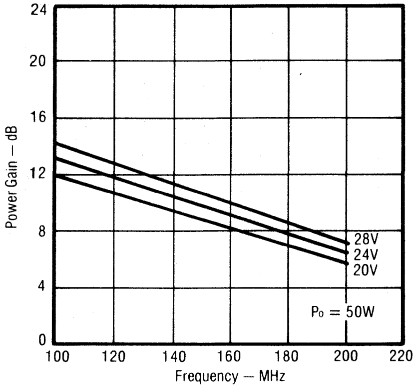


PT 9733 — 50 Watts

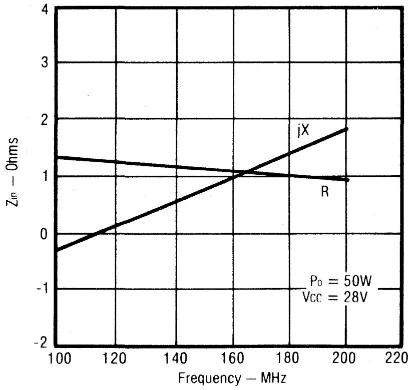
Power Output vs Power Input



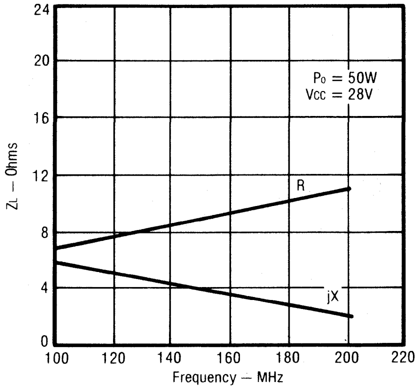
Power Gain vs Frequency



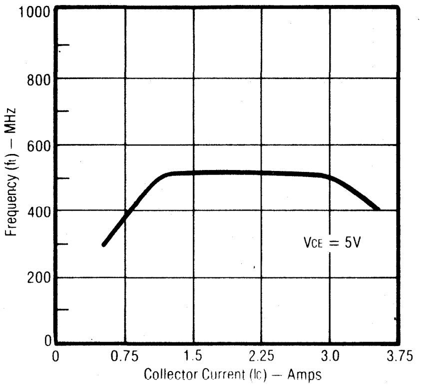
Series Input Impedance vs Frequency



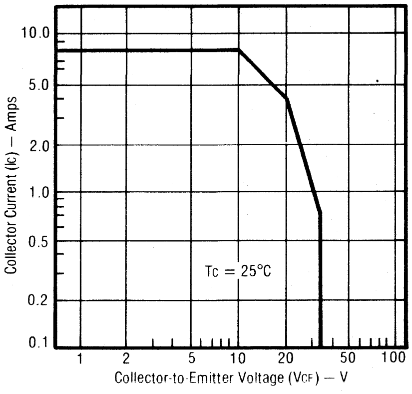
Series Load Impedance vs Frequency



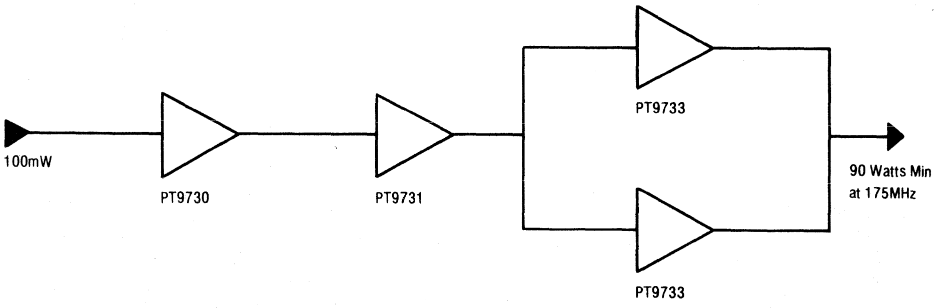
f_t vs t_C



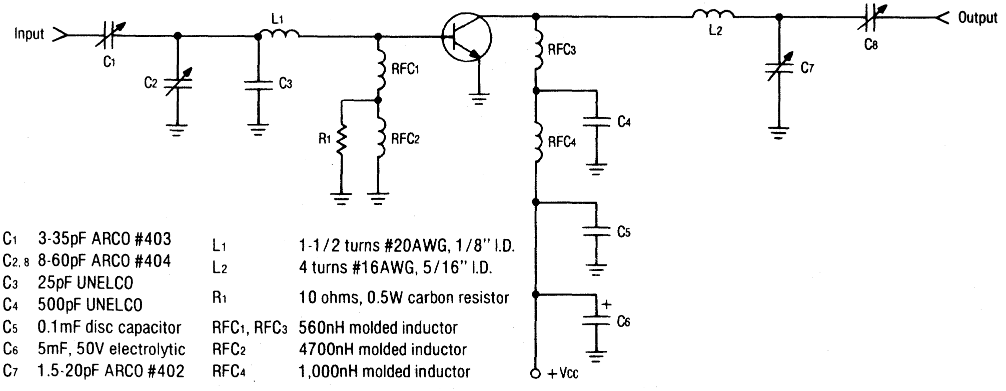
Safe Operating Area



TYPICAL APPLICATION
90 Watt VHF 28 V Power Amplifier



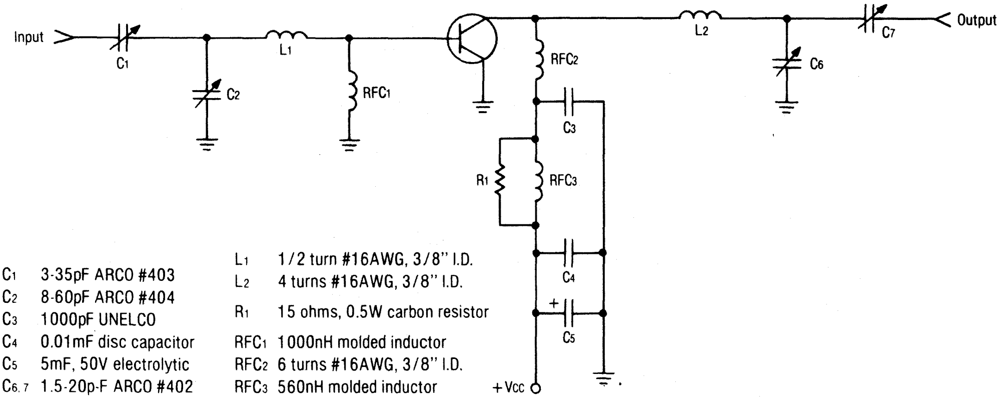
PT 9730 and PT 9732 175 MHz TEST CIRCUIT



C_1	3-35pF ARCO #403
$C_{2,8}$	8-60pF ARCO #404
C_3	25pF UNELCO
C_4	500pF UNELCO
C_5	0.1mF disc capacitor
C_6	5mF, 50V electrolytic
C_7	1.5-20pF ARCO #402

L_1	1-1/2 turns #20AWG, 1/8" I.D.
L_2	4 turns #16AWG, 5/16" I.D.
R_1	10 ohms, 0.5W carbon resistor
RFC_1, RFC_3	560nH molded inductor
RFC_2	4700nH molded inductor
RFC_4	1,000nH molded inductor

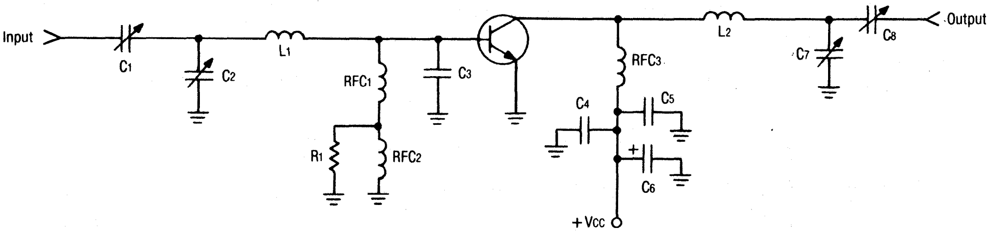
PT 9734 175 MHz TEST CIRCUIT



C_1	3-35pF ARCO #403
C_2	8-60pF ARCO #404
C_3	1000pF UNELCO
C_4	0.01mF disc capacitor
C_5	5mF, 50V electrolytic
$C_{6,7}$	1.5-20p-F ARCO #402

L_1	1/2 turn #16AWG, 3/8" I.D.
L_2	4 turns #16AWG, 3/8" I.D.
R_1	15 ohms, 0.5W carbon resistor
RFC_1	1000nH molded inductor
RFC_2	6 turns #16AWG, 3/8" I.D.
RFC_3	560nH molded inductor

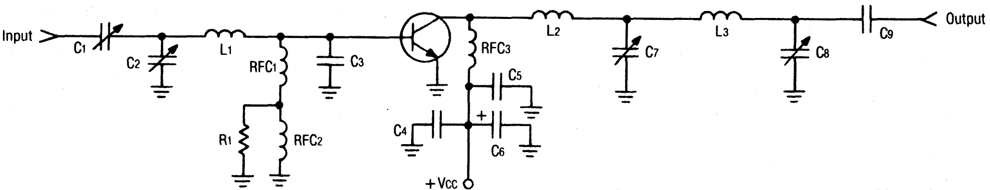
PT 9731 175 MHz TEST CIRCUIT



$C_{1,8}$	7-100pF ARCO #423
C_2	8-60pF ARCO #404
C_3	90pF UNELCO
C_4	1000pF UNELCO
C_5	0.1mF disc capacitor
C_6	5mF, 50V electrolytic
C_7	5-80pF ARCO #462

L_1	2 turns, 0.1" wide by 0.02" thick copper strip, 1/4" I.D.
L_2	4 turns, 0.1" wide by 0.02" thick copper strip, 1/4" I.D.
R_1	10 ohms, 0.5W carbon resistor
RFC_1	150nH molded inductor
RFC_2	10,000nH molded inductor
RFC_3	4 turns #16AWG, 5/16" I.D.

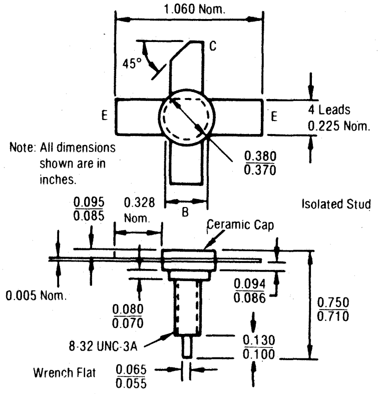
PT 9733 175 MHz TEST CIRCUIT



$C_{1,2,8}$	8-60pF ARCO #404
C_3	150pF UNELCO
C_4	500pF UNELCO
C_5	0.1mF disc capacitor
C_6	5mF, 50V electrolytic
C_7	5-80pF ARCO #462
C_9	0.001mF disc capacitor
L_1	1 turn, 0.1" wide by 0.02" thick copper strip, 5/16" I.D.

L_2	U-shaped copper strip, 0.1" wide by 0.02" wide thick, 0.25" high by 0.675" long
L_3	1-1/2 turns, 0.1" wide by 0.02" thick copper strip, 5/16" I.D.
R_1	10 ohms, 0.5W carbon resistor
RFC_1	150nH molded inductor
RFC_2	10,000nH molded inductor
RFC_3	4 turns #16AWG, 5/16" I.D.

PACKAGE OUTLINE



Note: All dimensions shown are in inches.

TRW® SEMICONDUCTORS

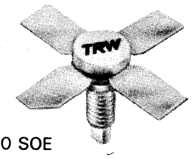
TPM 401

UHF Power Transistor

100 - 400 MHz
1 W 20 V
16 dB GAIN
NARROW BAND
GOLD RELIABILITY

The TM 401 is a NPN gold metallized transistor using diffused emitter ballast resistor design for operation in class A, B or C conditions.

The high gain reduces the need for complex broadband circuits and is ideally suited for 100-400 MHz broadband amplifier applications.



280 SOE

Electrical Characteristics (T_{case} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC TEST	BV_{EBO}	Emitter Base Breakdown Voltage	I_E = 0.3 mA	3.5			V
	BV_{CER}	Collector Emitter Breakdown Voltage	R_{BE} = 10 Ω I_C = 20 mA	50			V
	BV_{CEO}	Collector Emitter Breakdown Voltage	I_C = 20 mA	24			V
	BV_{CBO}	Collector Base Breakdown Voltage	I_C = 1 mA	45			V
	I_{CBO}	Collector Base Leakage	V_{CB} = 28 V			125	μA
	h_{FE}	DC Current Gain	V_{CE} = 5 V I_C = 100 mA	20		120	
RF TEST	P_G	Power Gain Class A Broad Band	F = 400 MHz V_{CE} = 20 V I_E = 200 mA P_O = .5 W	13			dB
	P_{sat}	Broad Band Min Saturated Output Power Class A	F = 400 MHz V_{CE} = 20 V I_E = 200 mA	1.3			W
	VSWR	Mismatch Tolerance	F_O = 400 MHz V_{CE} = 20 V I_C = 220 mA P_{out} = 1.0 WCW		∞		
	C_{ob}	Collector Base Capacitance	V_{CB} = 24 V F = 1 MHz			5	pF
	F_T	Cutoff Frequency	V_{CE} = 20 V I_E = 200 mA	2.2			GHz
THERMAL	I_C	Maximum Collector Current				0.7	A
	$\theta_{j.C}$	Thermal Resistance Junction Case	T_{case} = 70 °C			20	°C/W
	P_T	Power Dissipation	T_{case} = 25 °C			8.75	W
	T_{STG} T_J	Storage temperature Junction temperature		— 65		+ 200	°C

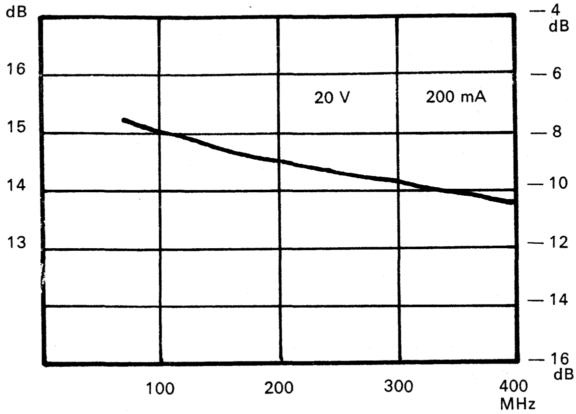
V_{CE} = 20 V - I_C = 200 mA - Class A

POLAR S-PARAMETERS IN 50 OHM SYSTEM								
F	S 11		S 21		S 12		S 22	
MHz	Magn	Angl°	Magn	Angl°	Magn	Angl°	Magn	Angl°
100 MHz	0.67	203°	12.6	112°	0.037	32°	0.41	— 90°
200 MHz	0.78	186°	7.6	93°	0.042	31°	0.33	— 122°
300 MHz	0.79	183°	5.5	82.5°	0.047	30°	0.34	— 135°
400 MHz	0.78	170°	4.21	72°	0.053	30°	0.34	— 137°
500 MHz	0.76	165°	3.39	66°	0.061	35°	0.33	— 138°

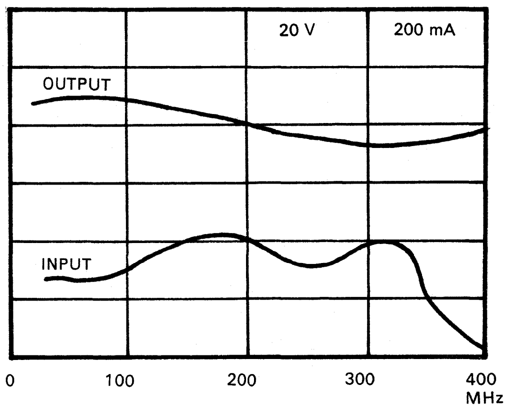
100-400 MHz AMPLIFIER PERFORMANCES

Class A 20 V 200 mA

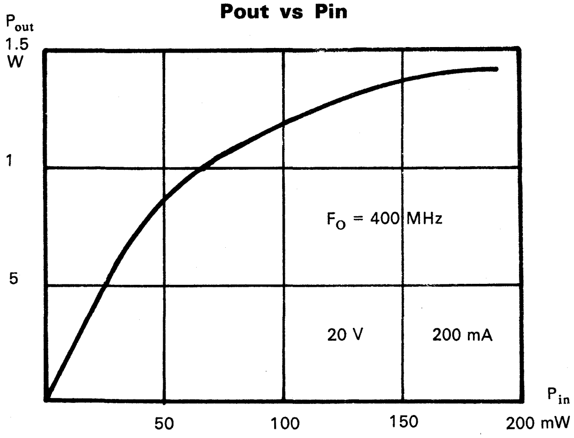
Small Signal Gain Variation



Input and Output VSWR

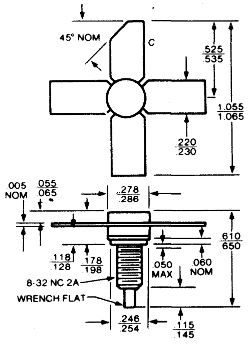


Pout vs Pin

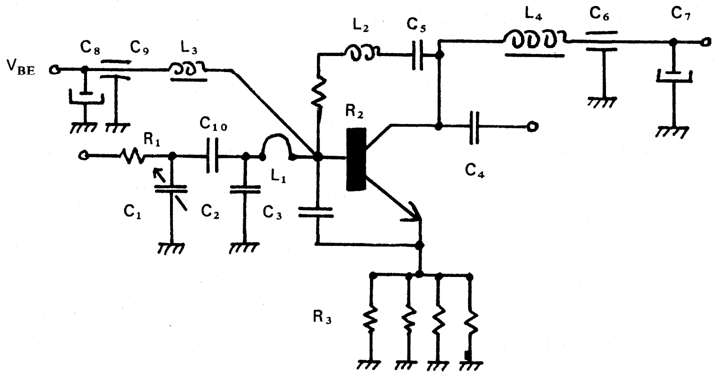


Package

.280 SOE

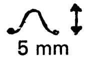


1 W - 100-400 MHz Class A AMPLIFIER



C_1 = 1-9 pF variable RTC
C_2 = 8.2 pF RTC C 330
C_3 = 2 × 2.2 pF RTC C 632
C_4 = 10 nF RTC C 331
C_5 = C_{10} = 1 nF C 331
C_6 = C_9 = 1 nF by-pass
C_7 = C_8 = 10 μF 25 V

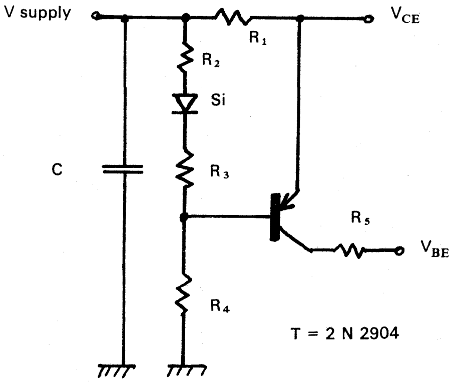
R_1 = 15 Ω carbon composition
R_2 = 300 Ω carbon composition
R_3 = 4 × 3.9 Ω 1/4 W
Carbon composition

L_1 =  5 mm wire 5/10 mm
5 mm

L_2 = 4 turns ID 4 mm wire 5/10 mm

L_3 = L_4 = choke

Bias Circuit



T = 2 N 2904

R_1 = 11 Ω 1/2 W
R_2 = 500 Ω
R_3 = 220 Ω
R_4 = 4.7 kΩ
R_5 = 22 Ω

TRW® SEMICONDUCTORS

TPM 405

Preliminary

UHF Power Transistor

5 W - 400 MHz

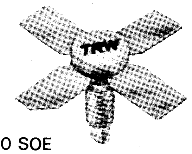
16 dB GAIN

GOLD RELIABILITY

The TPM 405 is a NPN gold metallized transistor using diffused emitter ballast resistors for operation at class A, AB and C.

Its high gain reduces the complexity of the broadband stages and make the TPM 405 ideal for 100-400 MHz applications.

A 100-400 MHz push-pull amplifier is described in the two last pages of this data sheet.



280 SOE

Electrical Characteristics (T_{case} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC TEST	BV_{EBO}	Emitter Base Breakdown Voltage	$I_E = 0.5$ mA	3.5			V
	BV_{CER}	Collector Emitter Breakdown Voltage	$I_C = 40$ mA $R_{BE} = 10\ \Omega$	50			V
	BV_{CBO}	Collector Base Breakdown Voltage	$I_C = 2$ mA	45			V
	I_{CBO}	Collector Base Leakage	$V_{CB} = 28$ V			250	µA
	h_{FE}	DC Current Gain	$V_{CE} = 5$ V $I_C = 200$ mA	20		120	
RF TEST	P_{GAIN}	Power Gain Class AB	$V_{CE} = 24$ V $P_{out} = 5$ W $F_O = 400$ MHz $I_Q = 50$ mA	16			dB
	η	Min Collector Efficiency	$V_{CE} = 24$ V $P_{out} = 5$ W $F_O = 400$ MHz $I_Q = 50$ mA	50			%
	VSWR	Mismatch Tolerance	$V_{CE} = 24$ V $P_{out} = 3$ W $F_O = 400$ MHz $I_Q = 50$ mA		∞		
	P_{SAT}	Min Saturated Power output	$V_{CE} = 24$ V $F_O = 400$ MHz $I_Q = 50$ mA	7			W
	C_{ob}	Collector Base Capacitance	$V_{CB} = 24$ V F = 1 MHz			7	pF
THERMAL	I_C	Maximum Collector Current				1.4	A
	$\theta_{J.C}$	Thermal Resistance Junction Case	$T_{case} = 70$ °C			9.5	°C/W
	T_{STG} T_j	Storage and Junction Temperature		— 65 °C		+ 200	°C

CLASS A - V_{CE} = 20 V - I_C = 440 mA - Small Signal

POLAR S-PARAMETERS IN 50 OHM SYSTEM								
F	S 11		S 21		S 12		S 22	
MHz	Magn	Angl°	Magn	Angl°	Magn	Asgl°	Magn	Angl°
100 MHz	0.871	190	6.130	108	0.028	17	0.537	205
200 MHz	0.902	182	4.9	90	.03	18	0.562	191
300 MHz	0.907	178	3.35	80	0.033	20	0.562	189
400 MHz	0.902	175	2.66	72	0.035	22	0.562	188
500 MHz	0.905	175	2.21	71	0.034	30	.540	192

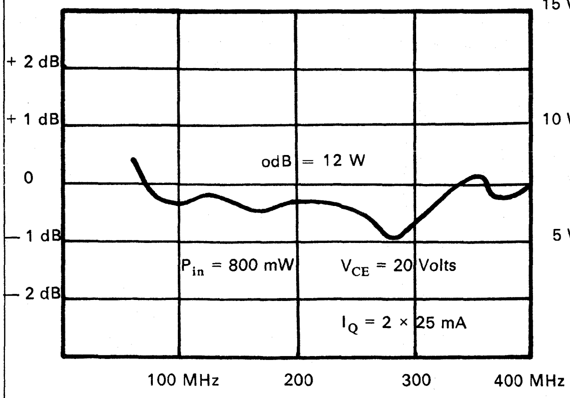
Large Signal Impedances

Class AB	I_Q = 50 mA	F_O = 400 MHz
P_{out} = 5 W	V_{CE} = 20 V	

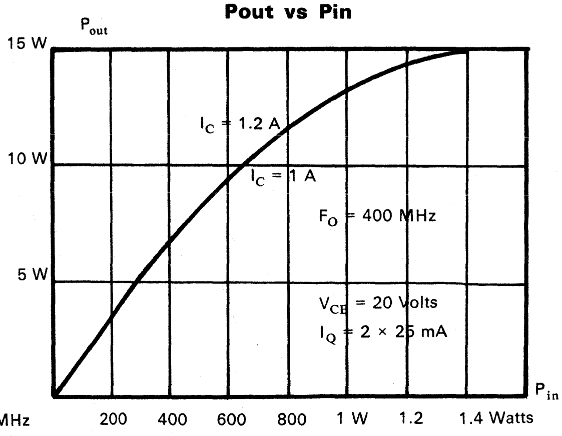
Z_{in}	Z_{out}
(1,5 — J 1) ohm	(15,5 — J 21,4) ohm

PUSH-PULL PERFORMANCES

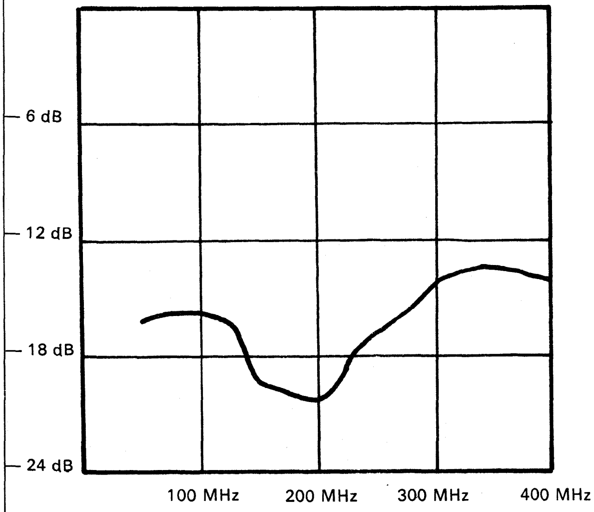
Pout vs Frequency



Pout vs Pin

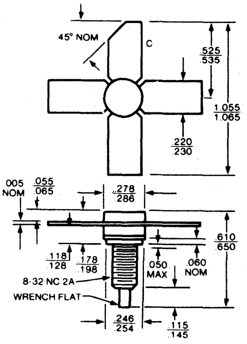


Input Return Loss

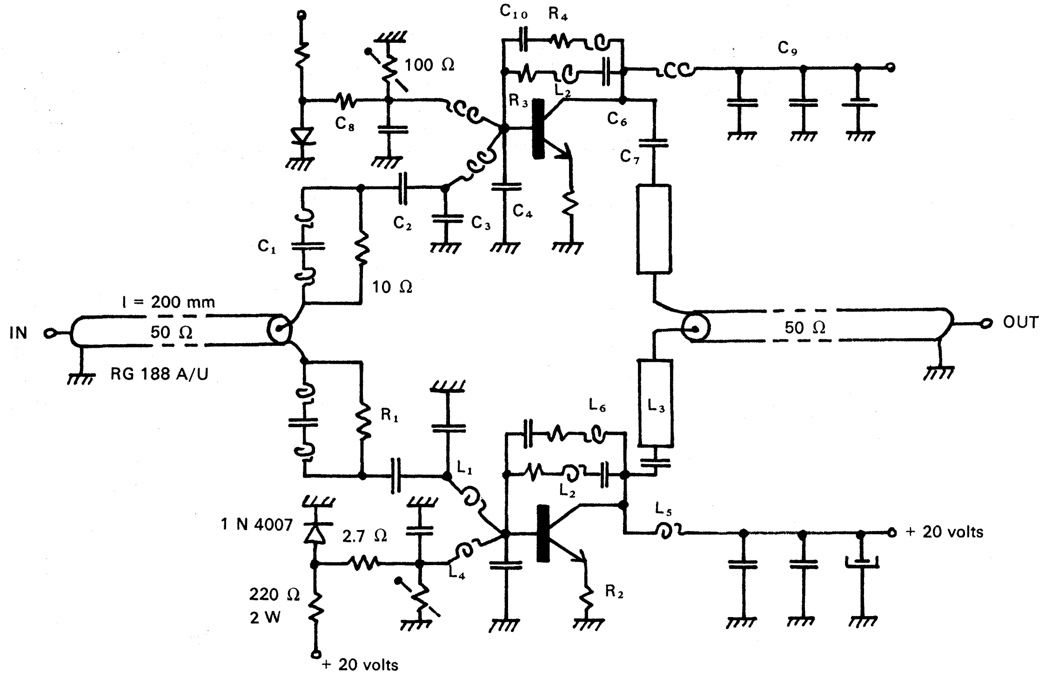


PACKAGE

.280 SOE



PUSH-PULL AMPLIFIER 100-400 MHz



L_1 : 1/2 turn  ↕ 5 mm 5/10 mm
5 mm
L_2 : 6 turns ∅ 3 mm 5/10 mm
L_3 : 25 Ω line 2 % λg at 400 MHz
L_4 : Moiled coil .47 µF
L_5 : Moiled coil 4.7 µH
L_6 : 17 turns ∅ 3 mm 5/10 mm

C_1 : 27 pF C 300 RTC with 12 mm leads
C_2 : C_7 = 10 nF chip
C_3 : 27 pF ATC 100 A
C_4 : 2 × 1.3 pF ATC 100 A
C_6 : C_{10} = 10 nF RTC C 331
C_8 : C_9 = 1 nF + 10 nF + 0.1 µF + 10 µF decoupling

R_1 = 10 Ω 1/4 W carbon
R_2 = 4 × 1 Ω 1/4 W carbon
R_3 = R_4 = 300 Ω 1/4 W carbon

TRW® SEMICONDUCTORS

TPM 425

PRELIMINARY

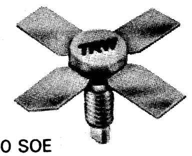
UHF Power Transistor

25 W - 400 MHz
9 dB GAIN

GOLD RELIABILITY

The TPM 425 is a high gain UHF transistor which has been specially designed for use in 100-400 MHz broadband amplifiers.

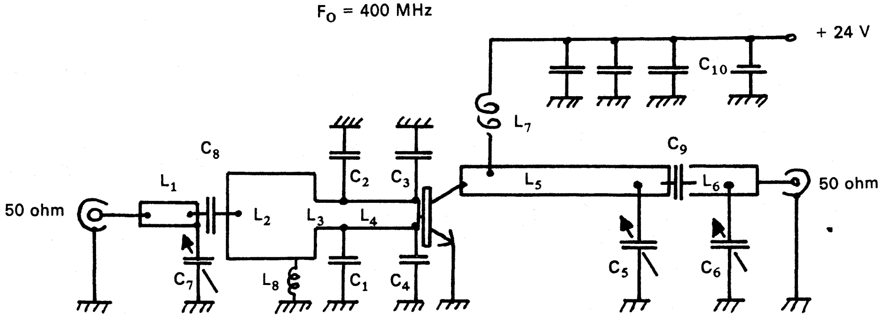
Its construction utilizes the new standard, gold metallization and diffused emitter ballast resistors, allowing class A, B or C operation and a high degree of ruggedability.



280 SOE

Electrical Characteristics (T_{case} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC TEST	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 1 mA	4			V
	BV_{CEO}	Collector - Emitter Breakdown Voltage	I_E = 20 mA	25			V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 10 mA	45			V
	H_{FE}	D.C Current Gain	V_{CE} = 5 V I_C = 100 mA	15			
RF TEST	P_{out}	Power Output	V_{CE} = 24 V F_O = 400 MHz P_{in} = 3 W	25			W
	η_C	Collector Efficiency	V_{CE} = 24 V F_O = 400 MHz P_{out} = 25 W	60	70		%
	C_{OB}	Collector - Base Capacitance	V_{CE} = 24 V F = 1 MHz			32	pF
	I_C	Maximum Collector Current				2	A
THERMAL	θ_{J-C}	Thermal Resistance Junction - Case	T_{case} = 25 °C			5	°C/W
	T_{STG} T_J	Storage Temperature Junction Temperature		— 65		+ 200	°C



L_1 = 50 ohm line
L_2 = 22 ohm line 3 % λg at 400 MHz
L_3 = 30 ohm line 0.5 % λg at 400 MHz
L_4 = 30 ohm line 1 % λg at 400 MHz
L_5 = 50 ohm line 5.5 % λg at 400 MHz
L_6 = 50 ohm line 3.5 % λg at 400 MHz

L_7 = 2 turns — ID 7 mm — wire 1 mm
L_8 = 0.68 μH - Molded — RFC

C_1 = C_2 = 18 pF — ATC — 100 A
C_3 = C_4 = 10 pF — ATC — 100 A
C_5 = AT 5501 — 1-20 pF — Tekelec
C_6 = C_7 = AT 5601 — 1-30 pF — Tekelec
C_8 = C_9 = 1 nF
C_{10} = 1 nF + 10 nF + .1 μF + 10 μF Decoupling.

POLAR S-PARAMETERS 50 OHM SYSTEM

FREQ. MHz	S 11		S 21		S 12		S 22	
	Magn	Angl°	Magn	Angl°	Magn	Angl°	Magn	Angl
100	0.957	181	3.89	99	0.019	35	0.707	190
200	0.957	178	1.97	95	0.019	45	0.724	186
300	0.957	176	1.29	75	0.025	45	0.741	184
400	0.957	174	1.06	68	0.032	50	0.749	184
500	0.957	172	0.86	63	0.035	57	0.746	183

V_{CE} = 25 V I_C = 850 mA

GENERAL PURPOSE
HYBRID AMPLIFIERS

GENERAL PURPOSE HYBRID AMPLIFIERS

PRODUCT SUMMARY

P/N	BANDWIDTH MHz	GAIN DB	OUTPUT POWER 1 DB COMPRESSION	PAGE
● CA 2800	10-400	17	800 mW	**221**
● CA 2810	10-350	33	800 mW	**225**
CA 2818	1-200	18	800 mW	**229**
CA 2820	1-520	30	400 mW	**233**
CA 2830	5-200	34	1 W	**237**
CA 2832	1-200	35	2 W	**239**
CA 2833	5-200	34	1 W	**237**
CA 2840	30-300	22	1 W	**241**
CA 2842	30-300	22	1 W	**241**
CA 2850	40-100	17	250 mW	**243**
CA 2851	40-100	17	250 mW	**243**
● CA 2870	20-400	34	400 mW	**245**
CA 2875	40-100	17	310 mW	**249**
CA 2876	40-100	22	100 mW	**251**
CA 2880	40-100	22	100 mW	**251**

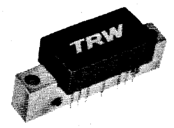
TRW® SEMICONDUCTORS

CA 2800

Wide Bandwidth Linear Hybrid Amplifier

Power Output, 800mW
17dB Gain
400mW PEP @-32dB IMD
Instantaneous Bandwidth, 10-400MHz
Low Noise Figure, 5dB

The CA 2800 is a high-reliability thin-film hybrid amplifier utilizing an all gold metalization system. Units are designed for wide bandwidth linear operation in 50 to 100 ohm systems. This hybrid provides excellent gain stability with temperature and very low distortion due to push-pull amplifier circuitry. This module is recommended for wide bandwidth, low noise and linear applications.

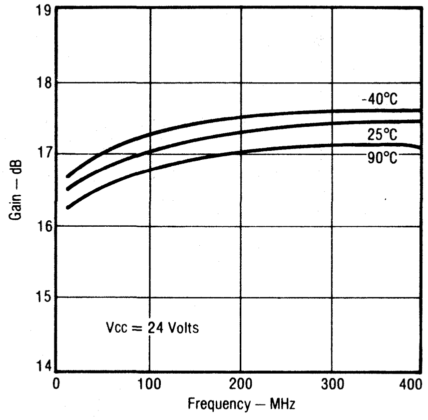


CA

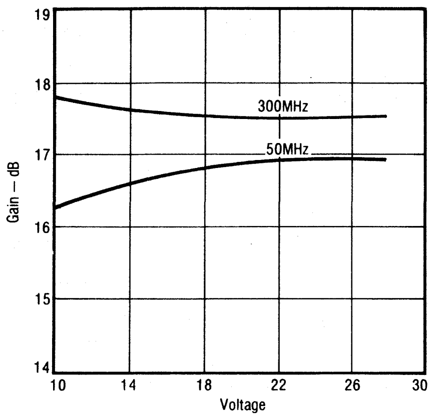
Electrical Characteristics (T_{flange} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
R F Test For 50 Ω Systems - T_{CASE} = 25 °C and V_{CC} = 24 V	P_G	Power Gain	f = 50 MHz	16.25	17	17.75	dB
	NF	Noise Figure, Broadband	f = 60 MHz f = 300 MHz		5.0 8.5		dB
	I_{TO}	Third Order Intercept (see Figure 1)	f_I = 300 MHz		+ 44		dBm
	VSWR	Input/Output VSWR for 50 Ω Systems	f = 10-400 MHz		2 : 1		
	P_O	Power Output 1 dB Compression	f = 200 MHz		800		mW
	P_{RI}	Reverse Isolation	f = 10-400 MHz		25		dB
	F_R	Frequency Response	f = 30-300 MHz f = 10-400 MHz			± 0.5 ± 1.0	dB
	d_{SO}	Second Harmonic Distortion	Tone at 10 mW f_{2H} = 10-300 MHz		— 66		dB
	P_{EP}	Peak Envelope Power for 2 Tone Distortion Test (see Figure 1)	f = 10-300 MHz At — 32 dB		400		mW
Absolute Maximum Ratings	V_{CC}	Supply Voltage				28	volts
	I_{CC}	Supply Current	24 V			220	mA
	P_{IN}	RF Power Input				+ 16	dBm
	T_{ST}	Storage Temperature		— 40		+ 100	°C
	T_{OP}	Operating Temperature		— 20		+ 90	°C

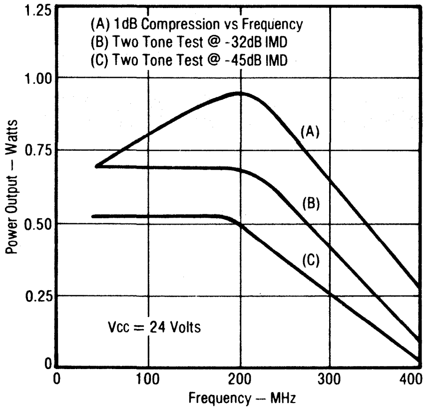
Gain vs Frequency



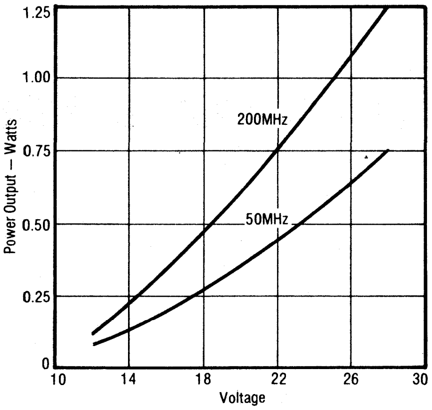
Gain vs Voltage



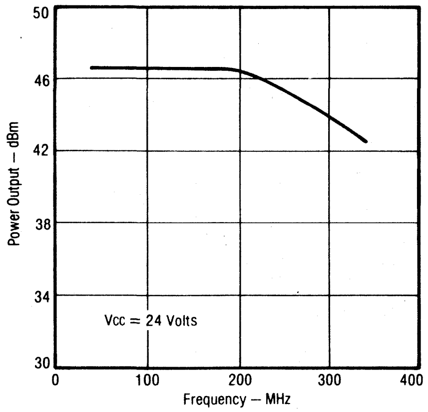
Power Output vs Frequency



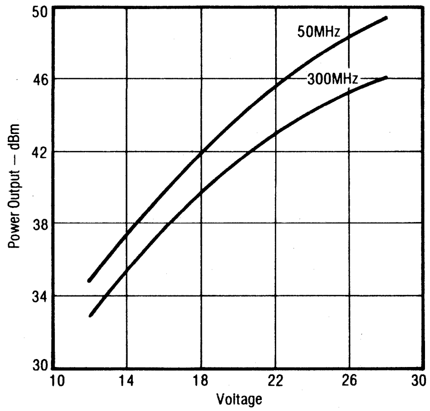
1dB Compression vs Voltage



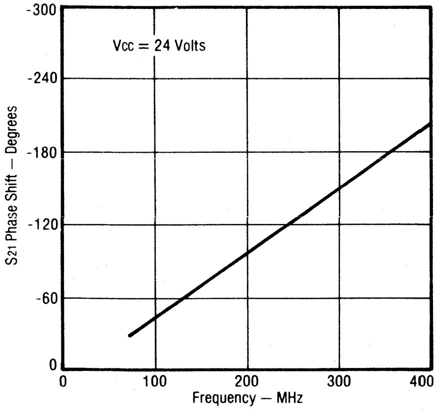
Third Order Intercept vs Frequency



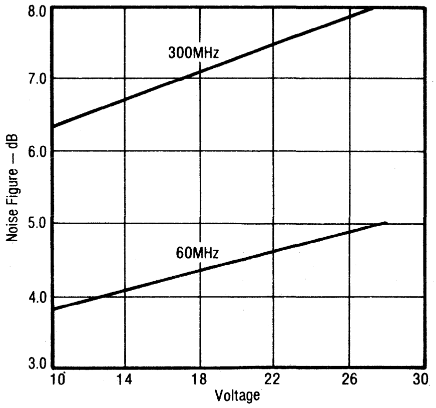
Third Order Intercept vs Voltage



Phase Shift vs Frequency

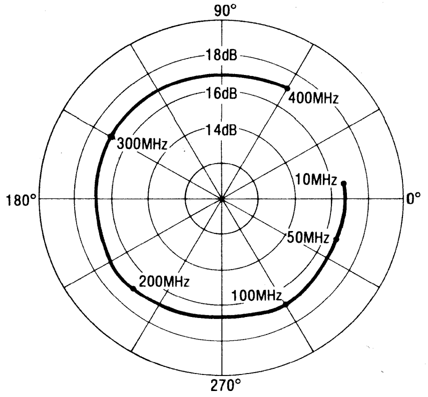


Noise Figure vs Voltage

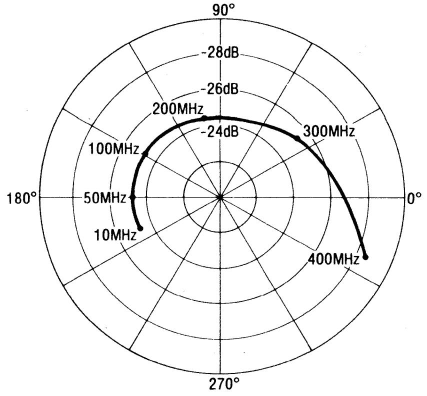


S-Parameters
Vcc = 24V, Zo = 50Ω

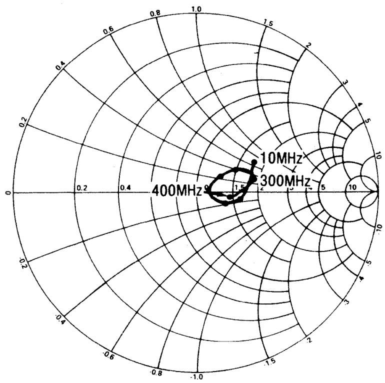
S21



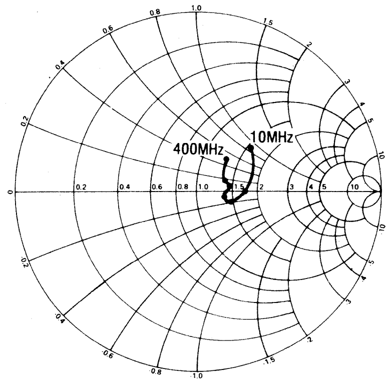
S12



S11



S22



CA Package Outline

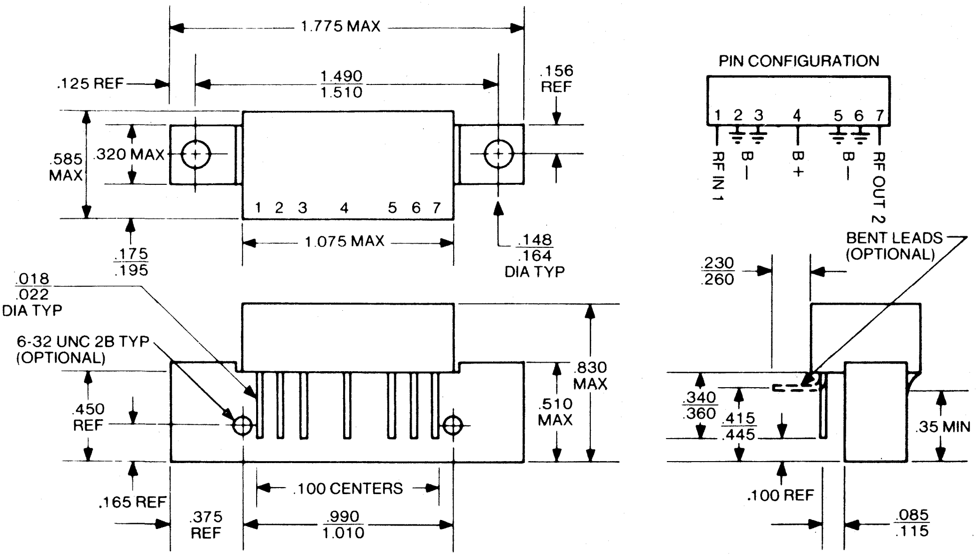
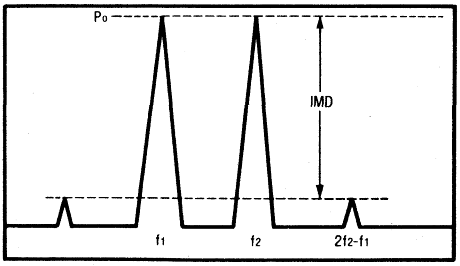


Figure 1. Intermodulation Test



$I_{TO} = P_o + \frac{IMD}{2}$ @ IMD > 60dB

PEP = P_o @ IMD = -32dB

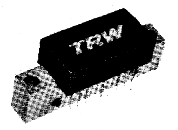
TRW® SEMICONDUCTORS

CA 2810

Wide Bandwidth Linear Hybrid Amplifier

Power Output, 800mW
33dB Gain
400mW PEP @ -32dB IMD
Instantaneous Bandwidth, 10-350MHz
Low Noise Figure, 4.5dB

The CA 2810 is a high-reliability thin-film hybrid amplifier utilizing an all gold metalization system. Units are designed for wide bandwidth linear operation in 50 to 100 ohm systems. This hybrid provides excellent gain stability with temperature and very low distortion due to push-pull amplifier circuitry. This module is recommended for wide bandwidth, low noise and linear applications.

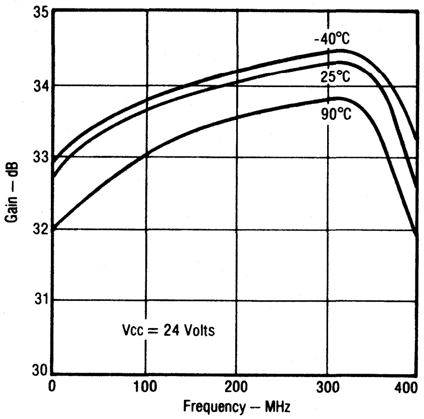


CA

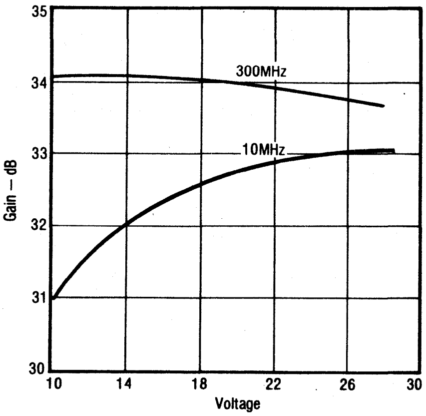
Electrical Characteristics (T_{flange} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
R F Test For 50 Ω systems - T_{CASE} = 25 °C and V_{CC} = 24 V	P_G	Power Gain	f = 50 MHz	32	33	34	dB
	NF	Noise Figure, Broadband	f = 60 MHz f = 300 MHz		4.5	 8.0	dB
	I_{TO}	Third Order Intercept (see Figure 1)	f_1 = 300 MHz		+ 43		dBm
	VSWR	Input/Output VSWR for 50 Ω Systems	f = 10-350 MHz		2 : 1		
	P_O	Power Output 1 dB Compression	f = 200 MHz		800		mW
	P_{RI}	Reverse Isolation	f = 10-350 MHz		40		dB
	F_R	Frequency Response	f = 30-300 MHz f = 10-350 MHz			± 1.0 ± 1.5	dB
	d_{SO}	Second Harmonic Distortion	Tone at 10 mW f_{2H} = 10-300 MHz		— 66		dB
	P_{EP}	Peak Envelope Power for 2-Tone Distortion Test (see Figure 1)	f = 10-300 MHz At — 32 dB		400		mW
Absolute Maximum Ratings	V_{CC}	Supply Voltage				28	volts
	I_{CC}	Supply Current	24 V			330	mA
	P_{IN}	R_F Power Input				+ 5	dBm
	T_{ST}	Storage Temperature		— 40		+ 100	°C
	T_{OP}	Operating Temperature		— 20		+ 90	°C

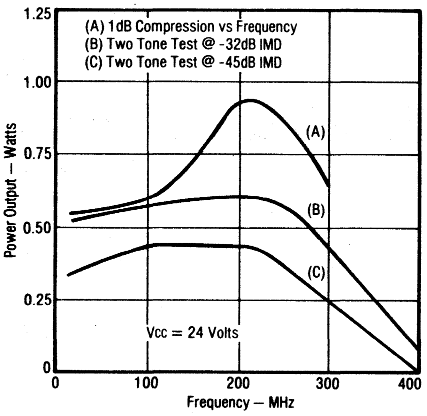
Gain vs Frequency



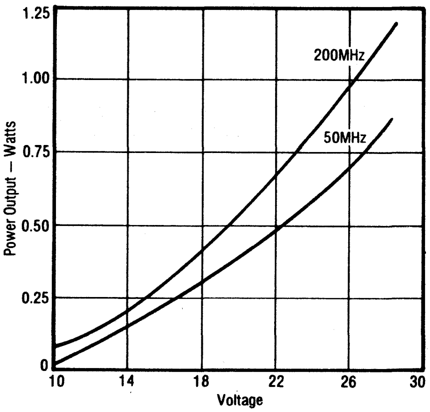
Gain vs Voltage



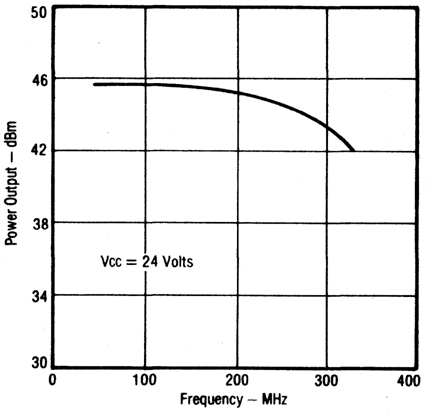
Power Output vs Frequency



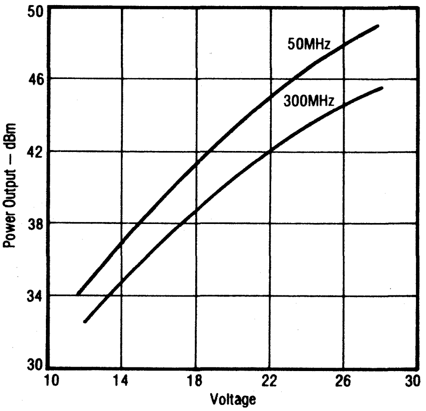
1dB Compression vs Voltage



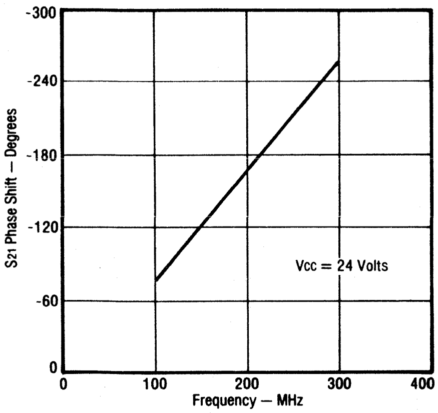
Third Order Intercept vs Frequency



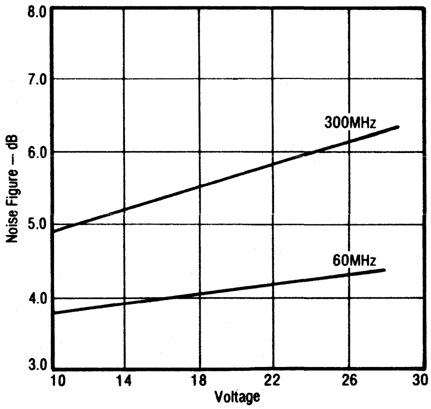
Third Order Intercept vs Voltage



Phase Shift vs Frequency

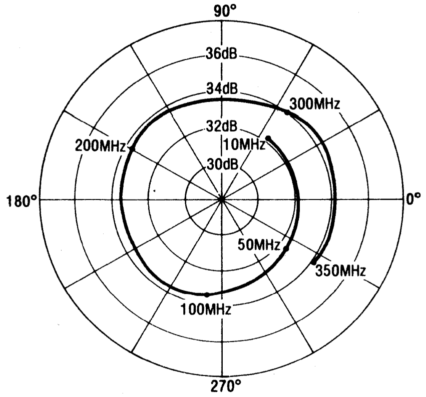


Noise Figure vs Voltage

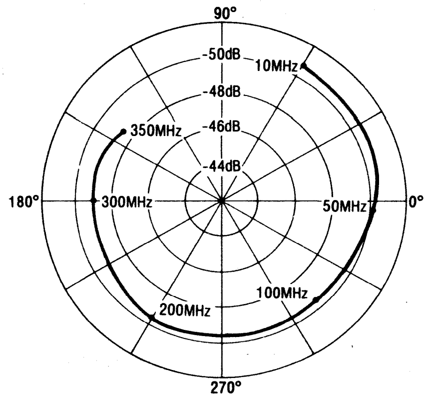


S-Parameters
Vcc = 24V, Z₀ = 50Ω

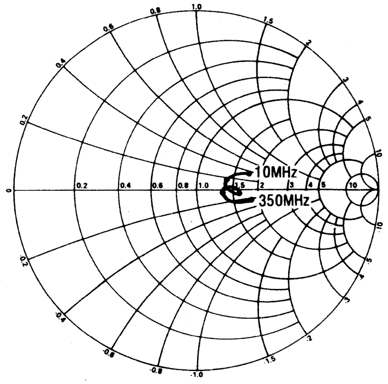
S21



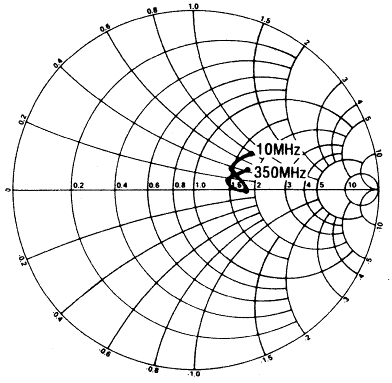
S12



S11



S22



CA Package Outline

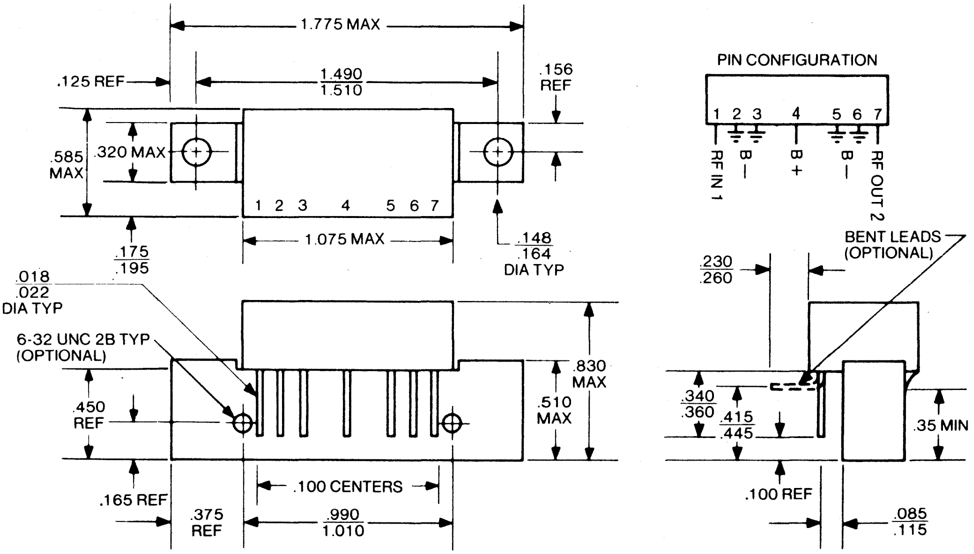
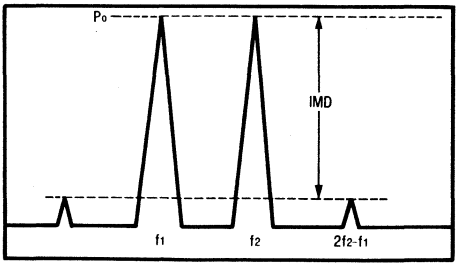


Figure 1. Intermodulation Test



$I_{TO} = P_o + \frac{IMD}{2}$ @ $IMD > 60dB$

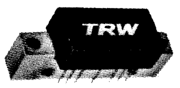
$PEP = P_o$ @ $IMD = -32dB$

TRW® SEMICONDUCTORS **CA 2818**

Wide Bandwidth Linear Hybrid Amplifier

POWER OUTPUT, 800 mW.
+ 47 dBm THIRD ORDER INTERCEPT.
18.5 dB GAIN.
INSTANTANEOUS BANDWIDTH, 1-200 MHz.
LOW NOISE FIGURE, 4.5 dB.

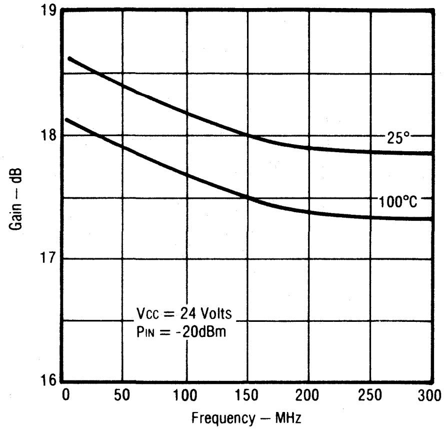
The CA 2818 is a high-reliability thin-film hybrid amplifier utilizing an all gold metallization system. This hybrid provides excellent gain stability and very low distortion due to push-pull amplifier circuitry. The CA 2818 is recommended for driver applications requiring high power capability and for « gain blocks » that demand maximum linearity. Excellent performance can be obtained with a supply voltage from 12 to 28 volts. For 75 ohm performance, refer to CATV equivalent model CA 2418.



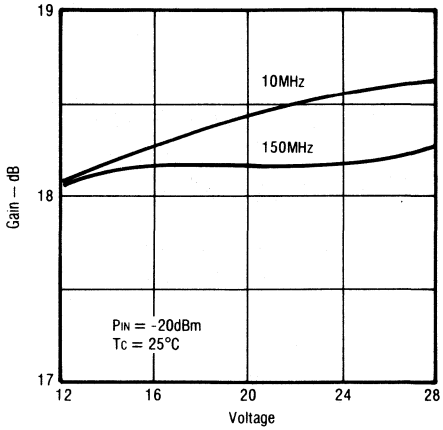
CA

Electrical Characteristics (T_{case} = 25 °C)

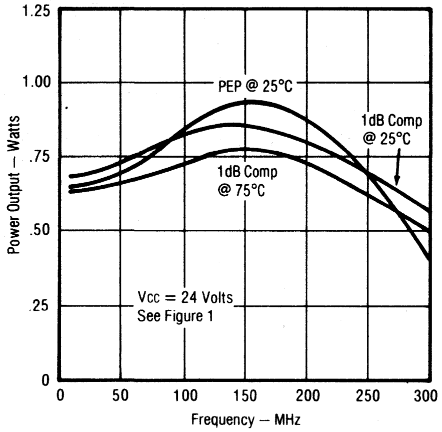
	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
RF TEST For 50 Ω system, Tcase 25 °C Vcc = 24 V	Pg	Power Gain	f = 50 MHz	17.75	18.5	19.25	dB
	NF	Noise figure, broadband	f = 30 MHz f = 150 MHz		4.5 5.5	6.0 7.0	dB
	Ito	Third order intercept (fig. 1)	f = 150 MHz	+ 44	+ 47		dBm
	VSWR	Input/Output VSWR for 50 Ω system Input/Output VSWR for 75 Ω system	f = 1-200 MHz		1.7 : 1 1.2 : 1	2.0 : 1 1.3 : 1	N/A
	Po	Power Output - 1 dB Compress.	f = 150 MHz	800	900		mW
	Pri	Reverse Isolation	f = 1-200 MHz		25		dB
	Fr	Frequency Response	f = 5-150 MHz f = 1-200 MHz		± 0.2 ± 0.5	± 0.5 ± 1.0	dB
	Dso	Second Harmonic Distortion	Po = 100 mW f 2 h = 1-200 MHz	— 55	— 60		dB
	PEP	Peak Envelope Power 2 tone Distortion Test (fig. 1)	f = 1-200 MHz at — 32 dB	600	800		mW
Absolute max. Ratings	Vcc	Supply voltage		12	24	28	V
	Icc	Supply Current	24 V	190	205	220	mA
	Pin	RF Power Input				+ 14	dBm
	TsT	Storage temperature		— 55		+ 125	°C
	Top	Operating temperature		— 40		+ 100	°C



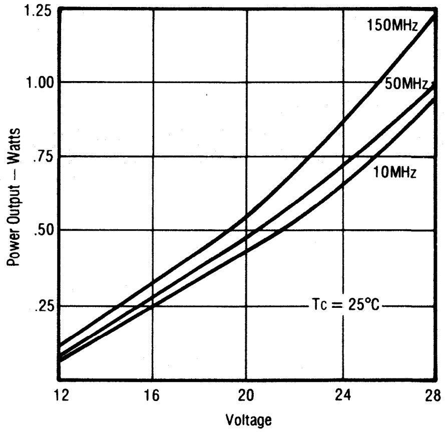
GAIN VS. FREQUENCY



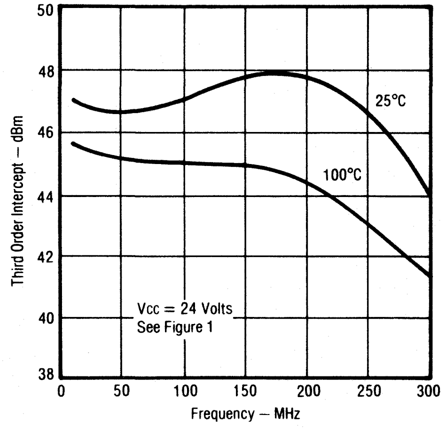
GAIN VS. VOLTAGE



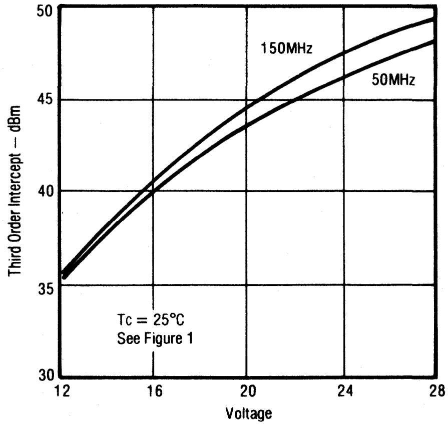
POWER OUTPUT VS. FREQUENCY



1dB COMPRESSION VS. VOLTAGE

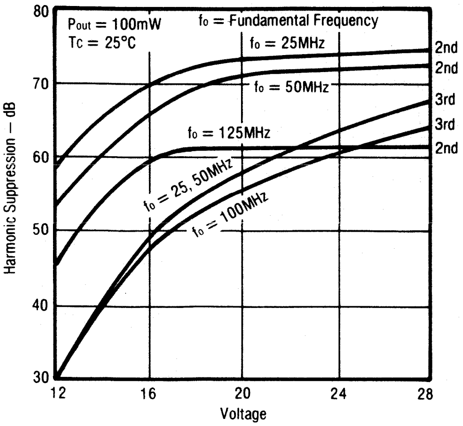


THIRD ORDER INTERCEPT VS. FREQUENCY

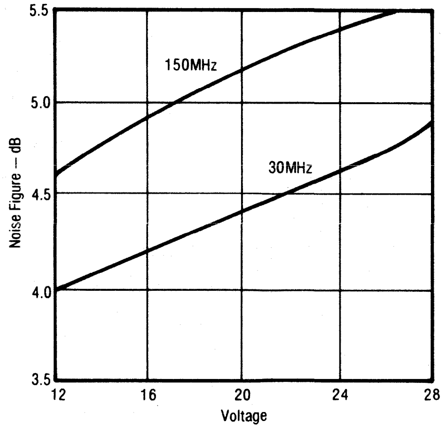


THIRD ORDER INTERCEPT VS. VOLTAGE

SECOND AND THIRD HARMONIC SUPPRESSION VS. VOLTAGE



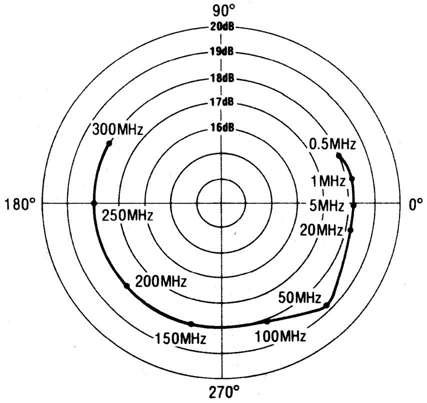
NOISE FIGURE VS. VOLTAGE



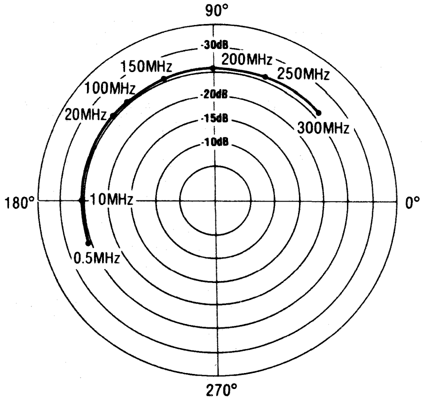
S-PARAMETERS

Zo = 50Ω, Vcc = 24V

S21



S12



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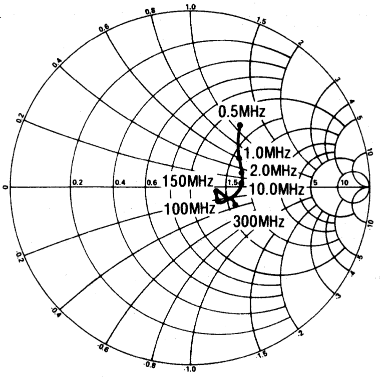
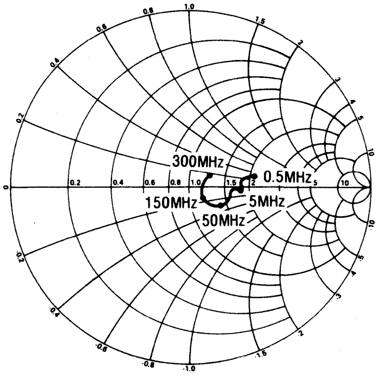
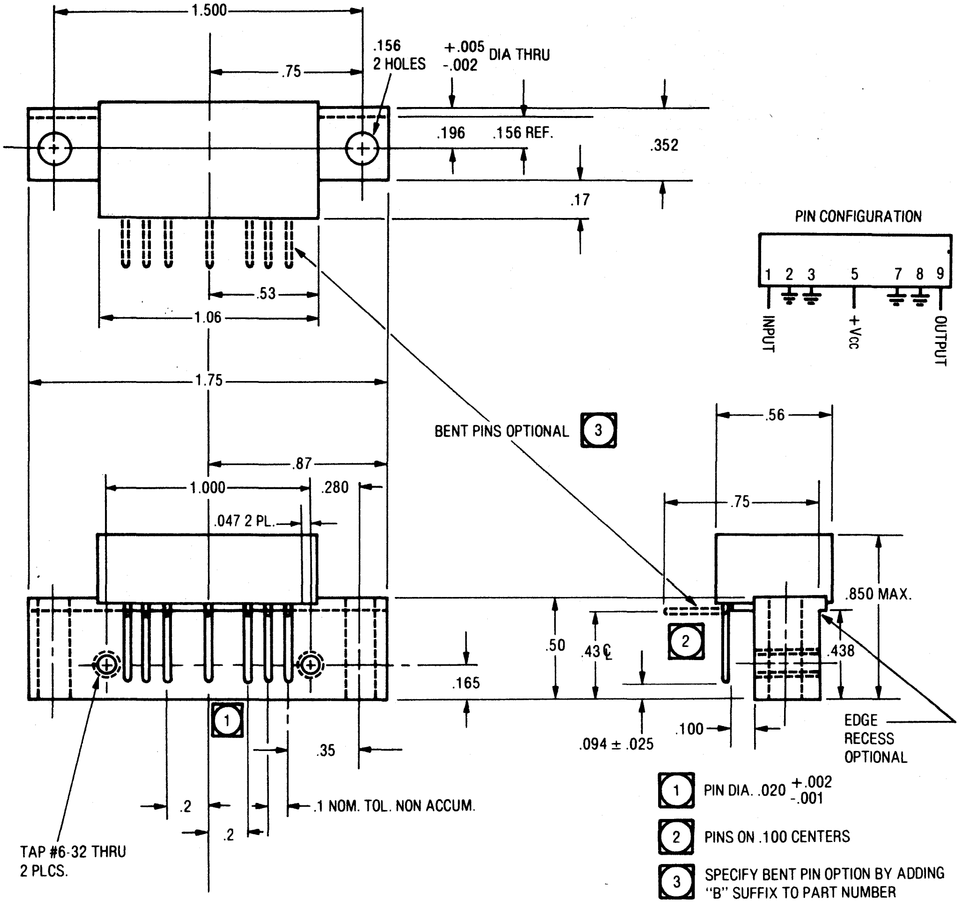


S22



PACKAGE OUTLINE



1. PIN DIA. .020 $^{+.002}_{-.001}$
2. PINS ON .100 CENTERS
3. SPECIFY BENT PIN OPTION BY ADDING "B" SUFFIX TO PART NUMBER

FUNCTIONAL SCHEMATIC

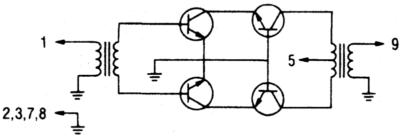
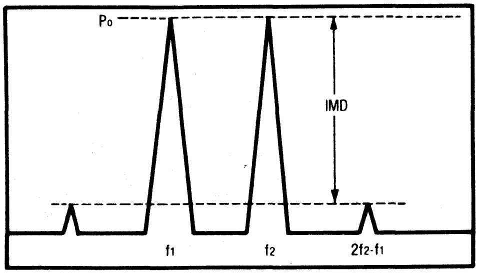


FIGURE 1. INTERMODULATION TEST



$I_{TO} = P_o + \frac{IMD}{2}$ @ IMD > 60dB

PEP = 4X P_o @ IMD = -32dB

TRW® SEMICONDUCTORS **CA 2820**

Wide Bandwidth Linear Hybrid Amplifier

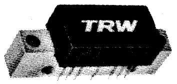
INSTANTANEOUS BANDWIDTH, 1-520 MHz.

POWER OUTPUT, 400 mW MIN.

LOW COST SINGLE ENDED DESIGN.

UNCONDITIONAL STABILITY UNDER ALL MISMATCH CONDITIONS.

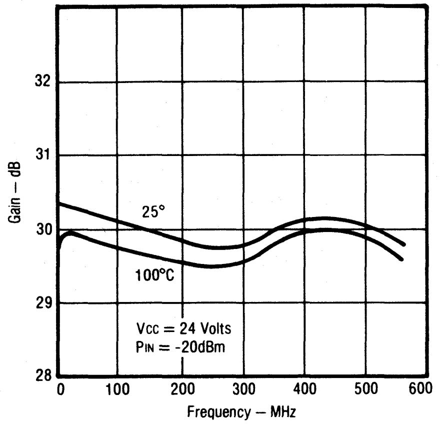
The CA 2820 is a high-reliability thin-film hybrid amplifier utilizing an all glod metallization system. Units are designed for widest bandwidth linear operation in 50 ohm systems, The linear class A bias enables the CA 2820 to drive highly reactive loads at large signal levels over its frequency range. Low end frequency response can be extended to 500 kHz by increasing the value of the external RF chokes. This module is recommended for wide bandwidth, low cost and linear applications in 25 to 75 ohm systems over a wide range of supply voltages.



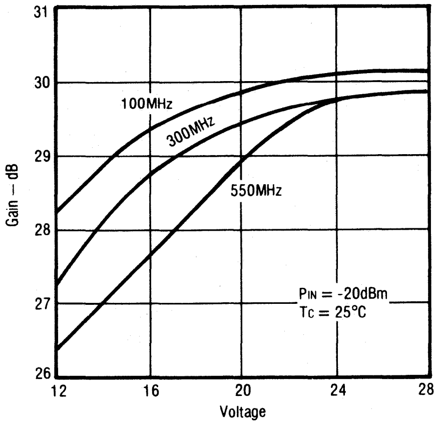
CA

Electrical Characteristics (T_{case} = 25 °C)

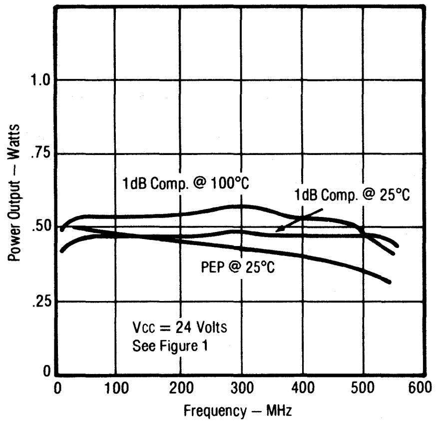
	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
RF TEST For 50 Ω system, Tcase 25 °C Vcc = 24 V	Pg	Power Gain	f = 100 MHz	29	30	31	dB
	NF	Noise figure, Broadband	f = 30 MHz f = 500 MHz		6.0 8.3	8 10	dB
	Ito	Third order intercept (fig. 1)	f = 520 MHz	+ 35	+ 37		dBm
	VSWR	Input VSWR for 50 systems Output VSWR for 50 systems	f = 1-520 MHz		1.5 : 1 1.8 : 1	2.0 : 1 2.0 : 1	N/A
	Po	Power Output - 1 dB Compression	f = 1-520 MHz	400	440		mW
	Pri	Reverse isolation	f = 1-520 MHz	49	52		dB
	Fr	Frequency Response	f = 1-520 MHz		± 0.8	± 1.5	dB
	Dso	Second Harmonic Distortion	Po = 10 mW f 2 h = 1-520 MHz	— 45	— 55		dB
	PEP	Peak Envelope Power for 2 tone distortion test (fig. 1)	f = 1-520 MHz at - 32 dB	300	400		mW
Absolute Max. Rating	Vcc	Supply Voltage			24	28	V
	Icc	Supply current	24 V	300	330	360	mA
	Pin	RF Power Current				+ 10	dBm
	Tst	Storage temperature		— 55		+ 125	°C
	Top	Operation Temperature		— 40		+ 100	°C



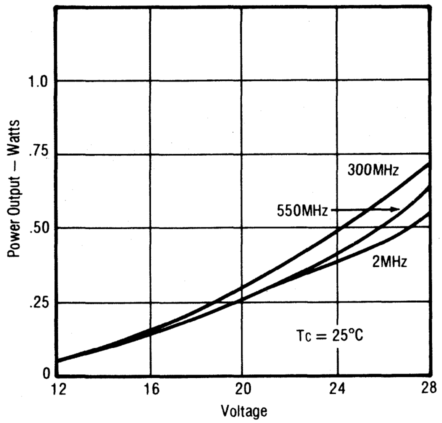
GAIN VS. FREQUENCY



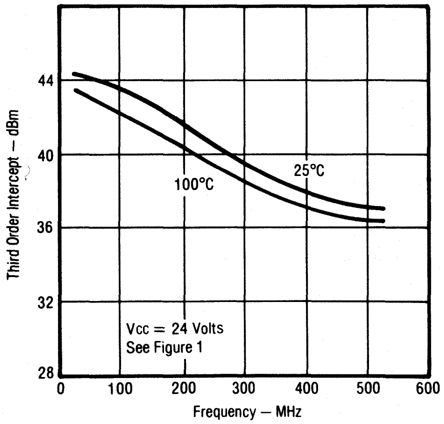
GAIN VS. VOLTAGE



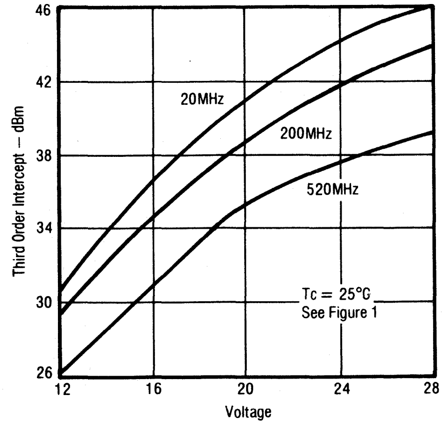
POWER OUTPUT VS. FREQUENCY



1dB COMPRESSION VS. VOLTAGE

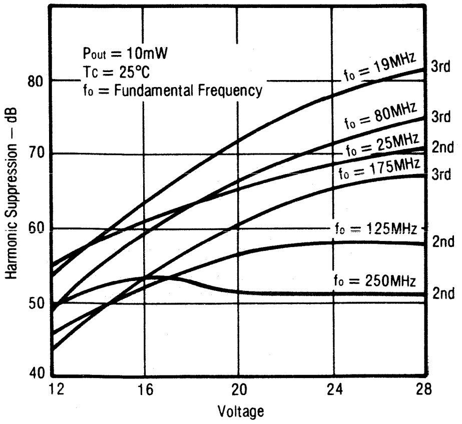


THIRD ORDER INTERCEPT VS. FREQUENCY

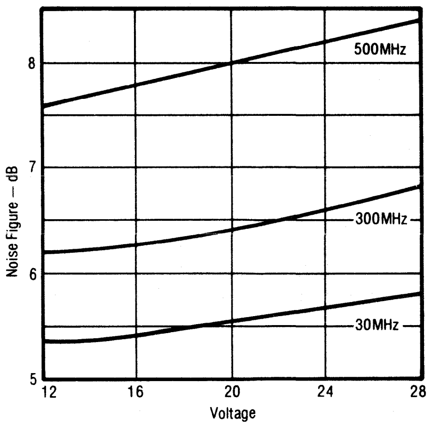


THIRD ORDER INTERCEPT VS. VOLTAGE

SECOND AND THIRD HARMONIC SUPPRESSION VS. VOLTAGE



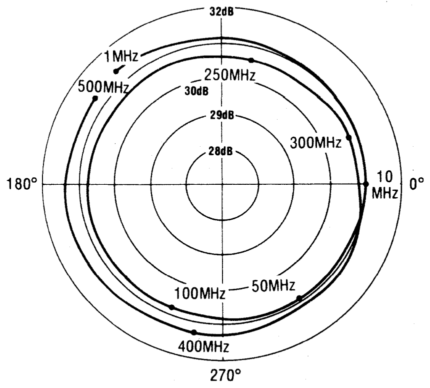
NOISE FIGURE VS. VOLTAGE



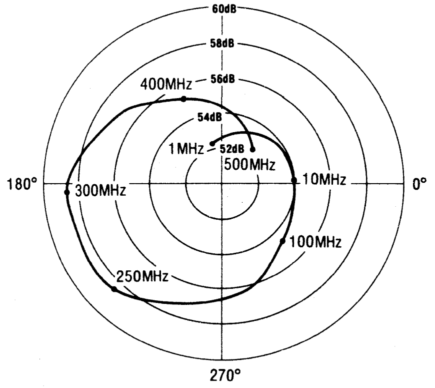
S-PARAMETERS

Zo = 50Ω, Vcc = 24V

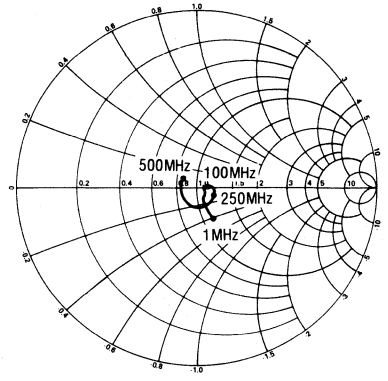
S21



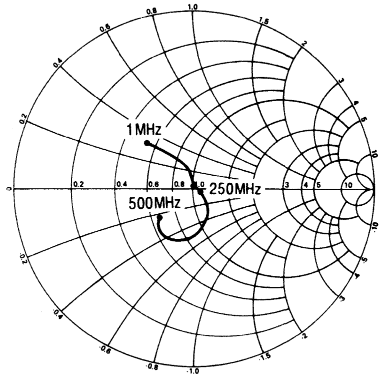
S12



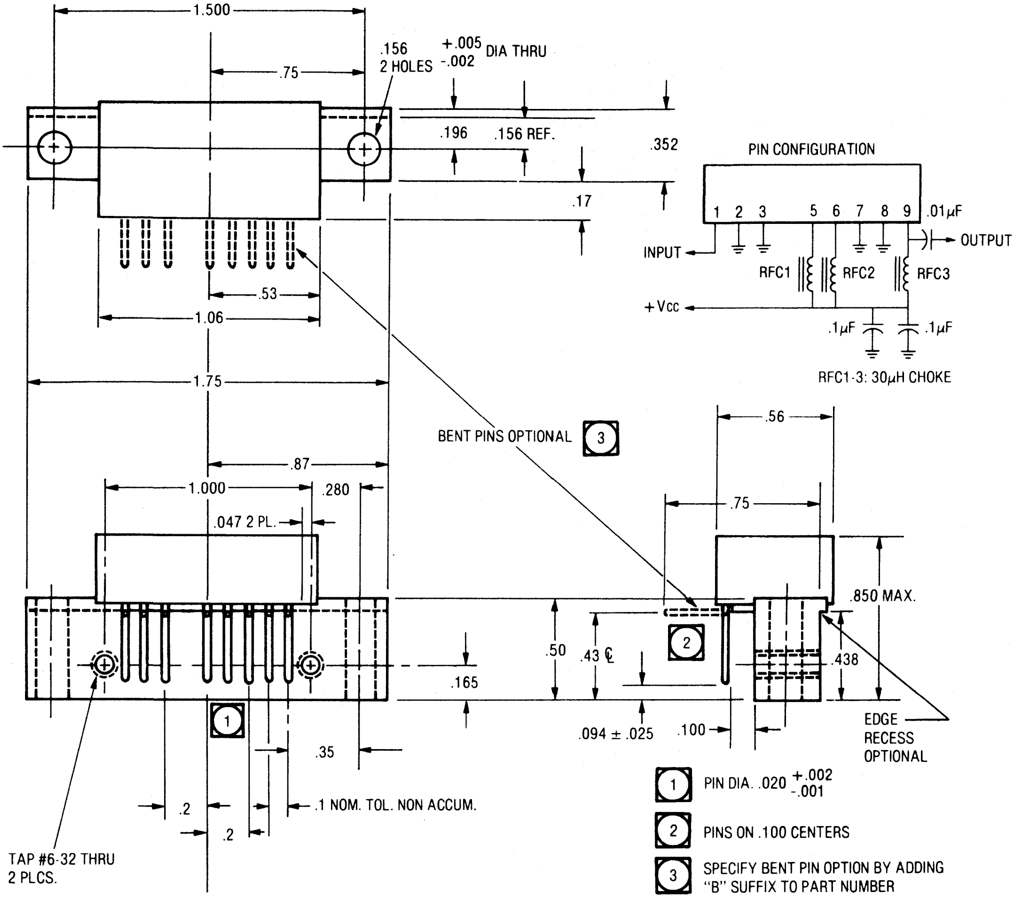
S11



S22



PACKAGE OUTLINE



① PIN DIA. .020 $^{+.002}_{-.001}$

② PINS ON .100 CENTERS

③ SPECIFY BENT PIN OPTION BY ADDING "B" SUFFIX TO PART NUMBER

FUNCTIONAL SCHEMATIC

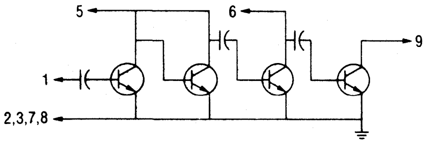
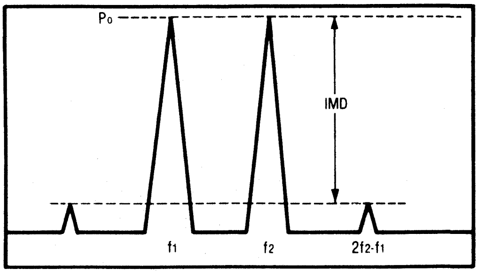


FIGURE 1. INTERMODULATION TEST



$I_{TO} = P_o + \frac{IMD}{2}$ @ IMD > 60dB

PEP = 4X P_o @ IMD = -32dB

TRW® **SEMICONDUCTORS**

CA 2830
CA 2833

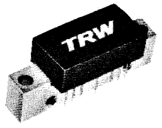
Thin Film RF Linear Hybrid Amplifier

The CA 2830 is a high reliability thin film hybrid amplifier utilizing an all gold metalization system. Units are designed for wide bandwith linear operation in 50 to 100 ohm systems.

Particular areas of interest are fiber optic driver for laser/LED diodes, driver for acousto-optic modulators, transmitter driver for HF, VHF communications radios.

CA 2830 B : BENT PIN OPTION
CA 2833 : OPTION FOR LOW HEATSINK PROFILE

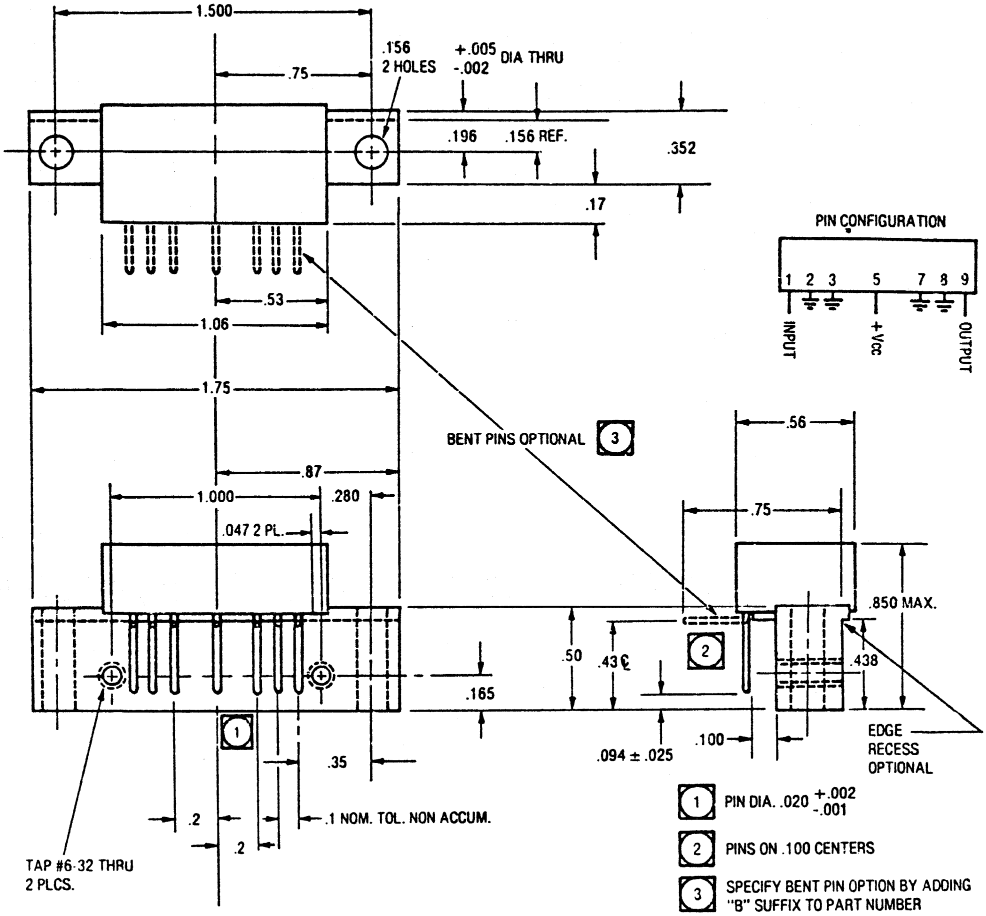
POWER OUTPUT 1 W
34 dB GAIN
BANDWITH 5 - 200 MHz
50 Ω MATCHED
UNCONDITIONNAL
STABILITY


CA

Electrical Characteristics (T_{case} = 25 °C)

		SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
RF TEST	T case 25 °C V_{CC} = 24 V	P_G	Power Gain	f = 100 MHz	33.5	34.5	35.5	dB
		NF	Noise Figure Broadband	f = 200 MHz	—	4.7	5.5	dB
		I_{TO}	3 Order Intercept (Figure 1)	f = 200 MHz	+ 44	+ 46	—	dBm
		VSWR	Input/Output VSWR (50 Ω)	f = 5 - 200 MHz	—	1.5 : 1	2.0 : 1	N/A
		P_O	Power Output 1 dB Compression	f = 5 - 200 MHz	+ 28	+ 29	—	dBm
	for 50 Ω system	P_O	Power Output 1 dB Compression V_{CC} = 28 V	f = 5 - 200 MHz	+ 30	+ 31	—	dBm
		F_R	Frequency Response	f = 5 - 200 MHz	—	± 0.5	± 1.0	dB
		D_{SO}	Second Harmonic Suppression	P_O = 100 mW f 2 h = 150 MHz	— 50	— 60	—	dB
		PEP	Peak Envelope Power for 2 Tone Distortion Test (figure 1)	f = 5 - 200 MHz o — 32 dB IMD	600	800	—	mW
Absolute max. ratings		V_{CC}	Supply Voltage			24	28	V
		I_{CC}	Supply Current	24 V	270	300	330	mA
		P_{in}	RF Power Input				+ 5	dBm
		T_{ST}	Storage Temperature		— 55		+ 125	°C
		T_{OP}	Operating Temperature		— 40		+ 100	°C

CA2830 PACKAGE OUTLINE



① PIN DIA. .020 $^{+.002}_{-.001}$

② PINS ON .100 CENTERS

③ SPECIFY BENT PIN OPTION BY ADDING "B" SUFFIX TO PART NUMBER

FUNCTIONAL SCHEMATIC

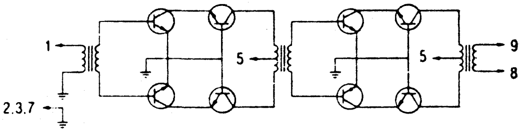
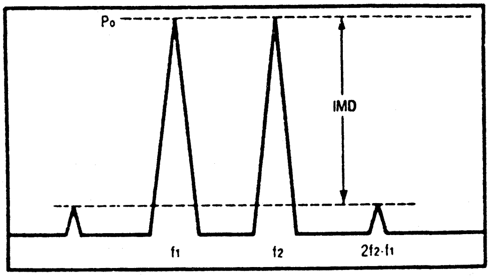


FIGURE 1. INTERMODULATION TEST



$I_{TO} = P_o + \frac{IMD}{2}$ @ IMD > 60dB

PEP = 4X P_o @ IMD = -32dB

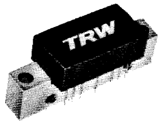
TRW ® **SEMICONDUCTORS** **CA 2832**

Thin Film RF Linear Hybrid Amplifier

The CA 2832 is a high reliability thin film hybrid amplifier utilizing an all gold metalization system. Units are designed for wide bandwith linear operation in 50 to 100 ohm systems.

Particular areas of interest are fiber optic driver for laser/LED diodes, driver for acousto-optic modulator, transmitter driver for HF, VHF communications radios.

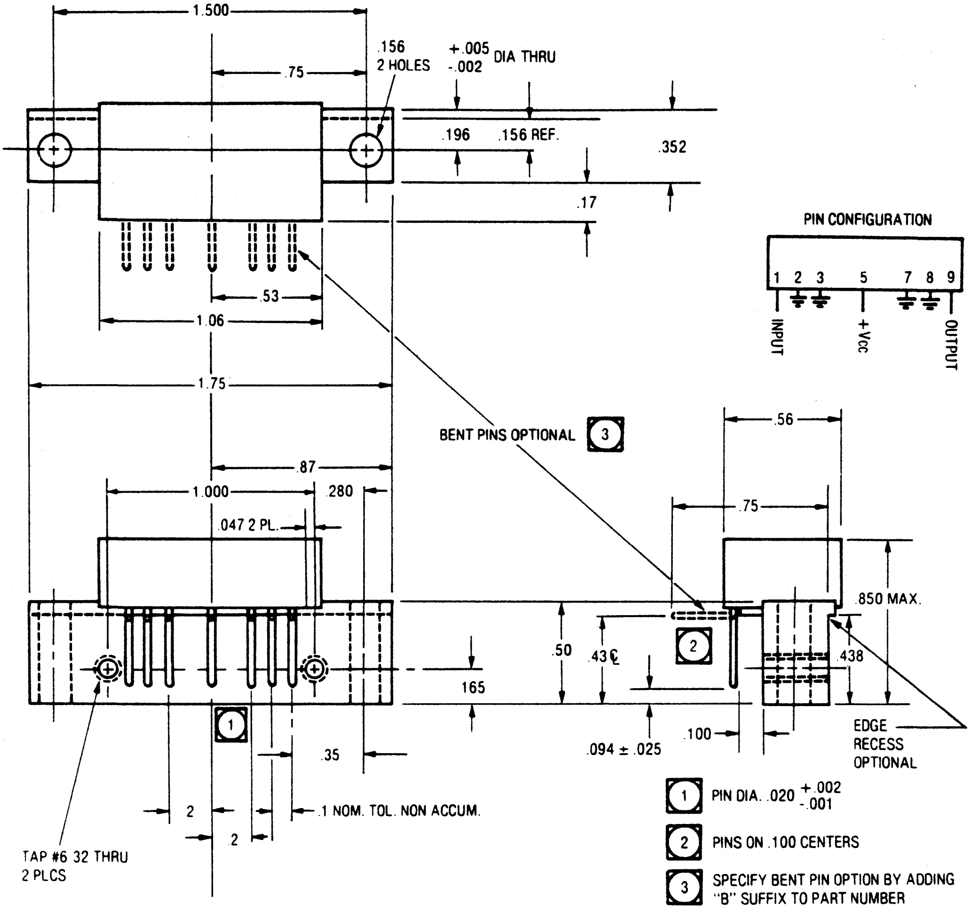
POWER OUTPUT 2 W
35.5 dB GAIN
BANDWITH 1-200 MHz
50Ω MATCHED


CA

Electrical Characteristics (T_{case} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
for 50 Ω system • RF Test T case 25 ° C V_{CC} = 28 V	P_G	Power Gain	f = 100 MHz	34.0	35.5	37.0	dB
	NF	Noise Figure Broadband	f = 200 MHz	—	6	7	dB
	I_{TO}	3 order intercept (figure 1)	f = 200 MHz	+ 45	+ 47	—	dBm
	VSWR	Input/Output VSWR 50 Ω	f = 1 - 200 MHz	—	1.5 : 1	2.0 : 1	N/A
	P_O	Power Output 1 dB Compression	f = 1 - 200 MHz	+ 31	+ 32	—	dBm
	P_O	Power Output 1 dB Compression V_{CC} = 28 V	f = 150 MHz	—	+ 33	—	dBm
	F_R	Frequency Response	f = 1 - 200 MHz	—	± 0.5	± 1.0	dB
	D_{SO}	Second Harmonic Suppression	P_O = 100 mW f 2 h = 150 MHz	— 60	— 70	—	dB
	PEP	Peak Envelope Power for 2 Tone dist. test (figure 1)	f = 1 - 200 MHz at — 32 dB IMD	—	900	—	mW
Absolute max. ratings	V_{CC}	Supply Voltage			28	30	V
	I_{CC}	Supply Current	28 V	400	435	470	mA
	P_{in}	RF Power Input				5	dBm
	T_{ST}	Storage Temperature		— 55		+ 125	°C
	T_{OP}	Operating Temperature		— 40		+ 90	°C

CA2832
PACKAGE OUTLINE



① PIN DIA. .020 $^{+.002}_{-.001}$

② PINS ON .100 CENTERS

③ SPECIFY BENT PIN OPTION BY ADDING "B" SUFFIX TO PART NUMBER

FUNCTIONAL SCHEMATIC

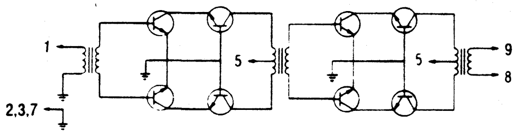
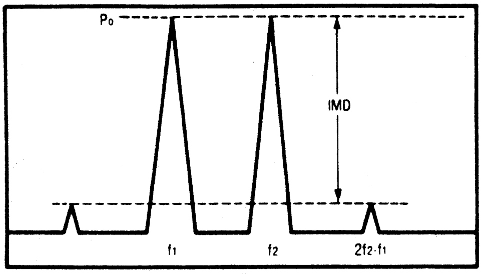


FIGURE 1. INTERMODULATION TEST



$I_{TO} = P_o + \frac{IMD}{2}$ @ IMD > 60dB

PEP = 4X P_o @ IMD = -32dB

TRW® SEMICONDUCTORS

CA 2840
CA 2842

Thin Film RF Linear Hybrid Amplifier

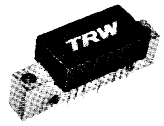
POWER OUTPUT 1 W
22 dB GAIN
BANDWITH 30-300 MHz
75 Ω MATCHED

The CA 2840 is a high reliability thin film hybrid amplifier utilizing an all gold metalization system. Units are designed for wide bandwith linear operation in 50 to 100 ohm systems.

Particular areas of interest are local oscillator buffer amplifier for high level mixer, 75 Ω IF post amplifier, high performance linear amplifier for all types of analog/digital waveforms.

CA 2840 B : BENT PIN OPTION

CA 2842 : OPTION FOR 50 Ω MATCHING AND 1.2 W OUTPUT POWER.

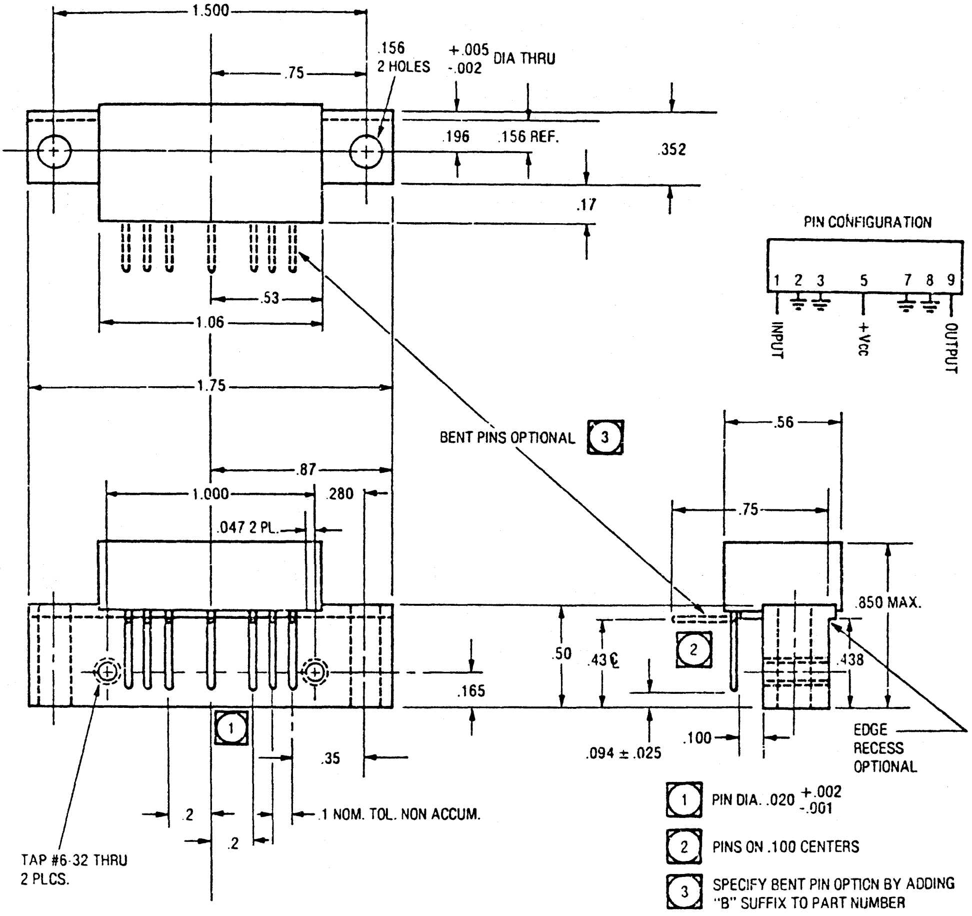


CA

Electrical Characteristics (T_{case} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
RF TEST T case 25 °C V_{CC} = 24 V	P_G	Power Gain	f = 100 MHz	21	22	23	dB
	NF	Noise Figure Broadband	f = 100 MHz	—	5	6	dB
	It_O	3 Order Intercept (fig. 1)	f = 30-300 MHz	+ 43	+ 46	—	dBm
	VSWR	Input/Output VSWR (75 Ω)	f = 30-300 MHz	—	1.2 : 1	1.3 : 1	N/A
	P_O	Power Output 1 dB Compression	f = 30-200 MHz	+ 29	+ 30	—	dBm
for 75 Ω system	P_O	Power Output 1 dB Compression V_{CC} = 28 V	f = 30-200 MHz	+ 30	+ 31	—	dBm
	F_R	Frequency Response	f = 30-300 MHz	—	± 0.5	± 1.0	dB
	D_{SO}	Second Harmonic Suppression	P_O = 100 mW f 2 h = 300 MHz	— 50	—	—	dB
	PEP	Peak Envelope Power for 2 Tone Dist. Test (fig. 1)	f = 200 MHz at — 32 dB IMD	550	650	—	mW
ABSOLUTE MAX. RATINGS	V_{CC}	Supply Voltage			24	28	V
	I_{CC}	Supply Current	24 V	210	230	250	mA
	P_{in}	RF Power Output				+ 14	dBm
	T_{ST}	Storage Temperature		— 55		+ 125	°C
	T_{OP}	Operating Temperature		— 40		+ 100	°C

CA2840
PACKAGE OUTLINE



FUNCTIONAL SCHEMATIC

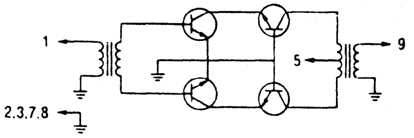
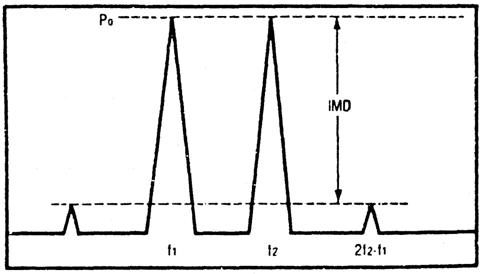


FIGURE 1. INTERMODULATION TEST



$$I_{TO} = P_o + \frac{IMD}{2} \text{ @ IMD} > 60\text{dB}$$

$$PEP = 4X\ P_o \text{ @ IMD} = -32\text{dB}$$

TRW® SEMICONDUCTORS

CA 2850
CA 2851

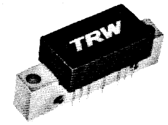
Thin Film RF Linear Hybrid Amplifier

POWER OUTPUT 250 mW
17 dB GAIN
BANDWITH 40-100 MHz
50 Ω MATCHED
LOW POWER CONSUMPTION

The CA 2850 is a high reliability thin film hybrid amplifier utilizing an all gold metalization system. Units are designed for wide bandwith linear operation in 50 to 100 ohm systems.

Particular areas of interest are high performance 50 Ω IF amplifier, local oscillator buffer amplifier for high level mixer, linear driver/repeater amplifier for 50 Ω cable communications systems.

CA 2850 B : BENT PIN OPTION
CA 2850 R : OPTION FOR NEGATIVE POLARITY SUPPLY.
CA 2851 : OPTION FOR LOW HEATSINK PROFILE.
CA 2851 R : OPTION FOR NEGATIVE POLARITY SUPPLY.

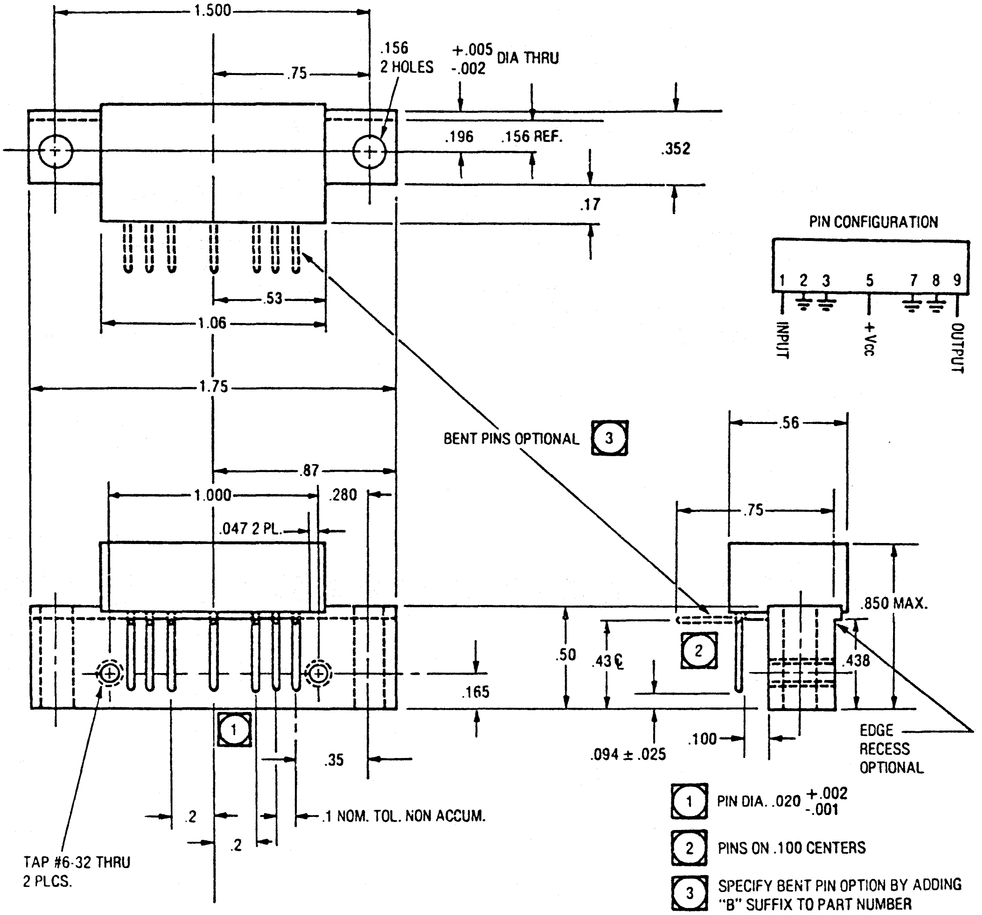


CA

Electrical Characteristics (T_{case} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN	TYP	MAX.	UNIT
RF TEST T case 25 °C V_{CC} = 19 V for 50 Ω systems	P_G	Power Gain	f = 100 MHz	17.0	17.5	18.0	dB
	NF	Noise Figure Broadband	f = 70 MHz	—	4.5	5.0	dB
	I_{TO}	3 Order Intercept (fig. 1)	f = 70 MHz	+ 37	+ 40		dBm
	VSWR	Input/Output VSWR (50 Ω)	f = 40-100 MHz		1.2 : 1	1.3 : 1	N/A
	P_O	Power Output 1 dB Compression	f = 40-200 MHz	+ 24	+ 25		dBm
	F_R	Frequency Response	f = 40-100 MHz		± 0.1	± 0.2	dB
	D_{SO}	Second Harmonic Suppression	P_O = + 24 dBm f 2 h = 100 MHz		— 40		dB
	PEP	Peak Envelope Power for 2 Tone Distortion Test (see figure 1)	f = 40 - 100 MHz at — 32 dB	250	300		mW
Absolute Max. ratings	V_{CC}	Supply Voltage		+ 15	+ 19	+ 28	V
	I_{CC}	Supply Current	19 V	110	125	140	mA
	P_{in}	RF Power Output				+ 14	dBm
	T_{ST}	Storage Temperature		— 55		+ 125	°C
	T_{OP}	Operating Temperature		— 40		+ 100	

CA2850
PACKAGE OUTLINE



1 PIN DIA. .020 $^{+.002}_{-.001}$

2 PINS ON .100 CENTERS

3 SPECIFY BENT PIN OPTION BY ADDING "B" SUFFIX TO PART NUMBER

FUNCTIONAL SCHEMATIC

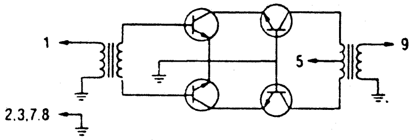
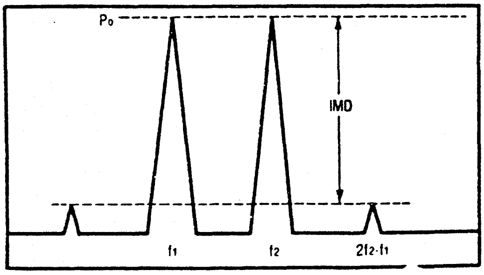


FIGURE 1. INTERMODULATION TEST



$I_{TO} = P_o + \frac{IMD}{2}$ @ IMD > 60dB

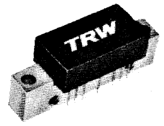
PEP = 4X P_o @ IMD = -32dB

TRW® SEMICONDUCTORS **CA 2870**

Wide Bandwidth Linear Hybrid Amplifier

AMPLITUDE LEVELING PROVISION
INSTANTANEOUS BANDWITH, 20 - 400 MHz
34 dB GAIN
POWER OUTPUT 400 mW MINI
LOW NOISE FIGURE 4.5 dB

The CA 2870 is a high reliability thin film hybrid amplifier utilizing an all gold metallization system with built-in provisions for amplitude leveling. The circuit covers the 20 - 400 MHz frequency range. Two B + inputs, one for the preamplifier and one for the final stage, provide a convenient means of RF leveling by variation of the final stage B + voltage. Load variations on the preceding stage are kept to a minimum by this provision. Although the uncorrected flatness of this module is superb (+ 0.5 dB typical). The leveling provisions provide convenient means of correcting for the frequency response of succeeding stages and injection of AM modulation. This module finds wide application in military and industrial service as gain blocks in RF amplifier for VHF and UHF transmitters.

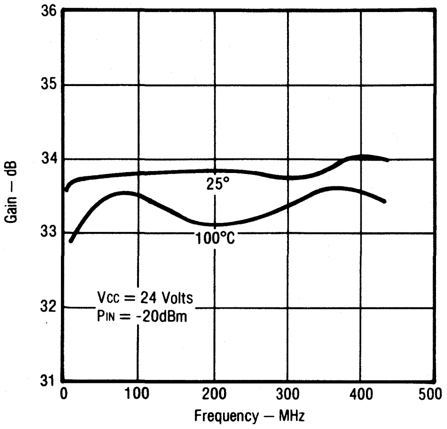


CA

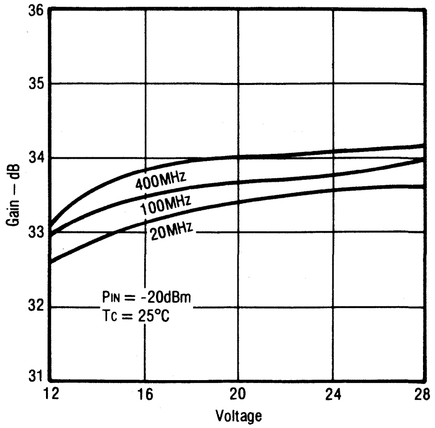
Electrical Characteristics (T_{case} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
T case 25 °C V_{CC} = 24 V	P_G	Power Gain	f = 100 MHz	32.5	34	35.5	dB
	NF	Noise Figure broadband	f = 30 MHz f = 400 MHz		4.5 7.5	6.0 8.5	dB
	I_{TO}	3 order Intercept (fig. 1)	f = 300 MHz	+ 42	+ 45		dBm
	VSWR	Input VSWR for 50 Ω systems Output VSWR for 50 Ω systems	f = 20 - 400 MHz		1.5 : 1 1.8 : 1	2.0 : 1 2.0 : 1	N/A
RF TEST	P_O	Power Output — 1 dB Compression	f = 225 MHz f = 400 MHz	800 400	850 500		mW
for 50 Ω systems	P_{RI}	Reverse Isolation	f = 20 - 400 MHz	45	48		dB
	F_R	Frequency Response	f = 20 - 400 MHz		± 0.5	± 1.0	dB
	D_{SO}	Second Harmonic Distortion	P_O = 100 mW f 2 h = 20 - 400 MHz	— 45	— 52		dB
	PEP	Peak Envelope Power for 2 Tone Distortion. Test (see figure 1)	f = 20 - 400 MHz at — 32 dB	400	500		mW
Absolute Max. ratings	V_{CC}	Supply voltage			24	28	V
	I_{CC}	Supply Current	24 V	270	300	330	mA
	P_{in}	RF Power Output				+ 5	dBm
	T_{ST}	Storage Temperature		— 55		+ 125	°C
	T_{OP}	Operating temperature		— 40		+ 100	°C

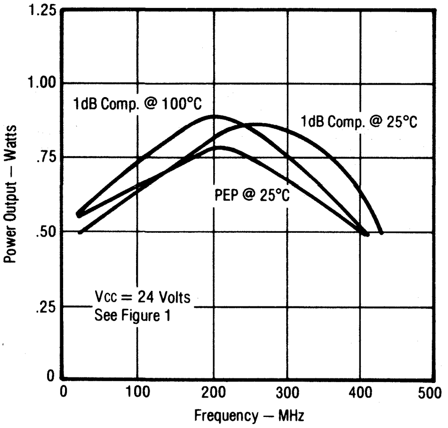
GAIN VS. FREQUENCY



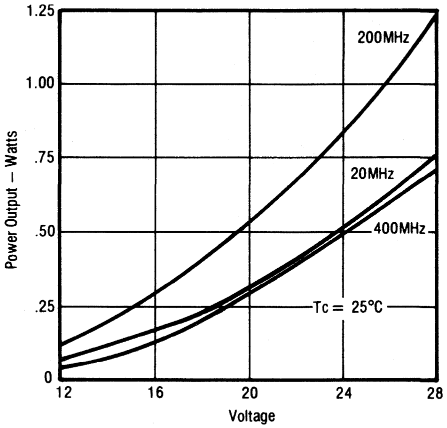
GAIN VS. VOLTAGE



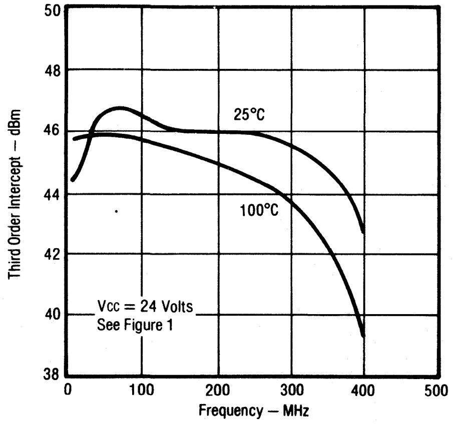
POWER OUTPUT VS. FREQUENCY



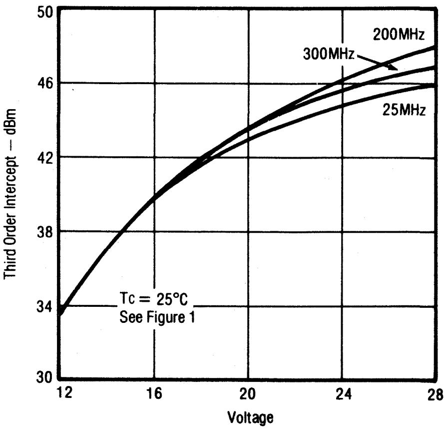
1dB COMPRESSION VS. VOLTAGE



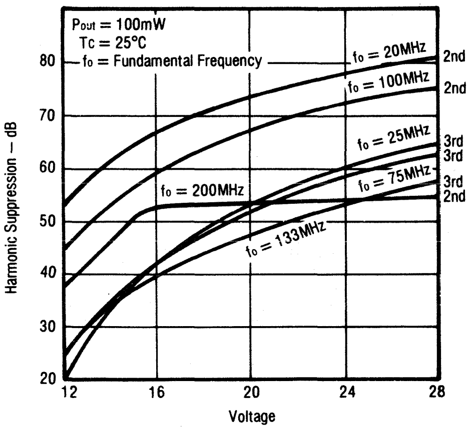
THIRD ORDER INTERCEPT VS. FREQUENCY



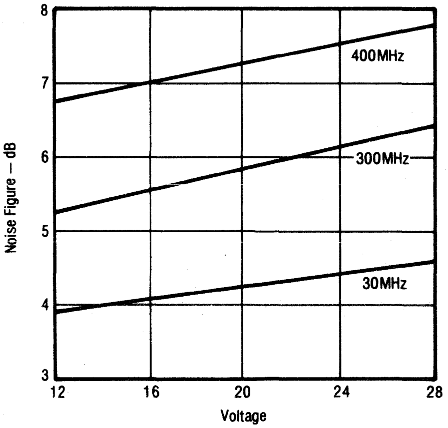
THIRD ORDER INTERCEPT VS. VOLTAGE



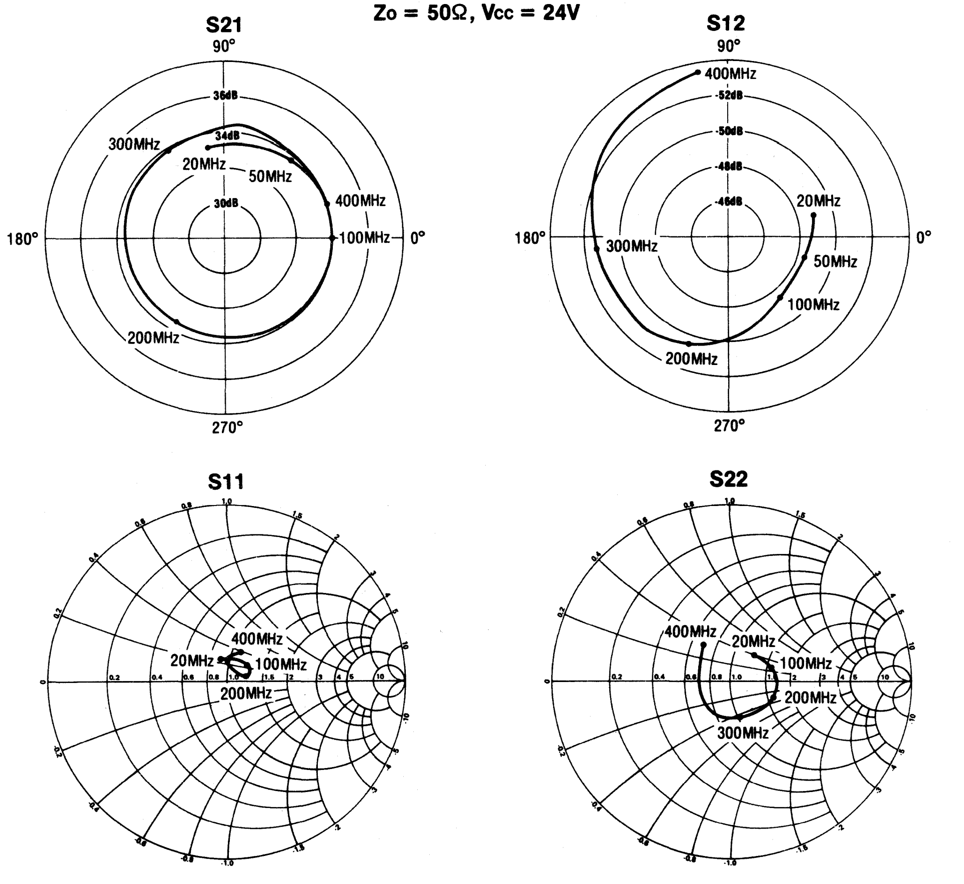
SECOND AND THIRD HARMONIC SUPPRESSION VS. VOLTAGE



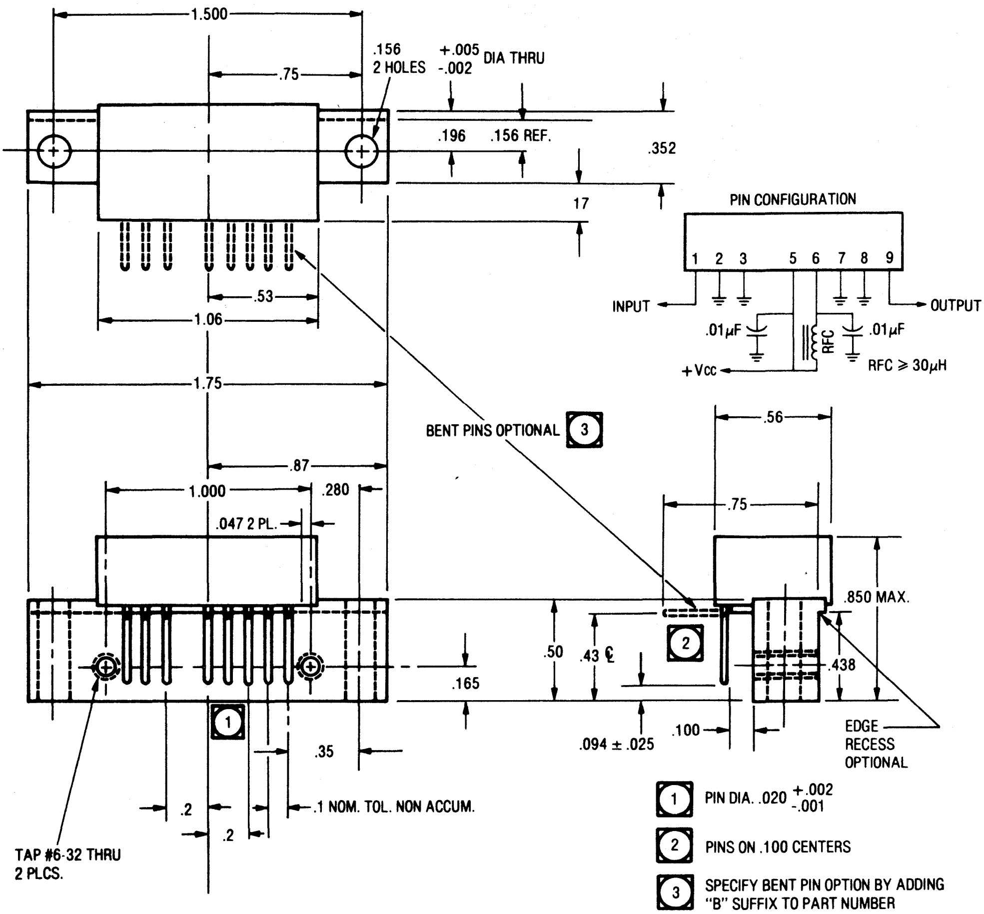
NOISE FIGURE VS. VOLTAGE



S-PARAMETERS
Zo = 50Ω, Vcc = 24V



CA2870 PACKAGE OUTLINE



① PIN DIA. .020 $^{+.002}_{-.001}$

② PINS ON .100 CENTERS

③ SPECIFY BENT PIN OPTION BY ADDING "B" SUFFIX TO PART NUMBER

FUNCTIONAL SCHEMATIC

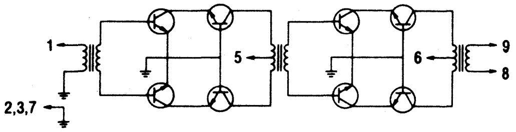
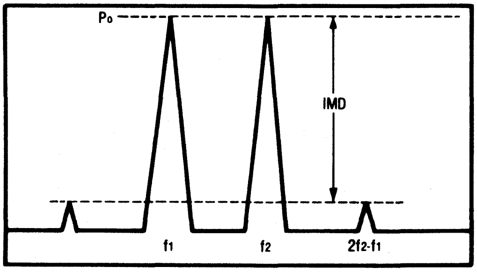


FIGURE 1. INTERMODULATION TEST



$$I_{TO} = P_o + \frac{IMD}{2} \text{ @ IMD} > 60\text{dB}$$

$$PEP = 4X\ P_o \text{ @ IMD} = -32\text{dB}$$

TRW® SEMICONDUCTORS **CA 2875**

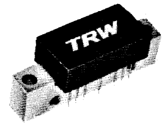
Thin Film RF Linear Hybrid Amplifier

The CA 2875 is a high reliability thin film hybrid amplifier utilizing an all gold metallization system. Units are designed for wide bandwith linear operation in 50 to 100 ohm systems.

Particular areas of interest are high performance 75 Ω IF amplifier, local oscillator buffer amplifier for high level mixer, linear driver/repeater amplifier for 75 Ω cable communications systems.

POWER OUTPUT 310 mW
17 dB GAIN
BANDWITH 40-100 MHz
75 Ω MATCHED

CA 2875 B : BENT PIN OPTION
CA 2875 R : OPTION FOR NEGATIVE POLARITY SUPPLY

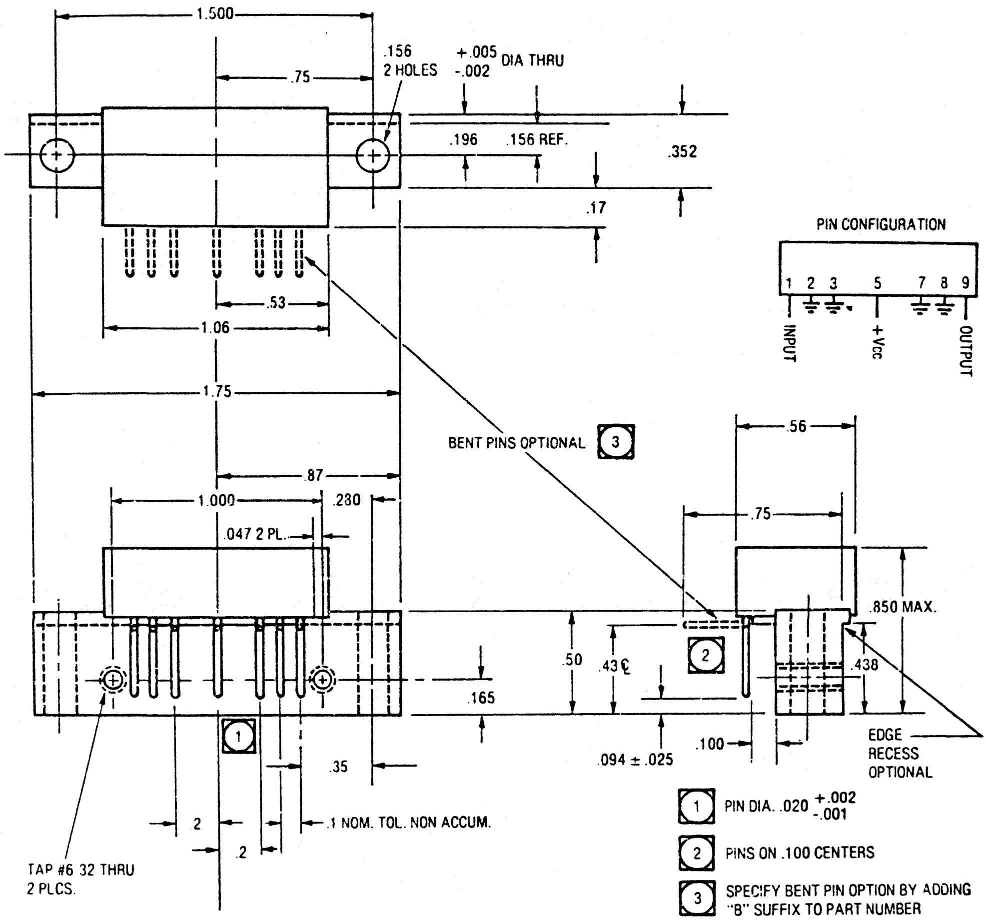


CA

Electrical Characteristics (T_{case} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
for 75 Ω systems RF TEST T case 25 °C V_{CC} = 19 V	P_G	Power Gain	f = 100 MHz	17.0	17.5	18.0	dB
	NF	Noise Figure broadband	f = 70 MHz		4.5	5.0	dB
	I_{TO}	3 Order Intercept (see figure 1)	f = 70 MHz	+ 42	+ 43		dBm
	RL	Input/Output Return loss (75 Ω)	f = 40 - 100 MHz	30			dB
	P_O	Power Output 1 dB Compression	f = 40 - 100 MHz	+ 25	+ 26		dBm
	F_R	Frequency Response	f = 40 - 100 MHz		± 0.1	± 0.2	dB
	D_{SO}	Second Harmonic Suppression	P_O = + 24 dBm f 2 h = 100 MHz		— 40		dB
	PEP	Peak Envelope Power for 2 Tone Distortion. Test (fig. 1)	f = 40 - 100 MHz at — 32 dB IMD	250	300		mW
Absolute max. ratings	V_{CC}	Supply Voltage		+ 15	+ 19	+ 28	V
	I_{CC}	Supply current	19 V	140	155	170	mA
	P_{in}	RF Power Input				+ 14	dBm
	T_{ST}	Storage Temperature		— 55		+ 125	°C
	T_{OP}	Operating Temperature		— 40		+ 100	°C

CA2875
PACKAGE OUTLINE



① PIN DIA. .020 $^{+.002}_{-.001}$

② PINS ON .100 CENTERS

③ SPECIFY BENT PIN OPTION BY ADDING "B" SUFFIX TO PART NUMBER

FUNCTIONAL SCHEMATIC

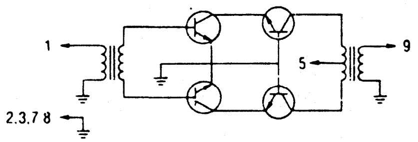
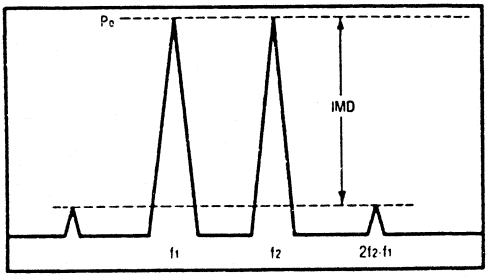


FIGURE 1. INTERMODULATION TEST



$$I_{TO} = P_o + \frac{IMD}{2} \text{ @ } IMD > 60dB$$

$$PEP = 4X\ P_o \text{ @ } IMD = -32dB$$

TRW® SEMICONDUCTORS

CA 2876
CA 2880

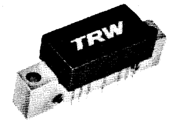
Thin Film RF Linear Hybrid Amplifier

The CA 2876 is a high reliability thin film hybrid amplifier utilizing an all gold metallization system. Units are designed for wide bandwith linear operation in 50 to 100 ohm systems.

Particular areas of interest are low noise 75 Ω IF amplifier, high performance linear amplifier for signal levels below 100 mW, linear amplifier applications requiring low current consumption.

POWER OUTPUT 100 mW
22 dB GAIN
BANDWITH 40-100 MHz
75 Ω MATCHED
LOW NOISE FIGURE

CA 2876 B : BENT PIN OPTION
CA 2876 R : OPTION FOR NEGATIVE POLARITY SUPPLY
CA 2880 : OPTION FOR LOW HEATSINK PROFILE
CA 2880 R : OPTION FOR NEGATIVE POLARITY SUPPLY

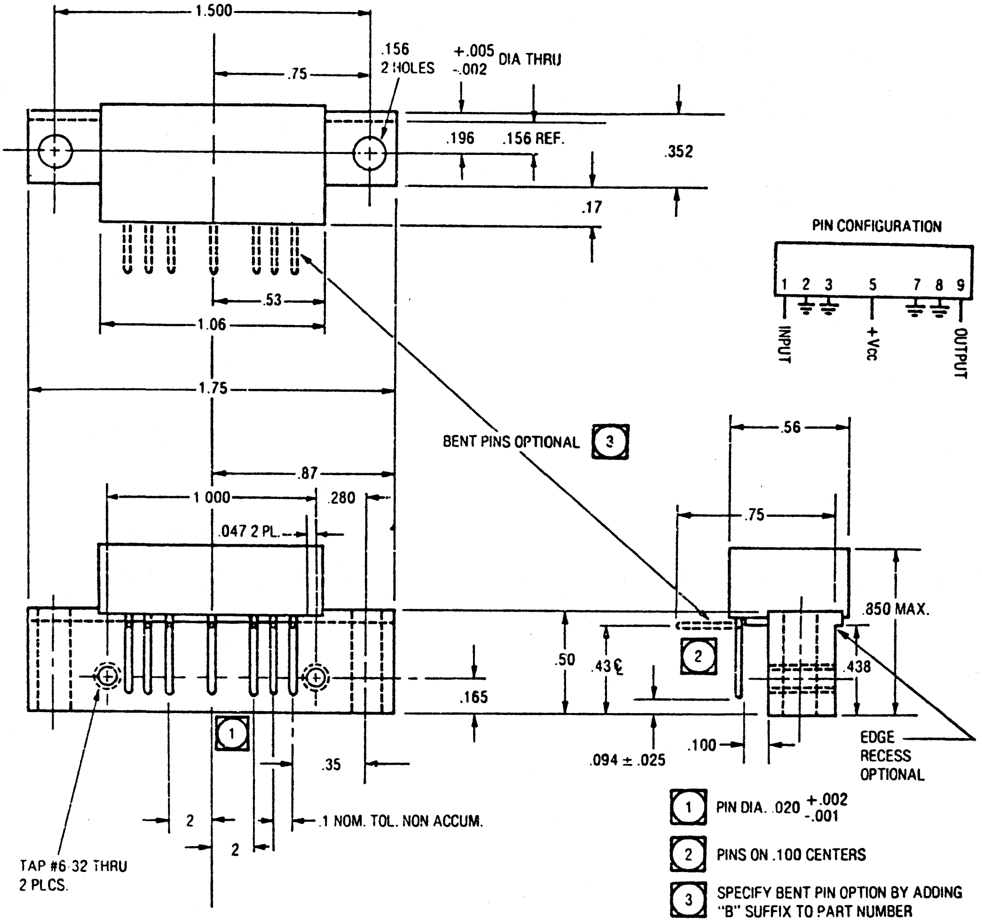


CA

Electrical Characteristics (T_{case} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
RF TEST T case 25 °C V_{CC} = 19 V for 75 Ω systems	P_G	Power Gain	f = 100 MHz	21.25	22	22.75	dB
	NF	Noise Figure Broadband	f = 70 MHz		3.0	3.5	dB
	I_{TO}	3 Order Intercept (see figure 1)	f = 70 MHz	+ 33	+ 36		dBm
	VSWR	Input/Output VSWR (75 Ω)	f = 40 - 100 MHz	1.1 : 1	1.2 : 1		N/A
	P_O	Power Output 1 dB Compression	f = 40 - 100 MHz	+ 20	+ 22		dBm
	F_R	Frequency Response	f = 40 - 100 MHz		± 0.1	± 0.3	dB
	D_{SO}	Second Harmonic Suppression	P_O = 100 mW f 2 h = 100 MHz	— 45	— 50		dB
	PEP	Peak Envelope Power for 2 Tone Dist. Test (fig. 1)	f = 40 - 100 MHz at — 32 dB IMD	100	175		mW
Absolute max. ratings	V_{CC}	Supply Voltage		15	19	28	V
	I_{CC}	Supply Current	19 V	65	73	80	mA
	P_{in}	RF Power Input				+ 14	dBm
	T_{ST}	Storage Temperature		— 55		+ 125	°C
	T_{OP}	Operating Temperature		— 40		+ 100	°C

CA2876
PACKAGE OUTLINE



① PIN DIA. .020 $^{+.002}_{-.001}$

② PINS ON .100 CENTERS

③ SPECIFY BENT PIN OPTION BY ADDING "B" SUFFIX TO PART NUMBER

FUNCTIONAL SCHEMATIC

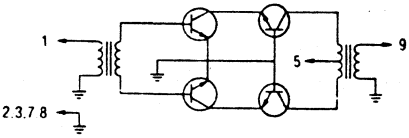
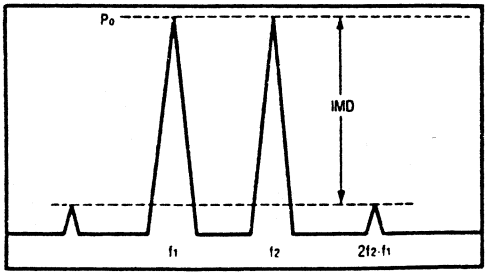


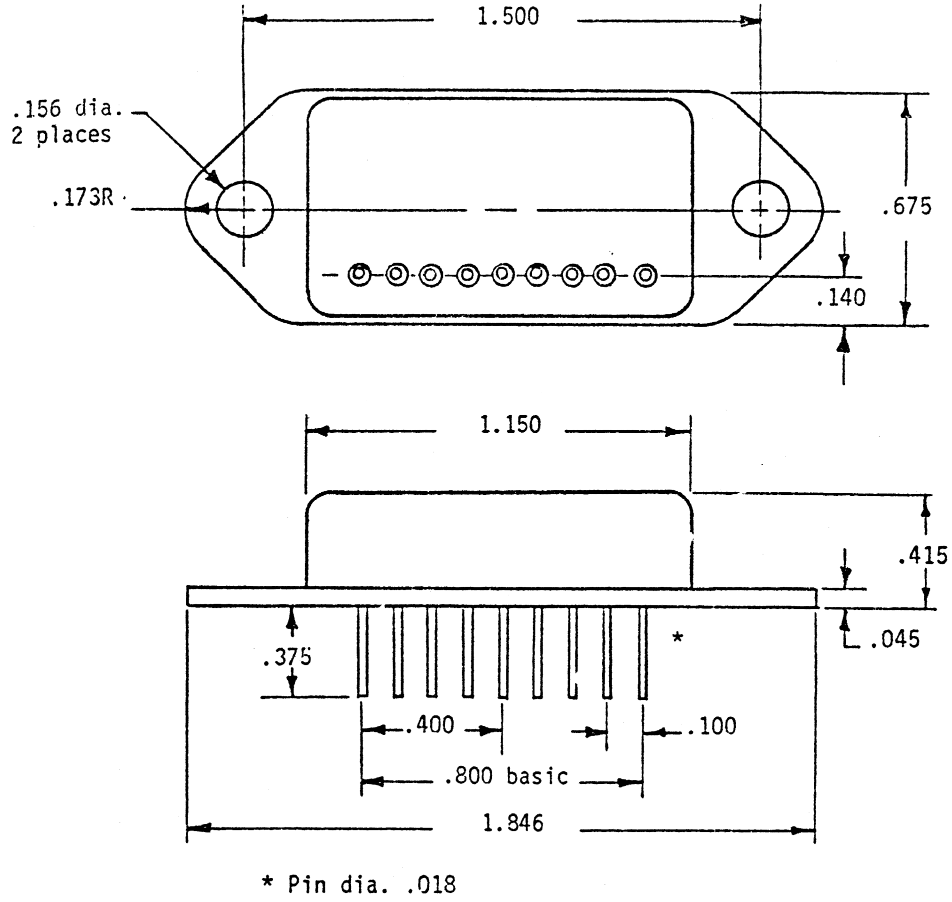
FIGURE 1. INTERMODULATION TEST



$I_{TO} = P_o + \frac{IMD}{2}$ @ IMD > 60dB

PEP = 4X P_o @ IMD = -32dB

The hermetic package option is available for all models in the CA 28 XX Serie. The hermetic specification is indicated by adding the « H » suffix to the part number.



HERMETIC PACKAGE OPTION FOR CA 28 XX SERIES
(Dimensions in inches)

MATV

MATV

PRODUCT SUMMARY

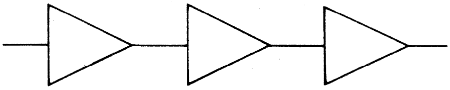
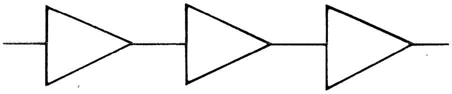
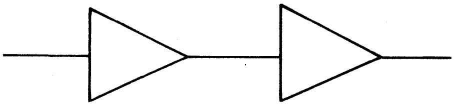
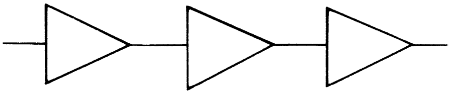
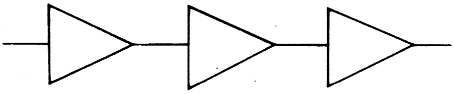
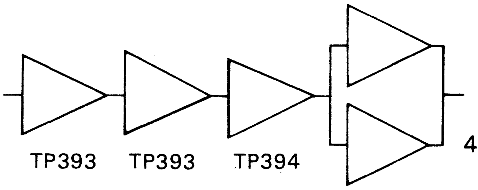
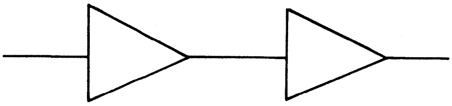
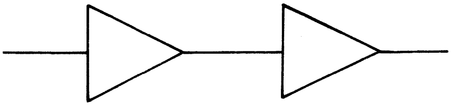
P/N	PACKAGE	FT	NF	OUTPUT* CAPABILITY	GU MAX (500 MHz)	PAGE
		GHz	DB	mVolt	DB	
TP 390	T-PACK	2.5	3	100	13.5	**263**
TP 393	T-PACK	3	2	300	15.5	**265**
TP 491	T-PACK	3.3	1.6	400	16.5	**273**
TP 312	T-PACK	3	4.5	600	13.5	**259**
TP 394	T-PACK	2.5	3.5	700	12.5	**269**
TP 3093	TO 39	2.8	3.5	1000	9.5	**277**
TP 3094	TO 117	2.6	4	1000	13.5	**281**
TPV 596	SOE 280	2.5		1500	17	**341**

* According to DIN 45004-B specification.

MATV

40-860 MHz

LINE-UP SUGGESTIONS

	BAND	GAIN	OUTPUT LEVEL	NOISE FIGURE
 3 X TP 390	40-860 MHz	24 dB	150 mV	3.5 dB
 3 X TP 393	40-860 MHz	27 dB	250 mV	2.5 dB
 2 X TP 491	40-860 MHz	20 dB	300 mV	2.0 dB
 TP491 TP491 TP312	40-860 MHz	25 dB	500 mV	2.0 dB
 TP491 TP491 TP394	40-860 MHz	27 dB	700 mV	2.0 dB
 TP393 TP393 TP394 TP394 push-pull	40-225 MHz	40 dB	1V	2.5 dB
	470-860 MHz	34 dB	1V	2.5 dB
 2 X TP 3094	40-860 MHz	15 dB	1V	
 TP3094 TPV596	40-860 MHz	17 dB	1.5V	

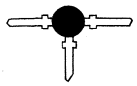
TRW® **SEMICONDUCTORS**

TP 312

UHF LINEAR TRANSISTOR

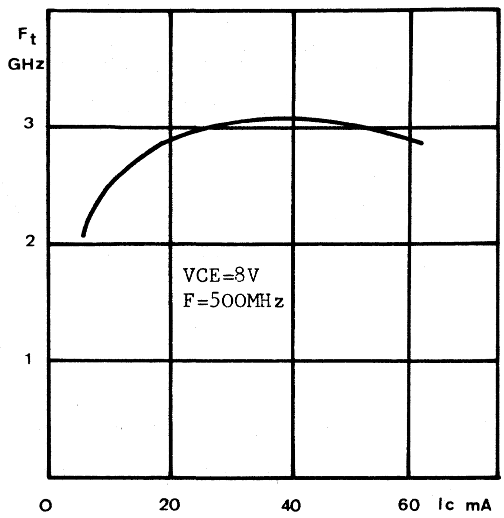
HIGH OUTPUT
AT LOW COST
0.7 V AT - 60 DB IMD
GOLD RELIABILITY
3 GHz FT

The TP 312 is a NPN transistor, gold metallized for reliability, using diffused ballast resistors for super linearity at low currents compatible with the power dissipation capability of a T-pack. TP 312 is the ideal candidate for up to **0.7 V** (DIN 45004/B) **MATV** amplifiers from **40 to 860 MHz.** The TP 312 has applications in driver stages of 12 volts VHF/UHF transmitters and broadband instrumentation equipment.

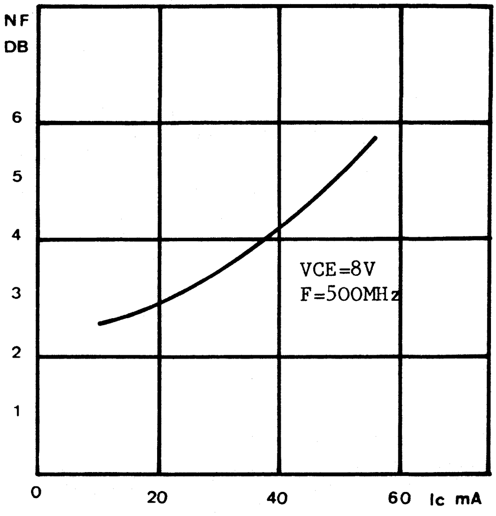


Electrical Characteristics (T_{flange} = 25 °C)

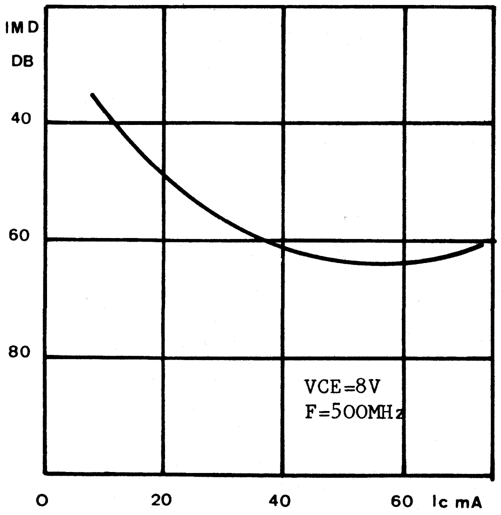
	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC Test	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 0.1 mA	3.5			V
	BV_{CEO}	Collector - Emitter Breakdown Voltage	I_C = 10 mA	14			V
	BV_{CER}	Collector - Emitter Breakdown Voltage	I_C = 10 mA R_{BE} = 10 ohms	20			V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 0.1 mA	20			V
	h_{FE}	D.C. Current Gain	V_{CE} = 8 V I_C = 40 mA	15			
RF Test	NF	Noise Figure	V_{CE} = 8 V I_C = 40 mA F = 500 MHz		4.5		dB
	f_T	Cutoff Frequency	V_{CE} = 8 V I_C = 40 mA F = 500 MHz		3		GHz
	G_{Umax}	Maximum Unilaterilized Gain	V_{CE} = 8 V I_C = 40 mA F = 500 MHz		13.5		dB
	$\lvert S_{21} \rvert$	Forward Gain 50 Ω/50 Ω	V_{CE} = 10 V I_C = 40 mA F = 500 MHz		12		dB
	IMD	Intermodulation Distortion 3 Tone - Din 45004/B F = 500 MHz R_{LOAD} = 75 ohms	V_{CE} = 8 V V_{out} = 700 mV I_C = 40 mA		— 60		dB
	C_{OB}	Collector - Base Capacitance	V_{CB} = 8 V f = 1 MHz		1.7		pF
Thermal	I_{Cmax}	Maximum Collector Current				300	mA
	P_T	Dissipated Power				0.7	W
	T_{STG}	Storage Temperature		— 65		+ 200	°C
	T_J	Junction Temperature					



Ft GHz
3
2
1
O
20
40
60
Ic mA
VCE=8V
F=500MHz



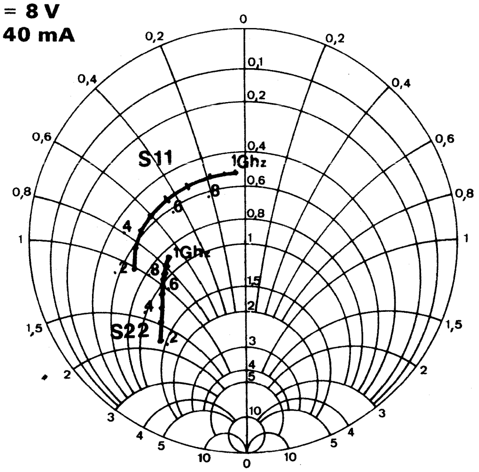
NF DB
6
5
4
3
2
1
0
20
40
60
Ic mA
VCE=8V
F=500MHz



IMD DB
40
60
80
O
20
40
60
Ic mA
VCE=8V
F=500MHz

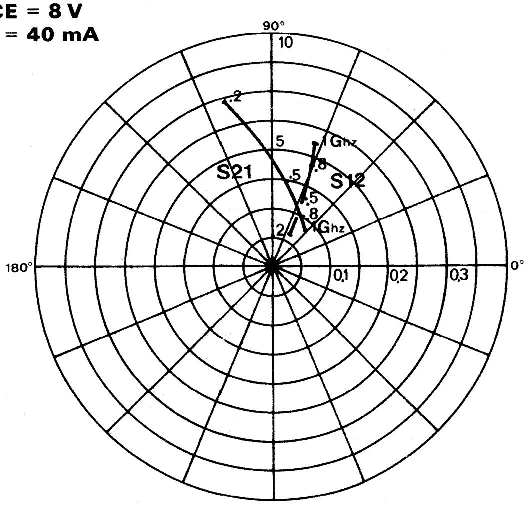
S11-S22 VS FREQUENCY

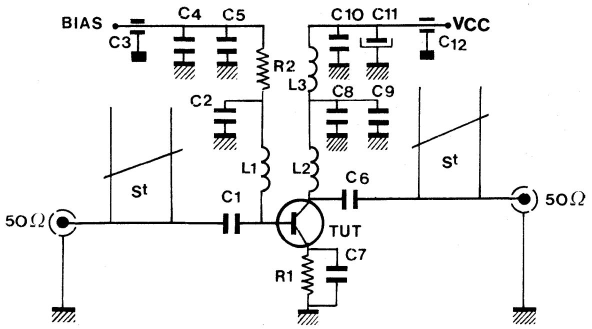
VCE = 8 V
IC = 40 mA



S12-S21 VS FREQUENCY

VCE = 8 V
IC = 40 mA

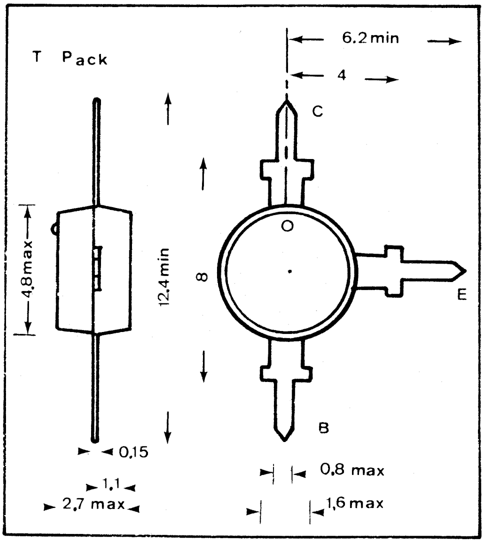




NF AND GAIN TEST CIRCUIT SHEMATIC

$L_{1,2}$	0.02 μH
L_3	0.1 μH - molded coil
$C_{1,6}$	220 pF ceramic chip
$C_{2,4,8}$	470 pF ceramic disc
$C_{3,12}$	1000 pF by pass
$C_{5,9}$	1000 pF ceramic disc
C_7	470 pF ceramic chip
C_{11}	100 μF/25 V - electrolytic
R_1	100 ohms 1/4 W carbon composition
R_2	1.5 K 1/4 W carbon composition
St	Stub tuner

PACKAGE OUTLINE



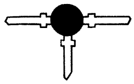
TRW® SEMICONDUCTORS

TP 390

UHF LINEAR TRANSISTOR

3 DB NOISE FIGURE
AT 500 MHz
3 GHz FT
LOW COST

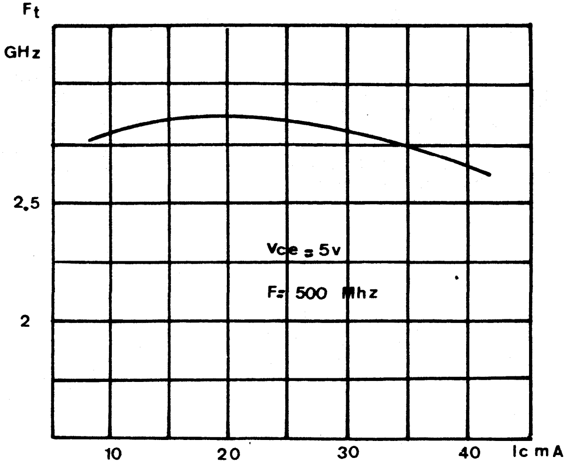
The TP 390 is a low level NPN silicon transistor mounted in T.pack for low cost. Its 3 GHz transition frequency makes it an ideal candidate for broadband UHF linear applications such as in small signal MATV amplifiers from 40 to 860 MHz TP 390 has applications in most VHF/UHF amplifiers such as instrumentation and communications equipments.



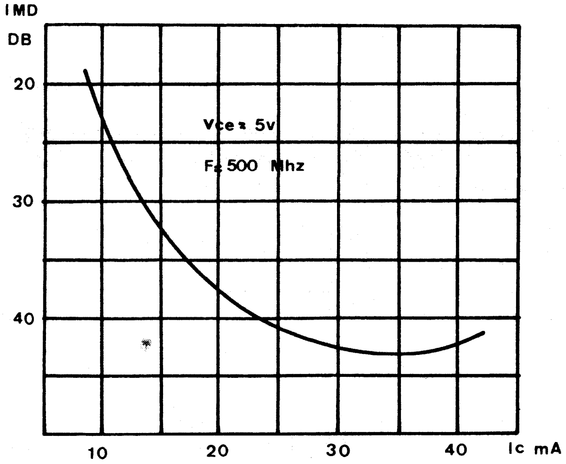
T PACK

Electrical Characteristics (T_{flange} = 25 °C)

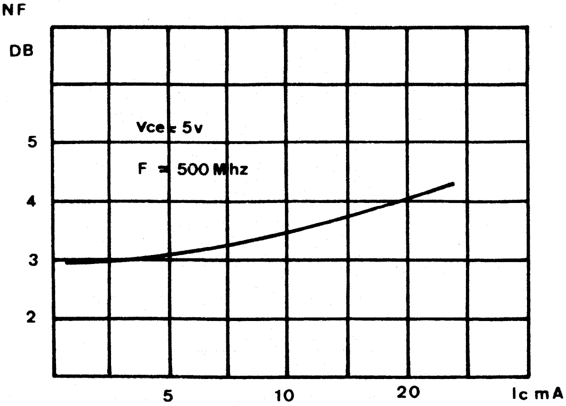
	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC Test	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 0.1 mA	2.5			V
	BV_{CEO}	Collector - Emitter Breakdown Voltage	I_C = 10 mA	15			V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 0.1 mA	25			V
	I_{CBO}	Collector - Base Leakage	V_{CB} = 10 V			0.05	µA
	h_{FE}	D.C. Current Gain	V_{CE} = 1 V I_C = 25 mA	20			
RF Test	NF	Noise Figure	V_{CE} = 5 V I_C = 2 mA F = 500 MHz		3		dB
	f_T	Cutoff Frequency	V_{CE} = 5 V I_C = 25 mA F = 500 MHz		2.8		GHz
	G_{Umax}	Maximum Unilaterilized Gain	V_{CE} = 10 V I_C = 25 mA F = 500 MHz		13.5		dB
	$\lvert S_{21} \rvert$	Forward Gain 50 Ω/50 Ω	V_{CE} = 10 V I_C = 25 mA F = 500 MHz		11.5		dB
	IMD	Intermodulation Distortion 3 Tone - Din 45004/B F = 500 MHz R_{LOAD} = 75 ohms	V_{CE} = 5 V V_{out} = 700 mV I_C = 30 mA		— 40		dB
	C_{OB}	Collector - Base Capacitance	V_{CB} = 10 V f = 1 MHz		0.7		pF
Thermal	I_{Cmax}	Maximum Collector Current				50	mA
	P_T	Dissipated Power				180	mW
	T_{STG}	Storage Temperature		— 65		+ 200	°C
	T_j	Junction Temperature					



Ft
GHz
2,5
2
Vce = 5v
F= 500 Mhz
10
20
30
40
Ic mA



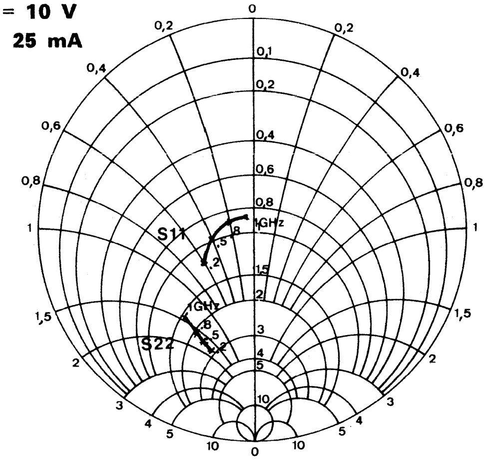
IMD
DB
20
30
40
Vce = 5v
F= 500 Mhz
10
20
30
40
Ic mA



NF
DB
5
4
3
2
Vce = 5v
F = 500 Mhz
5
10
20
Ic mA

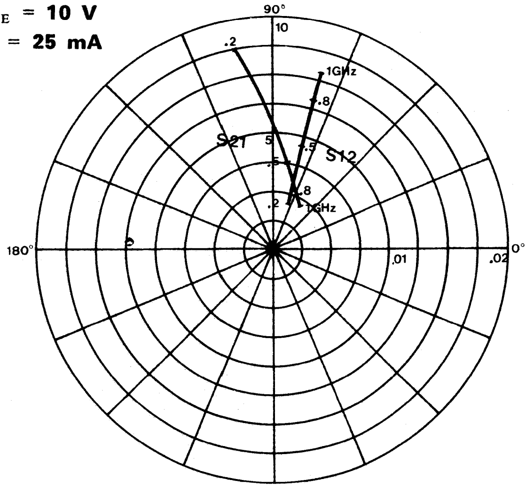
S 11 - S 22 PARAMETERS VS FREQUENCY

V_{CE} = 10 V
I_C = 25 mA

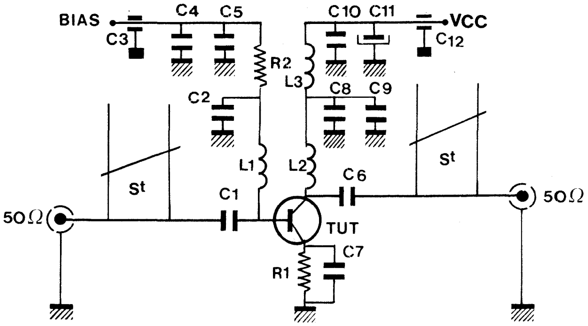


S 21 - S 12 PARAMETERS VS FREQUENCY

V_{CE} = 10 V
I_C = 25 mA

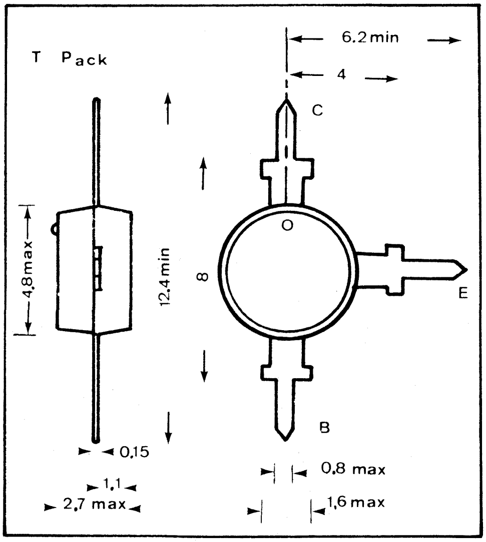


NF AND GAIN TEST CIRCUIT SHEMATIC



$L_{1,2}$	0.02 μH
L_3	0.1 μH - molded coil
$C_{1,6}$	220 pF ceramic chip
$C_{2,4,8}$	470 pF ceramic disc
$C_{3,12}$	1000 pF by pass
$C_{5,9}$	1000 pF ceramic disc
C_7	470 pF ceramic chip
C_{11}	100 μF/25 V - electrolytic
R_1	100 ohms 1/4 W carbon composition
R_2	1.5 K 1/4 W carbon composition
St	Stub tuner

PACKAGE OUTLINE



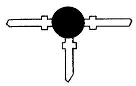
TRW SEMICONDUCTORS

TP 393

UHF LINEAR TRANSISTOR

2 DB NOISE FIGURE
AT 500 MHz
3 GHz FT
HIGH OUTPUT

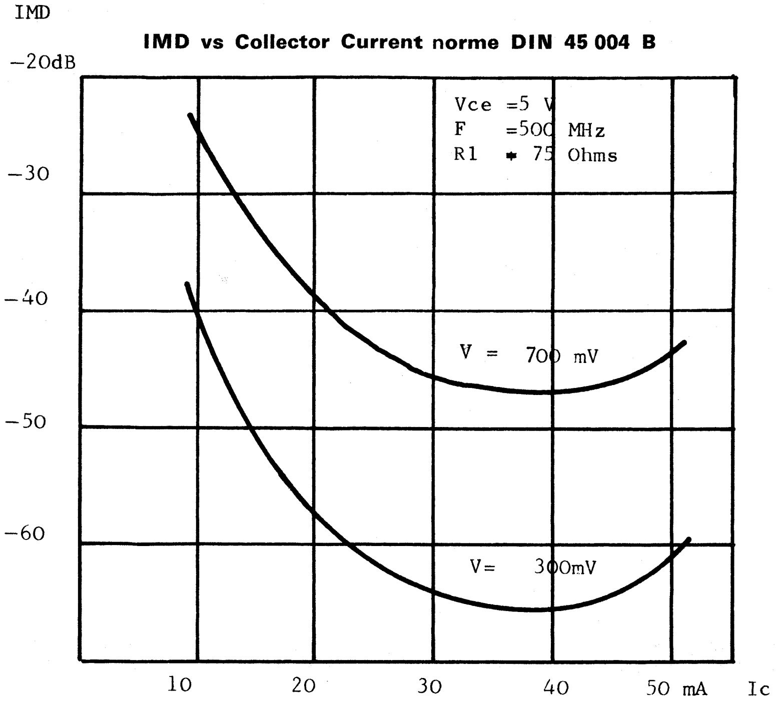
The TP 393 is a gold metallized NPN silicon transistor specifically designed for low noise, high frequency broadband operation. It is mounted in T-pack for high volume low cost applications. These characteristics make it an ideal choice for low noise, intermediate level **MATV/CATV** amplifiers from **40 to 860 MHz** TP 393 has applications in low noise **receivers** and **mixers** up to **2.5 GHz** in radio or cable communication, doppler radars and instrumentation equipment.

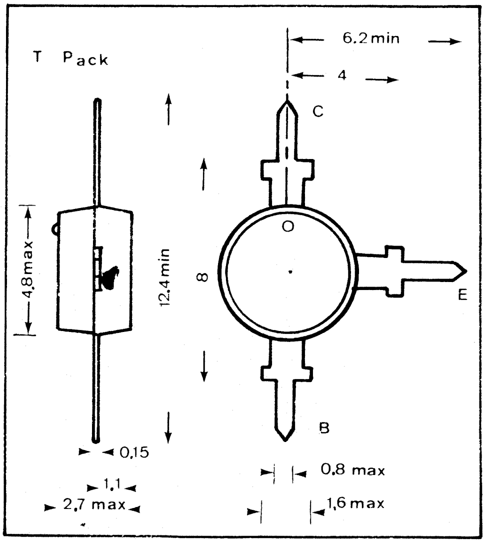


T - PACK

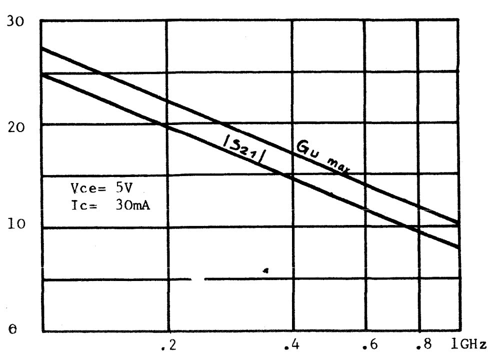
Electrical Characteristics (T_{CASE} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC Test	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 0.1 mA	2.5			V
	BV_{CEO}	Collector - Emitter Breakdown Voltage	I_C = 10 mA	15			V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 0.1 mA	25			V
	h_{FE}	D.C Current Gain	V_{CE} = 5 V I_C = 30 mA	25			
RF Test	NF	Noise Figure	V_{CE} = 5 V I_C = 2 mA F = 500 MHz		2	2.5	dB
	f_T	Cutoff Frequency	V_{CE} = 5 V I_C = 30 mA F = 500 MHz	2.8	3.0		GHz
	G_{Umax}	Maximum Unilaterilized Gain	V_{CE} = 5 V I_C = 30 mA F = 500 MHz	15	15.5		dB
	S_{21}	Forward Gain 50 Ω/50 Ω	V_{CE} = 5 V I_C = 30 mA F = 500 MHz		14		dB
	IMD	Intermodulation Distortion 3 Tone - Din 45004/B F = 500 MHz R_{LOAD} = 75 ohms	V_{CE} = 5 V V_{out} = 300 mV I_C = 30 mA V_{out} = 700 mV		— 60 — 45		dB dB
	C_{OB}	Collector - Base Capacitance	V_{CB} = 5 V f = 1 MHz		0.7		pF
Operating Thermal	I_{Cmax}	Maximum Collector Current				50	mA
	P_T	Dissipated Power				250	mW
	T_{STG}	Storage Temperature		— 65		+ 200	°C
	T_j	Junction Temperature				150	°C

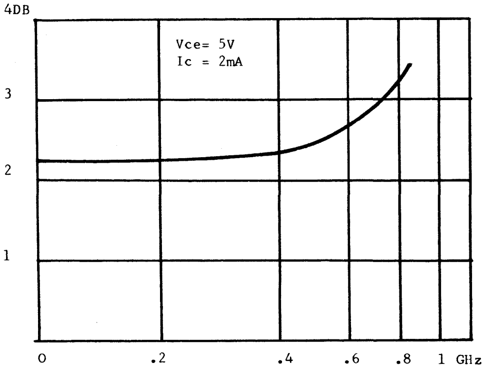

IMD
IMD vs Collector Current norme DIN 45 004 B
−20dB
−30
−40
−50
−60
Vce =5 V
F =500 MHz
R1 ✱ 75 Ohms
V = 700 mV
V= 300mV
10
20
30
40
50 mA
Ic


T Pack
6.2 min
4
C
O
E
B
4,8 max
12,4 min
8
0,15
1,1
2,7 max
0,8 max
1,6 max

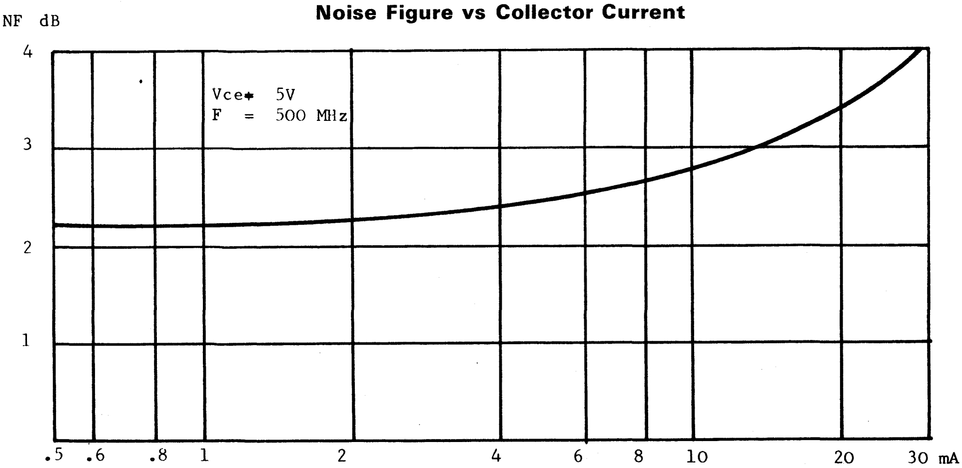
Gain vs frequency



Noise Figure vs Frequency



Noise Figure vs Collector Current



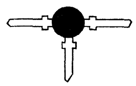
TRW® SEMICONDUCTORS

TP 394

UHF LINEAR TRANSISTOR

HIGH OUTPUT
AT LOW COST
0,7 V AT - 62 DB IMD
GOLD RELIABILITY
2,5 GHZ FT

The TP 394 is a NPN transistor, gold metallized for reliability, using diffused ballast resistors for super linearity at currents compatible with the power dissipation capability of a T-Pack. TP 394 is the ideal candidate for up to **0.8 V** (DIN 45004/B) **MATV** amplifiers from **40 to 860 MHz.** The TP 394 has applications in driver stages of 12 volts VHF/UHF transmitters and broadband instrumentation equipment.

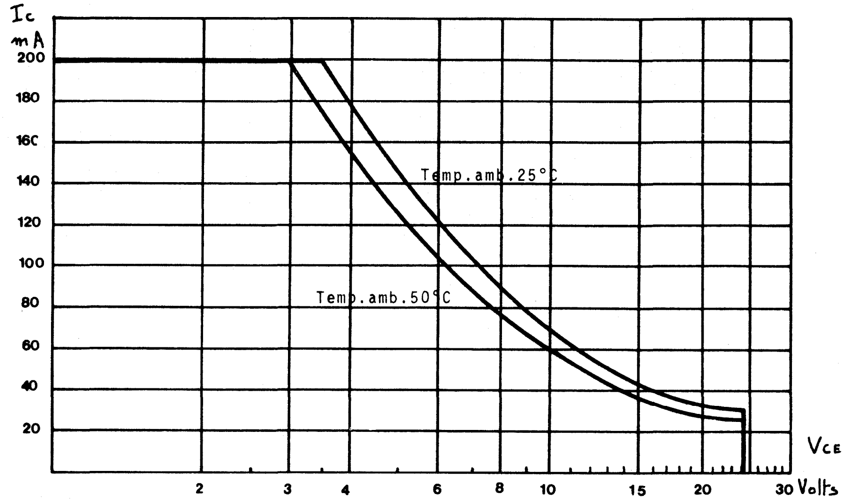


T - PACK

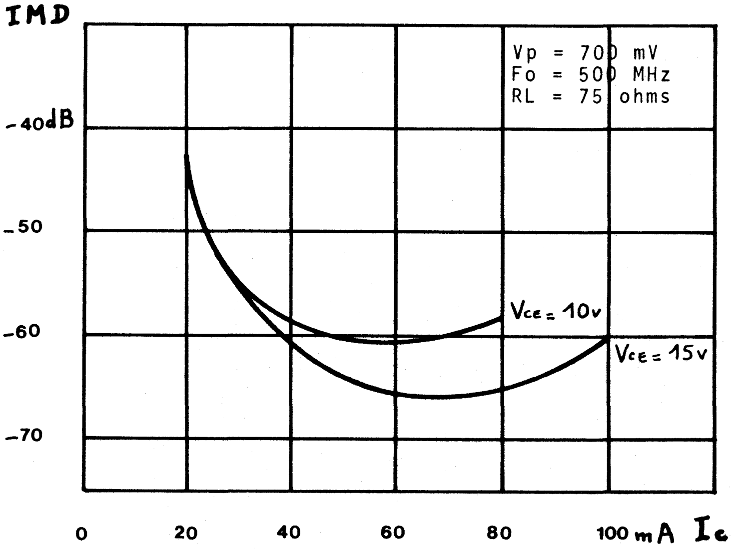
Electrical Characteristics (T_{CASE} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
D C Test	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 0.1 mA	3			V
	BV_{CEO}	Collector - Emitter Breakdown Voltage	I_C = 10 mA	25			V
	BV_{CER}	Collector - Emitter Breakdown Voltage	I_C = 10 mA R_{BE} = 10 ohms	30			V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 1 mA	35			V
	h_{FE}	D.C Current Gain	V_{CE} = 10 V I_C = 40 mA	15			
R F Test	NF	Noise Figure	V_{CE} = 10 V I_C = 20 mA F = 500 MHz		3.5		dB
	f_T	Cutoff Frequency	V_{CE} = 10 V I_C = 40 mA F = 500 MHz		2.5		GHz
	G_{Umax}	Maximum Unilaterilized Gain	V_{CE} = 10 V I_C = 40 mA F = 500 MHz		14		dB
	[S 21]	Forward Gain 50 Ω/50 Ω	V_{CE} = 10 V I_C = 40 mA F = 500 MHz		12.5		dB
	IMD	Intermodulation Distortion 3 Tone - DIN 45004/B F = 500 MHz R_{Load} = 75 ohms	V_{CE} = 10 V V_{out} = 700 mV I_C = 60 mA		— 62		dB
	C_{OB}	Collector - Base Capacitance	V_{CB} = 10 V f = 1 MHz		2.5		pF
Thermal	I_{Cmax}	Maximum Collector Current				200	mA
	P_T	Dissipated Power	T_{CASE} = 50 °C			0.6	W
	T_{STG}	Storage Temperature		— 65		+ 200	°C
	T_J	Junction Temperature					

Safe Operating Area

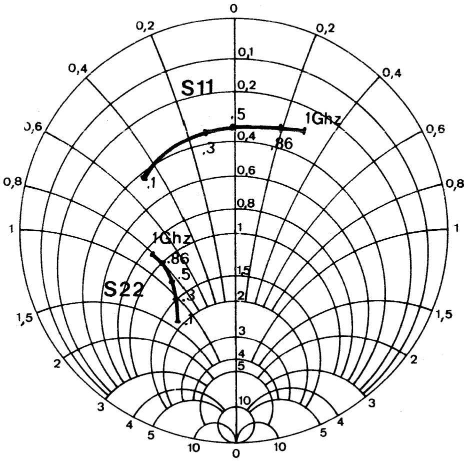


IMD vs Ic Collector Current



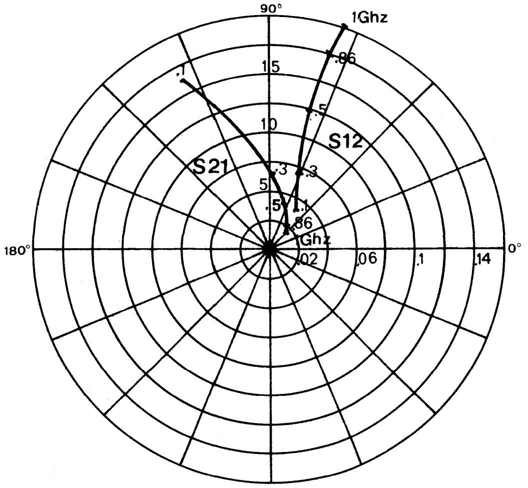
S11 - S22 Parameters vs Frequency

V_{CE} = 10 V - I_C = 40 mA

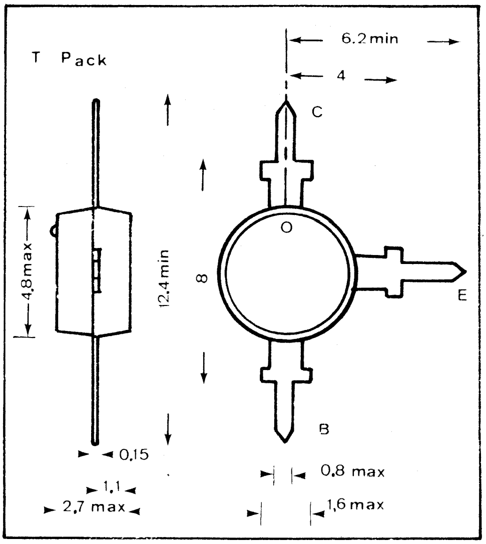


S21 - S12 Parameters vs Frequency

V_{CE} = 10 V - I_C = 40 mA



PACKAGE OUTLINE



TRW® **SEMICONDUCTORS**

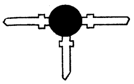
TP 491

UHF LINEAR TRANSISTOR

The TP 491 is a gold metallized NPN silicon transistor specifically designed for low noise, high frequency broadband operation, which is mounted in T-pack for high volume low cost applications. These characteristics make it an ideal for low noise, intermediate level **MATV/ CATV** amplifiers from **40 to 860 MHz.**

TP 491 has applications in low noise **receivers** and **mixers** up to **2.5 GHz** in radio or cable communication, doppler radars and instrumentation equipments.

1.6 DB NOISE FIGURE
AT 500 MHz
3.5 GHz FT
HIGH OUTPUT

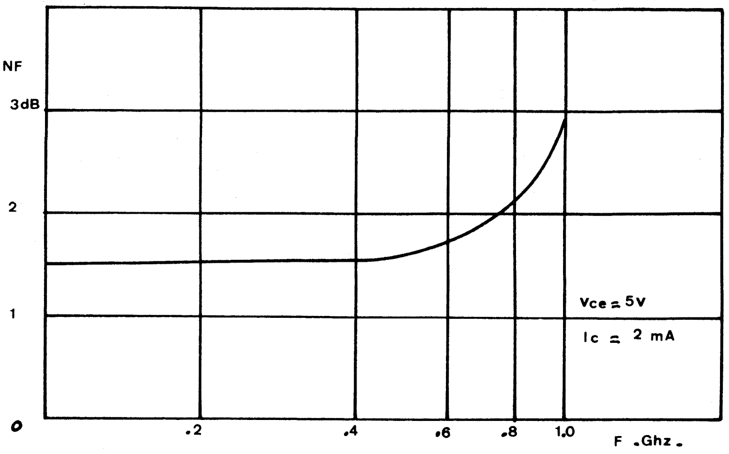


T - PACK

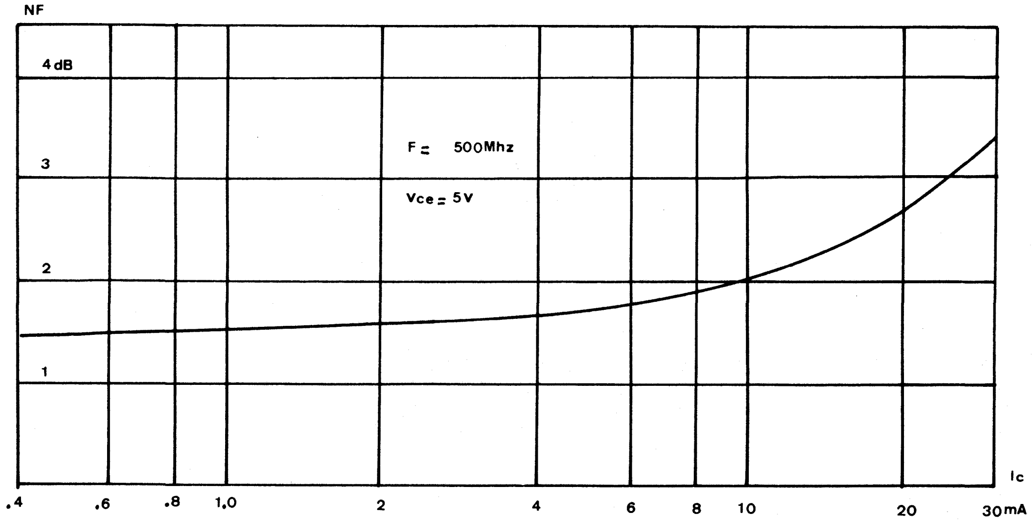
Electrical Characteristics (T_{flange} = 25 °C)

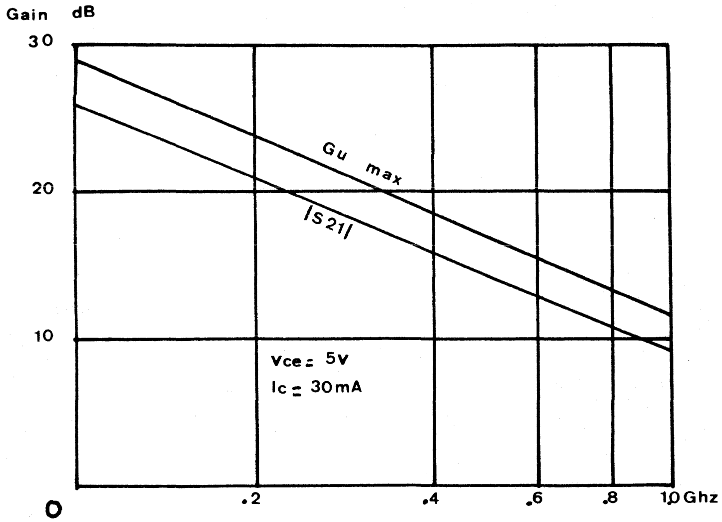
	SYMBOL	CHARACTERISTICS	TEST CONDITIONS		MIN.	TYP.	MAX.	UNIT
DC Test	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 0.1 mA		2.5			V
	BV_{CEO}	Collector - Emitter Breakdown Voltage	I_C = 10 mA		14			V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 0.1 mA		25			V
	I_{CBO}	Collector - Base Leakage	V_{CB} = 20 V				10	µA
	h_{FE}	D.C. Current Gain	V_{CE} = 1 V I_C = 2 mA		25			
RF Test	NF	Noise Figure	V_{CE} = 5 V I_C = 2 mA F = 500 MHz			1.6	2.0	dB
	f_T	Cutoff Frequency	V_{CE} = 5 V I_C = 30 mA F = 500 MHz			3.2		GHz
	G_{Umax}	Maximum Unilaterilized Gain	V_{CE} = 5 V I_C = 30 mA F = 500 MHz			16.4		dB
	$\|S_{21}\|$	Forward Gain 50 Ω/50 Ω	V_{CE} = 5 V I_C = 30 mA F = 500 MHz			14.8		dB
	IMD	Intermodulation Distortion 3 Tone - Din 45004/B F = 500 MHz R_{LOAD} = 75 ohms	V_{CE} = 5 V I_C = 30 mA	V_{out} = 300 mV			— 60	dB
				V_{out} = 700 mV			— 45	dB
	C_{OB}	Collector - Base Capacitance	V_{CB} = 5 V f = 1 MHz			0.8		pF
Thermal	I_{Cmax}	Maximum Collector Current					50	mA
	P_T	Dissipated Power					300	mW
	T_{STG}	Storage Temperature			— 65		+ 200	°C
	T_J	Junction Temperature						

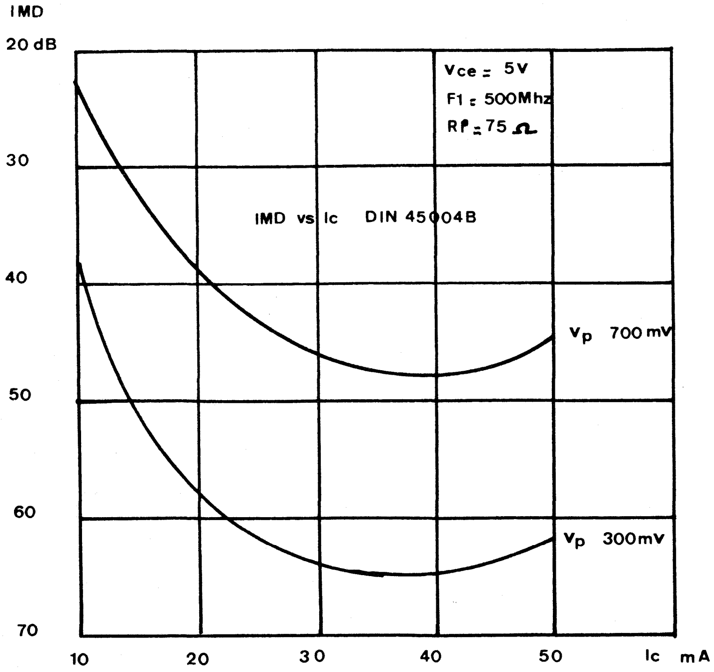
Noise Figure vs Frequency



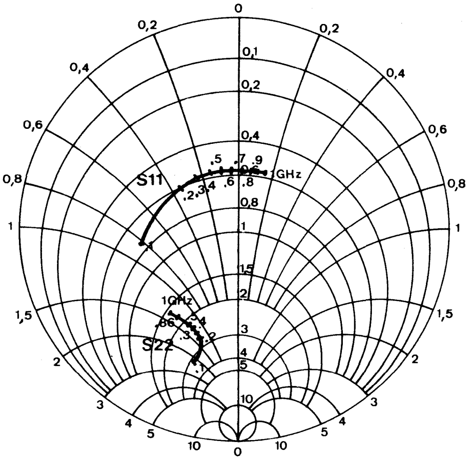
Noise Figure vs Collector Current



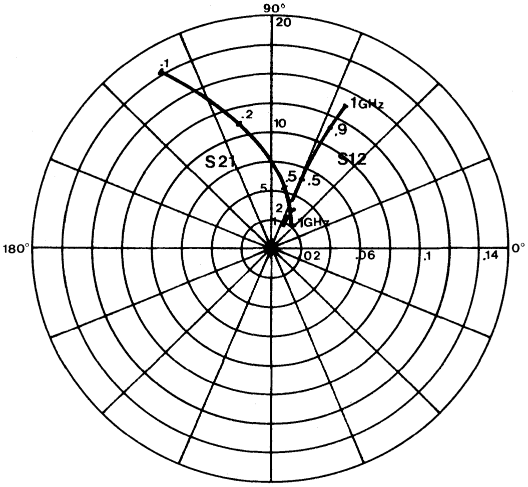

Gain dB
30
20
10
0
.2
.4
.6
.8
1,0 Ghz
Gu max
|S21|
Vce = 5V
Ic = 30 mA


IMD
20 dB
30
40
50
60
70
10
20
30
40
50
Ic mA
Vce = 5V
F1 = 500Mhz
Rf = 75 Ω
IMD vs Ic DIN 45004B
Vp 700 mV
Vp 300mV

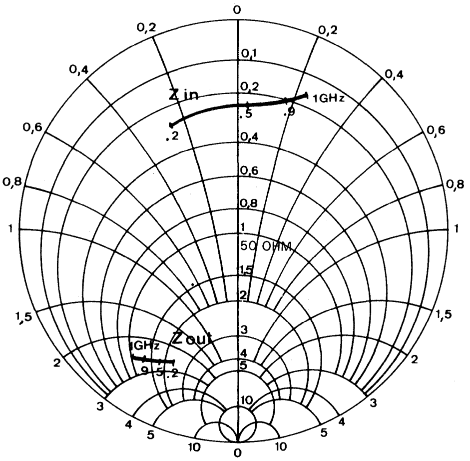
S11 - S22 Parameters vs Frequency
V_{CE} = 5 V - I_C = 30 mA



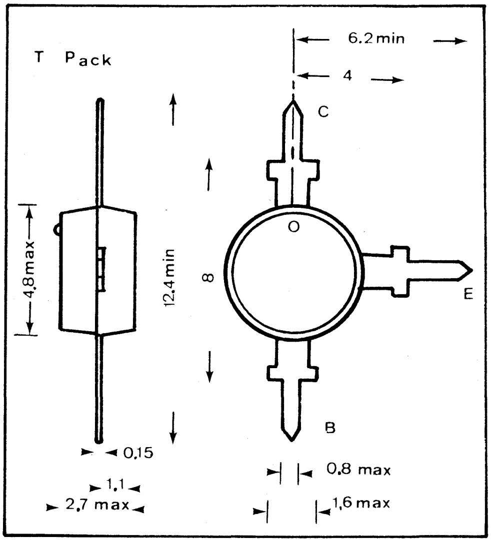
S21 - S12 Parameters vs Frequency
V_{CE} = 5 V - I_C = 30 mA



Z_{in} Z_{out} from « S » Parameters
V_{CE} = 5 V - I_C = 30 mA



PACKAGE OUTLINE

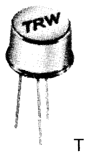


TRW® **SEMICONDUCTORS** **TP 3093**

UHF LINEAR TRANSISTOR

3 GHz FT
1 volt output DIN 45004 B
3,5 dB NF at 500 mHz

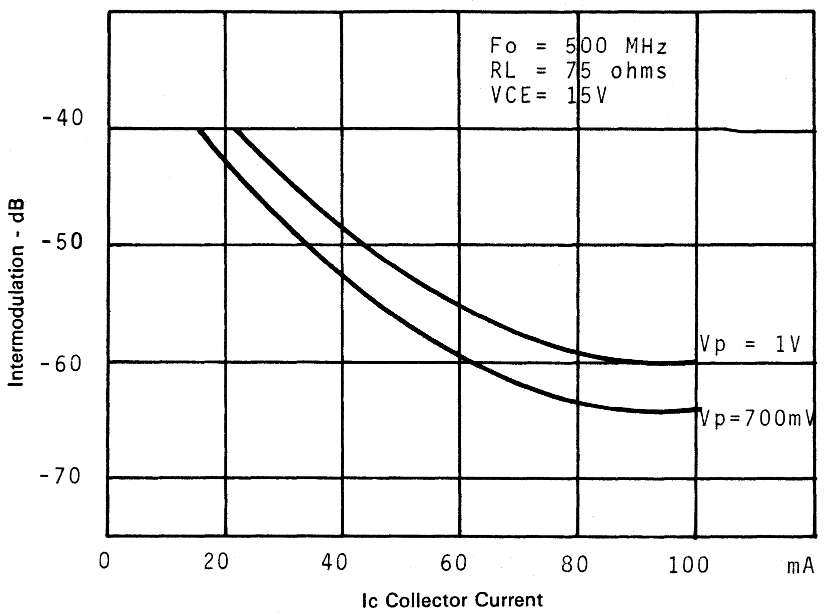
The TP 3093 is an NPN silicon transistor using gold metallization and diffused emitter ballast resistors for long term reliability. Its mains characteristics are high output level, low noise figure and high Ft. These features make TP 3093 an ideal candidate for broadband linear amplifier up to 1 GHz (MATV), oscillators, mixers, multipliers and others.



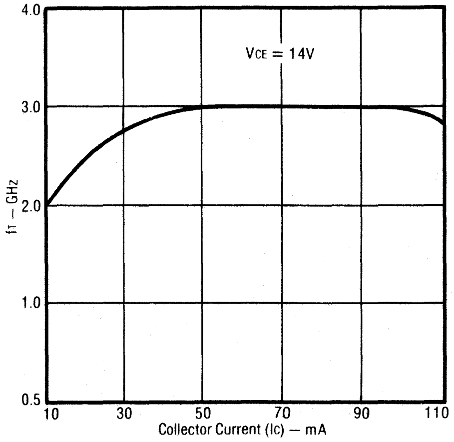
TO 39

Electrical Characteristics (T_{flange} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC Test	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 0.1 mA		3.5		V
	BV_{CEO}	Collector - Emitter Breakdown Voltage	I_C = 5 mA		20		V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 1 mA		30		V
	h_{FE}	D.C Current Gain	V_{CE} = 5 V I_C = 50 mA		35		
RF Test	NF	Noise Figure	V_{CE} = 15 V I_C = 20 mA F = 500 MHz		3.5		dB
	f_T	Cutoff Frequency	V_{CE} = 15 V I_C = 50 mA F = 500 MHz		3		GHz
	G_{Umax}	Maximum Unilaterilized Gain	V_{CE} = 15 V I_C = 50 mA F = 500 MHz		9.5		dB
	$\|S_{21}\|$	Forward Gain 50 Ω/50 Ω	V_{CE} = 15 V I_C = 50 mA F = 500 MHz		8.5		dB
	IMD	Intermodulation Distortion 3 Tone - DIN 45004/B F = 500 MHz R_{Load} = 75 ohms	V_{CE} = 15 V V_{out} = 700 mV I_C = 60 mA V_{out} = 1000 mV		— 60 — 56		dB dB
	C_{OB}	Collector - Base Capacitance	V_{CB} = 15 V f = 1 MHz			3	pF
Thermal	I_{Cmax}	Maximum Collector Current			200		mA
	θ_{JC}	Thermal Resistance Junction - Case	T_{CASE} = 25 °C		50°		°C/W
	P_T	Dissipated Power	T_{CASE} = 25 °C		3.5		W
	T_{STG}	Storage Temperature		— 65		+ 200	°C



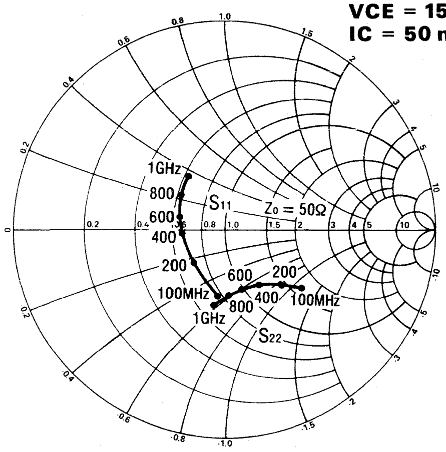
DIN 45004 B IMD VS Ic Collector Current



Cutoff Frequency

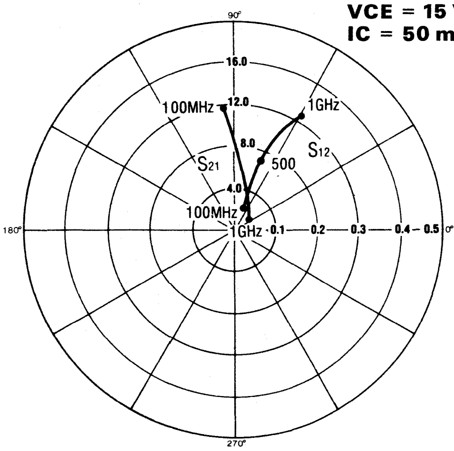
S 22 - S 11 Parameters vs Frequency

VCE = 15 V
IC = 50 mA



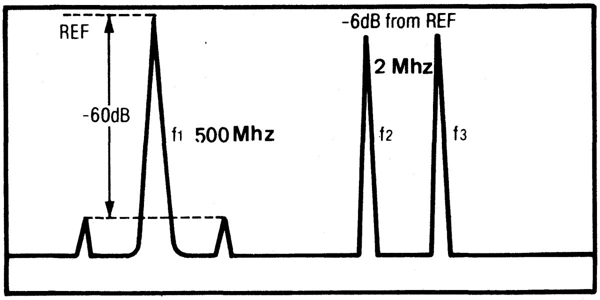
S 21 - S 12 Parameters vs Frequency

VCE = 15 V
IC = 50 mA

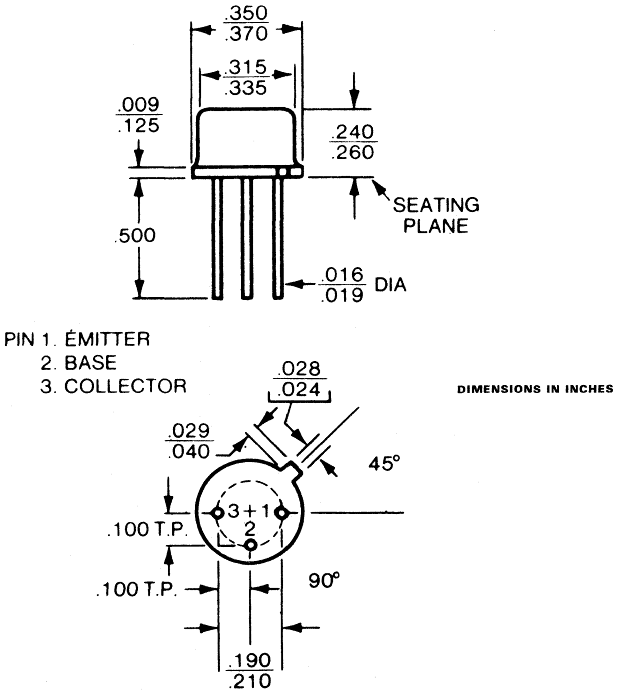


TRW COMPOSANTS ELECTRONIQUES S.A.

Intermodulation Distortion Test



Package Outline
TO-39



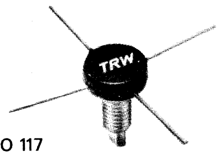
TRW® SEMICONDUCTORS

TP 3094

UHF LINEAR TRANSISTORS

HIGH OUTPUT
1 V (DIN 45004/B)
200 mw (DIN 45004/K)
10 DB GAIN AT 860 MHz
GOLD RELIABILITY

The TP 3094 is NPN transistor gold metallized for reliability. It use diffused emitter ballast resistors for super linearity. The transisition frequency of 3 GHz make these transistor ideal for UHF broadband linear amplification such as in high level **1 volt MATV** amplifier up to 860 MHz or low power **200 mW TV transposers** stages.

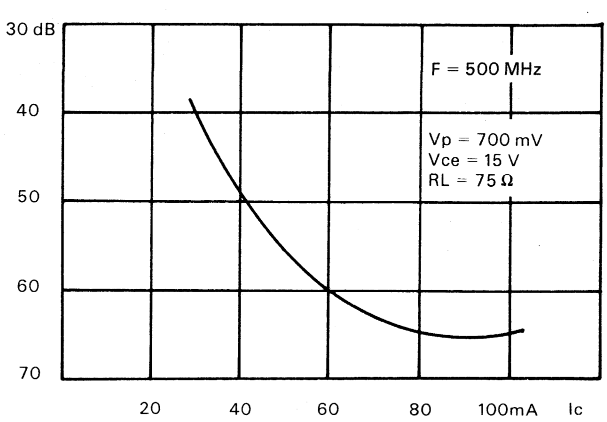


TO 117

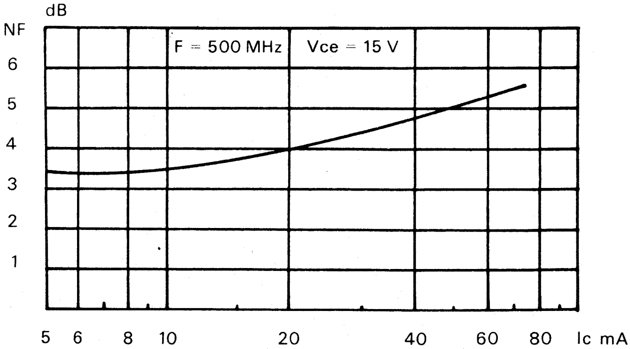
Electrical Characteristics (T_{CASE} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	TYP.	MIN.	TYP.	MAX.	UNIT
DC Test	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 0.1 ma		3.5			V
	BV_{CEO}	Collector - Emitter Breakdown Voltage	I_C = 10 mA		25			V
	BV_{CER}	Collector - Emitter Breakdown Voltage	I_C = 10 mA R_{BE} = 10 ohms		30			V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 1 mA		30			V
	I_{CBO}	Collector - Base Leakage	V_{CB} = 15 V				200	μA
	h_{FE}	D.C. Current Gain	V_{CE} = 10 V I_C = 90 mA		25			
RF Test	NF	Noise Figure	V_{CE} = 15 V I_C = 40 mA F = 500 MHz			4.7	5.2	dB
	f_T	Cutoff Frequency	V_{CE} = 15 V I_C = 100 mA F = 500 MHz			2.6		GHz
	G_{Umax}	Maximum Unilaterilized Gain	V_{CE} = 15 V I_C = 100 mA F = 500 MHz			13.6		dB
	$\|S_{21}\|$	Forward Gain 50 Ω/50 Ω	V_{CE} = 15 V I_C = 100 mA F = 500 MHz			11.5		dB
	IMD	Intermodulation Distortion 3 Tone - Din 45004/B F = 500 MHz R_{LOAD} = 75 ohms	V_{CE} = 15 V V_{out} = 700 mV I_C = 100 mA			− 65	− 60	dB
	C_{OB}	Collector - Base Capacitance	V_{CB} = 10 V f = 1 MHz			2.5		pF
Thermal	I_{Cmax}	Maximum Collector Current					200	mA
	θ_{JC}	Thermal Resistance Junction - Case	T_{CASE} = 25 °C				35	°C/W
	P_T	Dissipated Power					5.0	W
	T_{STG} T_J	Storage Temperature Junction Temperature			− 65		+ 200	°C

IMD DIN 45004 B VS Ic

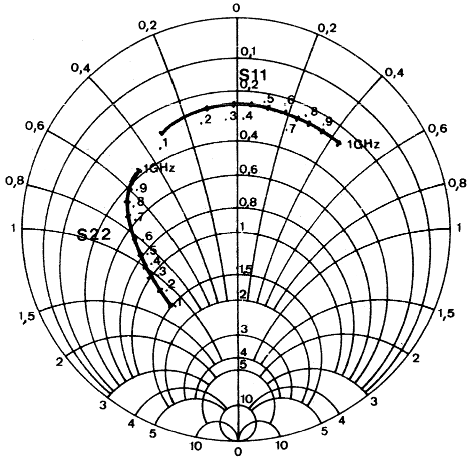


Noise Figure vs Collector current



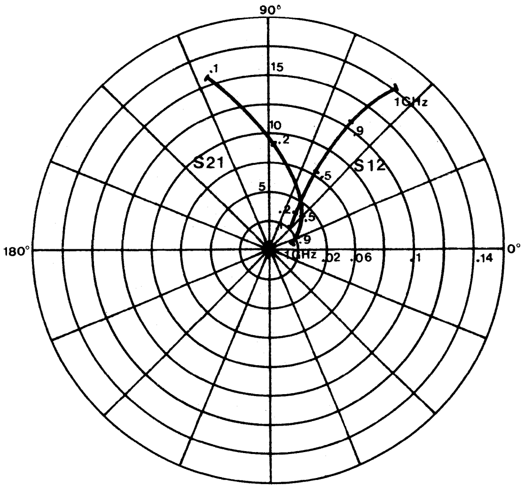
S11 and S22 vs Frequency

V_{CE} = 15 V - I_C = 100 mA

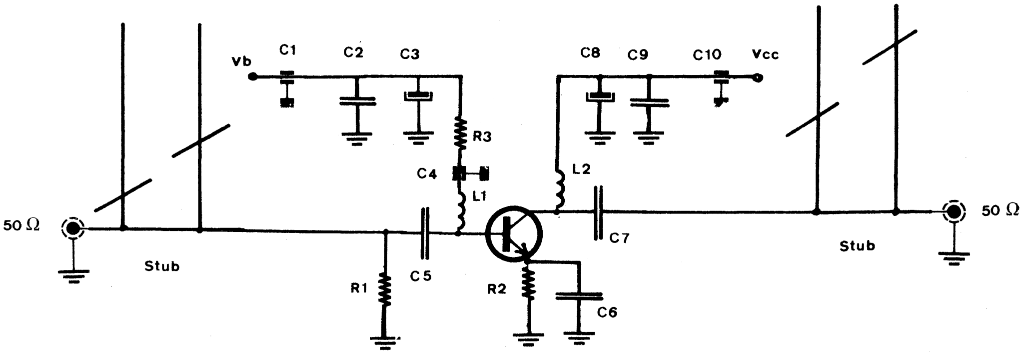


S21 - S 12 Parameters vs Frequency

V_{CE} = 15 V - I_C = 100 mA

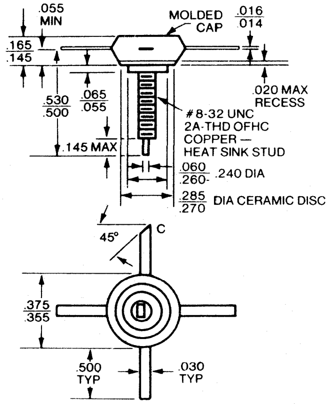


IMD AND NF TEST CIRCUIT AT 500 MHz



$L_{1,2}$	0.1 nH molded coil
$C_{1,4,10}$	1000 pF by pass
$C_{2,9}$	470 pF ceramic disc
$C_{5,7}$	220 pF ceramic chip
$C_{3,8}$	47 μF 40 V electrolytic
C_6	2 × 220 pF chip one at each emitter lead
R_1	100 ohms 1/4 W carbon resistor
R_2	39 ohms 1/4 W carbon resistor
R_3	1.5 K ohms 1/4 W carbon resistor

TO-117
Package Outline



CATV

CATV HYBRIDS

PRODUCT SUMMARY

P/N	GAIN DB	POWER OUTPUT DIN 45004 B	PAGE
CA 2150/CA 2250	17	61/63.5 dBmV	**289**
CA 2152/CA 2252	12	61/63.5 dBmV	**291**
CA 2270	17	65 dBmV	**293**
CA 2272	12	65 dBmV	**293**
CA 2350 A/CA 2350 B	22	61/63.5 dBmV	**295**
CA 2418	18	—	**297**
CA 2603	33	64 dBmV	**299**
CA 2650	33	63 dBmV	**301**
CA 2750	38	64 dBmV	**303**

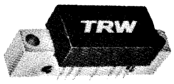
TRW® SEMICONDUCTORS

CA 2150
CA 2250

CATV Hybrid Amplifiers

The CA 2150 and CA 2250 amplifiers are thin film hybrid gain blocks using gold metallized transistors for long term reliability. They are specifically designed for the rigid requirements of the 75 ohm CATV mainline operation. The dual push-pull circuit configuration and the state of the art transistors provide unique noise figure and distortion characteristics, which combined with the flat, « signature » free frequency response allow for cascadeibility.

17 dB, GOLD
INPUT, OUTPUT
LOW LEVEL MAINLINE
HIGH LEVEL BRIDGER

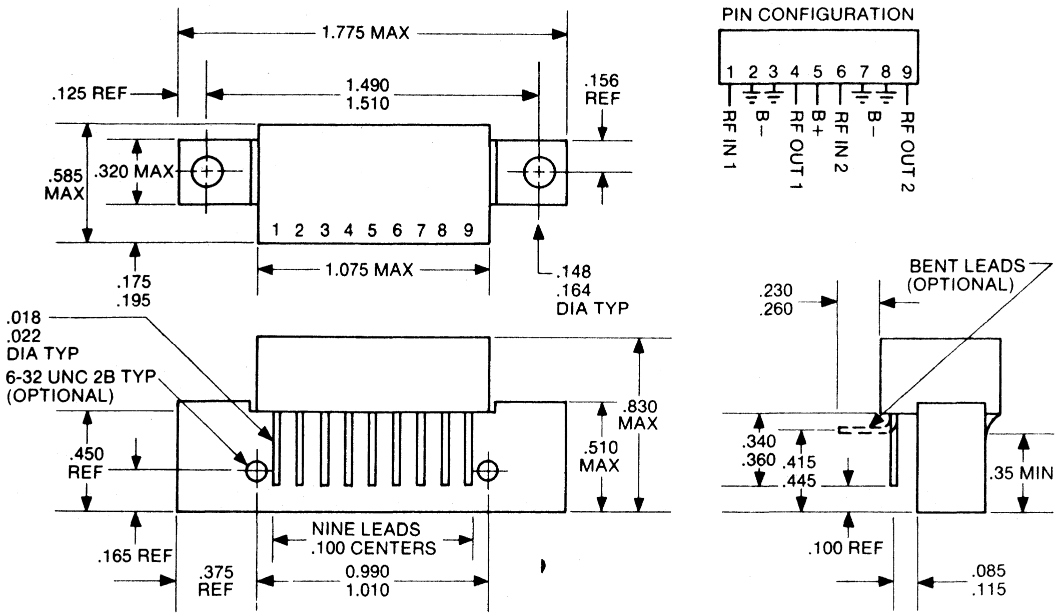


CA

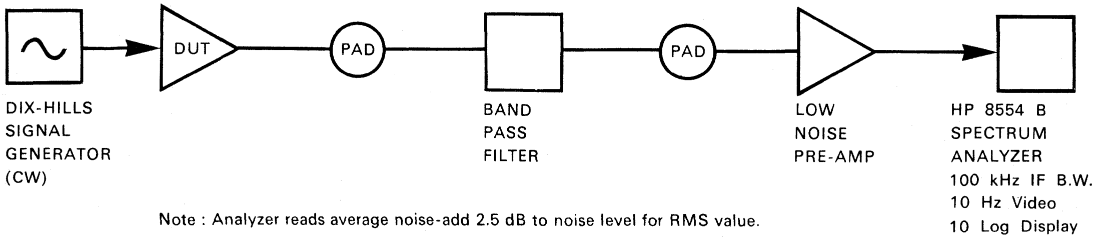
Electrical Characteristics (T_{case} = 25 °C)

PARAMETERS	CA 2150	CA 2250
Gain 50 MHz	17.0 ± 0.4 dB	17.0 ± 0.4 dB
Frequency Response	40-300 MHz (± 0.1 dB)	40-300 MHz (± 0.1 dB)
Slope Cable Capability	+ 0.3 to + 1.0 dB	+ 0.3 to + 1.0 dB
Output Capability		
— 57 dB X-MOD NCTA		
12 Channel Flat	52.0 dBmV	54.5 dBmV
20 Channel Flat	49.5 dBmV	52.0 dBmV
35 Channel Flat	47.0 dBmV	49.5 dBmV
Second Order Beat + 50 dBmV (Channels 2, 13, R)	— 68 dB	— 70 dB
Triple Beat DIN 45004 B		
220 MHz	63 dBmV	65.5 dBmV
300 MHz	61 dBmV	63.5 dBmV
Signal to Triple Beat Noise*		
35 Channel Flat 46 dBmV		
On Channel 13	— 62 dB	— 67 dB
On Channel W	— 59 dB	— 64 dB
Noise Figure		
200 MHz	6.5 dB Max.	7.0 dB Max.
300 MHz	7.5 dB Max.	8.0 dB Max.
Return Loss Input/Output	20 dB Minimum	20 dB Minimum
Return Loss Derate With Freq.	1 dB per Octave	1 dB per Octave
Power Requirement	160 mA (TYP) 24 Vdc	200 mA (TYP) 24 Vdc
Operating Temperature (Sink)	— 20 °C to + 90 °C	— 20 °C to + 90 °C
Storage Temperature	— 40 °C to + 100 °C	— 40 °C to + 100 °C

* See Test Procedure



Signal to Triple Beat Noise Test Set-up



Note : Analyzer reads average noise-add 2.5 dB to noise level for RMS value.

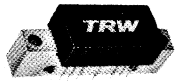
TRW® **SEMICONDUCTORS**

CA 2152
CA 2252

CATV Hybrid Amplifiers

12 dB GOLD
INPUT, OUTPUT
LOW LEVEL MAINLINE
HIGH LEVEL BRIDGER

The CA 2152 and CA 2252 amplifiers are thin film hybrid gain blocks using gold metallized transistors for long term reliability. They are specifically designed for the rigid requirements of the 75 ohm CATV mainline operation. The dual push-pull circuit configuration and the state of the art transistors provide unique noise figure and distortion characteristics, which combined with the flat, « signature » free frequency response allow for cascadeibility.

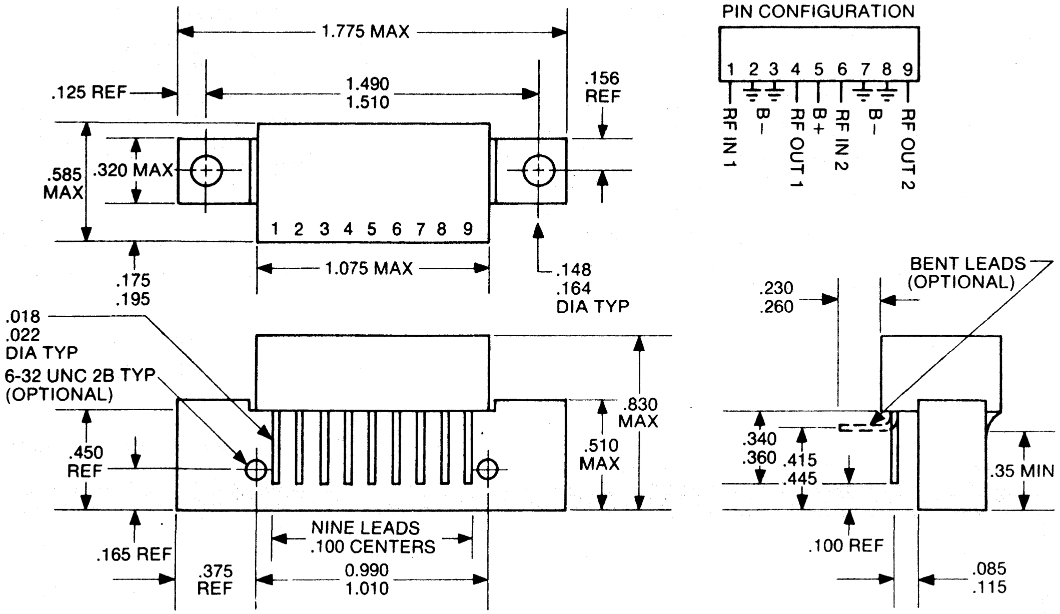


CA

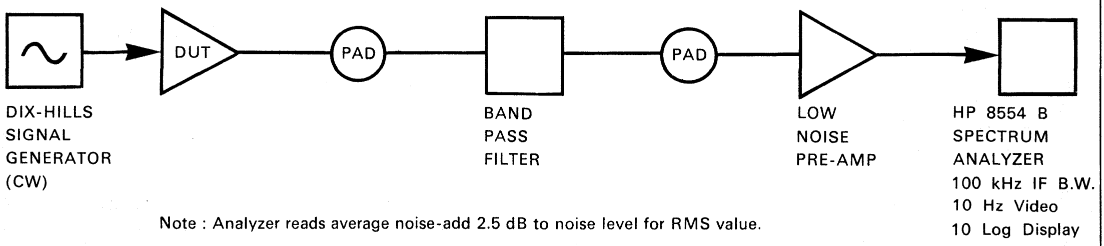
Electrical Characteristics (T_{case} = 25 °C)

PARAMETERS	CA 2152	CA 2252
Gain 50 MHz	12.0 ± 0.4 dB	12.0 ± 0.4 dB
Frequency Response	40-300 MHz (± 0.2 dB)	40-300 MHz (± 0.2 dB)
Slope Cable Equivalent	+ 1.0 to + 2.0 dB	+ 1.0 to + 2.0 dB
Output Capability — 57 dB X-MOD		
12 Channel Flat	52.0 dBmV	54.5 dBmV
20 Channel Flat	49.5 dBmV	52.0 dBmV
32 Channel Flat	47.5 dBmV	50.0 dBmV
Second Order Beat 50 dBmV (Channels 2, 13, R)	— 68 dB	— 70 dB
Triple Beat DIN 45004 B		
220 MHz	63 dBmV	65.5 dBmV
300 MHz	61 dBmV	63.5 dBmV
Signal to Triple Beat Noise* 35 Channel Flat 46 dBmV		
On Channel 13	— 62 dB	— 67 dB
On Channel W	— 59 dB	— 64 dB
Noise Figure (Channel 13)	7.5 dB Max.	8.0 dB Max.
(Channel W)	8.5 dB Max.	9.0 dB Max.
Return Loss Input/Output	18 dB Min.	18 dB Min.
Return Loss Derate with Freq.	1 dB per Octave	1 dB per Octave
Power Requirements	160 mA (TYP) 24 Vdc	200 mA (TYP) 24 Vdc
Operating Temperature (Sink)	— 20 °C to + 90 °C	— 20 °C to + 90 °C
Storage Temperature	— 40 °C to + 100 °C	— 40 °C to + 100 °C

* See Test Procedure



Signal to Triple Beat Noise Test Set-up



Note : Analyzer reads average noise-add 2.5 dB to noise level for RMS value.

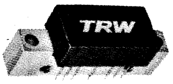
TRW® SEMICONDUCTORS

CA 2270
CA 2272

PRELIMINARY

The CA 2270 and CA 2272 are thin film hybrid gain block using gold metallized transistors for long term reliability. They are specifically designed for the highest standards of the 75 ohm CATV operation.

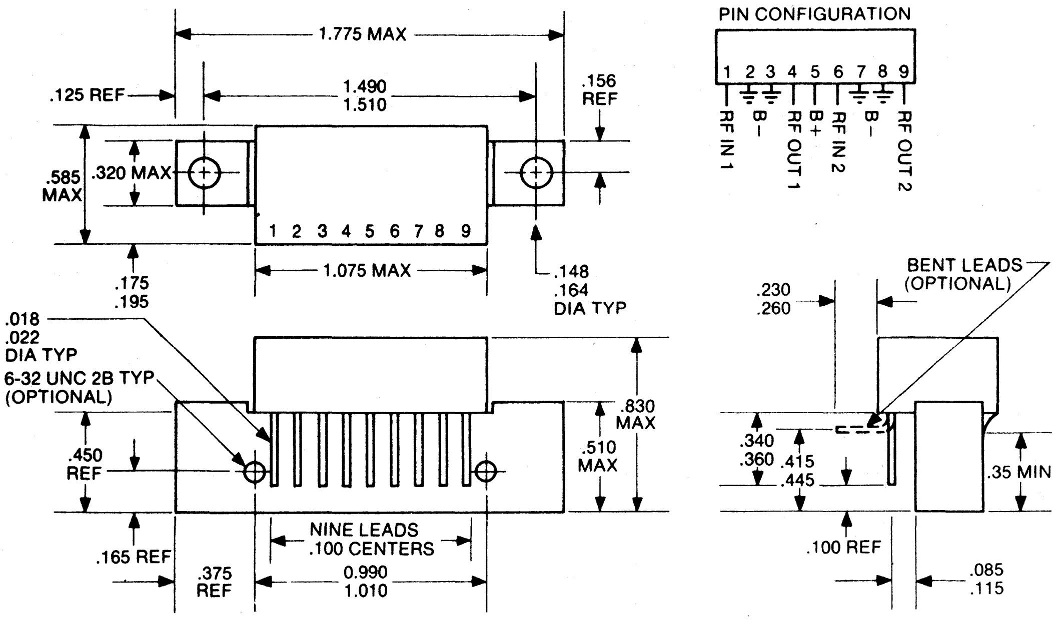
17 dB - 12 dB GAIN
OUTPUT AT
65 dBmV WITH
DIN 45004 B



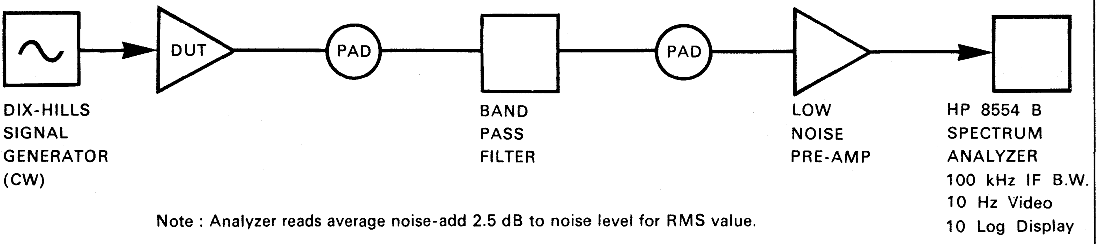
CA

PARAMETERS	CA 2270
Gain 50 MHz	17 ± 0.4 dB
Frequency response	40 - 300 MHz (± 0.1 dB)
Triple beat DIN 45004B 300 MHz	65 dBmV
Return loss Input/Output	20 dB
Power requirement	230 mA Max

PARAMETERS	CA 2272
Gain 50 MHz	12 ± 0.4 dB
Frequency response	40 - 300 MHz (± 0.2 dB)
Triple beat DIN 45004B 300 MHz	65 dBmV
Return loss Input/Output	20 dB
Power requirement	230 mA Max



Signal to Triple Beat Noise Test Set-up



Note : Analyzer reads average noise-add 2.5 dB to noise level for RMS value.

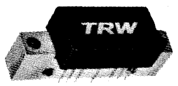
TRW® SEMICONDUCTORS

CA 2350 A
CA 2350 B

CATV Hybrid Amplifiers

The CA 2350 A and CA 2350 B amplifiers are thin film hybrid gain blocks using gold metallized transistors for long term reliability. They are specifically designed for the rigid requirements of the 75 ohm CATV mainline operation. The dual push-pull circuit configuration and the state of the art transistors provide unique noise figure and distortion characteristics, which combined with the flat, « signature » free frequency response allow for cascadeibility.

22 dB
INPUT, OUTPUT
MAINLINE, DISTRIBUTION
GOLD RELIABILITY

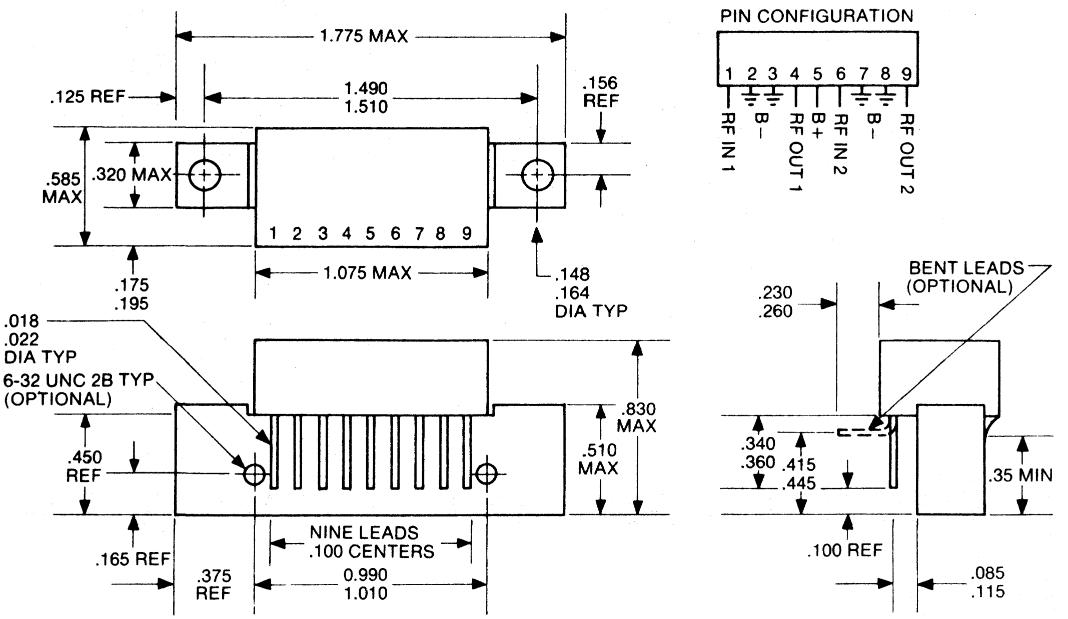


CA

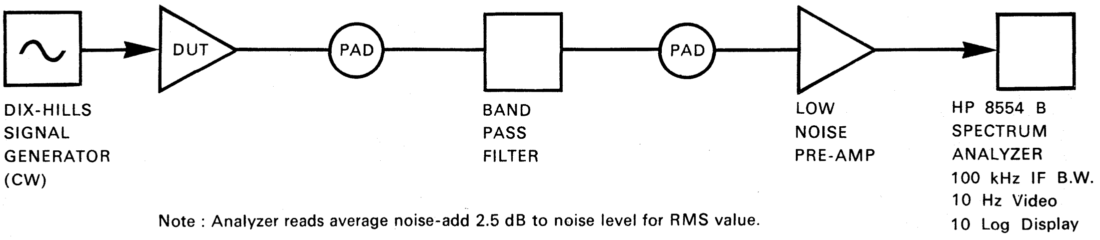
Electrical Characteristics (T_{case} = 25 °C)

PARAMETERS	CA 2350 A	CA 2350 B
Gain 50 MHz	22.0 ± .6 dB	22.0 ± .6 dB
Frequency Response	40-300 MHz (± 0.2 dB)	40-300 MHz (± 0.2 dB)
Slope Cable Equivalent	+ 0.0 to 1.0 dB	+ 0.0 to + 1.0 dB
Output Capability		
— 57 dB X-MOD NCTA		
12 Channel Flat	52.0 dBmV	54.5 dBmV
20 Channel Flat	49.5 dBmV	52.0 dBmV
32 Channel Flat	47.5 dBmV	50.0 dBmV
Second Order Beat 50 dBmV (Channels 2, 13, R)	— 64 dB	— 66 dB
Triple Beat DIN 45004 B		
200 MHz	63 dBmV	65.5 dBmV
300 MHz	61 dBmV	63.5 dBmV
Signal to Triple Beat Noise*		
35 Channel Flat 46 dBmV		
On Channel 13	— 62 dB	— 67 dB
On Channel W	— 59 dB	— 64 dB
Noise Figure (200 MHz)	5.5 dB Max.	6.5 dB Max.
(300 MHz)	6.5 dB Max.	7.5 dB Max.
Return Loss Input/Output	20 dB Minimum	20 dB Minimum
Return Loss Derate With Frequency	1 dB per Octave	1 dB per Octave
Power Requirements	180 mA (TYP) 24 Vdc	220 mA (TYP) 24 Vdc
Operating Temperature (Sink)	— 20 °C to + 90 °C	— 20 °C to + 90 °C
Storage Temperature	— 40 °C to + 100 °C	— 40 °C to + 100 °C

* See Test Procedure



Signal to Triple Beat Noise Test Set-up

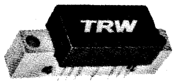


Note : Analyzer reads average noise-add 2.5 dB to noise level for RMS value.

CATV Hybrid Amplifiers

The CA 2418 amplifier is a thin film hybrid gain block using gold metallized transistors for long term reliability. It is specifically designed for the rigid requirements of the 75 ohm CATV mainline reverse path operation. The dual push-pull circuit configuration and the state of the art transistors provide unique noise figure and distortion characteristics, which combined with the flat, « signature » free frequency response allows for cascadeability.

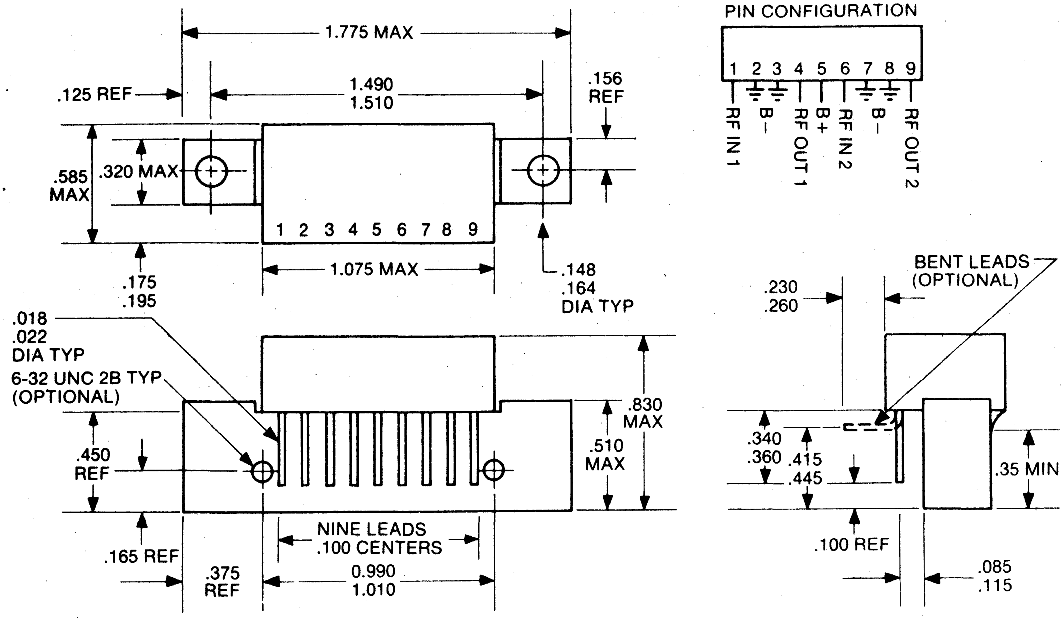
18 dB GAIN
5-120 MHz
REVERSE AMPLIFIERS
GOLD RELIABILITY



CA

Electrical Characteristics (T_{case} = 25 °C)

PARAMETERS	CA 2418
Gain 100 MHz	18.5 ± 0.5 dB
Frequency Response	5 — 120 MHz (± 0.25 dB)
Slope Cable Equivalent	+ 0.2 to — 0.5
Output Capability — 57 dB X-mod 12 channel Flat	54.5 dBmV
Second Order Beat 50 dBmV	— 72 dB
Triple Beat 50 dBmV	— 84 dB
Noise Figure (100 MHz)	6.5 dB
Return Loss Input/Output	20 dB Minimum
Power Requirement	200 mA (TYP) 24 Vdc
Operating Temperature (Sink)	— 20 °C to + 100 °C
Storage Temperature	— 40 °C to + 100 °C



PIN CONFIGURATION
1 2 3 4 5 6 7 8 9
RF IN 1
B−
RF OUT 1
B+
RF IN 2
B−
RF OUT 2
1.775 MAX
.125 REF
1.490
1.510
.156
REF
.585
MAX
.320 MAX
1 2 3 4 5 6 7 8 9
.175
.195
1.075 MAX
.148
.164
DIA TYP
.018
.022
DIA TYP
6-32 UNC 2B TYP
(OPTIONAL)
.450
REF
.830
MAX
.510
MAX
.165 REF
.375
REF
NINE LEADS
.100 CENTERS
0.990
1.010
.230
.260
BENT LEADS
(OPTIONAL)
.340
.360
.415
.445
.35 MIN
.100 REF
.085
.115

TRW® SEMICONDUCTORS

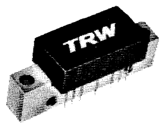
CA 2603

CATV Hybrid Amplifier

PRELIMINARY

The CA 2603 is a thin film hybrid gain block manufactured with a gold monometallic process for high reliablity. It features interstage accessability for gain control circuitry or filtering and extraordinary flatness and linearity. The CA 2603 has push-pull circuitry throughout giving it superior dynamic range, excellent flatness and making it a practical choice for economy trunk amplifiers and line extenders where up to 6 dB of interstage loss is tolerable. Typical performance for the preamp section is specified and facility for phase inversion is provided via the balanced output pins.

33,5 DB GAIN
HIGH OUTPUT
LOW NOISE

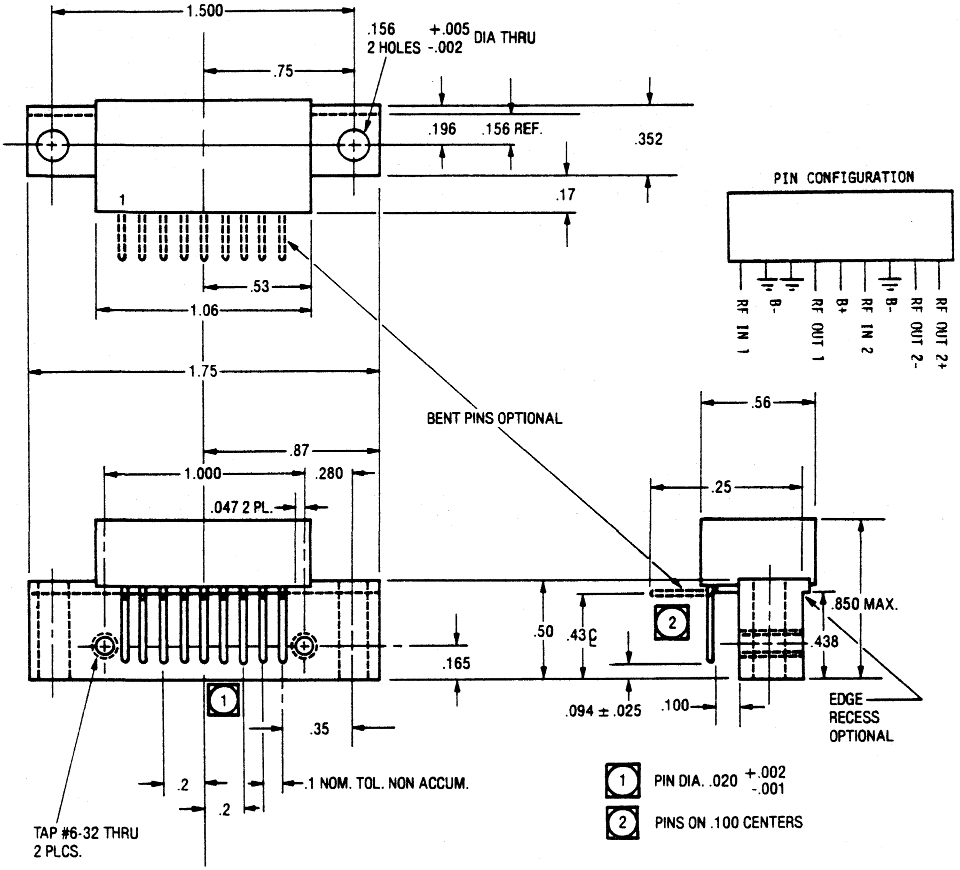


CA

Electrical Characteristics (T_{case} = 25 °C)

PARAMETERS	INPUT STAGE (TYP)	OVERALL (MAX)
Gain 50 MHz	16.5 ± 0.5 dB	33.5 ± 1 dB
Frequency Response	40 - 300 MHz	± 0.3 dB
Slope Cable Equivalent	0 to + 0.5 dB	+ 0.5 to 1.5 dB
Output Capability		
— 57 dB X-MOD NCTA		
12 Channel Flat	47.5 dBmV	54.5 dBmV
20 Channel Flat	45.0 dBmV	52.0 dBmV
35 Channel Flat	42.5 dBmV	49.5 dBmV
Second Order Beat 50 dBmV (Channels 2, 13, R)	— 68 dB	— 66 dB
Triple Beat DIN 45004 B		
200 MHz	—	65.5 dBmV
300 MHz	—	64.0 dBmV
Composite Triple Beat Output at — 60 dB		
On Channel 13	+ 43 dBmV	+ 49 dBmV
On Channel W	+ 42 dBmV	+ 48 dBmV
Noise Figure		
200 MHz	4.5 dB	5 dB
300 MHz	6.5 dB	7 dB
Return Loss Input/Output	18 dB	18 dB
Power Requirements	100 mA	330 mA
Operating Temperature	— 20 °C to + 90 °C	
Storage Temperature	— 40 °C to + 100 °C	

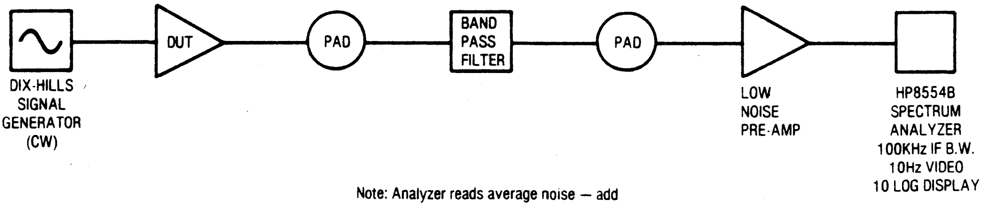
CA PACKAGE OUTLINE



① PIN DIA. .020 +.002 -.001

② PINS ON .100 CENTERS

COMPOSITE TRIPLE BEAT

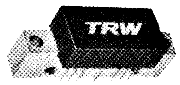


Note: Analyzer reads average noise — add 2.5dB to noise level for RMS value.

CATV Hybrid Amplifiers

33 dB
HIGH OUTPUT
DISTRIBUTION
GOLD RELIABILITY

The CA 2650 amplifier is a thin film hybrid gain block using gold metallized transistors for long term reliability. It is specifically designed for the rigid requirements of the 75 ohm CATV distribution operation. The four stages push-pull configuration and the state of the art transistors allow its use as high gain distribution amplifier with optimum cross-modulation and intermodulation distortion performances.

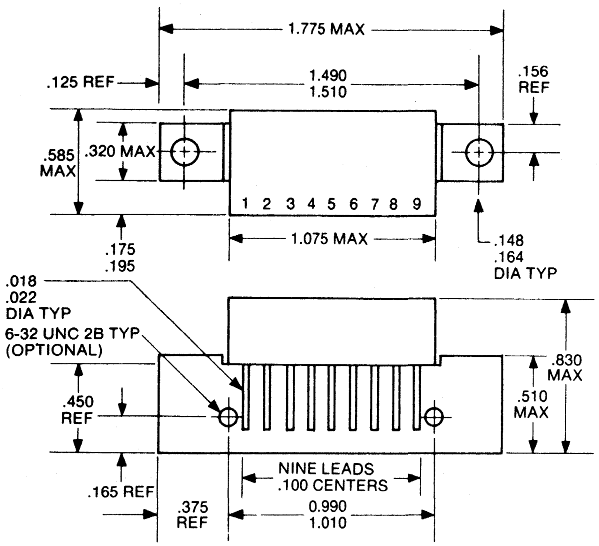


CA

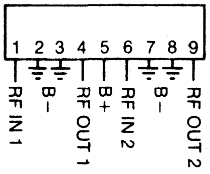
Electrical Characteristics (T_{case} = 25 °C)

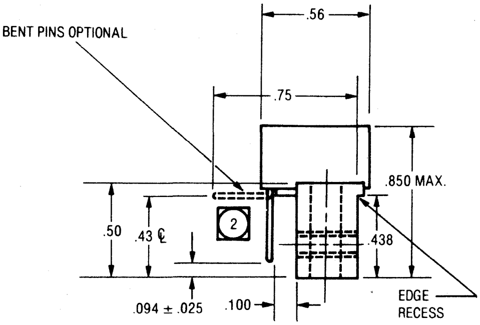
PARAMETERS	CA 2650
Gain 50 MHz	33.5 ± 1.0 dB
Frequency Response	40-300 MHz (± 0.3 dB)
Slope Cable Equivalent	+ 0.5 to + 1.5 dB
Output Capability	
— 57 dB X-MOD NCTA	
12 Channel Flat	53.5 dBmV
20 Channel Flat	51.0 dBmV
35 Channel Flat	48.5 dBmV
Second Order Beat 50 dBmV (Channels 2, 13, R)	— 68 dB
Triple Beat DIN 45004 B	
200 MHz	64.5 dBmV
300 MHz	63 dBmV
Signal to Triple Beat Noise*	
35 Channel Flat 46 dBmV	
On Channel 13	— 65 dB
On Channel W	— 63 dB
Noise Figure	
200 MHz	6 dB Max.
300 MHz	7 dB Max.
Return Loss Input/Output	20 dB Minimum
Return Loss Derate with Frequency	1 dB per Octave
Power Requirements	290 mA (TYP) 24 Vdc
Operating Temperature (Sink)	— 20 °C to + 90 °C
Storage Temperature	— 40 °C to + 100 °C

* See Test Procedure

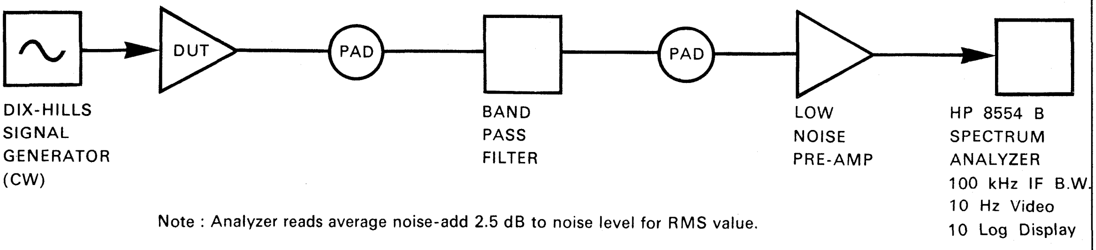


PIN CONFIGURATION





Signal to Triple Beat Noise Test Set-up



Note : Analyzer reads average noise-add 2.5 dB to noise level for RMS value.

TRW® SEMICONDUCTORS

CA 2750

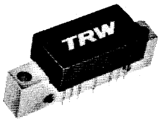
CATV Hybrid Amplifier

PRELIMINARY

The CA 2750 amplifier is optimized for 75 Ω CATV applications where signature free flat response, excellent impedance match and low distortion and noise figure are required.

High reliability is achieved through a monometalic gold assembly process using state-of-art gold transistors. These hybrids utilizing push-pull circuitry provide low distortion and superior thermal stability.

38 dB GAIN
ALL GOLD DIE
CHARACTERIZED FOR ALL CATV PARAMETERS
LOW DISTORTION, HIGH OUTPUT CAPABILITY
LOW NOISE FIGURE



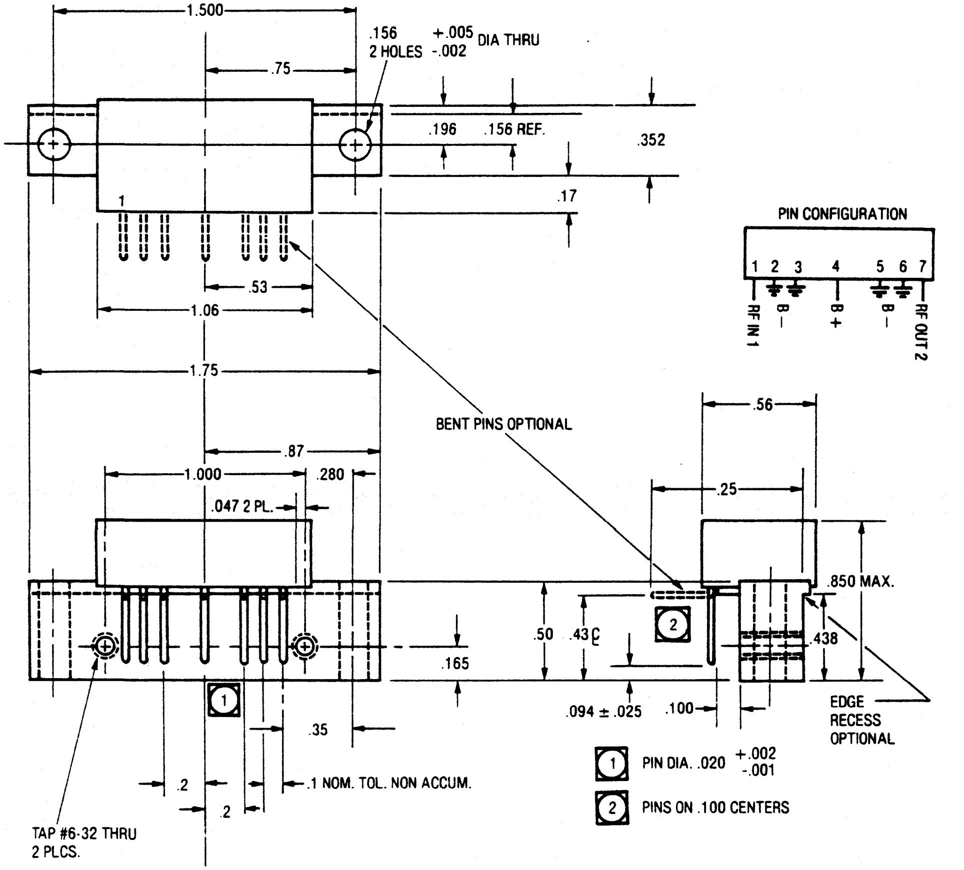
CA

Electrical Characteristics (T_{case} = 25 °C)

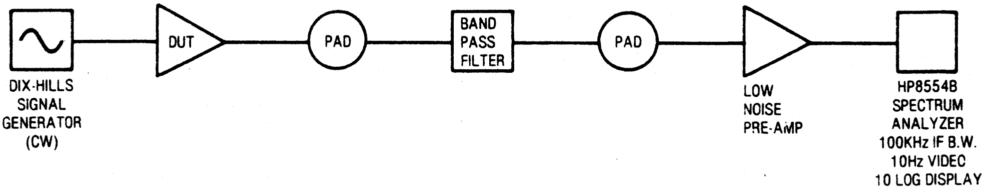
PARAMETERS	CA 2750
Gain 50 MHz	38.5 + 1 dB
Frequency Response	40 - 300 MHz ± 0.3 dB
Slope Cable Equivalent	+ 0.5 to + 1.5 dB
Output Capability	
— 57 dB X-MOD NCTA	
12 channel Flat	54.5 dBmV
20 channel Flat	52 dBmV
35 channel Flat	49.5 dBmV
Second Order Beat 50 dBmV (channels 2, 13, R)	— 68 dB
Triple Beat DIN 45004 B	
200 MHz	65.5 dBmV
300 MHz	64 dBmV
Signal to Triple Beat Noise * 35 channel Flat 46 dBmV	
on channel 13	— 66 dB
on channel W	— 64 dB
Return Loss Input/Output	18 dB Minimum
Power Requirements	320 mA Typ
Operating Temperature (sink)	— 20 °C to + 90 °C
Storage Temperature	— 40 °C to + 100 °C

* See Test Procedure

CA PACKAGE OUTLINE



COMPOSITE TRIPLE BEAT



Note: Analyzer reads average noise — add 2.5dB to noise level for RMS value.

TV TRANSPOSERS
AND TRANSMITTERS

TV TRANSPOSERS AND TRANSMITTERS

PRODUCT SUMMARY

	P/N	POWER W	IMD* DB	GAIN DB	PACKAGE	PAGE
BAND 3						
170-230 MHz	TPV 366	1.5	— 60	17	SOE 280	**313**
	TPV 394	5	— 58	15	SOE 280	**325**
	TPV 364	10	— 55	10	SOE 380	**309**
	TPV 375	14	— 55	8.5	SOE 500	**317**
		20	— 51			
	TPV 376	30	— 53	7.5	SOE 500	**321**
		70	— 45	7.5		
		(class AB)				
BAND 4-5						
470-860 MHz	TPV 590	0.250	— 60	14	SOE 200	**333**
	TPV 591	0.500	— 60	13	SOE 200	**337**
	TPV 596	0.5	— 60	12	SOE 280	**341**
	TPV 597	1.0	— 60	11	SOE 280	**345**
	TPV 502	2	— 58	10	SOE 280	**329**
	TPV 598	4.0	— 60	7	SOE 280	**349**
	TPV 599	7.5	— 60	8	MRA	**350**

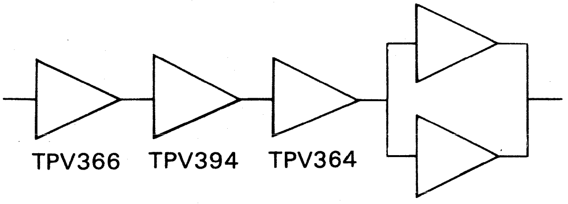
* VISION –8 DB, SOUND –7 DB, SIDEBAND –17 DB.

TV TRANSPOSERS AND TRANSMITTERS

LINE-UP SUGGESTIONS

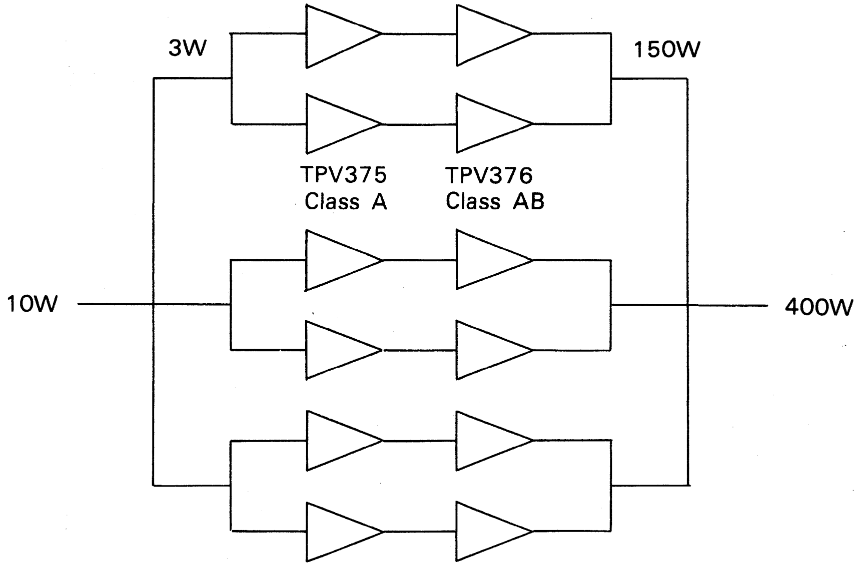
BAND 3 – 170-230 MHz

- VISION AND SOUND COMBINED – CLASS A



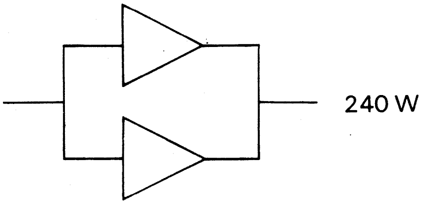
2 x TPV375
push-pull or
hydrid combined

- VISION ONLY – CLASS AB



Push-pull or
hydrid combined

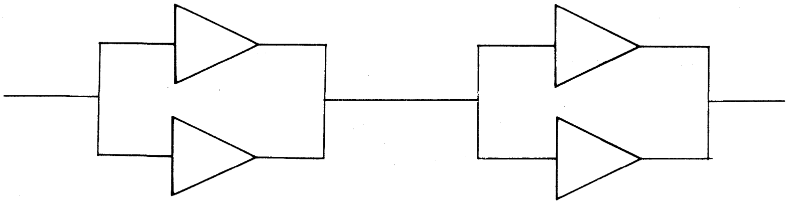
- SOUND – CLASS C



TPV 376

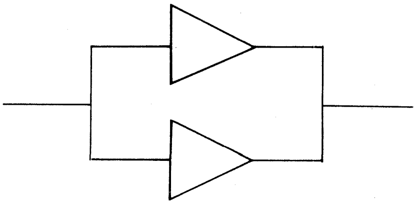
TV TRANSPOSERS AND TRANSMITTERS
LINE-UP SUGGESTIONS

BAND 4-5 – 470-860 MHz



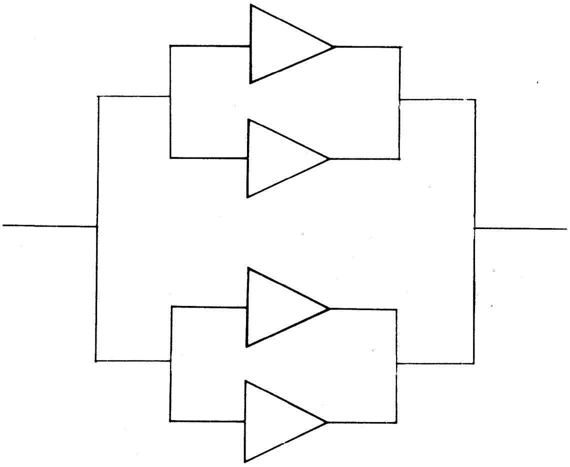
2W AT –60 DB IMD
20 DB GAIN

TPV596 TPV597



7 W AT –60 DB IMD
7 DB GAIN

2 x TPV 598



22 W AT –60 DB IMD
6.5 DB GAIN

4 x TPV 599

TRW® SEMICONDUCTORS

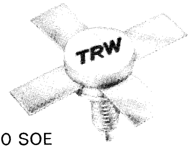
TPV 364

VHF LINEAR TRANSISTOR

TV TRANSPOSER AND TRANSMITTER BAND 3
10 W AT - 55 DB IMD
10 DB GAIN

The TPV 364 is a NPN gold metallized transistor using diffused ballast resistors for super linearity. This transistor is designed for high power band 3 TV transposers and transmitters.

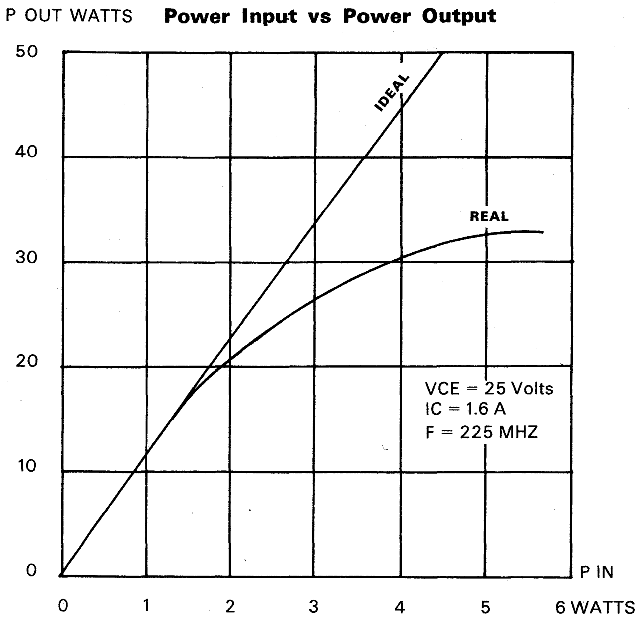
The TPV 364 is used in the final stages of 20 W transposers or in the driver stages of 100 W plus transposers and transmitters. Its high gain allows to reduce the complexity of lower power stages.

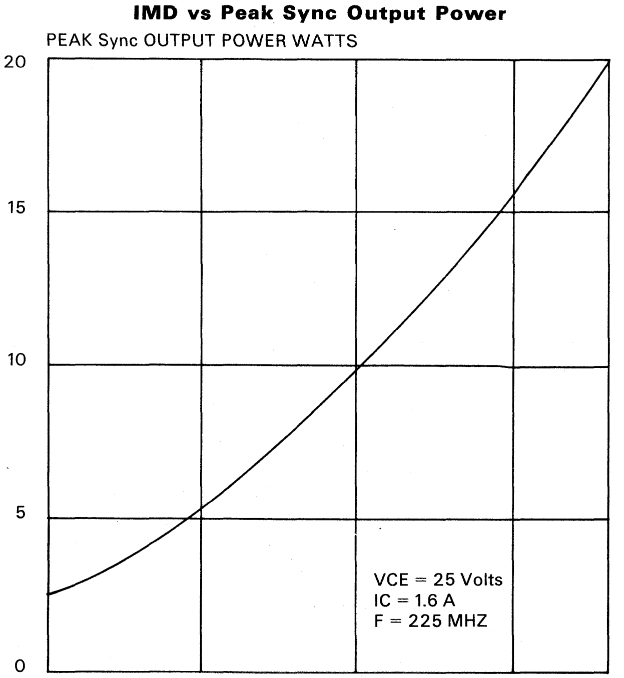


380 SOE

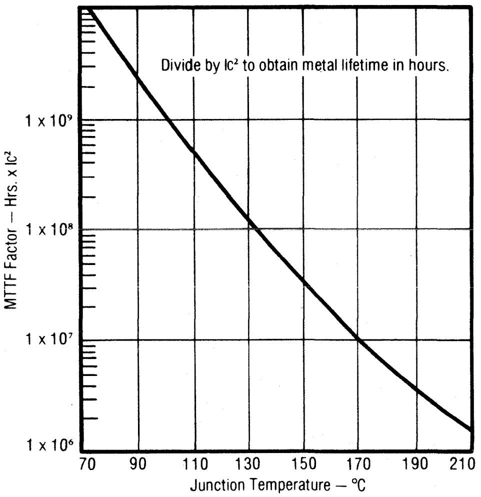
Electrical Characteristics (T_{CASE} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC Test	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 10 mA	4			V
	BV_{CEO}	Collector - Emitter Breakdown Voltage	I_C = 50 mA	35			V
	BV_{CER}	Collector - Emitter Breakdown Voltage	I_C = 50 mA R_{BE} = 10 ohms	65			V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 50 mA	65			V
	h_{FE}	D.C Current Gain	V_{CE} = 5 V I_C = 1000 mA	20		120	
RF Test	IDM_1	Intermodulation Distortion - 3 Tone Vision Carrier = Reference - 8 dB Sound Carrier = Reference - 7 dB Sideband Carrier = Reference - 16 dB	F = 225 MHz V_{CE} = 25 V I_E = 1.6 A P_{REF} = 10 W			– 54 – 55	dB
	IMD 2	Idem	F = 225 MHz V_{CE} = 25 V I_E = 1.6 A P_{REF} = 15 W			— 52	dB
	P_G	Power Gain 10 REF	F = 225 MHz V_{CE} = 25 V I_E = 1.6 A	10			dB
	VSWR	Mismatch Tolerance	P_{REF} = 20 W F = 225 MHz V_{CE} = 25 V I_E = 1.6 A P_{REF} = 15 W		∞		
	C_{OB}	Collector - Base Capacitance	V_{CB} = 30 V F = 1 MHz		58	85	pF
Thermal	I_C.	Maximum collector current				9	A
	θ_{JC}	Thermal Resistance Junction - Case	T_{CASE} = 70 °C			2.0	°C/W
	θ_{CH}	Thermal Resistance Case - Heatsink				0.5	°C/W
	P_T	Dissipated Power	$T_{HEATSINK}$ = 25 °C			70	W
	T_{STG} T_J	Storage Temperature Junction Temperature		— 65		+ 200	°C

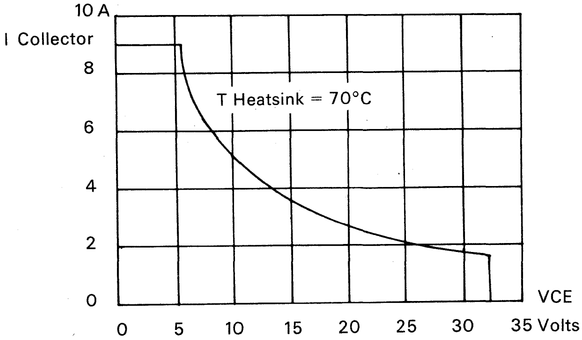

P OUT WATTS
Power Input vs Power Output
50
40
30
20
10
0
0
1
2
3
4
5
6 WATTS
P IN
IDEAL
REAL
VCE = 25 Volts
IC = 1.6 A
F = 225 MHZ


IMD vs Peak Sync Output Power
PEAK Sync OUTPUT POWER WATTS
20
15
10
5
0
65
60
55
50 DB
IMD
VCE = 25 Volts
IC = 1.6 A
F = 225 MHZ

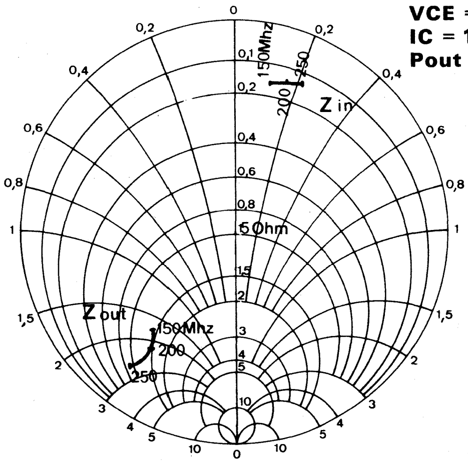
MTTF Factor vs Tj



Safe Operating Area

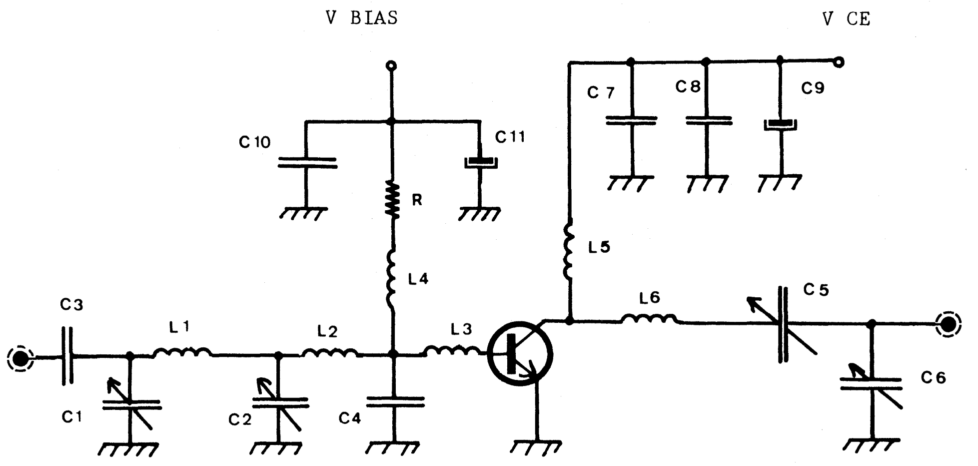


Large Signal Impedances vs Frequency



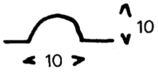
VCE = 25 V
IC = 1.6 A
Pout = 15 W peak

TEST CIRCUIT FOR 225 MHz

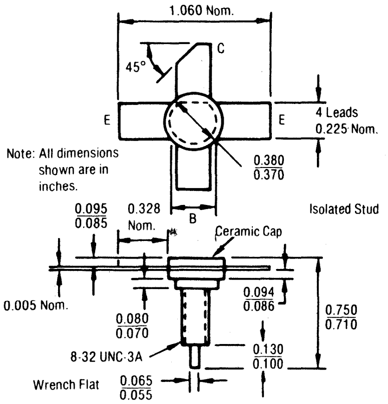


C_1	ARCO 403
$C_{2,6}$	ARCO 404
C_5	ARCO 423
$C_{3,7}$	chip capacitor 470 pF
C_4	UNELCO-capacitor 80 pF
$C_{8,10}$	UNELCO-capacitor 1000 pF
$C_{9,11}$	100 μF electrolytic - 63 V
R	4.7 ohms - 1/2 W

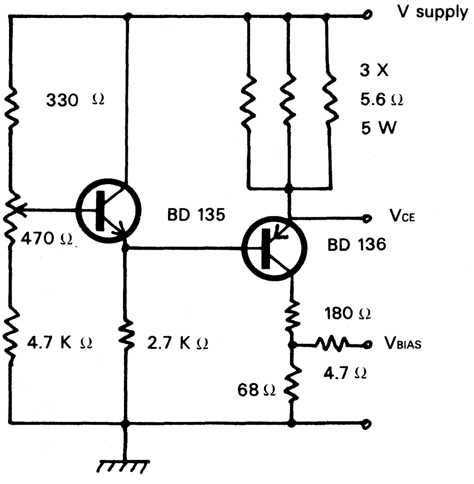
L_1	1.5 turns closely wound - Cu wire 1 mm - I.D. 5 mm
L_2	2.5 cm - 50 ohms line
L_3	length of the base lead
L_6	Cu wire 1.5 mm
L_5	3 cm - 50 ohms line
L_4	5 turns closely wound - Cu wire 8 mm - I.D. 5 mm



380 SOE



BIAS CIRCUIT



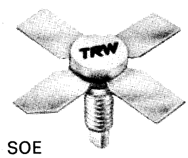
TRW® **SEMICONDUCTORS**

TPV 366

VHF LINEAR TRANSISTOR

TV TRANSPOSER
BAND 3
1.5 W AT - 60 DB
17 DB GAIN

The TPV 366 is a NPN gold metallized transistor using diffused emitter ballast resistors for super linearity. This transistor is designed for **low power band 3 TV transposers** amplifiers. Its **super high gain** makes it an ideal choice for driver stages.

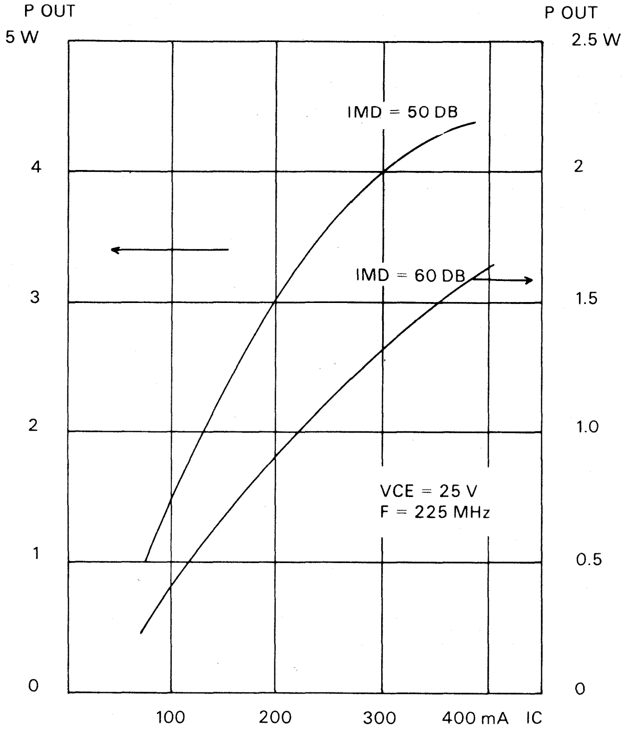


280 SOE

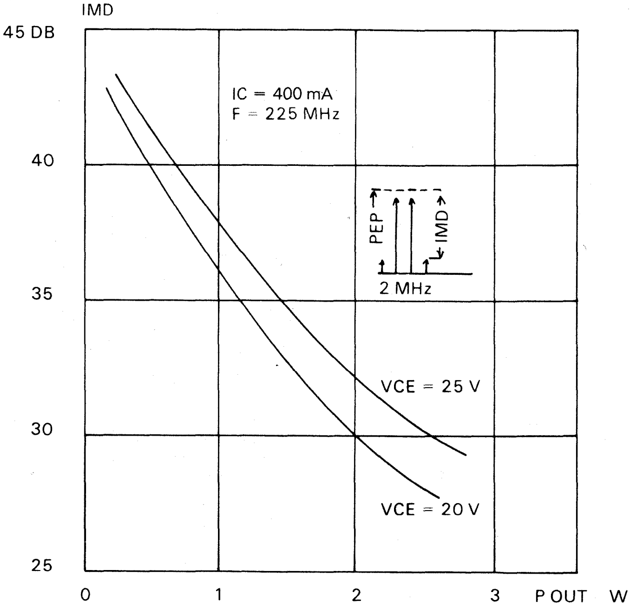
Electrical Characteristics (T_{case} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC Test	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 1 mA	4			V
	BV_{CEO}	Collector - Emitter Breakdown Voltage	I_C = 50 mA	30			V
	BV_{CER}	Collector - Emitter Breakdown Voltage	I_C = 50 mA R_{BE} = 10 ohms	55			V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 10 mA	55			V
	h_{FE}	D.C. Current Gain	V_{CE} = 5 V I_C = 100 mA	10		150	
RF Test	IMD 1	Intermodulation Distortion - 3 Tone Vision Carrier = Reference - 8 dB Sound Carrier = Reference - 7 dB Sideband Carrier = Reference - 16 dB	F = 225 MHz V_{CE} = 25 V I_E = 0.4 A P_{REF} = 1.5 W			— 60	dB
	IMD 2	Intermodulation Distortion 2 Tone F + (F + 2 MHz)	F = 225 MHz V_{CE} = 25 V I_E = 0.4 A P_{PEP} = 2 W			— 30	dB
	P_G	Power Gain	F = 225 MHz V_{CE} = 25 V I_E = 0.4 A P_{REF} = 1.5 W	16	17.5		dB
	VSWR	Mismatch Tolerance	F = 225 MHz V_{CE} = 25 V I_E = 0.4 A P_{REF} = 1 W		∞		
	C_{OB}	Collector - Base Capacitance	V_{CB} = 28 V F = 1 MHz			12	pF
Thermal	I_C	Maximum Collector Current				0.75	A
	θ_{JC}	Thermal Resistance Junction - Case	T_{CASE} = 70 °C			8.0	°C/W
	θ_{CH}	Thermal Resistance Case - Heatsink				1.0	°C/W
	P_T	Dissipated Power	$T_{HEATSINK}$ = 25 °C			19	W
	T_{STG}	Storage Temperature		— 65		+ 200	°C
	T_J	Junction Temperature					

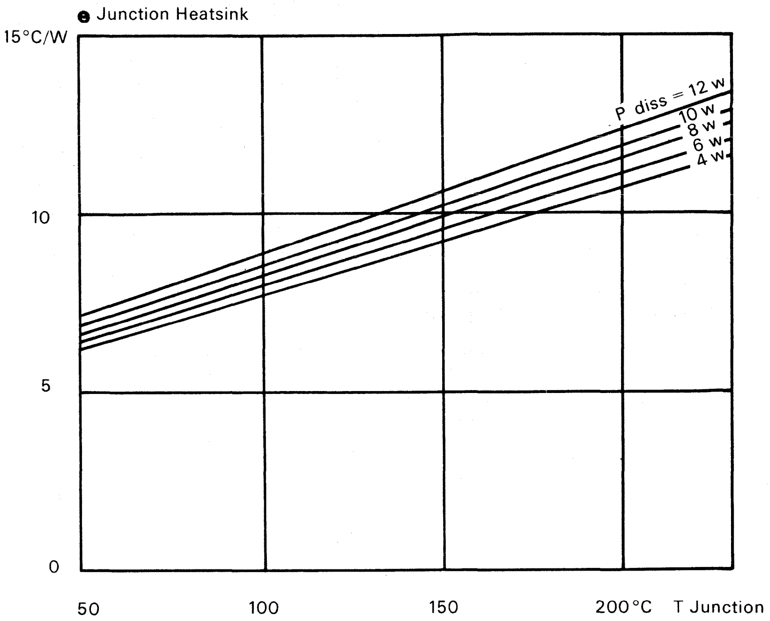
Peak Sync Output Power vs Collector current for IMD = -50 and -60 DB



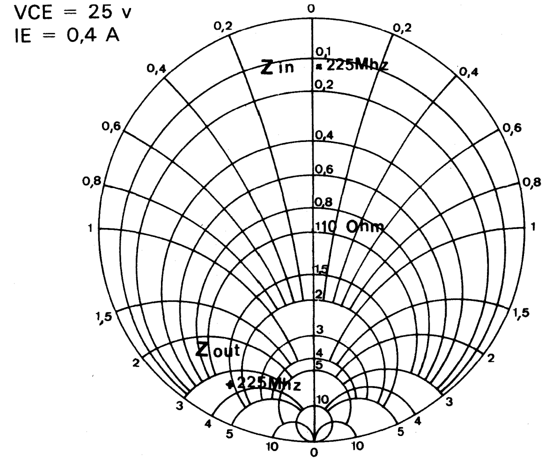
2 Tones Intermodulation Distortion vs Power Out PEP



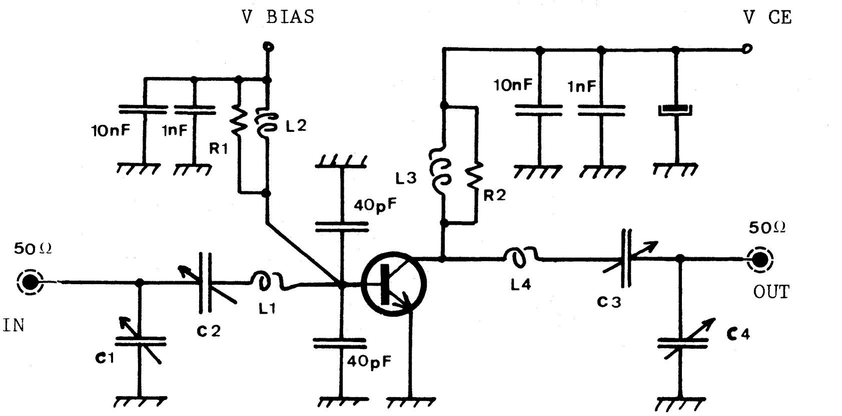
Thermal Resistance Junction Heatsink vs Temperature of Junction for Various Power Dissipated



large signal impedances

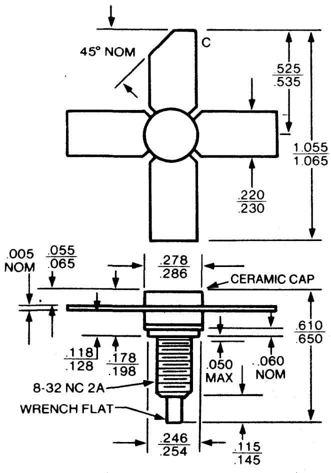


TEST CIRCUIT AT F = 225 MHz



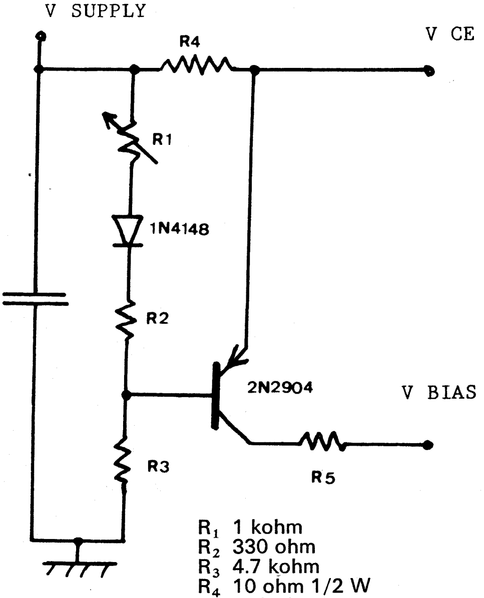
$C_{1,2,5,6}$	ARCO 404
L_1	2 turns I.D. = 5 mm 6/10 wire
L_4	3 turns I.D. = 5 mm 6/10 wire
L_2	0.22 H molded RFC
L_3	8 turns I.D. = 5 mm 6/10 wire
R_1	560 ohm 1/4 W
R_2	1000 ohm 1/4 W

SOE 280
Package Outline



To convert inches to millimeters multiply by 2.54.

CLASS A BIAS CIRCUIT



R_1	1 kohm
R_2	330 ohm
R_3	4.7 kohm
R_4	10 ohm 1/2 W
R_5	470 ohm

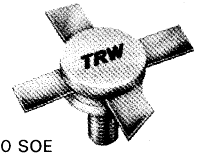
TRW® SEMICONDUCTORS

TPV 375

VHF LINEAR TRANSISTOR

TV TRANSPOSER
AND TRANSMITTER
BAND 3
20 W AT - 51 DB IMD
14 W AT - 55 DB IMD
HIGH SATURATION POWER

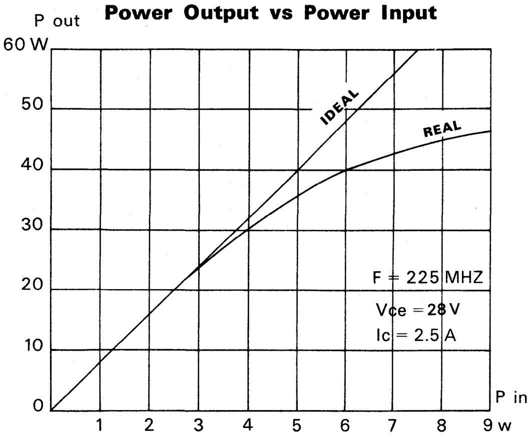
The TPV 375 is a NPN gold metallized transistor using diffused ballast resistors for super linearity. The TPV 375 is specifically designed for **high power band 3. TV transposers and transmitters amplifiers.** Due to its high saturation power (over 70 watts), the TPV 375 shows good linearity characteristics at powers over 25 W. This performance allows to build a 50 W transposer using 2 TPV 375 in parallel with linearity correction circuit.

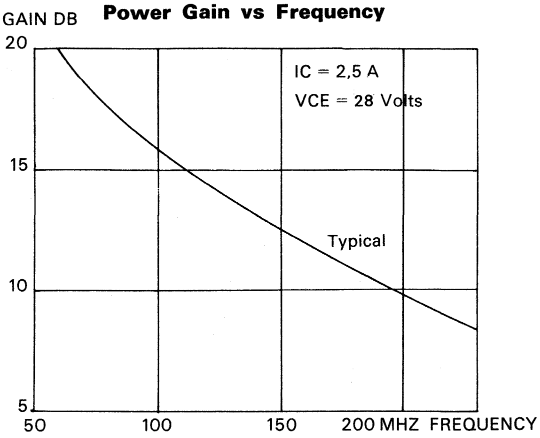


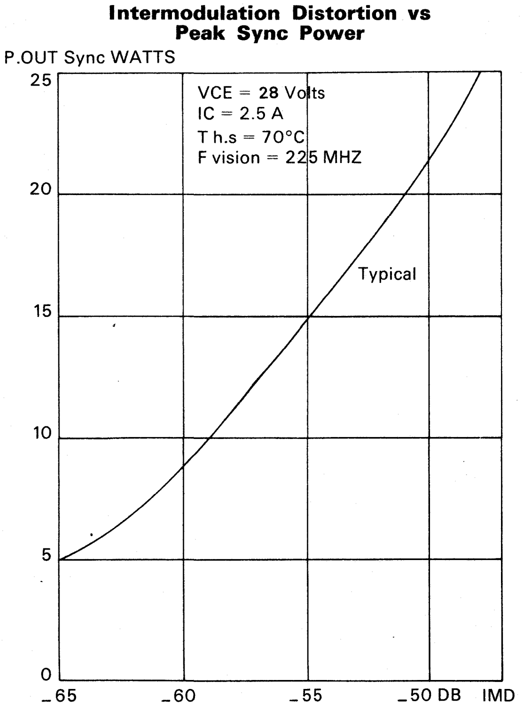
500 SOE

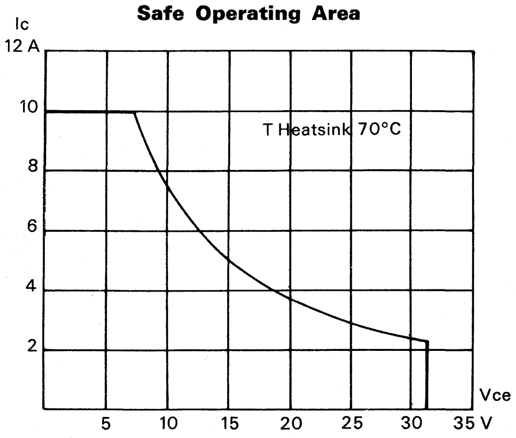
Electrical Characteristics (T_{CASE} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC Test	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 10 mA	4			V
	BV_{CEO}	Collector - Emitter Breakdown Voltage	I_C = 50 mA	35			V
	BV_{CER}	Collector - Emitter Breakdown Voltage	I_C = 50 mA R_{BE} = 10 ohms	60			V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 50 mA	65			V
	h_{FE}	D.C. Current Gain	V_{CE} = 5 V I_C = 1000 mA	20		120	
RF Test	IMD 1	Intermodulation Distortion - 3 Tone Vision Carrier = Reference - 8 dB Sound Carrier = Reference - 7 dB Sideband Carrier = Reference - 16 dB	F = 225 MHz V_{CE} = 28 V I_E = 2.5 A P_{REF} = 14 W			— 55	dB
	IMD 2	Idem	F = 225 MHz V_{CE} = 28 V I_E = 2.5 A P_{REF} = 20 W			— 51	dB
	P_G	Power Gain	F = 225 MHz V_{CE} = 28 V I_E = 2.5 A P_{REF} = 20 W	8	9		dB
	VSWR	Mismatch Tolerance	F = 225 MHz V_{CE} = 28 V I_E = 2.5 A P_{REF} = 20 W		∞		
	C_{OB}	Collector - Base Capacitance	V_{CB} = 30 V F = 1 MHz		58	85	pF
Thermal	I_C	Maximum Collector Current				10	A
	θ_{JC}	Thermal Resistance Junction - Case	T_{CASE} = 70 °C			1.5	°C/W
	θ_{CH}	Thermal Resistance Case - Heatsink				0.25	°C/W
	P_T	Dissipated Power	$T_{HEATSINK}$ = 25 °C			100	W
	T_{STG} T_J	Storage Temperature Junction Temperature		— 65		+ 200	°C


P out
Power Output vs Power Input
60 W
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9 w
P in
IDEAL
REAL
F = 225 MHZ
Vce = 28 V
Ic = 2.5 A

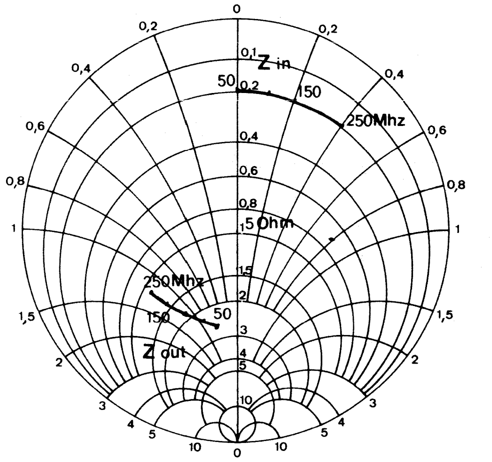

GAIN DB
Power Gain vs Frequency
20
15
10
5
50
100
150
200 MHZ
FREQUENCY
IC = 2,5 A
VCE = 28 Volts
Typical


Intermodulation Distortion vs Peak Sync Power
P.OUT Sync WATTS
25
20
15
10
5
0
_65
_60
_55
_50 DB
IMD
VCE = 28 Volts
IC = 2.5 A
T h.s = 70°C
F vision = 225 MHZ
Typical

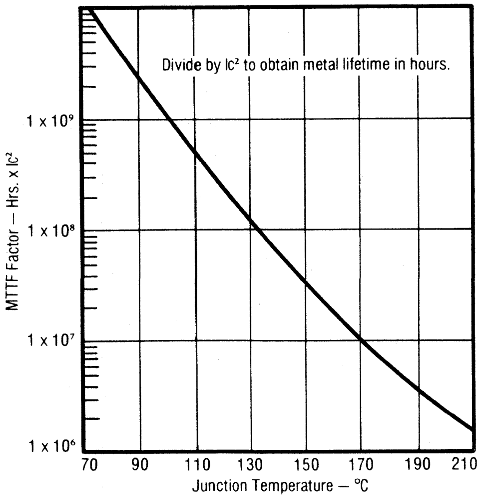

Safe Operating Area
Ic
12 A
10
8
6
4
2
5
10
15
20
25
30
35 V
Vce
T Heatsink 70°C

Large signal Impedances vs Frequency

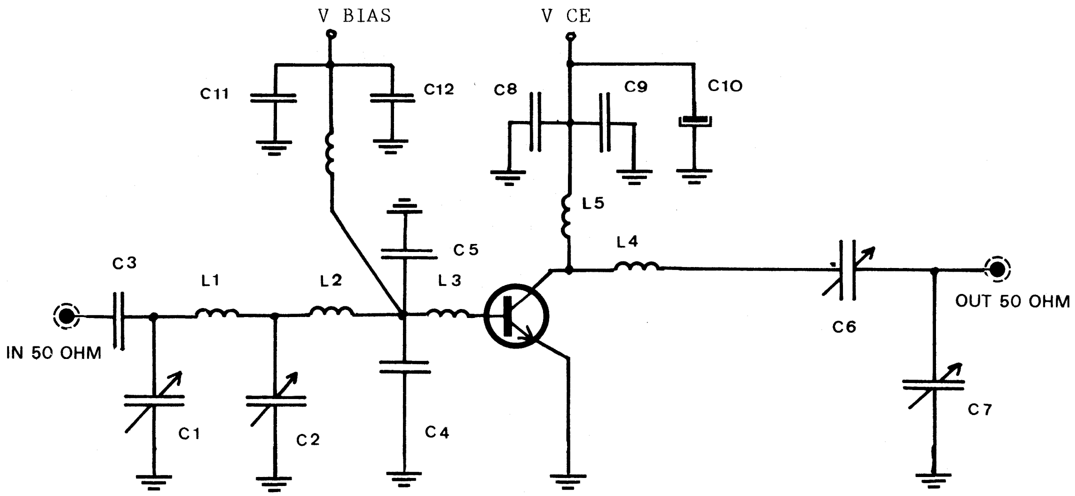
V_{CE} = 28 V - I_C = 2.5 A



MTTF Factor vs T_j

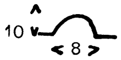


TEST CIRCUIT FOR F = 225 MHz



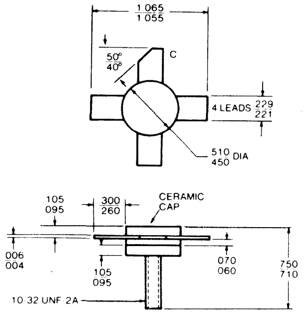
$C_{1,7}$	ARCO 403
C_2	ARCO 404
$C_{3,8}$	chip capacitor 470 pF
$C_{4,5}$	UNELCO 80 pF
C_6	ARCO 423
$C_{9,11}$	UNELCO 1000 pF
C_{10}	470 µF electrolytic
C_{12}	10 nF

L_1	1.5 turns closely wound. Cu wire 0.7 mm I.D. 4.5 mm
L_2	2.1 cm - 50 ohms - line
L_3	length of the base lead
L_4	Cu wire 1.6 mm
L_5	3.5 cm - 50 ohms line
L_6	4 turns closely wound Cu wire 0.8 mm I.D. 4.5 mm

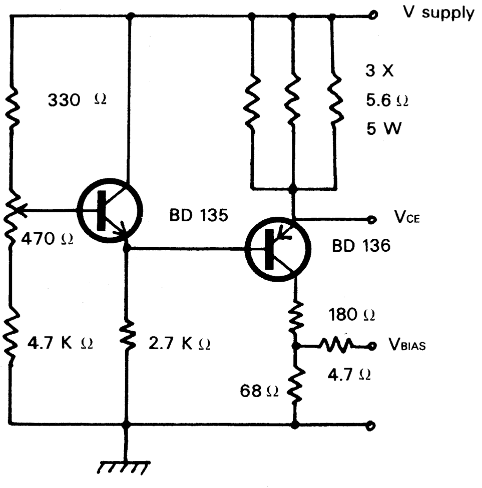


PACKAGE OUTLINE

.500 SOE



BIAS CIRCUIT



TRW® SEMICONDUCTORS

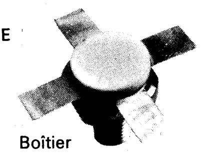
TPV 376

UHF LINEAR TRANSISTOR

Band
30 W at - 53 dB IMD
8 dB gain
CLASS A or AB

TPV 376 is a gold metallized NPN silicon transistor using high value diffused emitter ballast resistors. It is packaged in a low thermal resistance header. A combination of state of the art die mounting technique and on-line 100 percent thermal resistance testing ensures unsurpassed long term reliability. The above features make TPV 376 the highest Power transistor available for **class A and class AB band 3 TV transmitters and transposers** applications.

500 SOE
¼" Stud

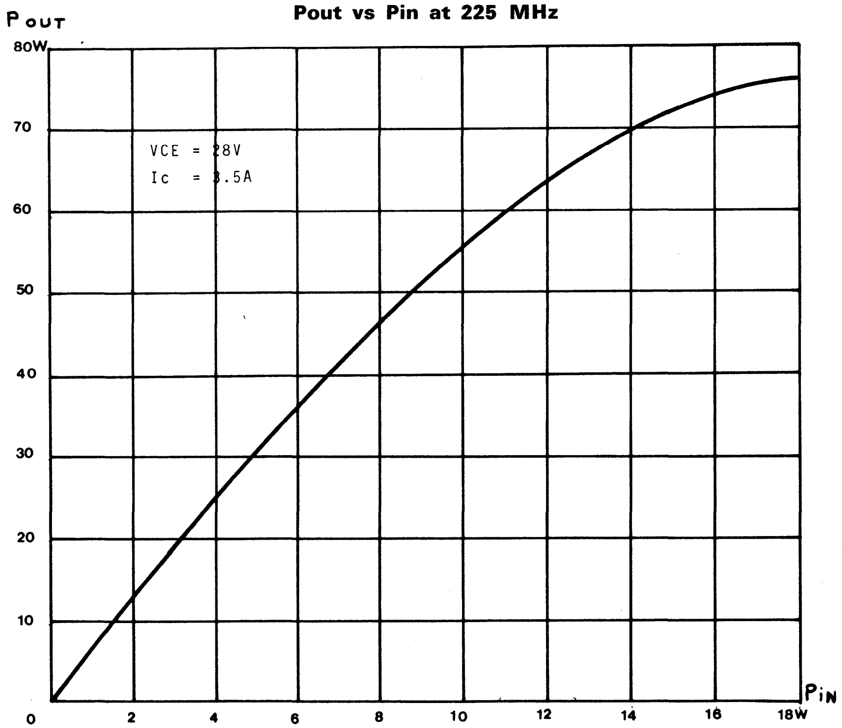


Boîtier

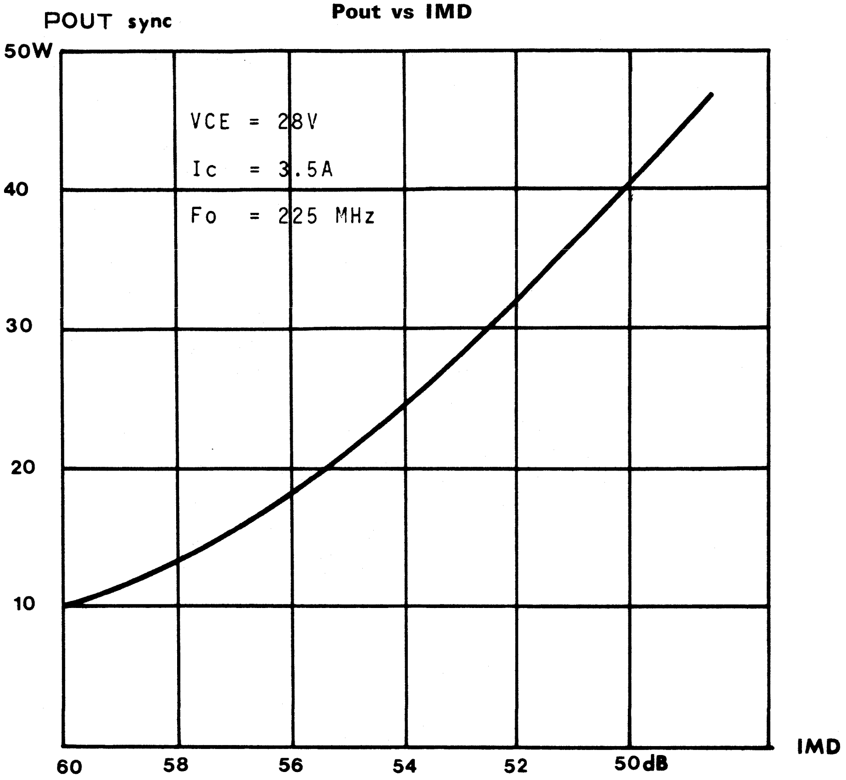
Electrical Characteristics (T_{CASE} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
D C Test	BV_{EBO}	Emitter-Base Breakdown Voltage	I_E = 20 mA	4			V
	BV_{CEO}	Collector - Emitter Breakdown Voltage	I_C = 100 mA	35			V
	BV_{CER}	Collector - Emitter Breakdown Voltage	I_C = 100 mA R_{BE} = 10 ohms	60			V
	BV_{CBO}	Collector-Base Breakdown Voltage	I_C = 100 mA	65			V
	h_{FE}	D.C Current Gain	V_{CE} = 5 V I_C = 1000 mA	20		120	
R F Test	IMD 1	Intermodulation Distortion - 3 Tone Vision Carrier = Reference - 8 dB Sound Carrier = Reference - 7 dB Sideband = Reference - 16 dB	F = 225 MHz V_{CE} = 28 V I_E = 3.5 A P_{REF} = 30 W			– 53	dB
	P_G	Power Gain	F = 225 MHz V_{CE} = 28 V I_E = 3.5 A P_{REF} = 20 W	7.5		8	dB
	VSWR	Mismatch Tolerance	F = 225 MHz V_{CE} = 28 V I_E = 3.5 A P_{REF} = 20 W	∞			
	C_{OB}	Collector - Base Capacitance	V_{CB} = 30 V F = 1 MHz		100	150	pF
Thermal	I_C	Maximum Collector Current			16		A
	θ_{JC}	Thermal Resistance Junction - Case	T_{CASE} = 70 °C		0.9	1	°C/W
	θ_{CH}	Thermal Resistance Case - Heatsink			0.15		°C/W
	P_T	Dissipated Power	$T_{HEATSINK}$ = 25 °C		150		W
	T_{STG} T_J	Storage Temperature Junction Temperature		— 65		+ 200	°C

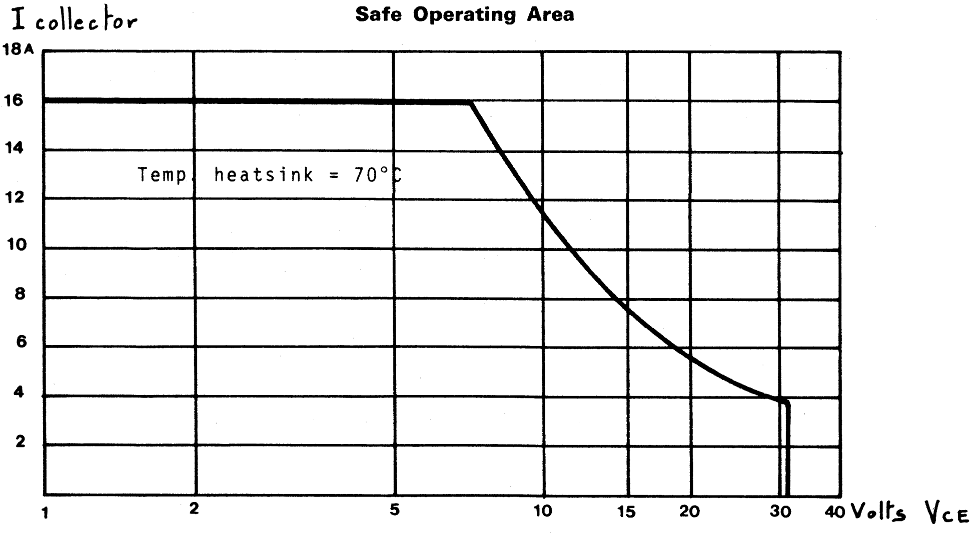
Pout vs Pin at 225 MHz



Pout vs IMD

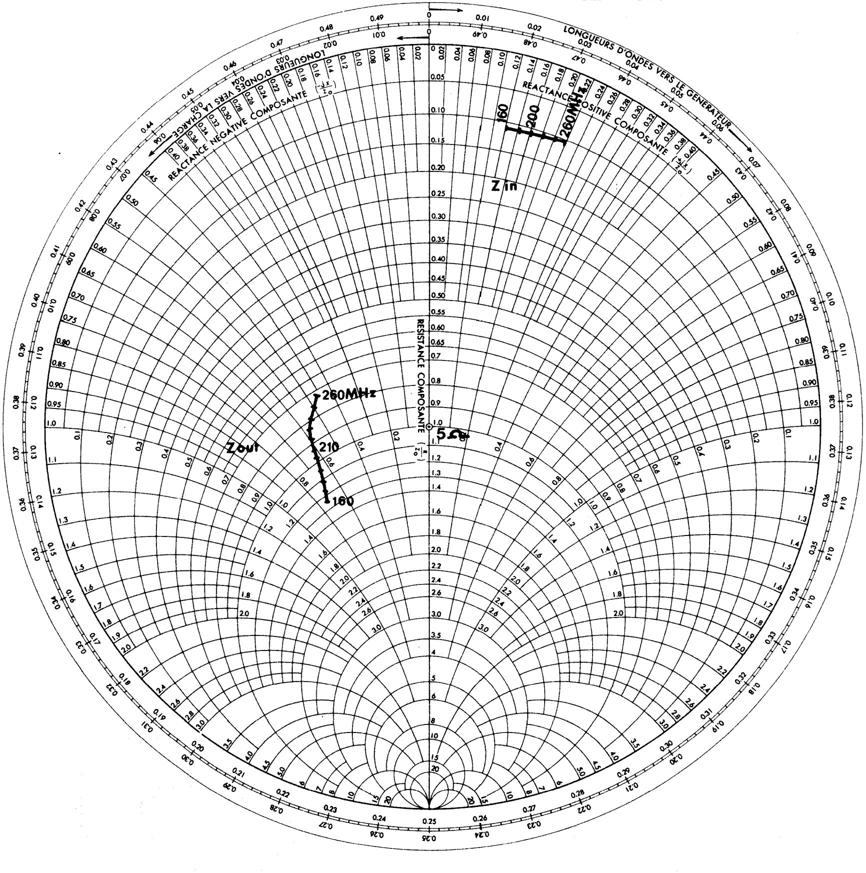


Safe Operating Area



Large Signal Zout Zin

VCE = 28 V
IE = 3.5 A



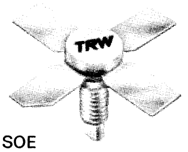
TRW SEMICONDUCTORS

TPV 394

VHF LINEAR TRANSISTOR

TV TRANSPOSER AND TRANSMITTER BAND 3
5 W AT - 58 DB IMD
16 DB GAIN

The TPV 394 is a NPN gold metallized transistor using diffused ballast resistors for super linearity. This transistor is designed for **medium power band 3 TV transposers.** The TPV 394 is used in the output stage of 10 W transposers or in the driver stages of higher power transposers and transmitters. Its exceptional **high gain** reduces the complexity of driver stages.

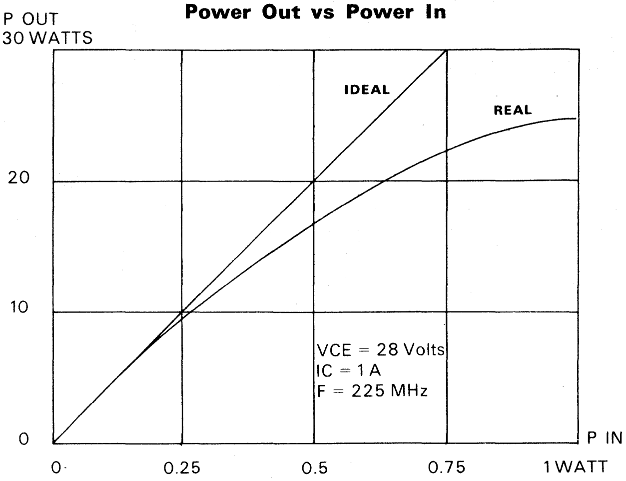


280 SOE

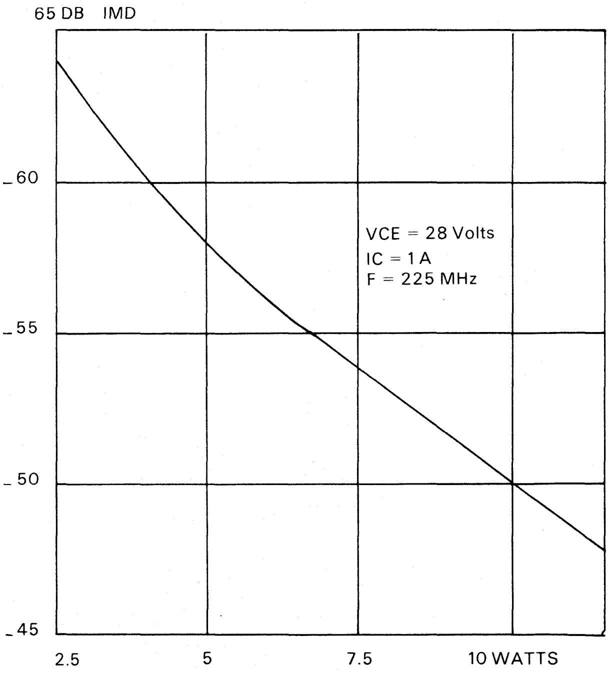
Electrical Characteristics (T_{CASE} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC Test	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 2 mA	4			V
	BV_{CEO}	Collector - Emitter Breakdown Voltage	I_C = 50 mA	30			V
	BV_{CER}	Collector - Emitter Breakdown Voltage	I_C = 50 mA R_{BE} = 10 ohms	55			V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 20 mA	55			V
	h_{FE}	D.C. Current Gain	V_{CE} = 5 V I_C = 100 mA	10		150	
RF Test	IMD 1	Intermodulation Distortion - 3 Tone Vision Carrier = Reference - 8 dB Sound Carrier = Reference - 7 dB Sideband Carrier = Reference - 16 dB	F = 225 MHz V_{CE} = 28 V I_E = 1 A P_{REF} = 5 W			— 58	dB
	IMD 2	Idem	F = 225 MHz V_{CE} = 28 V I_E = 1 A P_{REF} = 10 W			— 50	dB
	P_G	Power Gain	F = 225 MHz V_{CE} = 28 V I_E = 1 A P_{REF} = 5 W	15	16		dB
	VSWR	Mismatch Tolerance	F = 225 MHz V_{CE} = 28 V I_E = 1 A P_{REF} = 5 W		∞		
	C_{OB}	Collector - Base Capacitance	V_{CB} = 28 V F = 1 MHz			35	pF
Thermal	I_C	Maximum Collector Current				4	A
	θ_{JC}	Thermal Resistance Junction - Case	T_{CASE} = 70 °C			2.5	°C/W
	θ_{CH}	Thermal Resistance Case - Heatsink				1.0	°C/W
	P_T	Dissipated Power	$T_{HEATSINK}$ = 25 °C			50	W
	T_{STG} T_J	Storage Temperature Junction Temperature		— 65		+ 200	°C

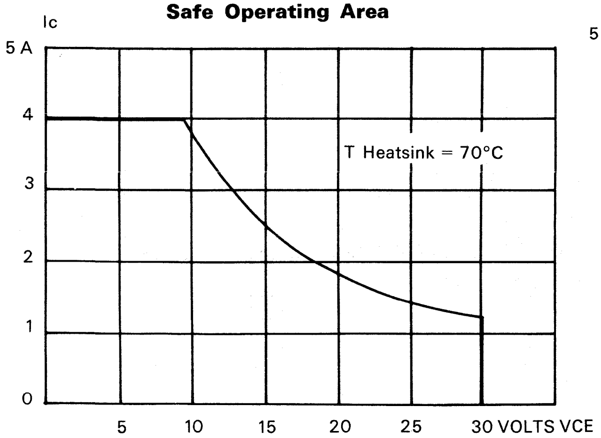
Power Out vs Power In



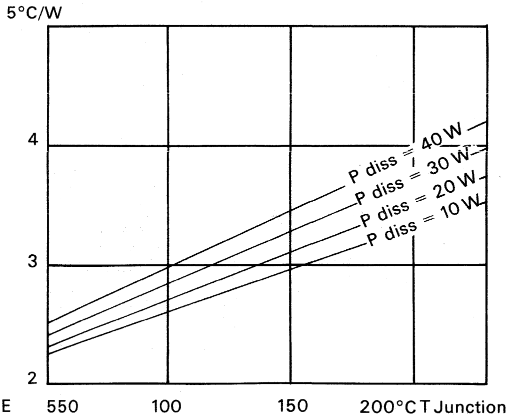
Intermodulation Distortion vs Power Out



Safe Operating Area

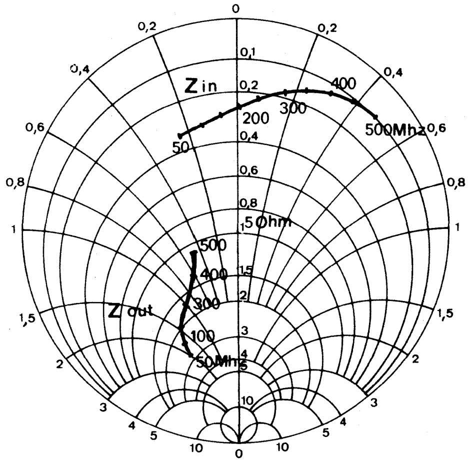


Thermal Resistance Junction Heatsink vs Temperature of Junction for Various Power's Dissipated

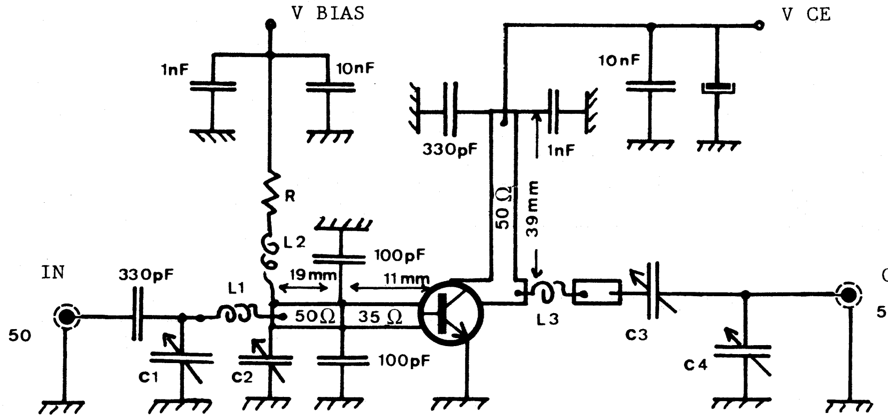


Large Signal Impedances vs Frequency

V_{CE} = 28 V - I_C = 1 A



TEST CIRCUIT AT F = 225 MHz

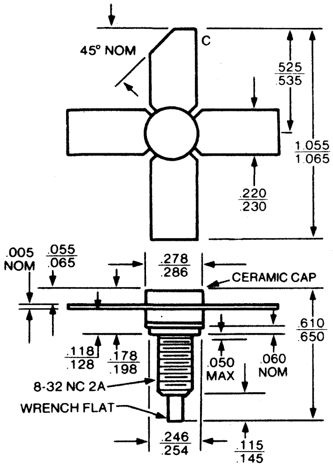


Lines are printed on G 10 epoxy glass material

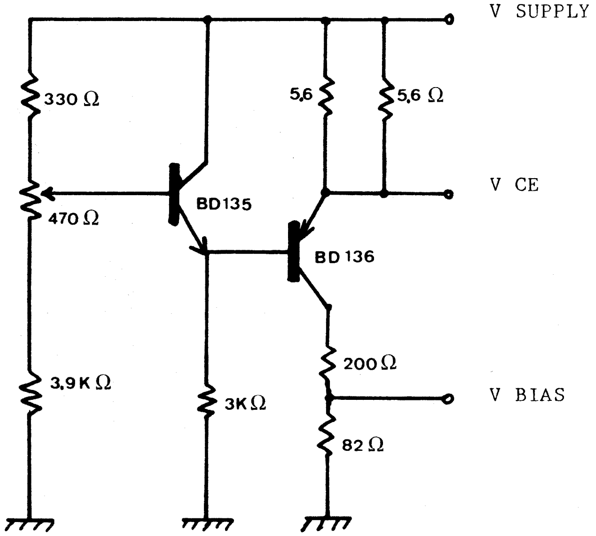
$C_{1,4}$	ARCO 403
C_2	ARCO 404
C_3	ARCO 423
L_1	1 turn 1/2 I.D. = 5 mm
L_2	RFC 10 turns I.D. = 5 mm
L_3	1.5 mm shaped :

CLASS A BIAS CIRCUIT

Package Outline



To convert inches to millimeters multiply by 2.54.



TRW® SEMICONDUCTORS

TPV 502

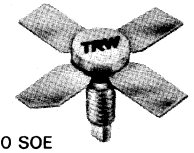
PRELIMINARY

The TPV 502 is a NPN gold metallized transistor using diffused emitter ballast resistor for super linearity.

The chip design using microwave techniques provides typical gain in excess of 10 dB at 860 MHz.

The TPV 502 is an ideal candidate for medium power band V TV transposer applications.

TV TRANSPOSER
BAND V
10 dB GAIN
2 W



280 SOE

Electrical Characteristics (T_{case} = 25 °C)

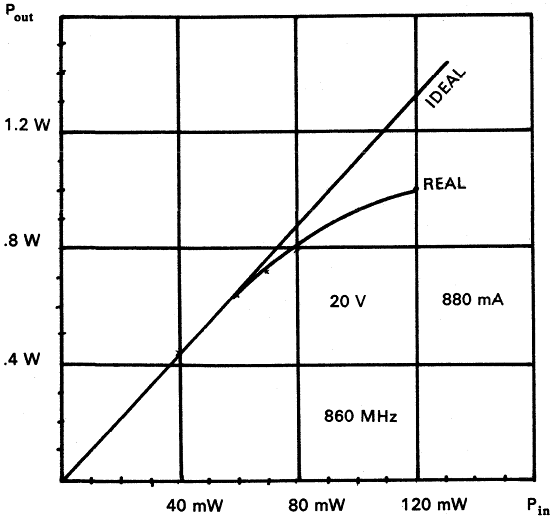
	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC TEST	BV_{CEO}	Collector-Emitter Breakdown Voltage	I_C = 80 mA	24			V
	BV_{CER}	Collector-Emitter Breakdown Voltage	I_C = 10 mA R_{BE} = 10 Ω	45			V
	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 1 mA	3.5			V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 4 mA	50			V
	H_{FE}	DC Current Gain	V_{CE} = 5 V I_C = 400 mA	20		120	
RF TEST	IMD	Intermodulation distortion — 8 dB — 16 dB — 7 dB	F = 860 MHz V_{CE} = 20 V I_C = 880 mA Psync = 2 W			— 58	dB
	P_G	Power Gain CW		10	10.5		dB
	VSWR	Mismatch Tolerance			∞		
	C_{OB}	Collector - Base Capacitance	V_{CB} = 24 V F = 1 MHz			12	pF
	F_T	Cutoff Frequency	V_{CE} = 20 V I_C = 880 mA	2.2			GHz
THERMAL	I_C	Maximum Collector current				3	A
	θ_{j-F}	Thermal Resistance Junction Heatsink	T° Heatsink = 70 °C			6.3	°C/W
	T_j	Max. Junction and Storage Temperature		— 65		+ 200	°C

POLAR S-PARAMETERS IN 50 OHM SYSTEM								
F	**S 11**		**S 21**		**S 12**		**S 22**	
MHz	**Magn**	**Angl°**	**Magn**	**Angl°**	**Magn**	**Angl°**	**Magn**	**Angl°**
900	0.954	165°	0.785	54°	0.040	54°	0.724	180°
800	0.952	168°	0.851	56°	0.035	54°	0.724	180°
700	0.954	169°	0.954	60°	0.032	54°	0.737	180°
600	0.954	171°	1.089	68°	0.028	54°	0.724	180°
500	0.954	171°	1.33	70°	0.025	49°	0.724	181°
400	0.954	173°	1.585	72°	0.020	41°	0.707	182°
300	0.954	175°	2.11	77°	0.018	37°	0.707	182°
200	0.954	177°	2.82	86°	0.015	30°	0.707	182°
100	0.954	180°	5.3	95°	0.014	22.5°	0.688	188°

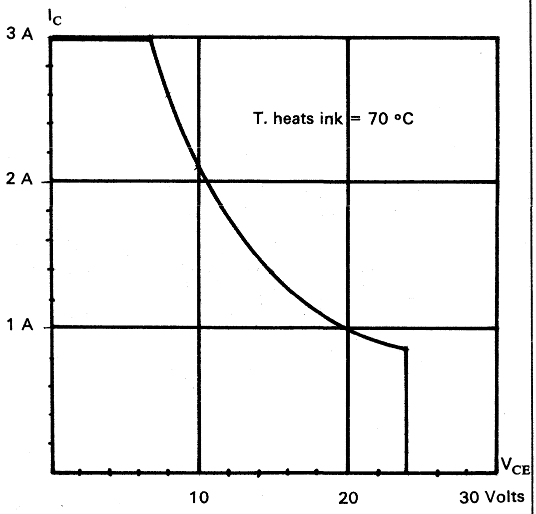
*LARGE SIGNAL IMPEDANCES - V_{CE} = 20 V - I_C = 880 mA	
Z_{in}	Z_{out}
(0.7 + j 4.5) Ω	(4 — j 7.5) Ω

* For best input and output return loss at 860 MHz.

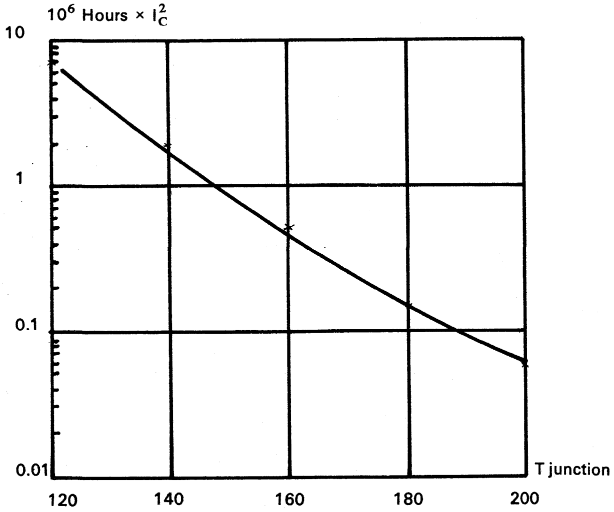
POWER OUTPUT V_S POWER INPUT



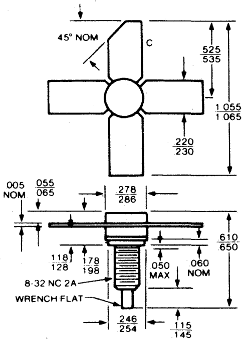
D_C SAFE OPERATING AREA



MTTF FACTOR V_S JUNCTION T°



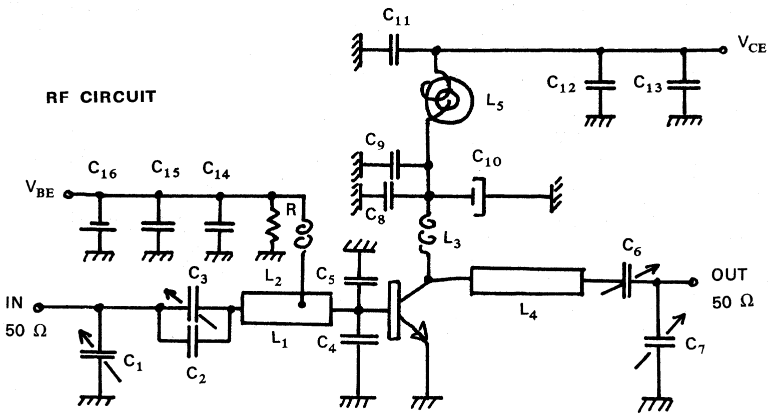
PACKAGE OUTLINE



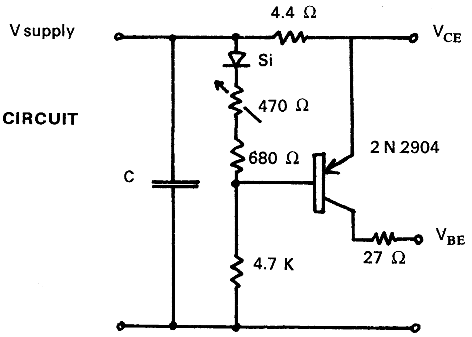
280 SOE

860 MHz

RF CIRCUIT



BIAS CIRCUIT



C = 100 µF + 10 nF + 1 nF

C_1 = AIR TRIMMER AT 5201 0.8 - 10 pF TEKELEC
C_2 = CHIP ATC 4.7 pF
C_3 = AIR TRIMMER AT 5751 0.6 - 6 pF TEKELEC
C_4 = C_5 = CHIP ATC 3.3 pF
C_6 = C_7 = AIR TRIMMER AT 5501 1 - 20 pF TEKELEC
C_8 = C_{13} = C_{14} = 1 nF CHIP CAPACITOR
C_9 = C_{11} = C_{15} = 10 nF RTC
C_{12} = 0.1 µF RTC
C_{10} = C_{16} = 10 µF 63 V electrolytic

L_1 = 30 Ω line l = 6.5 % λg
L_2 = choke 0.47 µH
L_3 = **1 turn - ID 6 mm - wire 10/10**
L_4 = 30 Ω line l = 19 % λg
L_5 = 8 turns on a CN 20 FERRITE BEAD - CERAMICS - MAGNETICS

R = 43 Ω 1/4 Watt

TRW® **SEMICONDUCTORS** **TPV 590**

Preliminary

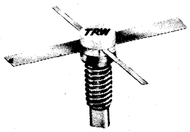
UHF Linear Transistor

TV TRANSPOSER
0.25 W - BAND 5
14 dB GAIN at 860 MHz

GOLD RELIABILITY

The TPV 590 is a NPN gold metallized transistor using emitter ballast resistors for super linearity. The fine chip geometry gives typical gain in excess of 14 dB at 860 MHz.

These characteristics make TPV 590 an ideal candidate for very efficient low power stages in UHF transposers applications.



.200 SOE

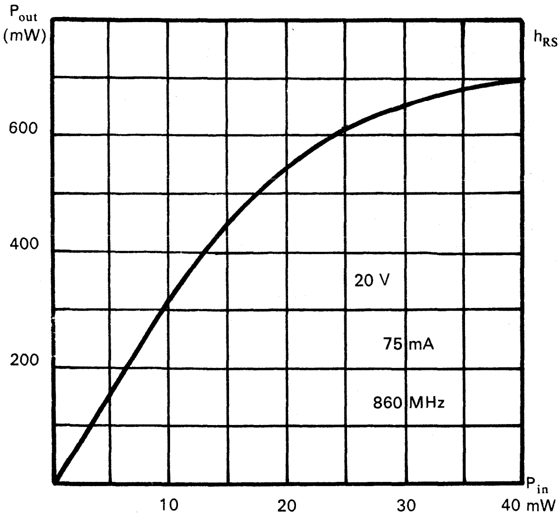
Electrical Characteristics (T_{case} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC TEST	BV_{EBO}	Emitter Base Breakdown Voltage	I_E = 0.25 mA	3.5			V
	BV_{CEO}	Collector Emitter Breakdown Voltage	I_C = 10 mA	24			V
	BV_{CBO}	Collector Base Breakdown Voltage	I_C = 1 mA	45			V
	BV_{CER}	Collector Emitter Breakdown Voltage	R_{BE} = 10 I_C = 10 mA	50			V
	I_{CBO}	Collector Cutoff Current	V_{CB} = 28 V			0.25	mA
	H_{FE}	DC Current Gain	V_{CE} = 5 V I_C = 100 mA	20		120	
RF TEST	I_{MD}	Intermodulation Distortion — 8 dB — 16 dB — 7 dB	F = 860 MHz V_{CE} = 20 V I_E = 75 mA P_{ref} = 0.25 W		— 60	**— 58**	dB
	P_G	Power Gain		14	14.5		dB
	VSWR	Mismatch Tolerance			∞		
	C_{ob}	Collector Base Capacitance	V_{CB} = 20 V F = 1 MHz			3	pF
	F_T	Cutoff Frequency	V_{CE} = 20 V I_E = 75 mA	3			GHz
THERMAL	I_C	Maximum Collector Current				.4	A
	θ_{JF}	Thermal Resistance Junction Heatsink	Theatsink = 70 °C			30	°C/W
	T_J T_{STG}	Max Junction and Storage Temper		— 65		+ 200	°C

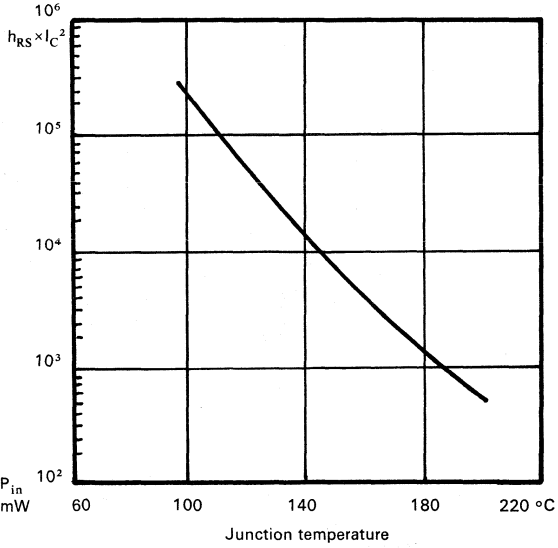
TPV 590 V_{CE} = 20 V I_C = 100 mA

POLAR S-PARAMETERS IN 50 OHM SYSTEM								
F	S 11		S 21		S 12		S 22	
MHz	Magn	Angl°	Magn	Angl°	Magn	Angl°	Magn	Angl°
100 MHz	0.613	226°	17.78	126°	0.0199	35°	0.530	320°
200 MHz	0.732	203°	12.88	103°	0.028	33°	0.316	305°
300 MHz	0.767	192.5°	9.22	93°	0.029	33°	0.266	297°
400 MHz	0.767	185°	6.91	84°	0.033	33°	0.266	295°
500 MHz	0.754	179.5°	5.16	79°	0.033	38°	0.266	300°
600 MHz	0.776	174°	4.67	72°	0.035	42°	0.237	300°
700 MHz	0.776	170°	4.02	66°	0.039	43°	0.237	290°
800 MHz	0.767	167°	3.34	61°	0.044	44°	0.266	285°
900 MHz	0.767	163°	3.16	56°	0.047	44°	0.237	290°
1 GHz	0.776	160°	2.786	52°	0.053	45°	0.266	280°

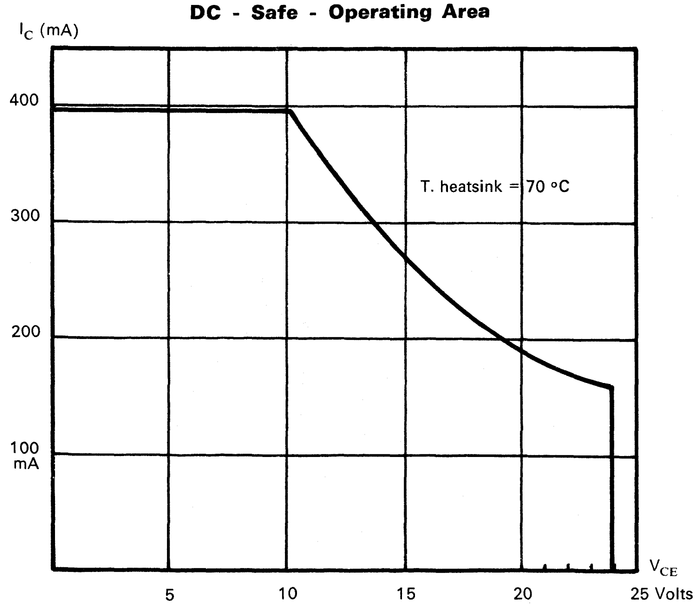
Power Output vs Power Input



MTTF Factor vs Junction Temperature

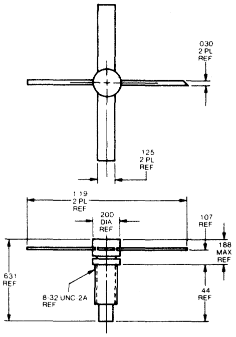


DC - Safe - Operating Area

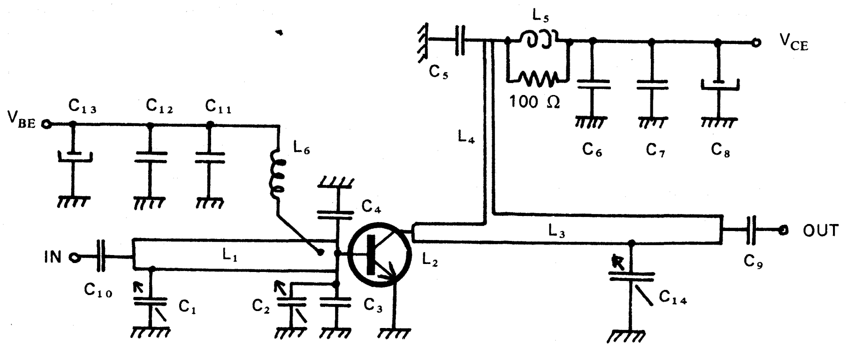


Package

.200 SOE STUD

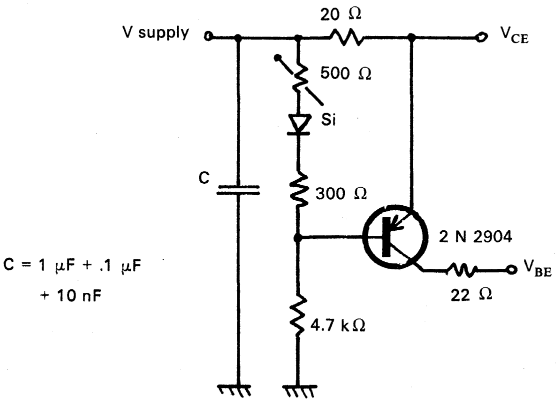


V_{CE} = 20 V I_C = 75 mA F_O = 860 MHz



L_1 : 50 Ω line l = 10 % λg at 860 MHz
L_2 : 100 Ω line l = 12 % λg at 860 MHz
L_3 : 50 Ω line l = 7 % λg at 860 MHz
L_4 : 120 Ω line l = 10 % λg at 860 MHz
L_5 : 6 turns ID 3 mm wire .5 mm
L_6 : 6 turns ID 3 mm wire .5 mm

C_1 = C_2 = C_{14} = variable AIRTRONIC C max 4.7 pF AT 7275
C_3 = C_4 = ATC chip 10 pF
C_5 = 680 pF ATC chip
C_6 = C_{11} = 1 nF
C_7 = C_{12} = 10 nF
C_8 = 10 µF 63 V
C_{13} = 10 µF 25 V
C_9 = C_{10} = 1 nF chip



Bias Circuit

TRW® SEMICONDUCTORS

TPV 591

PRELIMINARY

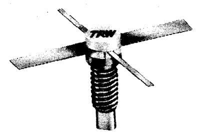
UHF Linear Transistor

TV TRANSPOSER
0.5 W BAND 5
14 dB GAIN AT 860 MHz
HIGH EFFICIENCY
GOLD RELIABILITY

The TPV 591 is a NPN gold metallized transistor using diffused emitter ballast resistors.

The sophisticated chip geometry allows the TPV 591 to expand the gain-efficiency frontier.

Its characteristics make the TPV 591 the best device available for very efficient low power stages in UHF transposers applications.



200 SOE

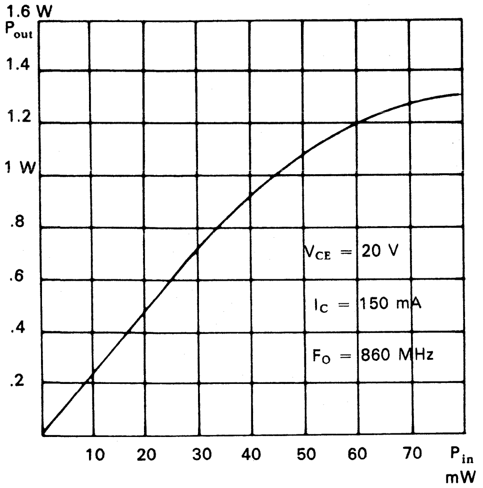
Electrical Characteristics (T_{case} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC TEST	BV_{CEO}	Collector - Emitter Breakdown Voltage	I_C = 20 mA	24			V
	BV_{CER}	Collector - Emitter Breakdown Voltage	R_{BE} = 10 Ω I_C = 20 mA	50			V
	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 0.5 mA	3.5			V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 2 mA	45			V
	I_{CBO}	Collector Cutoff Current	V_{CB} = 28 V			0.5	mA
	H_{FE}	Forward Current Transfer Ratio	V_{CE} = 5 V I_C = 200 mA	20		120	
RF TEST	IMD	Intermodulation Distortion — 8 dB, — 16 dB, — 7 dB	F_o = 860 MHz		— 60	— 58	dB
	P_G	Power Gain	V_{CE} = 20 V I_C = 150 mA	13	14		dB
	VSWR	Mismatch tolerance	P_{REF} = 0.5 W		∞		
	F_T	Cutoff Frequency	V_{CE} = 20 V I_E = 75 mA	3			GHz
	C_{OB}	Collector - Base Capacitance	V_{CB} = 20 V F = 1 MHz			5.5	pF
THERMAL	I_C	Maximum Collector Current				.8	A
	θ_{JF}	Thermal Resistance Junction - Heatsink	$T_{Heatsink}$ = 70 °C			16	°C/W
	T_J T_{STG}	Maximum Junction and Storage Temperature		— 65		+ 200	°C

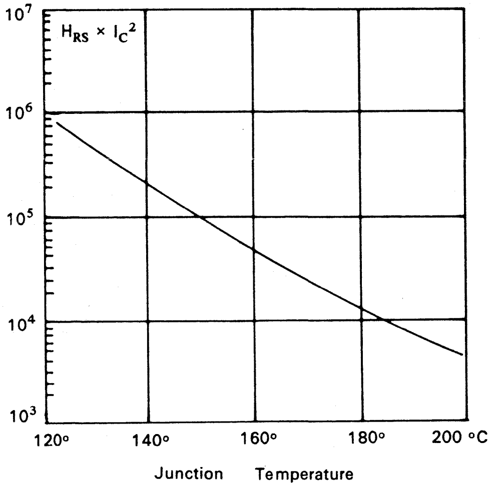
V_{CE} = 20 V I_C = 150 mA

POLAR S-PARAMETERS IN 50 OHM SYSTEM								
F	S 11		S 21		S 12		S 22	
MHz	Magn	Angl°	Magn	Angl°	Magn	Angl°	Magn	Angl°
100	0.733	190	13.8	117	0.025	27	0.365	280
200	0.841	187	8.13	100	0.028	27	0.266	241
300	0.861	181	5.62	88	0.033	27	0.266	241
400	0.861	177	4.27	79	0.035	30	0.282	225
500	0.861	173	3.47	72	0.040	36	0.282	225
600	0.865	169	2.82	68	0.045	36	0.282	218
700	0.865	167	2.44	61	0.045	37	0.316	214
800	0.866	163	2.15	54	0.050	40	0.316	216
860	0.866	162	2.03	54	0.050	43	0.331	218
900	0.866	160	1.94	52	0.053	44	0.331	217
1 000	0.876	158	1.66	46	0.056	44	0.376	214

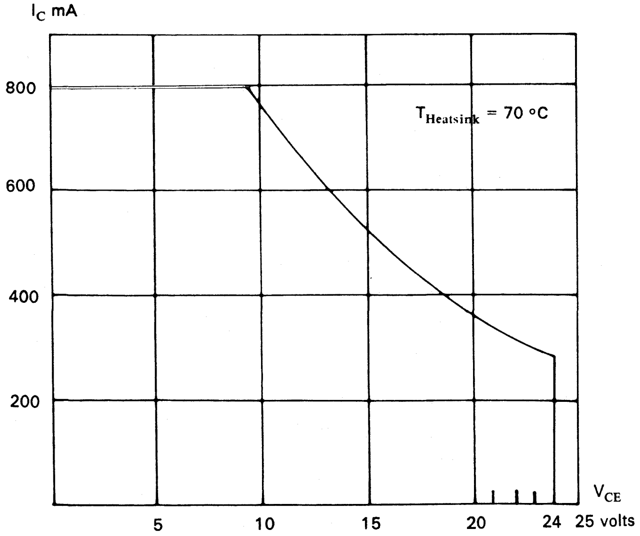
Power Output vs Power Input



MTTF Factor vs Junction Temperature

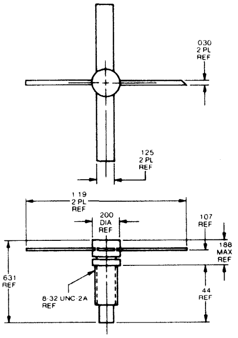


D.C Safe Operating Area

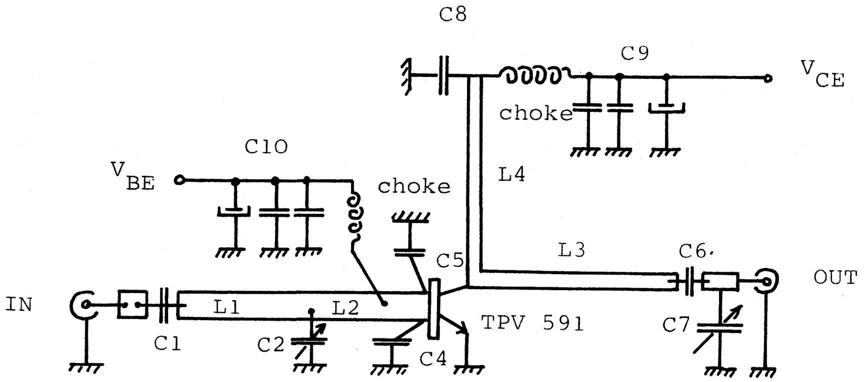


Package

.200 SOE STUD



F_O = 860 MHz — V_{CE} = 20 V — I_C = 150 mA

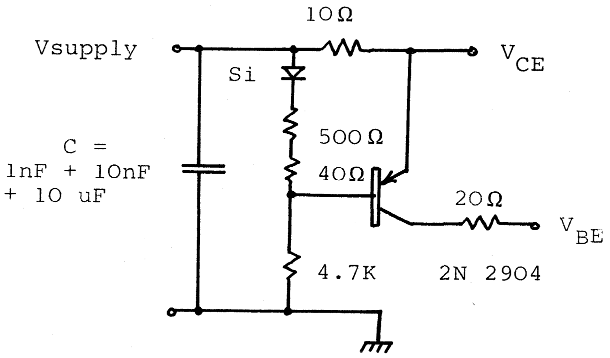


C_1 = C_6 = 1 nF
C_2 = C_7 = Variable Airtronic AT 7285 - max. 2.5 pF
C_4 = ATC 100 A 10 pF
C_5 = ATC 100 A 6.8 pF + 4.7 pF
C_8 = 1 nF
C_9 = C_{10} = 1 nF + 10 nF + 10 μF

Choke : 8 turns — ID 6 mm — wire .5 mm

L_1 = 50 line — ℓ = 10 % λg at 860 MHz
L_2 = 50 line — ℓ = 5 % λg at 860 MHz
L_3 = 80 line — ℓ = 13 % λg at 860 MHz
L_4 = 100 line — ℓ = 8 % λg at 860 MHz

BIAS CIRCUIT



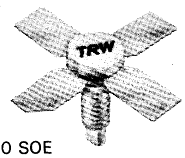
TRW® SEMICONDUCTORS

TPV 596

UHF LINEAR TRANSISTOR

TV TRANSPOSER
0.5 W BAND 5
MATV 1.5 V - 860 MHz
12 DB GAIN
GOLD RELIABILITY

The TPV 596 is a NPN gold metallized transistor using diffused emitter ballast resistors for super linearity. The chip design using microwave techniques provides more than 12 dB gain at 860 MHz thereby reducing the complexity of the lower amplifier stages. The TPV 596 is specifically designed for very high output **1.5 volt MATV** amplifier up to 860 MHz and **500 mW band 5 TV transposers** stages.

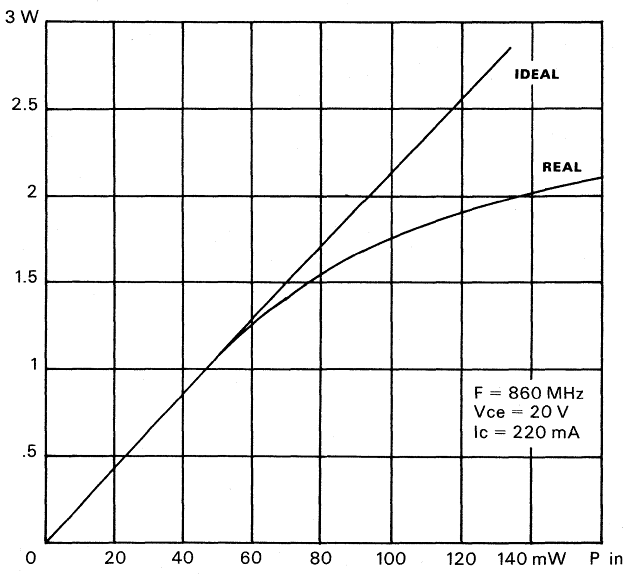


280 SOE

Electrical Characteristics (T_{flange} = 25 °C)

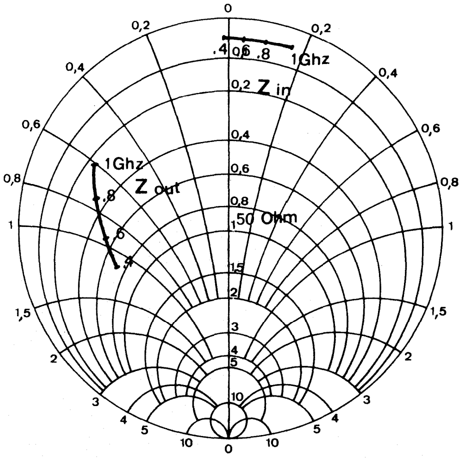
	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC Test	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 0.25 mA	3.5			V
	BV_{CEO}	Collector - Emitter Breakdown Voltage	I_C = 20 mA	24			V
	BV_{CER}	Collector - Emitter Breakdown Voltage	I_C = 20 mA R_{BE} = 10 ohms	50			V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 1 mA	45			V
	I_{CBO}	Collector - Base Leakage	V_{CB} = 28 V			125	µA
	h_{FE}	D.C. Current Gain	V_{CE} = 5 V I_C = 100 mA	20		120	
RF Test	IMD 1	Intermodulation Distortion - 3 Tone Vision Carrier = Reference - 8 dB Sound Carrier = Reference - 7 dB Sideband Carrier = Reference - 16 dB	F = 860 MHz V_{CE} = 20 V I_E = 0.22 A P_{REF} = 1 W			— 50	dB
	IMD 2	Idem	F = 860 MHz V_{CE} = 20 V I_E = 0.22 A P_{REF} = 0.5 W		— 60	— 58	dB
	P_G	Power Gain	F = 860 MHz V_{CE} = 20 V I_E = 0.22 A P_{REF} = 1 W	11.5	12		dB
	VSWR	Mismatch Tolerance	F = 860 MHz V_{CE} = 20 V I_E = 0.22 A P_{REF} = 1 W		∞		
	C_{OB}	Collector - Base Capacitance	V_{CB} = 28 V F = 1 MHz			5	pF
	f_T	Cutoff Frequency	V_{CE} = 20 V I_E = 220 mA	2.2	2.5		GHz
Thermal	I_C	Maximum Collector Current				0.7	A
	θ_{JC}	Thermal Resistance Junction - Case	T_{CASE} = 70 °C			20	°C/W
	P_T	Dissipated Power	$T_{HEATSINK}$ = 25 °C			8.75	W
	T_{STG} T_J	Storage Temperature Junction Temperature		— 65		+ 200	°C

Power Output vs Power Input

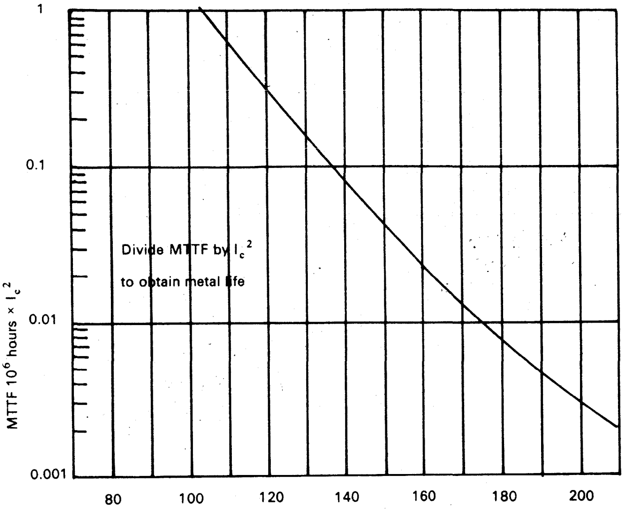


LARGE SIGNAL IMPEDANCES

Vce = 20 v
Ic = 220 mA

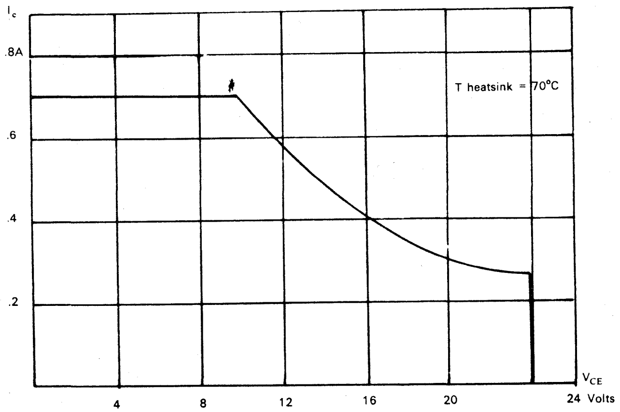


MTTF FACTOR vs JUNCTION TEMPERATURE

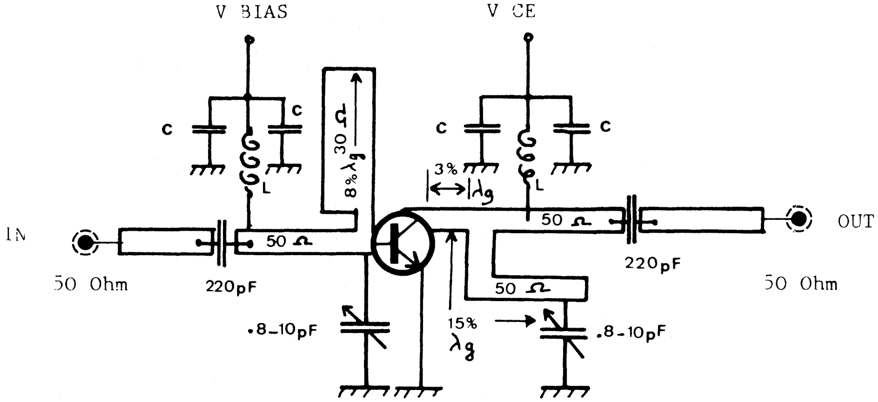


JUNCTION TEMPERATURE — °C

DC-SAFE OPERATING AREA



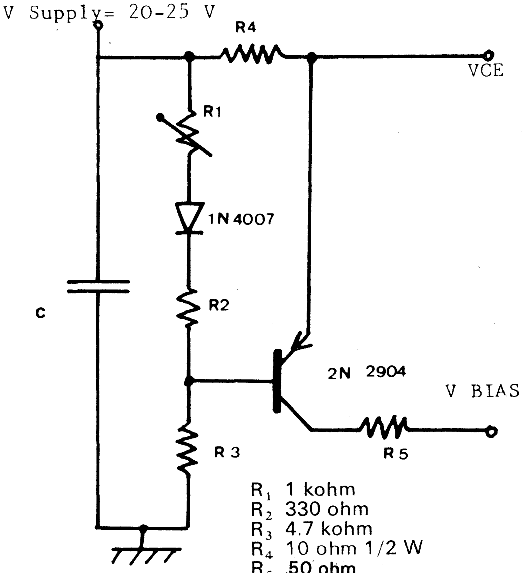
TEST CIRCUIT AT 860 MHz



L = 6 turns ID = 1 mm Wire diameter = 0.6 mm

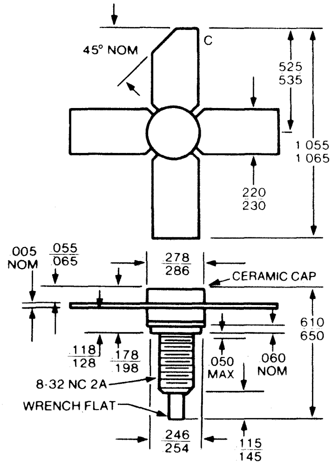
The lengths are given for F = 860 MHz

CLASS A BIAS CIRCUIT



R_1 1 kohm
R_2 330 ohm
R_3 4.7 kohm
R_4 10 ohm 1/2 W
R_5 50 ohm
C 100 F + 10 nF + 1 nF

Package Outline



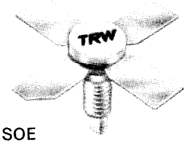
To convert inches to millimeters multiply by 2.54

TRW® **SEMICONDUCTORS** **TPV 597**

UHF LINEAR TRANSISTOR

TV TRANSPOSER
BAND 5
1 W
11 DB GAIN
GOLD RELIABILITY

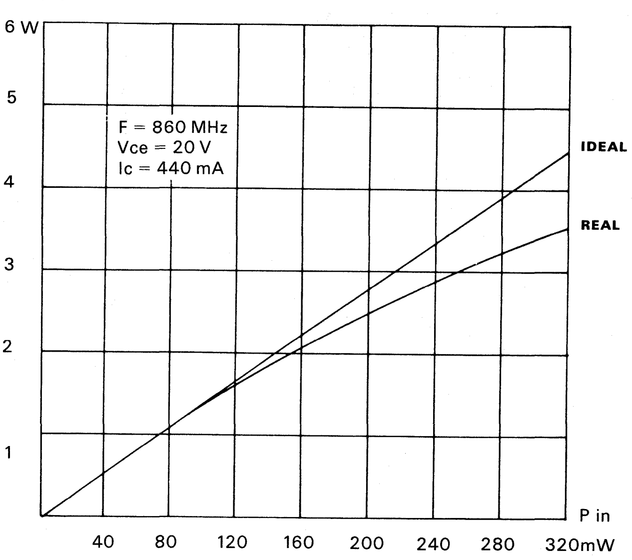
The TPV 597 is a NPN gold metallized transistor using diffused emitter ballast resistors for super linearity. The chip design using microwave techniques provides more than 11 dB gain at 860 MHz thereby reducing the complexity of the lower amplifier stages. The TPV 597 is specifically designed for **1 W - band 5 - TV transposers** stages.


280 SOE

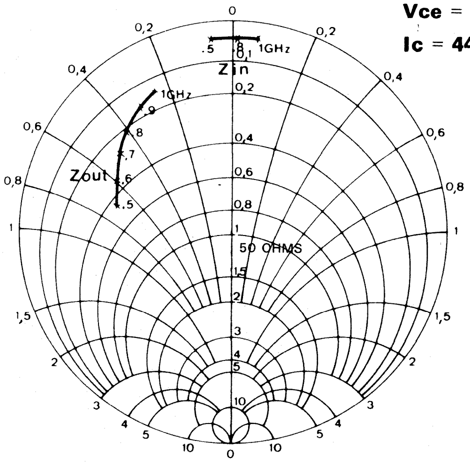
Electrical Characteristics (T_{flange} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC Test	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 0.5 mA	3.5			V
	BV_{CEO}	Collector - Emitter Breakdown Voltage	I_C = 40 mA	24			V
	BV_{CER}	Collector - Emitter Breakdown Voltage	I_C = 40 mA R_{BE} = 10 ohms	50			V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 2 mA	45			V
	I_{CBO}	Collector - Base Leakage	V_{CB} = 28 V			250	µA
	h_{FE}	D.C. Current Gain	V_{CE} = 5 V I_C = 200 mA	20		120	
RF Test	IMD 1	Intermodulation Distortion - 3 Tone Vision Carrier = Reference - 8 dB Sound Carrier = Reference - 7 dB Sideband Carrier = Reference - 16 dB	F = 860 MHz V_{CE} = 20 V I_E = 0.44 A P_{REF} = 1 W		- 60	- 58	dB
	IMD 2	Idem	F = 860 MHz V_{CE} = 20 V I_E = 0.44 A P_{REF} = 2 W			- 51	dB
	P_G	Power Gain	F = 860 MHz V_{CE} = 20 V I_E = 0.44 A P_{REF} = 1 W	10.5	11		dB
	VSWR	Mismatch Tolerance	F = 860 MHz V_{CE} = 20 V I_E = 0.44 A P_{REF} = 2 W		∞		
	C_{OB}	Collector - Base Capacitance	V_{CB} = 28 V F = 1 MHz			7	pF
	f_T	Cutoff Frequency	V_{CE} = 20 V I_E = 440 mA	2.2	2.5		GHz
Thermal	I_C	Maximum Collector Current				1.4	A
	θ_{JC}	Thermal Resistance Junction - Case	T_{CASE} = 70 °C			9	°C/W
	P_T	Dissipated Power	$T_{HEATSINK}$ = 25 °C			19	W
	T_{STG} T_J	Storage Temperature Junction Temperature		— 65		+ 200	°C

Power Output vs Power Input

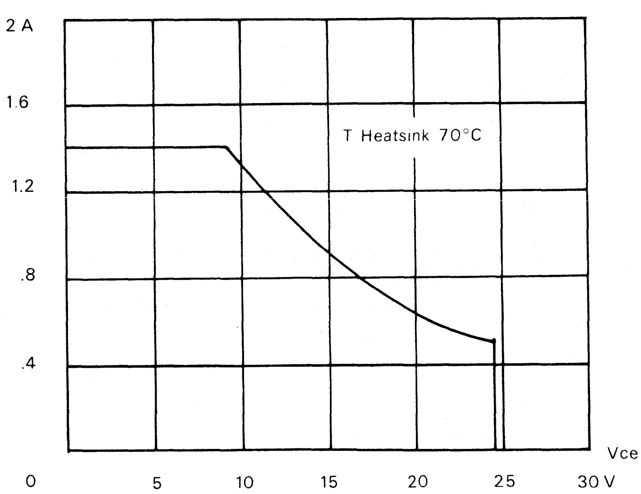


LARGE SIGNAL IMPEDANCES

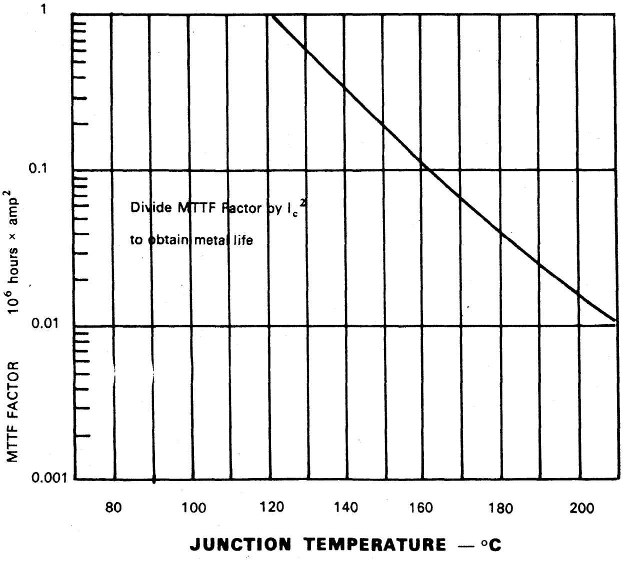


Vce = 20 v
Ic = 440 mA

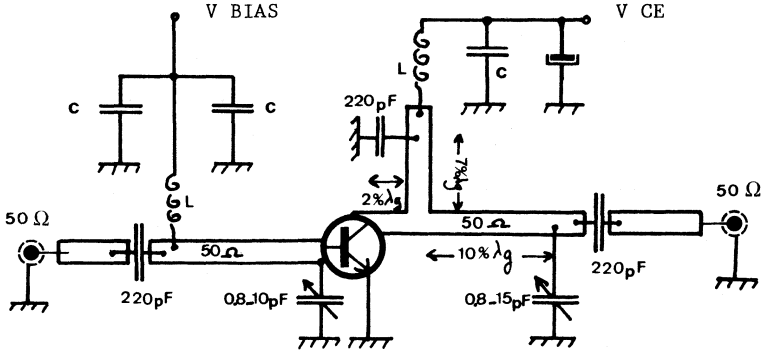
Safe Operating Area



MTTF FACTOR vs JUNCTION TEMPERATURE

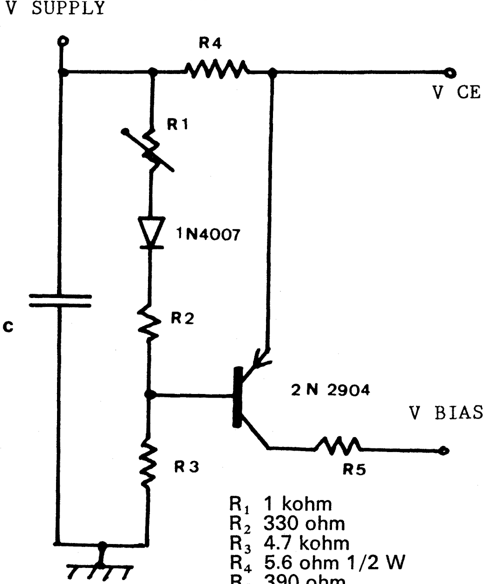


TEST CIRCUIT AT 860 MHz



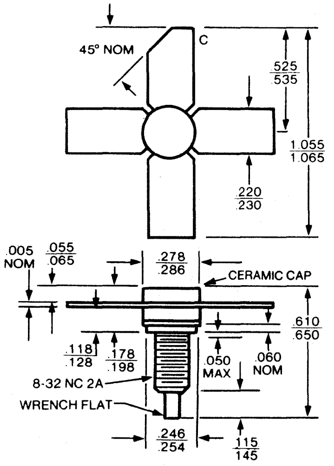
L = 6 turns ID = 1 mm Wire diameter = 0.6 mm
The lengths are given for F = 860 MHz

CLASS A BIAS CIRCUIT



R_1 1 kohm
R_2 330 ohm
R_3 4.7 kohm
R_4 5.6 ohm 1/2 W
R_5 390 ohm
C 100 μF + 10 nF + 1 nF

Package Outline



To convert inches to millimeters multiply by 2.54.

TRW® SEMICONDUCTORS

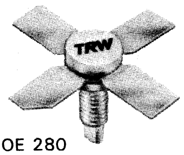
TPV 598

UHF LINEAR TRANSISTOR

(PRELIMINARY)

TV TRANSPOSER
BAND 4 - 5
4 W
6,5 DB GAIN
GOLD

The TPV 598 is a NPN gold metallized transistor using diffused emitter ballast resistors for super linearity. The chip design using microwave techniques provides over 6.5 dB gain at 860 MHz thereby reducing the complexity of the lower amplifier stages. The TPV 598 is specifically designed for **high power band 4 and 5 TV transposers.**



SOE 280

Electrical Characteristics (T_{CASE} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC Test	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 1 mA	4			V
	BV_{CEO}	Collector - Emitter Breakdown Voltage	I_C = 20 mA	25			V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 10 mA	45			V
	h_{FE}	D.C. Current Gain	V_{CE} = 5 V I_C = 500 mA	15	30		
RF Test	IMD	Intermodulation Distortion 3 Tone Vision Carrier = Reference - 8 dB Sound Carrier = Référence - 7 dB Sideband Carrier = Reference - 16 dB	F = 860 MHz V_{CE} = 25 V I_E = 850 mA P_{REF} = 4 W			— 60	dB
	P_G	Power Gain	F = 860 MHz V_{CE} = 25 V I_E = 850 mA P_{REF} = 4 W	7,0	7.5		dB
	C_{OB}	Collector - Base Capacitance	V_{CB} = 25 V F = 0.1 MHz		20		pF
	f_T	Cutoff Frequency	V_{CE} = 25 V I_E = 850 mA		2		GHz
Thermal	θ_{JC}	Thermal Resistance Junction - Case	T_{CASE} = 40 °C			5	°C/W
	T_{STG}	Storage Temperature		— 65		+ 200	°C
	T_J	Junction Temperature		- 65		+ 200	°C

TRW® SEMICONDUCTORS

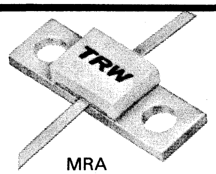
TPV 599

UHF LINEAR TRANSISTOR

(PRELIMINARY)

TV TRANSPOSER
BAND 4-5
7,5 W
6,5 DB GAIN
GOLD

The TPV 599 is a NPN gold metallized transistor using diffused emitter ballast resistors for super linearity. The chip design using microwave techniques provides over 6.5 dB gain at 860 MHz. Broadbandibility of the TPV 599 is insured by the insertion of input matching network inside the MRA package. The TPV 599 is specifically Designed for **high power band 4-5 TV transposers** and solid state **transmitters.**



MRA

Electrical Characteristics (T_{CASE} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC Test	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 2 mA	4			V
	BV_{CEO}	Collector - Emitter Breakdown Voltage	I_C = 40 mA	25			V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 20 mA	45			V
	h_{FE}	D.C. Current Gain	V_{CE} = 5 V I_C = 500 mA	15	30		
RF Test	IMD	Intermodulation Distortion 3 Tone Vision Carrier = Reference - 8 dB Sound Carrier = Reference - 7 dB Sideband Carrier = Reference - 16 dB	F = 860 MHz V_{CE} = 20 V I_E = 2 A P_{REF} = 7.5 W			— 60	dB
	P_G	Power Gain	F = 860 MHz V_{CE} = 20 V I_E = 2 A P_{REF} = 7.5 W	6,5	7		dB
	C_{OB}	Collector - Base Capacitance	V_{CB} = 20 V F = 0.1 MHz		40		pF
	f_T	Cutoff Frequency	V_{CE} = 20 V I_E = 2 A				GHz
Thermal	θ_{JC}	Thermal Resistance Junction - Case	T_{CASE} = 40 °C			2.5	°C/W
	T_{STG}	Storage Temperature		— 65		+ 200	°C
	T_J	Junction Temperature		- 65		+ 200	°C

FM

FM TRANSMITTERS

PRODUCT SUMMARY

P/N	OUTPUT POWER at 108 MHz (W)	GAIN DB	PAGE
MF 20	20	20	**353**
TP 9380	75	10.3	**355**
TP 9381	100	7.4	**359**
TP 9382	175	6.4	**363**
TP 9383	150	9.2	**367**

TRW® SEMICONDUCTORS **MF 20**

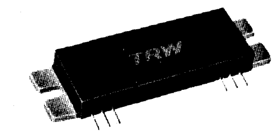
RF Power Module

88 - 108 MHz

20 W - 12.5 V

The MF modules are designed primarily for use in the broadcast band 88-108 MHz. They feature 50 Ω input and output impedance, to gether with 20 dB gain.

Application include the replacement of lover power PA stages by a single module which offers significant savings in size as well as cost of design, production and repair.

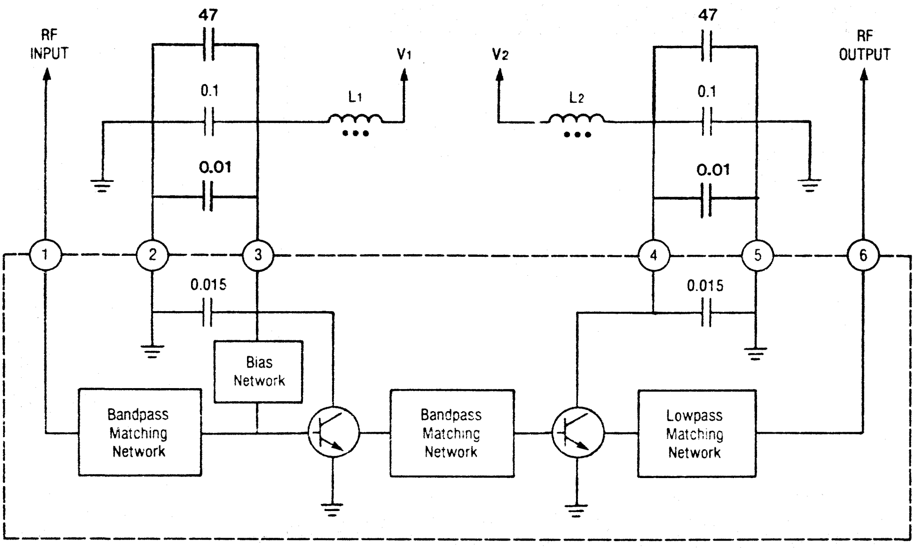


MVM

Preliminary Specification (T_{flange} = 25 °C)

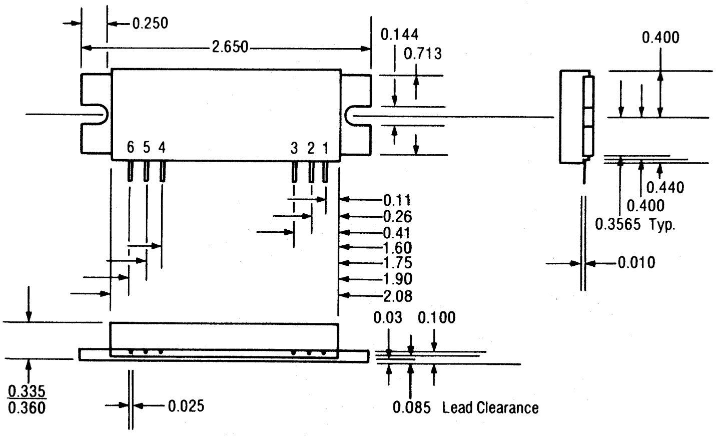
CHARACTERISTICS	TEST CONDITIONS	MF 20	Units/Limit
Frequency range		88-108	MHz
Supply Voltage V_{CC}		12.5	Vdc Nom.
Power Output	Rated V_{CC} Any in Band Frequency $P_{in} \leqslant 200$ mW	20	W-Min
Efficiency	Rated P_{out} — V_{CC}	40	%-Min
Harmonic Outputs	Rated P_{out} — V_{CC}	— 30	dB-Max
Input Return Loss	Rated P_{out} $Z_O = 50\ \Omega$	— 10	dB-Max
Output Impedance		50	Ω-Nom
Quiescent Current	$V_{CC} = 16$ V $P_{in} = 0$ W	0.1	Adc-Max
Power Slump	Rated P_{out} — V_{CC} 25 °C — 30 °C to + 80 °C	1	dB-Max
Load VSWR 0-360° (Degradation)	$V_{CC} = 16$ V $P_{in} = 300$ mW Lowest Frequency	20 : 1	No degradation
Load VSWR 0-360° (Stability)	$10\ \text{V} \leqslant V_{CC} \leqslant 16$ V $0 \leqslant P_{in} \leqslant 0.3$ W Any in band frequency	3 : 1 5 : 1	Min Typ
Temperature range	Operating, T_{Flange}	— 30 + 100	°C Min °C Max

CIRCUIT DIAGRAM FOR MF 20



L1, L2: Ferroxcube VK211173B, 2½ turns
All capacitor values in μF

MVM PACKAGE OUTLINE



TRW® **SEMICONDUCTORS** **TP 9380**

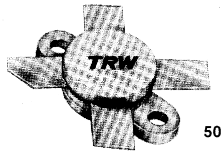
FM Power Transistor

PRELIMINARY DATA SHEET

75 W
108 MHz - 28 V
HIGH GAIN
RF POWER TRANSISTOR
NPN SILICON

The TP 9380 is designed for use in the new generation of VHF-FM broadcast transmitters operating from a 28 V supply in class A, B or C.

Its construction, which now incorporates the new standard TRW process of gold metallization and diffused ballast resistors, ensures a long operational life even when run at its maximum ratings.

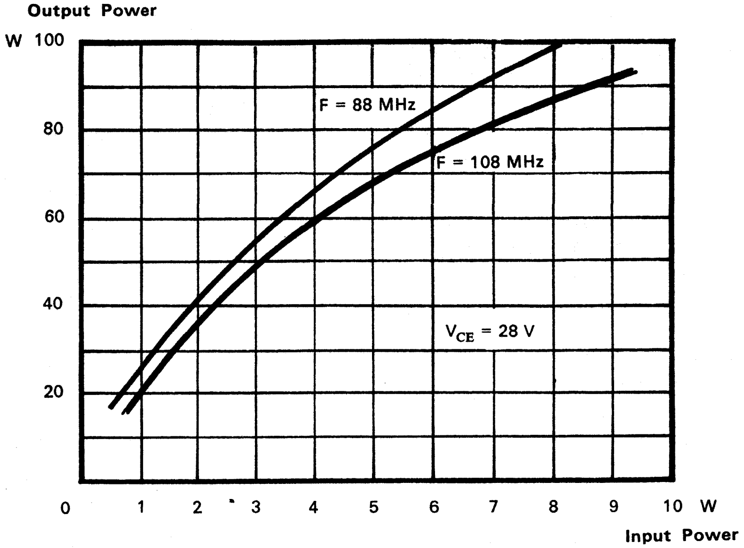


500 SOE F

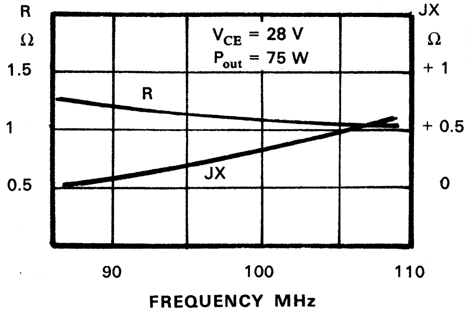
Electrical Characteristics (T_{case} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC TEST	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 10 mA	4			V
	BV_{CEO}	Collector - Emitter Breakdown Voltage	I_C = 50 mA	35			V
	BV_{CER}	Collector - Emitter Breakdown Voltage	I_C = 50 mA R_{BE} = 10 Ω	60			V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 50 mA	65			V
	H_{FE}	DC Current Gain	V_{CE} = 5 V I_C = 1 A	20		150	—
RF TEST	P_G	RF Power Gain	V_{CE} = 28 V P_{in} = 7 W F = 108 MHz	75			W
	η_C	Collector Efficiency	V_{CE} = 28 V P_{out} = 75 W F = 108 MHz	70	75		%
	C_{OB}	Output Capacitance	V_{CB} = 30 V F = 1 MHz			85	pF
	VSWR	Mismatch Tolerance (All phases)	V_{CE} = 28 V P_{out} = 75 W F = 108 MHz All phases	4 : 1			—
THERMAL	I_C	Maximum Collector Current				10	A
	θ_{jc}	Thermal Resistance Junction Case	T case = 70 °C			1.5	°C/W
	θ_{CH}	Thermal Resistance Case Heatsink				0.25	°C/W
	P_S	Power Dissipated	T heatsink = 25 °C			100	W
	T_{STG}	Storage and Junction Temperature		— 65		+ 200	°C

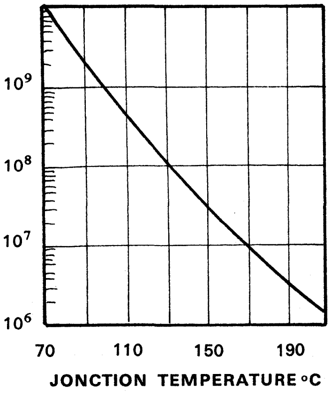
TYPICAL POWER OUTPUT vs POWER INPUT



SERIES INPUT IMPEDANCE vs FREQUENCY

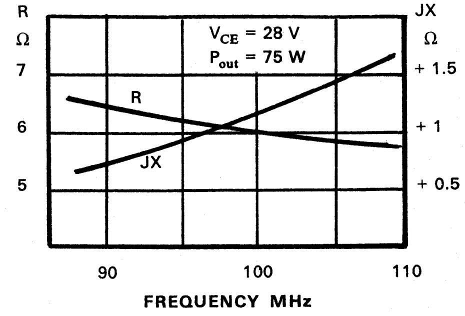


MTTF FACTOR vs Tj

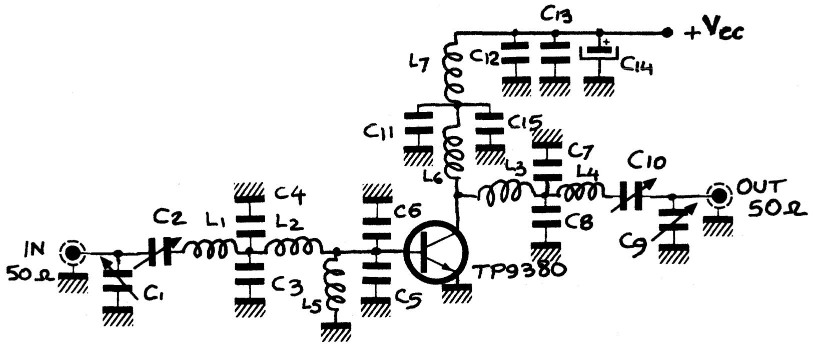


DIVIDE BY Ic2 TO OBTAIN METAL
LIFETIME IN HOURS

SERIES LOAD IMPEDANCE vs FREQUENCY



88-108 MHz NARROW BAND TEST FIXTURE



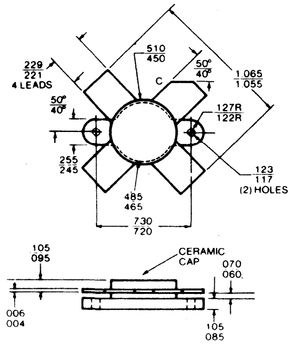
C_1	Arco 425 Variable capacitor (24 - 200 pF).
C_2	Arco 425 Variable capacitor (24 - 200 pF).
C_3	60 pF UNELCO.
C_4	60 pF UNELCO (108 MHz).
	100 pF UNELCO (88 MHz).
C_5	330 pF chip capacitor (closed to the transistor).
C_6	330 pF chip capacitor (closed to the transistor).
C_7	40 pF UNELCO.
C_8	40 pF UNELCO (108 MHz).
	80 pF UNELCO (88 MHz).
C_9	Arco 423 variable capacitor (7 - 100 pF).
C_{10}	Arco 425 variable capacitor (24 - 200 pF).
C_{11}	1 000 pF UNELCO.
C_{12}	1 000 pF UNELCO.
C_{13}	0.1 μF disc capacitor.
C_{14}	100 μF/40 V capacitor.
C_{15}	10 nF disc capacitor.

L_1	3 turns ID = 6 mm 1 mm wire.	
L_2	« Hair pin » made with a 1.4 mm wire	L = 15 mm
L_3	« Hair pin » made with a 2 mm wire	L = 20 mm for 108 MHz.
	« Hair pin » made with a 2 mm wire	L = 30 mm for 88 MHz.
L_4	3 turns ID = 8 mm 1.4 mm wire.	
L_5	0.7 μH chocke.	
L_6	6 turns ID = 6 mm 1.2 mm wire	L = 15 mm.
L_7	4 turns 1.2 mm wire on fenite.	

Use an ultra flat heatsink.

Use a few of silicon thermal grease.

PACKAGE
500 SOE F



TRW® **SEMICONDUCTORS** **TP 9381**

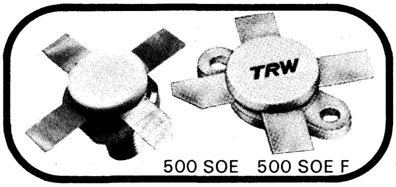
FM Power Transistor

PRELIMINARY DATA SHEET

100 W
108 MHz
28 V
RF POWER
NPN SILICON

The TP 9381 is designed for use in the new generation of VHF-FM broadcast transmitters operating from a 28 V supply in class A, B, or C.

Its construction, which now incorporates the new standard TRW process of gold metallization and diffused ballast resistors ensures a long operational life even when run at its maximum ratings.



500 SOE 500 SOE F

Electrical Characteristics (T_{case} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC TEST	BV_{EBO}	Emitter Base Breakdown Voltage	I_E = 5 mA	4			V
	BV_{CEO}	Collector Emitter Breakdown Voltage	I_C = 50 mA	35			V
	BV_{CES}	Collector Emitter Breakdown Voltage	I_C = 100 mA Emitter base short circuited	60			V
	I_{CES}	Collector cut off current	V_{CE} = 25 V			10	mA
	h_{FE}	DC current gain	V_{CE} = 10 V I_C = 1 A	20		150	—
RF TEST	P_{out}	Commun Emitter Amplifier output power	V_{CE} = 28 V P_{in} = 18 W F = 108 MHz	100			W
	η_C	Collector Efficiency	V_{CE} = 28 V P_{out} = 100 W F = 108 MHz	75			%
	C_{ob}	Output Capacitance	V_{CB} = 28 V F = 1 MHz			200	pF
	VSWR	Voltage Standing wave ratio	V_{CE} = 28 V P_{out} = 100 W F = 108 MHz All phases	∞			—
THERMAL	$Rth_{J.C}$	Thermal Resistance Junction - Case	Pd = 80 W t = 25 °C t = 70 °C		0,85 1	 1,1	°C/W °C/W
	$Rth_{C.H}$	Thermal Resistance Case - Heatsink			0,15		°C/W

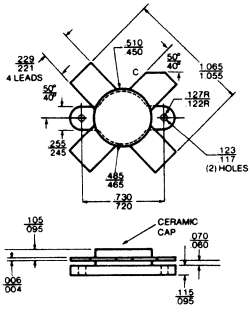
TP 9381/A

Absolute Maximum Ratings

Emitter Base Voltage	V_{EB}	4 V
Collector Emitter Voltage	V_{CE}	35 V
Collector Base Voltage	V_{CB}	60 V
Collector current	I_C	12 A
Total device power dissipation t_{case} = 25 °C	P_d	150 W
Storage and Junction temperature	T_{STG}	— 65 to 200 °C

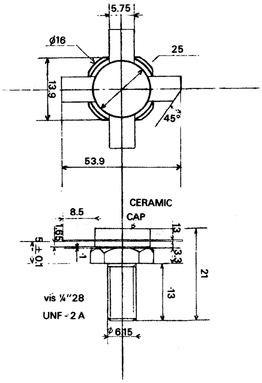
TP 9381

500 SOE F



TP 9381 A

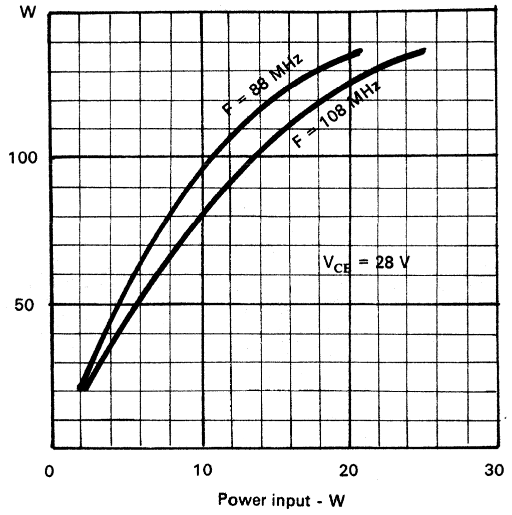
500 SOE I/4 STUD



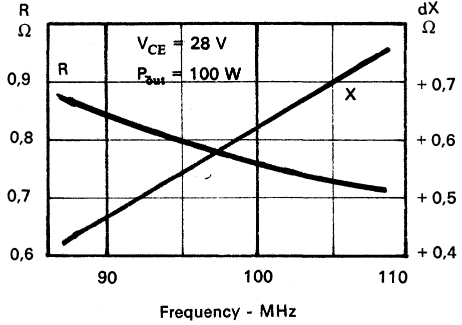
Stud torque :
min 21 kg.cm
max 25 kg.cm

Use ultra flat heat sink. Make stud hole as small as possible. Use a few of silicon grease.

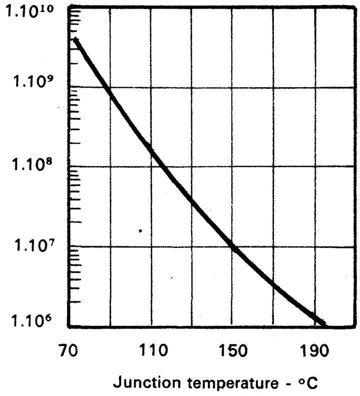
Power Output vs Power Input



Series Input Impedance vs frequency

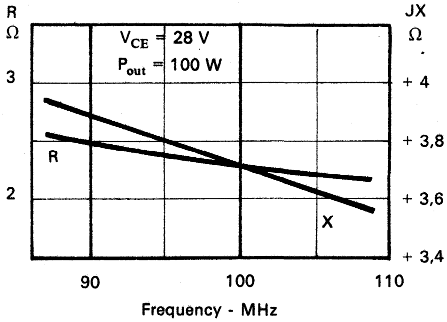


MTTF Factor vsTj

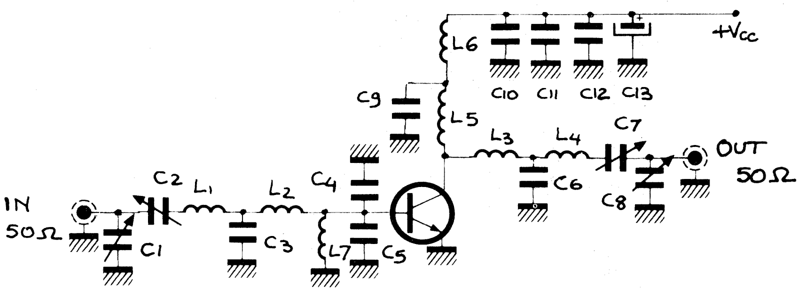


Divide by Ic^2 to obtain metal lifetime in hours

Series load Impedance vs frequency



Test Circuit 88-108 MHz
Narrow band



C_1	ARCO 425 Variable capacitor 24-200 pF
C_2	ARCO 425
C_3	150 pF UNELCO
C_4	470 pF Chip capacitor (very close to the transistor) ATC
C_5	470 pF Chip capacitor (very close to the transistor) ATC
C_6	300 pF UNELCO
C_7	ARCO 425
C_8	ARCO 425
C_9	1000 pF UNELCO
C_{10}	1000 pF UNELCO
C_{11}	10000 pF
C_{12}	0.1 μF
C_{13}	100 μF/40 V electrolytic

L_1	3 turns 6 mm ID 1.2 mm wire
L_2	2 cm wire 1.2 mm Ω (hair pin)
L_3	1.2 cm wire 1.2 mm Ω (hair pin)
L_4	3 turns 6 mm ID 1.2 mm wire
L_5	6 turns 8 mm ID 1.5 mm wire
L_6	6 turns 1.5 mm wire on ferrite core
L_7	10 μH chocke

TRW® **SEMICONDUCTORS** **TP 9382**

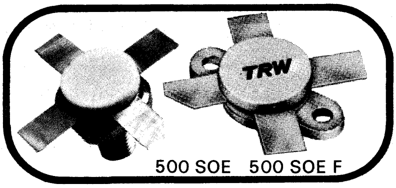
FM Power Transistor

PRELIMINARY DATA SHEET

175 W
108 MHz 28 V
HIGH POWER RF
TRANSISTOR
NPN SILICON

The TP 9382 is designed for use in new generation of VHF-FM broadcast transmitters operating from a 28 V supply in class A, B, or C.

Its construction, which incorporates the now standard TRW process of gold metallization and diffused ballast resistors, ensures a long operational life even when run at its maximum ratings.



500 SOE 500 SOE F

Electrical Characteristics (T_{case} = 25 °C)

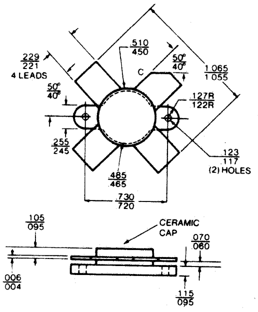
	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC TEST	BV_{EBO}	Emitter Base Breakdown Voltage	I_E = 10 mA	4			V
	BV_{CEO}	Collector Emitter Breakdown Voltage	I_C = 100 mA	35			V
	BV_{CES}	Collector Emitter Breakdown Voltage	I_C = 200 mA Emitter Base Short circuited	60			V
	I_{CES}	Collector cutoff current	V_{CE} = 25 V			20	mA
	h_{FE}	DC current gain	V_{CE} = 10 V I_C = 1 A	20		150	—
RF TEST	P_{out}	Commun Emitter Amplifier Output power	V_{CE} = 28 V P_{in} = 40 W F = 108 MHz	175			W
	η_C	Collector Efficiency	V_{CE} = 28 V P_{out} = 175 W F = 108 MHz	75			%
	C_{ob}	Output Capacitance	V_{CB} = 28 V F = 1 MHz			380	pF
	VSWR	Voltage Standing Wave Ratio	V_{CE} = 28 V P_{out} = 175 W F = 108 MHz				—
THERMAL	$Rth_{J.C}$	Thermal Resistance Junction - Case	Pd = 100 W t = 25 °C t = 70 °C		0,5 0,6	0,7	°C/W
	$Rth_{C.H}$	Thermal Resistance Case - Heatsink			0,15		°C/W

Absolute Maximum Ratings

Emitter Base Voltage	V_{EB}	4 V
Collector Emitter Voltage	V_{CE}	35 V
Collector Base Voltage	V_{CB}	60 V
Collector Current	I_C	24 A
Total device Power dissipation (t_{case} = 25 °C)	P_d	250 W
Storage and Junction temperature	$T°_S$	— 65 to 200 °C

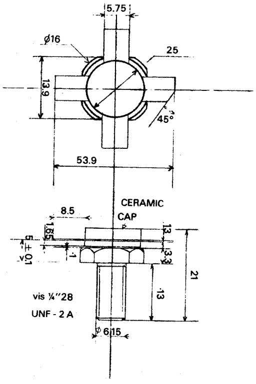
TP 9382

500 SOE F



TP 9382 A

500 SOE I/4 STUD



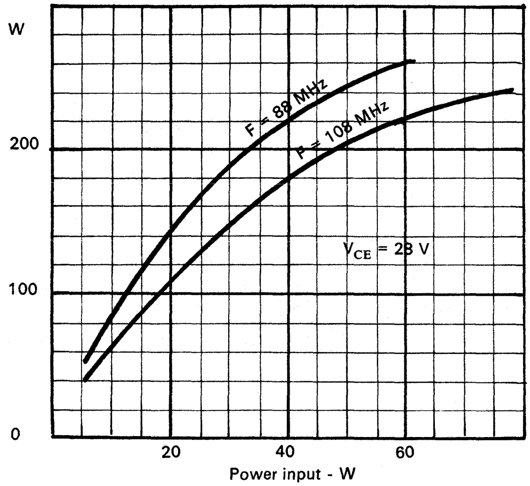
TP 9382/A

Stud torque :

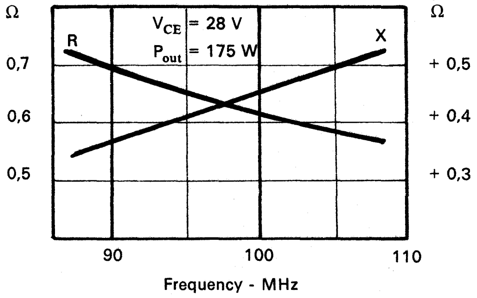
min 21 kg.cm
max 25 kg.cm

Use ultra flat heat sink. Make stud hole as small as possible. Use a few of silicon grease.

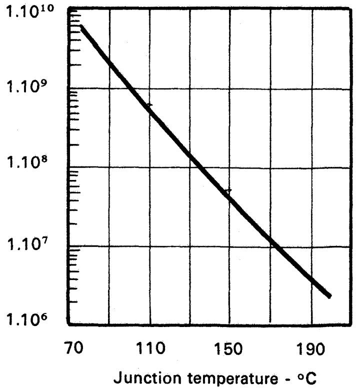
Power Output vs Power Input



Series Input Impedance vs frequency

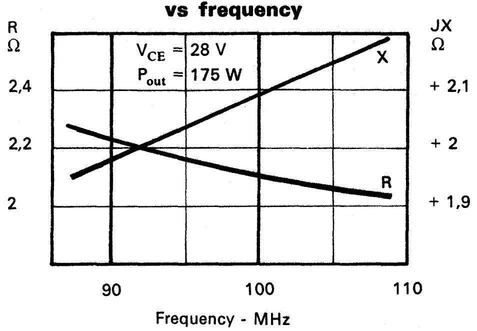


MTTF factor vs Tj

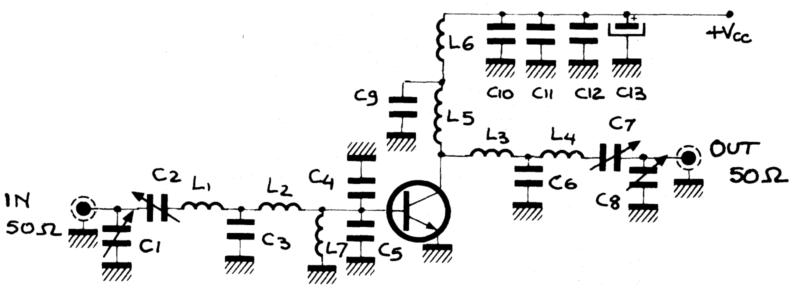


Divide by Ic^2 to obtain metal lifetime in hours.

Series load Impedance vs frequency



Test Circuit 88-108 MHz
Narrow band



C_1	ARCO 425 Variable capacitor 24-200 pF
C_2	ARCO 425
C_3	150 pF UNELCO
C_4	470 pF Chip capacitor (very close to the transistor) ATC
C_5	470 pF Chip capacitor (very close to the transistor) ATC
C_6	300 pF UNELCO
C_7	ARCO 425
C_8	ARCO 425
C_9	1000 pF UNELCO
C_{10}	1000 pF UNELCO
C_{11}	10000 pF
C_{12}	0.1 μF
C_{13}	100 μF/40 V electrolytic

L_1	3 turns 6 mm ID 1.2 mm wire
L_2	2 cm wire 1.2 mm Ω (hair pin)
L_3	1.2 cm wire 1.2 mm Ω (hair pin)
L_4	3 turns 6 mm ID 1.2 mm wire
L_5	6 turns 8 mm ID 1.5 mm wire
L_6	6 turns 1.5 mm wire on ferrite core
L_7	10 μH chocke

TRW® SEMICONDUCTORS **TP 9383**

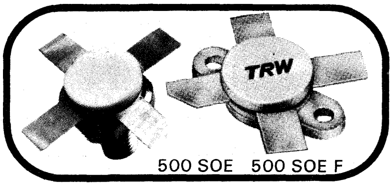
FM Power Transistor

PRELIMINARY DATA SHEET

150 W
108 MHz 28 V
HIGH GAIN
RF POWER
TRANSISTOR
NPN SILICON

The TP 9383 is designed for use in the new generation of VHF-FM broadcast trasmitters operating from a 28 V supply in class A, B, or C.

Its construction, which now incorporates the new standard TRW process of gold metallization and diffused ballast resistors, ensures a long operational life even when run at its maximum ratings.



500 SOE 500 SOE F

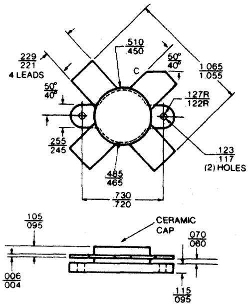
Electrical Characteristics (T_{case} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC TEST	BV_{EBO}	Emitter Base Breakdown Voltage	I_E = 20 mA	4			V
	BV_{CEO}	Collector Emitter Breakdown Voltage	I_C = 100 mA	25			V
	BV_{CER}	Collector Emitter Breakdown Voltage	I_C = 100 mA R_{BE} = 10 Ω	60			V
	BV_{CBO}	Collector Base Breakdown Voltage	I_C = 100 mA	65			V
	h_{FE}	DC current gain	V_{CE} = 5 V I_C = 1 A	20		150	—
RF TEST	P_{out}	Commun Emitter Amplifier output power	V_{CE} = 28 V P_{in} = 18 W F = 108 MHz	150			W
	η_C	Collector Efficiency	V_{CE} = 28 V P_{out} = 150 W F = 108 MHz	70	75		%
	C_{ob}	Output Capacitance	V_{CB} = 28 V F = 1 MHz			150	pF
	VSWR	Voltage Standing wave Ratio	V_{CE} = 28 V P_{out} = 100 W F = 108 MHz P_{out} = 150 W All phases	∞ 4 : 1			— —
THERMAL	$Rth_{J.C}$	Thermal Resistance Junction - Case	Pd = 100 W t = 25 °C t = 70 °C		0,75 0,9	 1	°C/W
	$Rth_{C.H}$	Thermal Resistance Case - Heatsink			0,15		°C/W

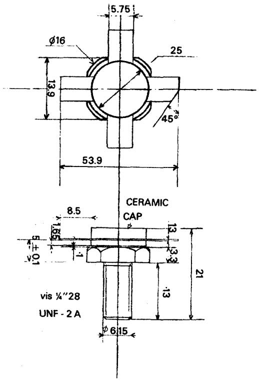
Absolute Maximum Ratings

Emitter Base Voltage	V_{EB}	4 V
Collector Emitter Voltage	V_{CE}	35 V
Collector Base Voltage	V_{CB}	60 V
Collector Current	I_C	16 A
Total device power dissipation $t_{case} = 25$ °C	P_d	150 W
Storage and junction temperature	T_{STG}	— 65 to + 200 °C

TP 9383
500 SOE Flange



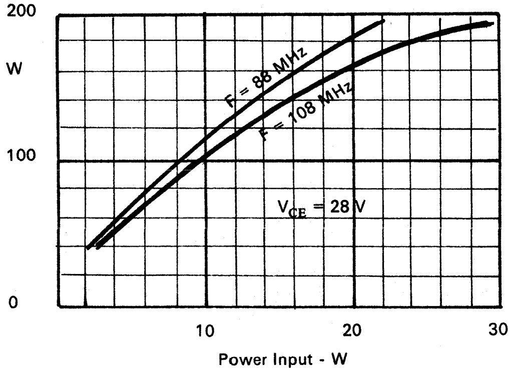
TP 9383 A
500 SOE 1/4″ Stud



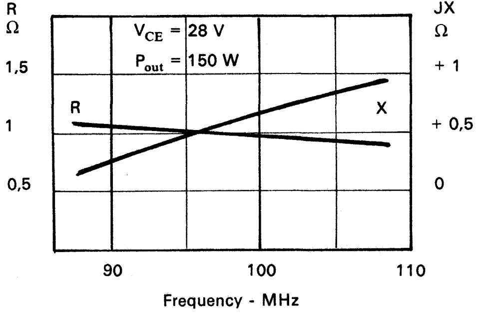
Stud Torque :
Min : 21 kg.cm
Max : 25 kg.cm

Use ultra flat heatsink. Make Stud hole as small as possible.
Use a few of silicon grease.

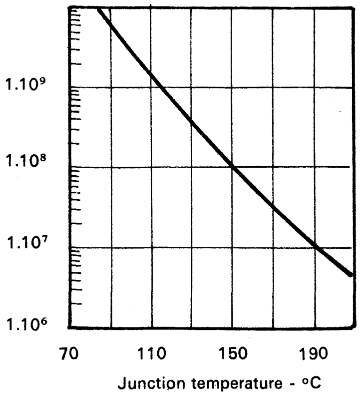
Power Output vs Power Input



Series Input Impedance vs frequency

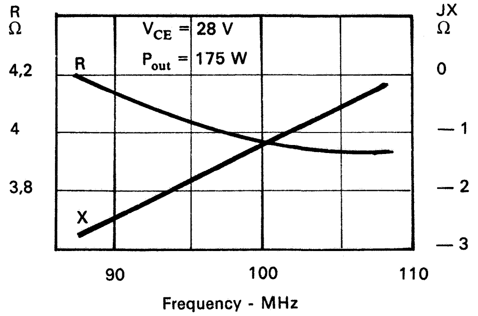


MTTF factor vs Tj

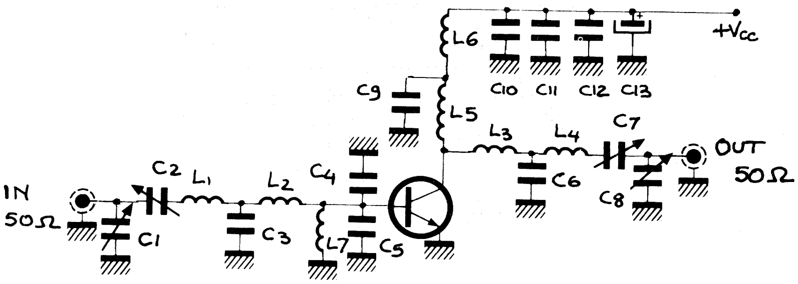


Divide by Ic^2 to obtain metal lifetime in hours.

Series load impedance vs frequency



Test circuit 88-108 MHz
Narrow band



C_1	ARCO 425 Variable capacitor 24-200 pF
C_2	ARCO 425
C_3	150 pF UNELCO
C_4	470 pF Chip capacitor (very close to the transistor) ATC
C_5	470 pF Chip capacitor (very close to the transistor) ATC
C_6	300 pF UNELCO
C_7	ARCO 425
C_8	ARCO 425
C_9	1000 pF UNELCO
C_{10}	1000 pF UNELCO
C_{11}	10000 pF
C_{12}	0.1 μF
C_{13}	100 μF/40 V electrolytic

L_1	3 turns 6 mm ID 1.2 mm wire
L_2	2 cm wire 1.2 mm Ω (hair pin)
L_3	1.2 cm wire 1.2 mm Ω (hair pin)
L_4	3 turns 6 mm ID 1.2 mm wire
L_5	6 turns 8 mm ID 1.5 mm wire
L_6	6 turns 1.5 mm wire on ferrite core
L_7	10 μF chocke

MICROWAVE

MICROWAVE POWER TRANSISTORS

PRODUCT SUMMARY

LINEAR MICROWAVE TRANSISTORS

			PAGE
TRW 52601/602/604	2 GHz	TO 6 W	**461/465/469**
TRW 53601/602	3 GHz	0,8 AND 1,6 W	**473/477**
TRW 54601	4 GHz	0,5 W	**481**

MICROWAVE OSCILLATOR TRANSISTORS

TRW 62601/602	2 GHz	1 AND 2 W	**485/489**
TRW 63601/602	3 GHz	0,4 AND 0,8 W	**493/497**
TRW 64601/602	4 GHz	0,3 W	**501/505**

MICROWAVE POWER TRANSISTORS

2 N 4429/4430/4431	1 GHz	TO 5 W	**375**
TRW 2001/03/05/10/15/20	2 GHz	TO 20 W	**437**
TRW 2301/04/07	2,3 GHz	TO 7 W	**449/450/451**
TRW 3001/03/05	3 GHz	TO 5 W	**453**

BROADBAND MICRO AMP'S

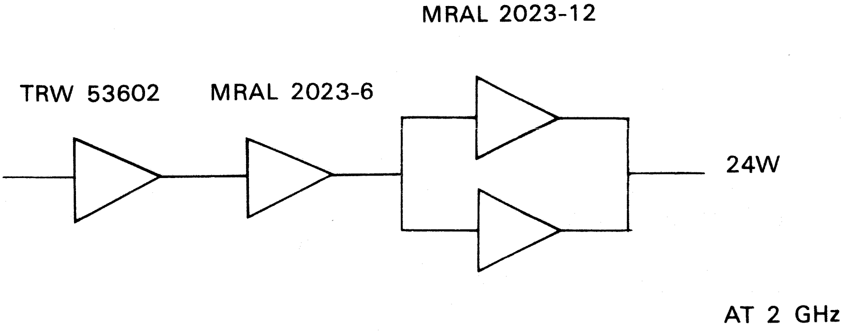
MRA 0610-SERIES	0.6-1.0 GHz	TO 40 W	**379**
MRA 1014-SERIES	1.0-1.4 GHz	TO 35 W	**387**
MRA 1417-SERIES	1.4-1.7 GHz	TO 25 W	**395**
MRA 1720-SERIES	1.7-2.0 GHz	TO 20 W	**403**
MRAL 2023-SERIES	2.0-2.3 GHz	TO 12 W	**417**

BROADBAND PULSE MICROWAVE TRANSISTORS

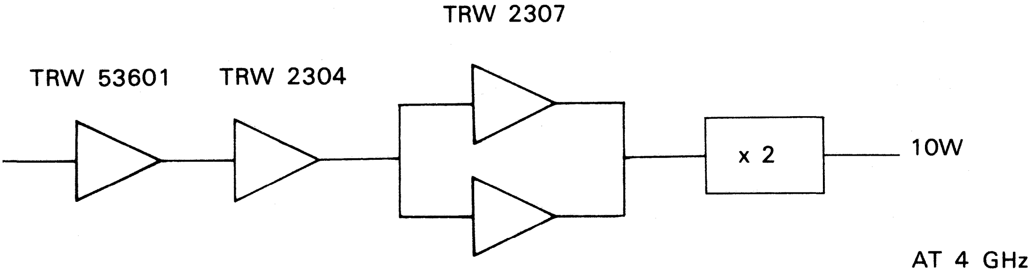
MRP 0912-50	0.9-1.2 GHz	50 W	**419**
MRP 0912-75	0.9-1.2 GHz	75 W	**423**
MRP 0912-150	0.9-1.2 GHz	150 W	**427**
MRP 0912-250	0.9-1.2 GHz	250 W	**431**
MRP 1115-1.5 E	1.1-1.5 GHz	1,5 W	**435**
MRP 1214-8	1.2-1.4 GHz	8 W	**435**
MRP 1214-12 A	1.2-1.4 GHz	12 W	**436**
MRP 1214-30	1.2-1.4 GHz	30 W	**435**
MRP 1214-40 A	1.2-1.4 GHz	40 W	**436**
MRP 1214-60	1.2-1.4 GHz	60 W	**435**
MRP 1214-85 A	1.2-1.4 GHz	85 W	**436**

MICROWAVE
LINE-UP SUGGESTIONS

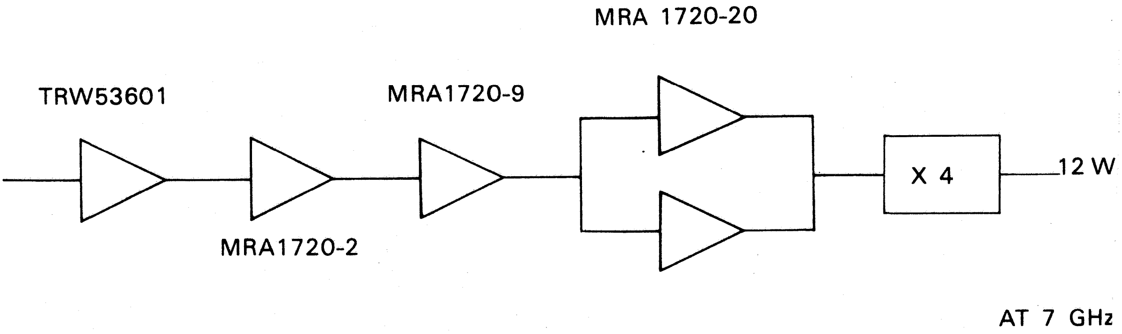
2 GHz FUNDAMENTAL



4 GHz MULTIPLICATION

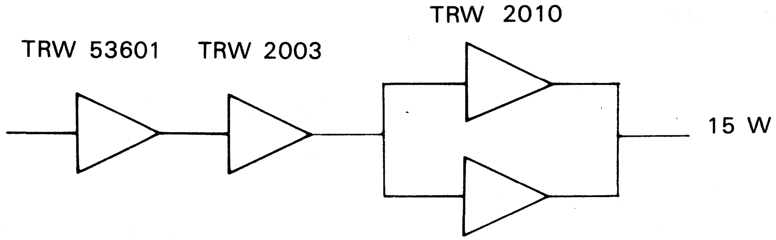


7 GHz MULTIPLICATION

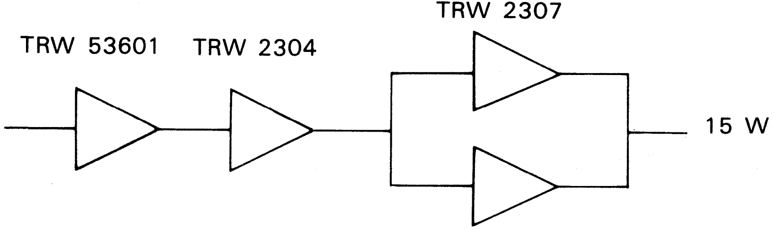


MICROWAVE
LINE-UP SUGGESTIONS

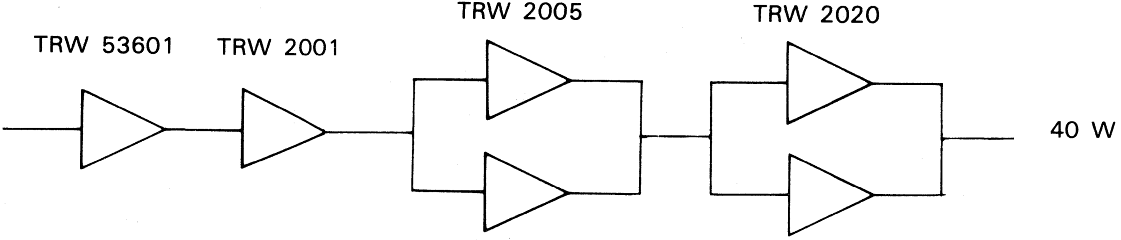
L BAND TELEMETRY 1.4 GHz



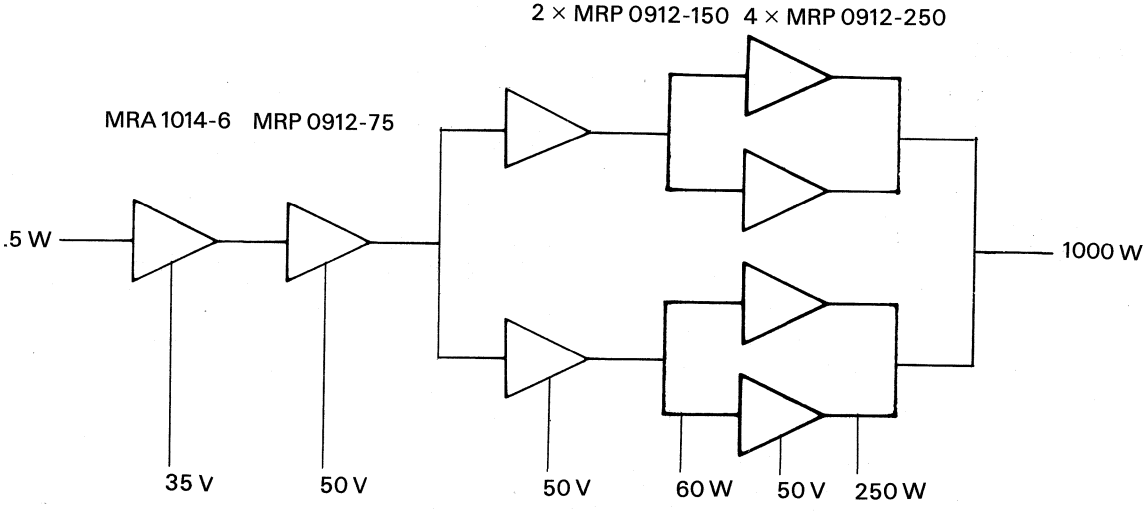
S BAND TELEMETRY 2.2 GHz



MARISAT SHIPBOAD 1.6 GHz



DME - TACAN AIRCRAFT 960 - 1215 MHz - 1 kW



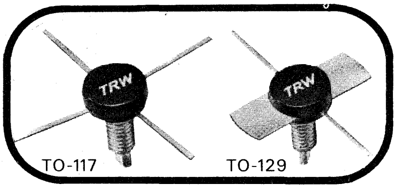
TRW® SEMICONDUCTORS **1GHz SERIES**

Microwave Power Transistors

2N 4429 - 1W
2N 4430 - 3W
2N 4431 - 5W

These are the first series of high power gigahertz transistors introduced in 1966 and in continuous production since that time.

The low cost and continuity of these products along with their lona production history continues to make this family a good choice for oscillators, amplifier and multiplier below 1 GHz.

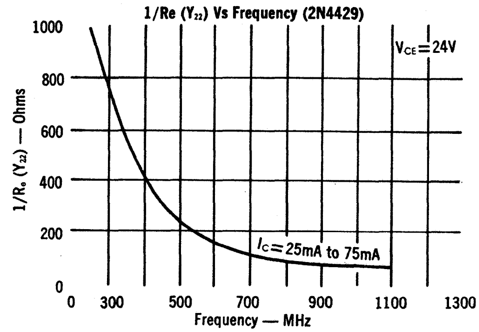


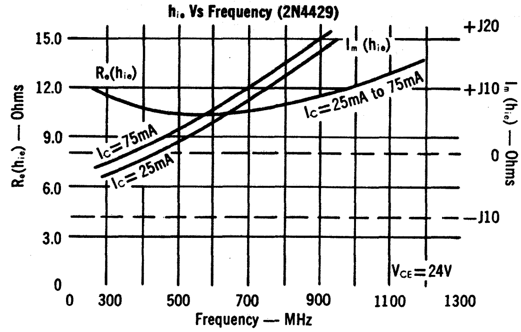
Electrical Characteristics (T_{stud} = 25 °C)

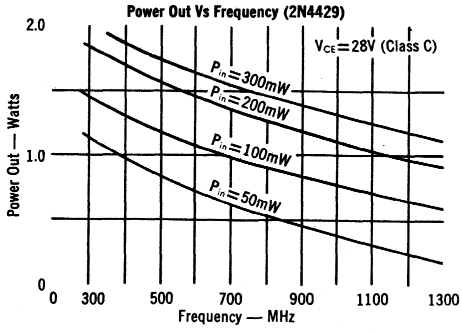
					2N4431		2N4430		2N4429	
	SYMBOL	CHARACTERISTICS	TEST CONDITIONS		Min.	Max.	Min.	Max.	Min.	Max.
DC Tests	I_{CEX}	Collector Cutoff Current	V_{CE} = 55 V	V_{BE} = — 1.5 V		4.0 mA		2.0 mA		1.0 mA
	V_{CEO}	Collector to Emitter Voltage	I_C = 50 mA I_C = 20 mA	I_b = 0 I_b = 0	40 V		40 V		35 V	
	V_{CER}	Collector to Emitter Voltage	R = 10 Ω R = 10 Ω	I_C = 50 mA I_C = 20 mA	55 V		55 V		55 V	
	V_{EBO}	Emitter to Base Voltage	I_e = 0.50 mA I_e = 0.20 mA I_e = 0.10 mA		3.5 V		3.5 V		3.5 V	
	h_{FE}	DC Current Gain	V_{CE} = 5 V V_{CE} = 5 V	I_C = 100 mA I_C = 50 mA	20	200	20	200	20	200
RF Tests	f_t	Gain-Bandwidth Product Measured at 200 MHz	V_{CE} = 20 V V_{CE} = 20 V	I_C = 100 mA I_C = 50 mA	600 MHz		600 MHz		700 MHz	
	C_{ob}	Collector to Base Capacitance	V_{CB} = 28 V	f = 1.0 MHz		10 pF		5.0 pF		3.5 pF
	P_{out}	Power Output V_{CE} = 28 Volts n = Collector Efficiency > 35 %	f = 1000 MHz f = 1000 MHz f = 1000 MHz	P_{in} = 1.57 W P_{in} = 750 mW P_{in} = 300 mW	5.0 W		2.5 W		1.0 W	
Operating	I_C	Continuous Collector Current			2.0 A		1.0 A		425 mA	
	P_T	Total Dissipation at 25 °C Stud			18 W		10 W		5.0 W	
	θ_{JC}	Thermal Resistance (Junction to Stud)			9.7 °C/W		17.5 °C/W		35 °C/W	
	T_{stg}	Storage Temperature			— 65 to 200 °C		— 65 to 200 °C		— 65 to 200 °C	
	T_J	Junction Temperature			— 65 to 200 °C		— 65 to 200 °C		— 65 to 200 °C	

Typical Performance Characteristics

2 N 4429


1/Re (Y₂₂) Vs Frequency (2N4429)

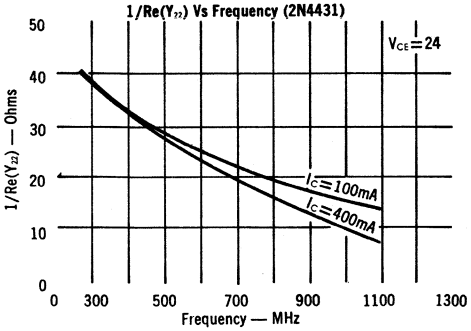

hᵢₑ Vs Frequency (2N4429)


Power Out Vs Frequency (2N4429)

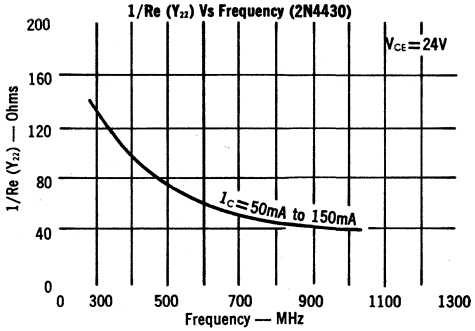
Typical Performance Characteristics

2 N 4431/2 N 4430

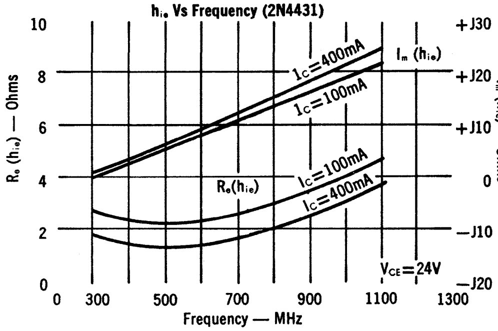
1/Re(Y$_{22}$) Vs Frequency (2N4431)



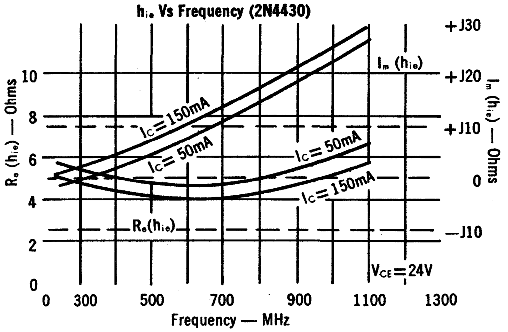
1/Re (Y$_{22}$) Vs Frequency (2N4430)



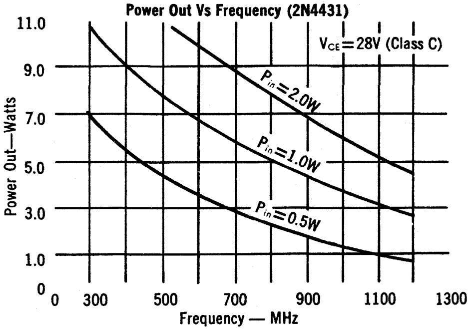
h$_{ie}$ Vs Frequency (2N4431)



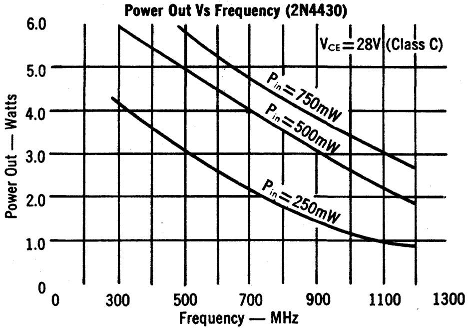
h$_{ie}$ Vs Frequency (2N4430)



Power Out Vs Frequency (2N4431)

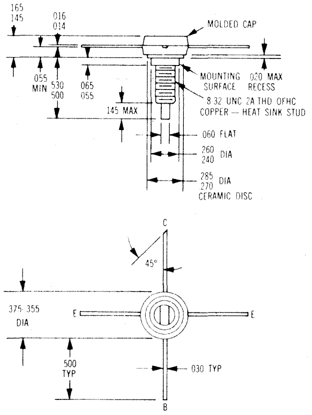


Power Out Vs Frequency (2N4430)

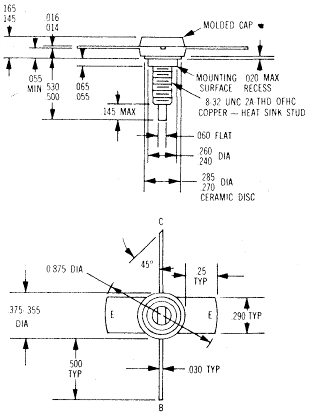


Case Drawings and Test Circuits

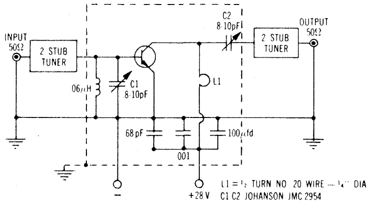
UHF Low Profile Package
(2N4429)



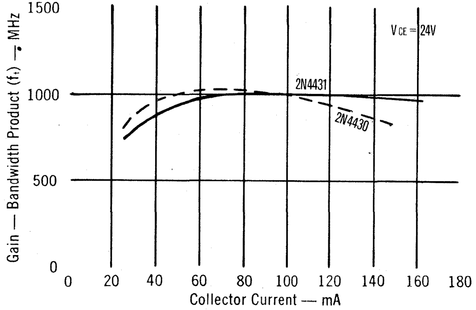
UHF Stripline Package
(2N4431 / 2N4430)



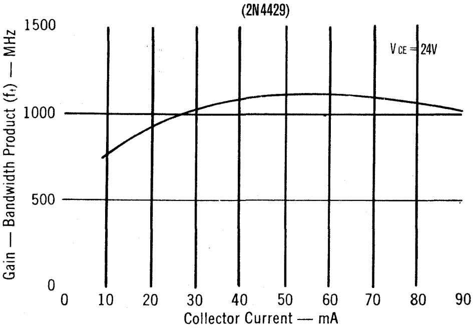
1.0 GHz Test Circuit
(2N4431 / 2N4430 / 2N4429)



Gain — Bandwidth Product Vs Collector Current
(2N4430 & 2N4431)



Gain — Bandwidth Product Vs Collector Current
(2N4429)



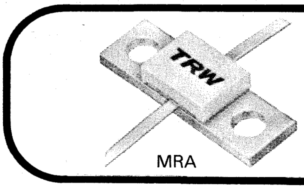
TRW® **SEMICONDUCTORS**

MRA 0610 Series

MICROAMP

MRA 0610-3
MRA 0610-9
MRA 0610-18
MRA 0610-40

- **3-9-18-40 Watts**
- **Broadband 600-1000 MHz**
- **Internally Compensated***
- **Gold Metalized**
- **Diffused Ballast Resistors**
- **MTTF Data**



MRA

Electrical Characteristics (T_{flange} = 25 °C)

Symbol	Characteristic	MRA0610-3	MRA0610-9	MRA0610-18	MRA0610-40
BV_{CER}	Collector-Base Breakdown Voltage $R_{BE} = 10\ \Omega$	I_C = 20 mA 50 V Min	I_C = 60 mA 50 V Min	I_C = 100 mA 50 V Min	I_C = 200 mA 50 V Min
BV_{EBO}	Emitter-Base Breakdown Voltage	I_E = 0.25 mA 3.5 V Min	I_B = 0.5 mA 3.5 V Min	I_B = 1.25 mA 3.5 V Min	I_E = 2.5 mA 3.5 V Min
I_{CBO}	Collector Cutoff Current I_E = 0	V_{CB} = 28 V 0.5 mA	V_{CB} = 28 V 1.5 mA	V_{CB} = 28 V 2.5 mA	V_{CB} = 28 V 5.0 mA
		V_{CB} = 45 V 1.0 mA	V_{CB} = 45 V 3.0 mA	V_{CB} = 45 V 5.0 mA	V_{CB} = 45 V 10.0 mA
I_C	Max Continuous Collector Current V_{CE} = 4 V	0.5 A	1.5 A	5.0 A	10.0 A
h_{FE}	Forward Current Transfer Ratio V_{CE} = 5 V	I_C = 0.1 A 10-100	I_C = 0.3 A 10-100	I_C = 0.5 A 10-100	I_C = 1.0 A 10-100
θ_{jF}	Thermal Resistance Junction to Flange	15 °C/W	6 °C/W	4 °C/W	2.5 °C/W
P_o	Min Broadband Power Output	3.0 W	9.0 W	18.0 W	40.0 W
C_{ob}	Max Collector-Base Capacitance V_{CB} = 28 V, f = 1 MHz	4.5 pF	10 pF	14 pF	28 pF
$P_{G(dB)}$	Min Power Gain in dB V_{CB} = 28 V	P_o = 3.0 W 7.8 dB	P_o = 9.0 W 7.8 dB	P_o = 18.0 W 7.8 dB	P_o = 40.0 W 7.0 dB
MTTF	Metal Failure Factor Hrs × Amps^2 T_j = 150 °C*	60,692	546,227	1,517,298	6,069,192
η_c	Min Broadband Collector Efficiency	P_o = 3.0 W 50 %	P_o = 9.0 W 55 %	P_o = 18.0 W 55 %	P_o = 40.0 W 55 %
T_j & T_{STG}	Maximum Junction and Storage Temperatures : — 65 to + 200 °C				

* Based on Black's equation and using $\varphi = 0.96$ EV, $\beta = 1.07 \times 10^{-12}$ 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 output matching using MOS capacitors, wire bonds and other techniques is patented by TRW, Inc. (US # 3,713,006).

The TRW MRA0610 series offers a complete family of broadband, high-gain transistors for applications in the 600-1000MHz band.

Using internal compensation (a patented* technique developed and first offered for sale by TRW), the MRA0610 series is intended for use in a variety of military and industrial applications including ECM, radio relay and the "960" mobile band for fixed station use.

The smooth, broadband transfer characteristics of the MRA0610 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 3, 9, 18 and 40 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 MRA0610 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 MRA0610 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 such as 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 MRA0610 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 reason, TRW RF Semiconductors uses a gold metalization system on all microwave transistors including the MRA0610 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 $Z(R_{bb})$ 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.

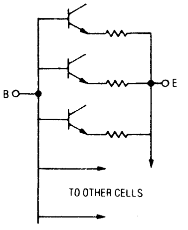


Figure 1. Elementary Method of Cell Combining

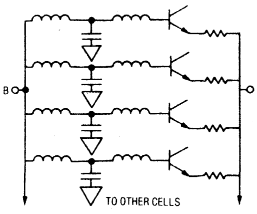


Figure 2. Cells Combined with Transformers

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

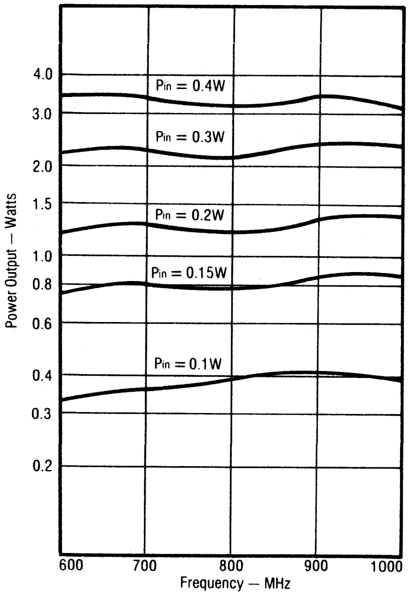
Because of the nature of source impedance driving the transistor cell (essentially a voltage source), as much as 10dB additional usable dynamic range without noticeably altering bandwidth or tuning is possible with the MICroAMP.

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.

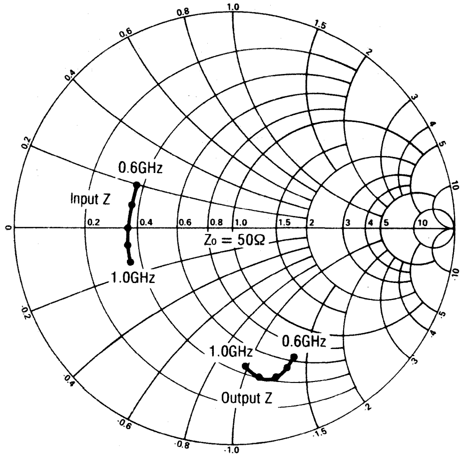
*TRW U.S. Patent #3,713,006

MRA0610-3 — 3 WATTS BROADBAND

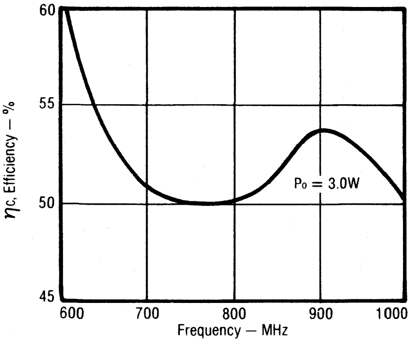
Typical Power Output vs Frequency



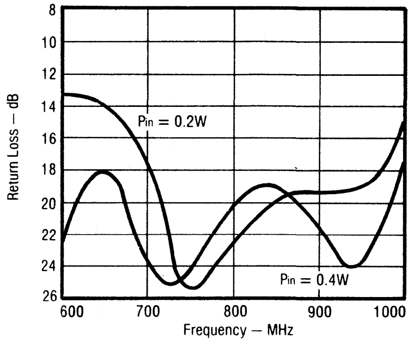
Impedance Data
Vcc = 28V



Typical Efficiency vs Frequency

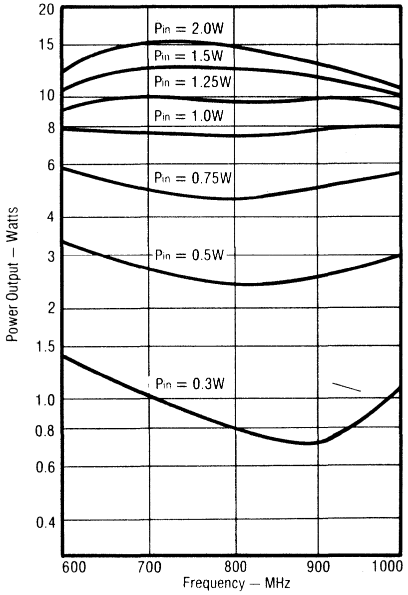


Typical Return Loss vs Frequency

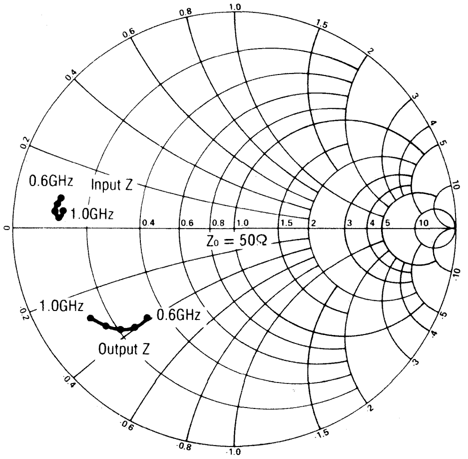


MRA0610-9 — 9 WATTS BROADBAND

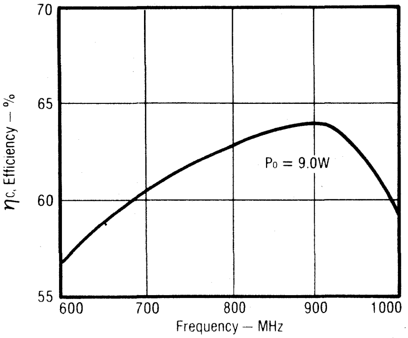
Typical Power Output vs Frequency



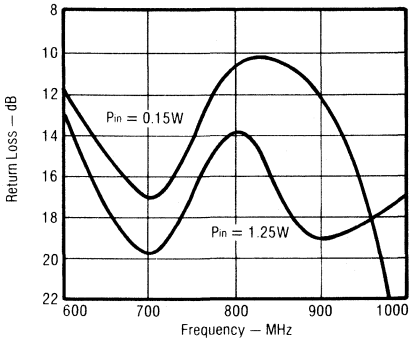
Impedance Data
Vcc = 28V



Typical Efficiency vs Frequency

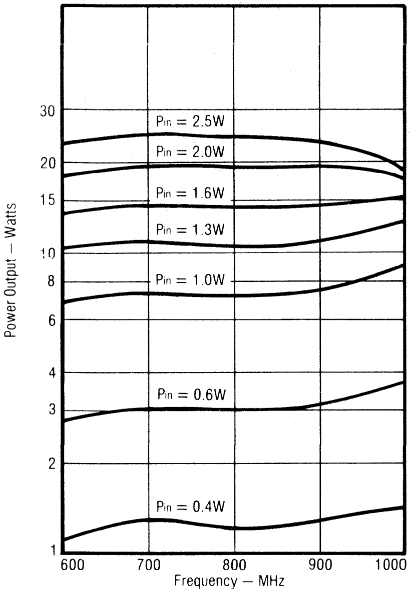


Typical Return Loss vs Frequency

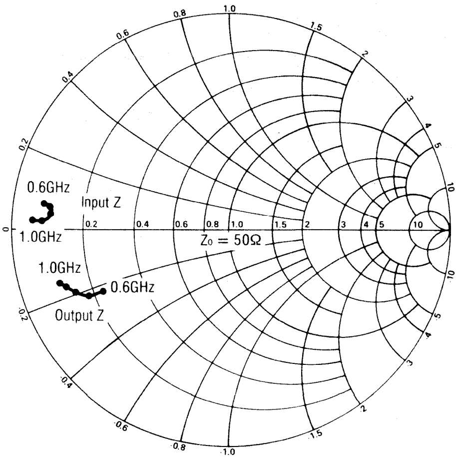


MRA0610-18 — 18 WATTS BROADBAND

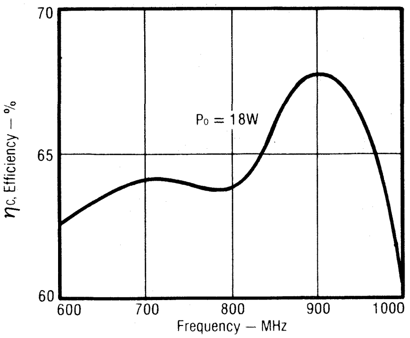
Typical Power Output vs Frequency



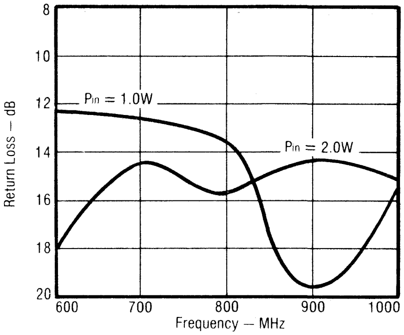
Impedance Data
Vcc = 28V



Typical Efficiency vs Frequency

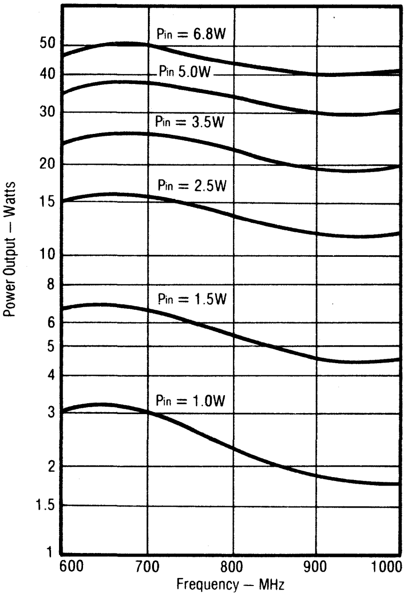


Typical Return Loss vs Frequency

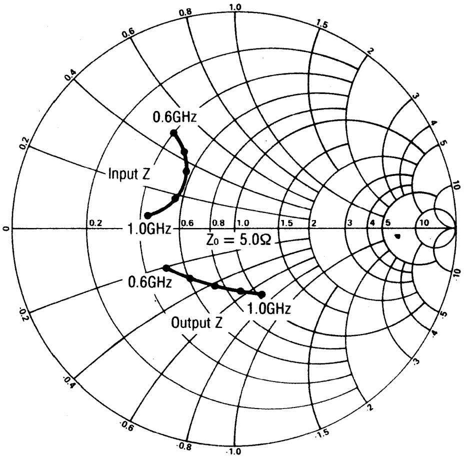


MRA0610-40 — 40 WATTS BROADBAND

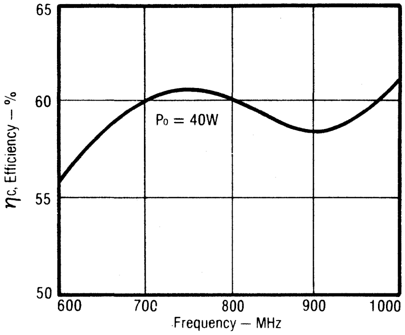
Typical Power Output vs Frequency



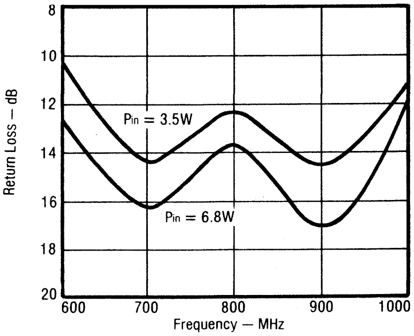
Impedance Data
Vcc = 28V



Typical Efficiency vs Frequency

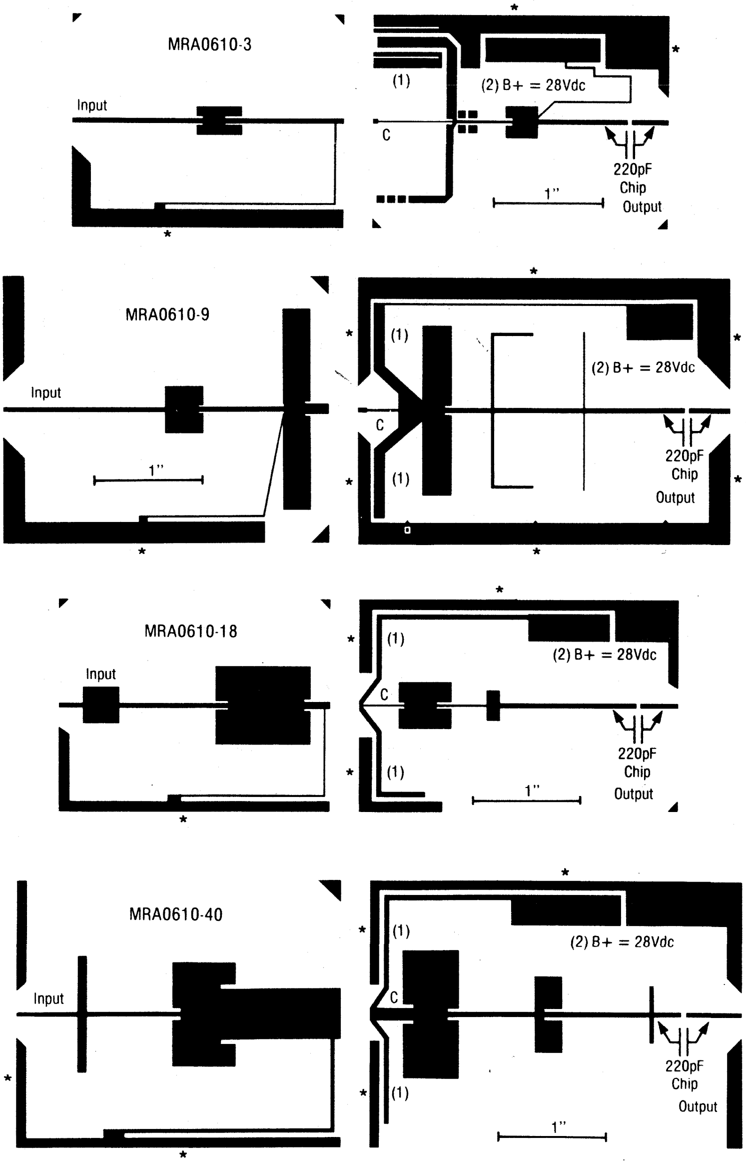


Typical Return Loss vs Frequency



TEST CIRCUIT BOARDS FOR MRA0610 SERIES

NOTE: Scale is not 1:1.



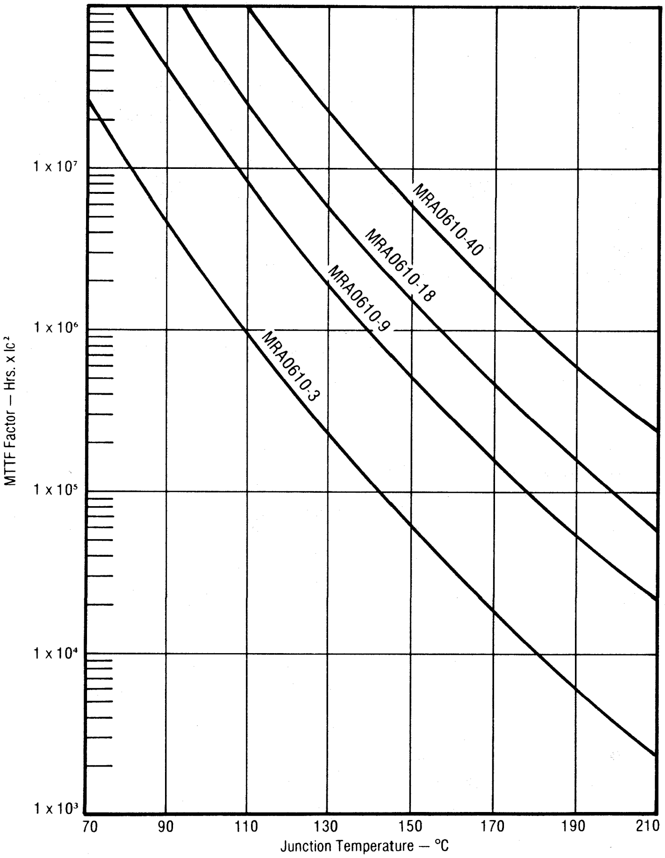
*Foil wrap or plate around to ground plane. Board material 0.020 inch glass-teflon $\varepsilon_r = 2.55$.

(1) Bypass capacitor to ground for shunt inductor (220pF chip).

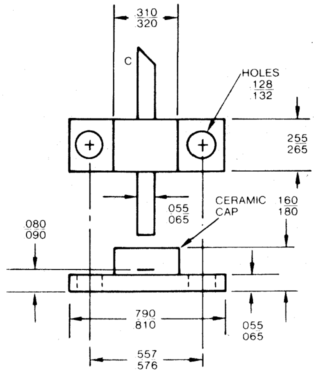
(2) Use B+ bypass of 0.01 and 1μF capacitors at this point.

MTTF FACTOR vs Tj

(Divide by I_C^2 to obtain metal lifetime in hours.)



MRA Series Package



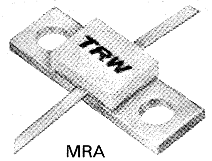
TRW® **SEMICONDUCTORS**

MRA 1014 Series

MICROAMP

MRA 1014-2
MRA 1014-6
MRA 1014-12
MRA 1014-35

- **2-6-12-35 Watts**
- **Broadband 1000-1400 MHz**
- **Internally Compensated***
- **Gold Metalized**
- **Diffused Ballast Resistors**
- **MTTF Data**


MRA

Electrical Characteristics (T_{flange} = 25 °C)

Symbol	Characteristic	MRA1014-2	MRA1014-6	MRA1014-12	MRA1014-35
BV_{CER}	Collector-Base Breakdown Voltage $R_{BE} = 10\ \Omega$	I_C = 20 mA 50 V Min	I_C = 40 mA 50 V Min	I_C = 80 mA 50 V Min	I_C = 200 mA 50 V Min
BV_{EBO}	Emitter-Base Breakdown Voltage	I_E = 0.25 mA 3.5 V Min	I_E = 0.5 mA 3.5 V Min	I_E = 1.0 mA 3.5 V Min	I_E = 2.5 mA 3.5 V Min
I_{CBO}	Collector Cutoff Current $I_E = 0$	V_{CB} = 28 V 0.5 mA	V_{CB} = 28 V 1.0 mA	V_{CB} = 28 V 2.0 mA	V_{CB} = 28 V 5.0 mA
		V_{CB} = 45 V 1.0 mA	V_{CB} = 45 V 2.0 mA	V_{CB} = 45 V 4.0 mA	V_{CB} = 45 V 10.0 mA
I_C	Max Continuous Collector Current V_{CE} = 4 V	0.5 A	1.5 A	5.0 A	10.0 A
h_{FE}	Forward Current Transfer Ratio V_{CE} = 5 V	I_C = 0.1 A 10-100	I_C = 0.2 A 10-100	I_C = 0.4 A 10-100	I_C = 1.0 A 10-100
θ_{jF}	Thermal Resistance Junction to Flange	15 °C/W	8 °C/W	4.5 °C/W	2 °C/W
P_o	Min Broadband Power Output	3.0 W	6.0 W	12.0 W	35.0 W
C_{ob}	Max Collector-Base Capacitance V_{CB} = 28 V, f = 1 MHz	4.5 pF	8 pF	12 pF	28 pF
$P_{G(dB)}$	Min Power Gain in dB V_{CB} = 28 V	P_o = 2.0 W 8.2 dB	P_o = 6.0 W 7.4 dB	P_o = 12.0 W 7.8 dB	P_o = 35.0 W 7.0 dB
η_c	Min Broadband Collector Efficiency	P_o = 2.0 W 45 %	P_o = 6.0 W 50 %	P_o = 12.0 W 50 %	P_o = 35.0 W 50 %
T_j & T_{STG}	Maximum Junction and Storage Temperatures : — 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).

The TRW MRA1014 series offers a complete family of broadband, high-gain transistors for applications in the 1000-1400MHz band.

Using internal compensation (a patented* technique developed and first offered for sale by TRW), the MRA1014 series is intended for use in a variety of military and industrial applications including ECM, radio relay and telemetry for fixed station use.

The smooth, broadband transfer characteristics of the MRA1014 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 2, 6, 12 and 35 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 MRA1014 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 MRA1014 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 MRA1014 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 MRA1014 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 $Z(R_{bb})$ 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.

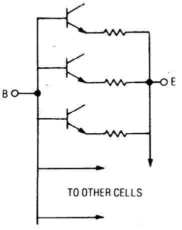


Figure 1. Elementary Method of Cell Combining

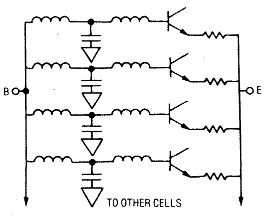


Figure 2. Cells Combined with Transformers

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.

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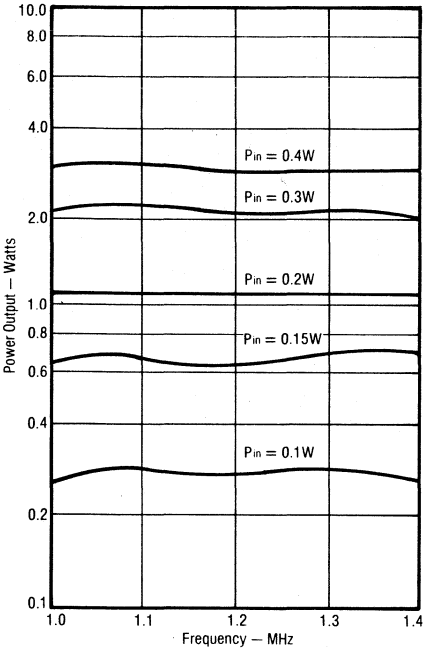
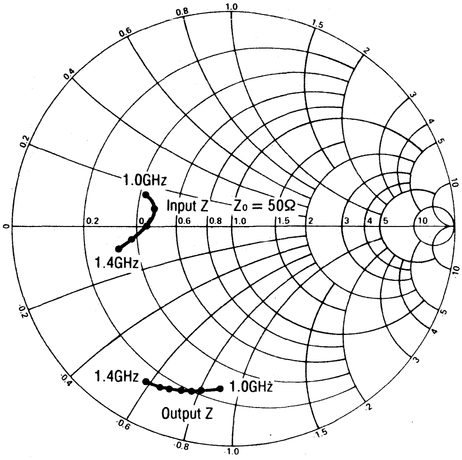
*TRW U.S. Patent #3,713,006

MRA1014-2 — 2 WATTS BROADBAND

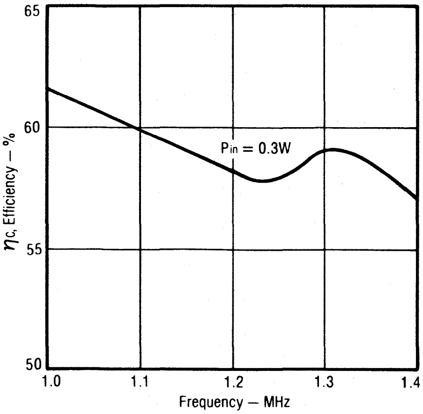
Typical Power Output vs Frequency



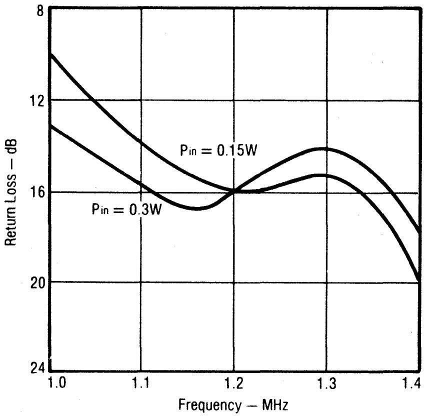
Impedance Data
Vcc = 28V



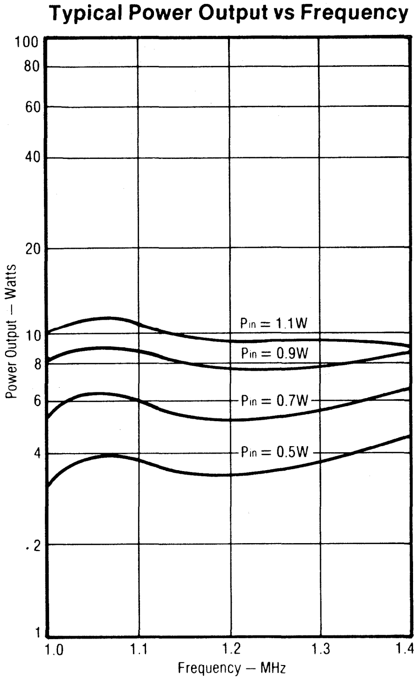
Typical Efficiency vs Frequency



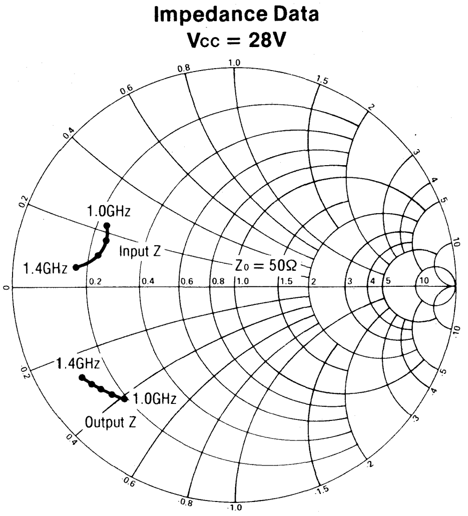
Typical Return Loss vs Frequency



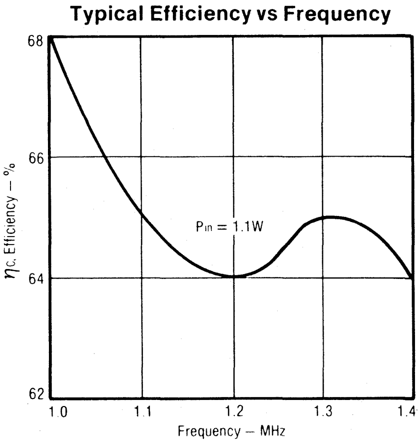
MRA1014-6 — 6 WATTS BROADBAND



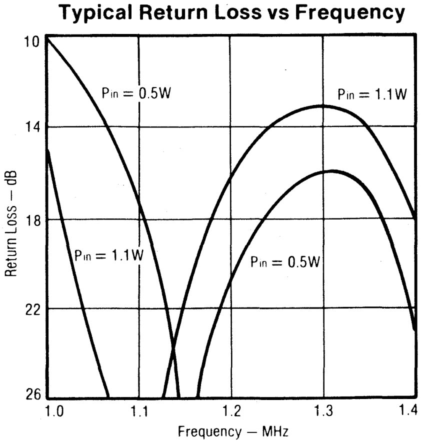
Typical Power Output vs Frequency



Impedance Data
Vcc = 28V



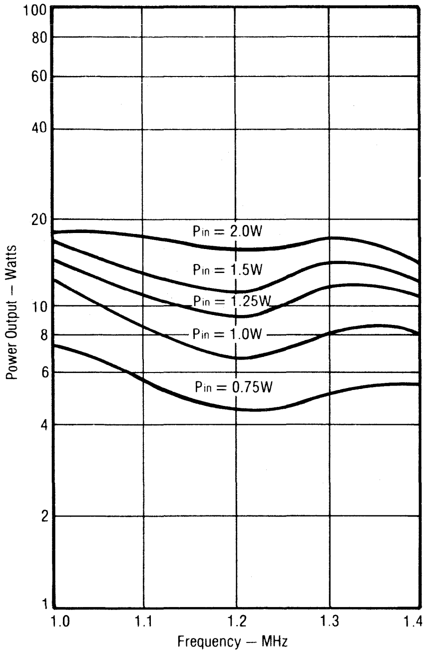
Typical Efficiency vs Frequency



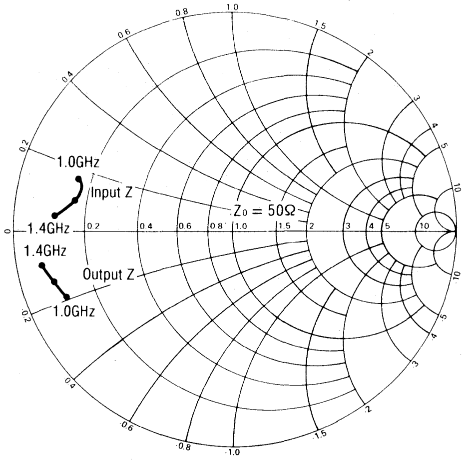
Typical Return Loss vs Frequency

MRA1014-12 — 12 WATTS BROADBAND

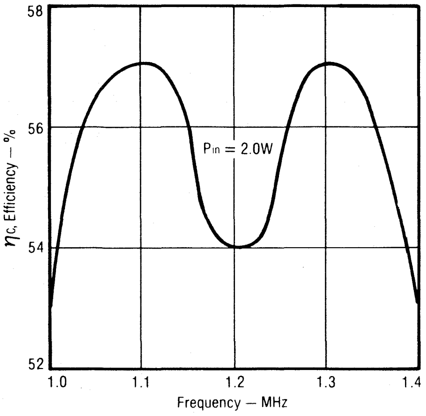
Typical Power Output vs Frequency



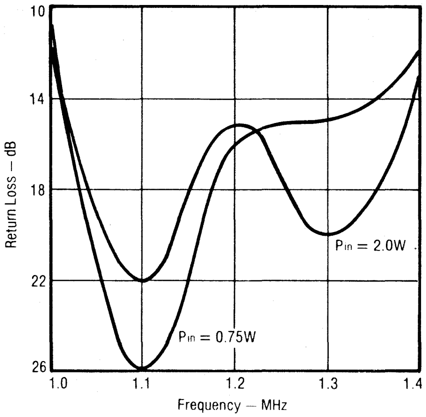
Impedance Data
Vcc = 28V



Typical Efficiency vs Frequency

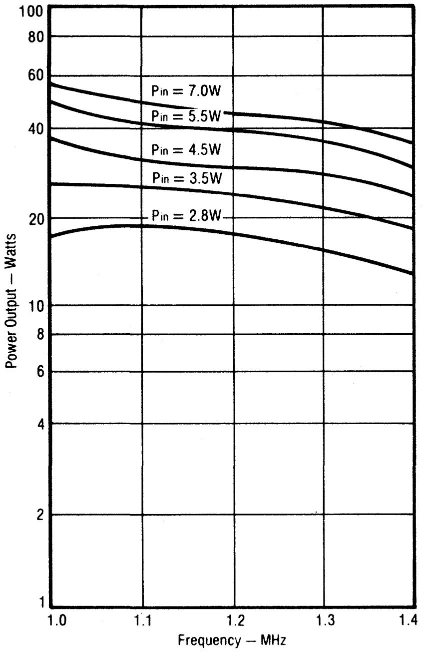


Typical Return Loss vs Frequency

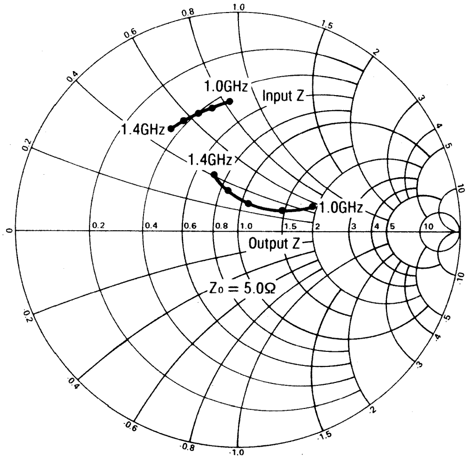


MRA1014-35 — 35 WATTS BROADBAND

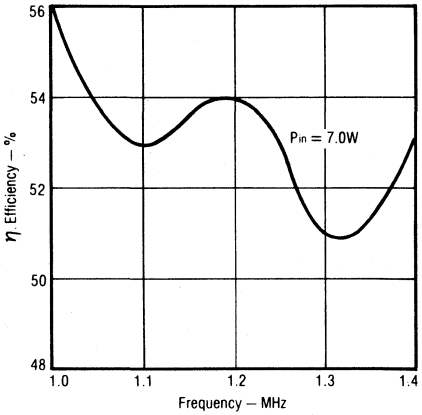
Typical Power Output vs Frequency



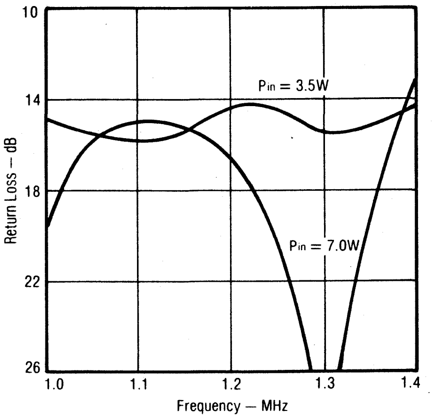
Impedance Data
Vcc = 28V



Typical Efficiency vs Frequency

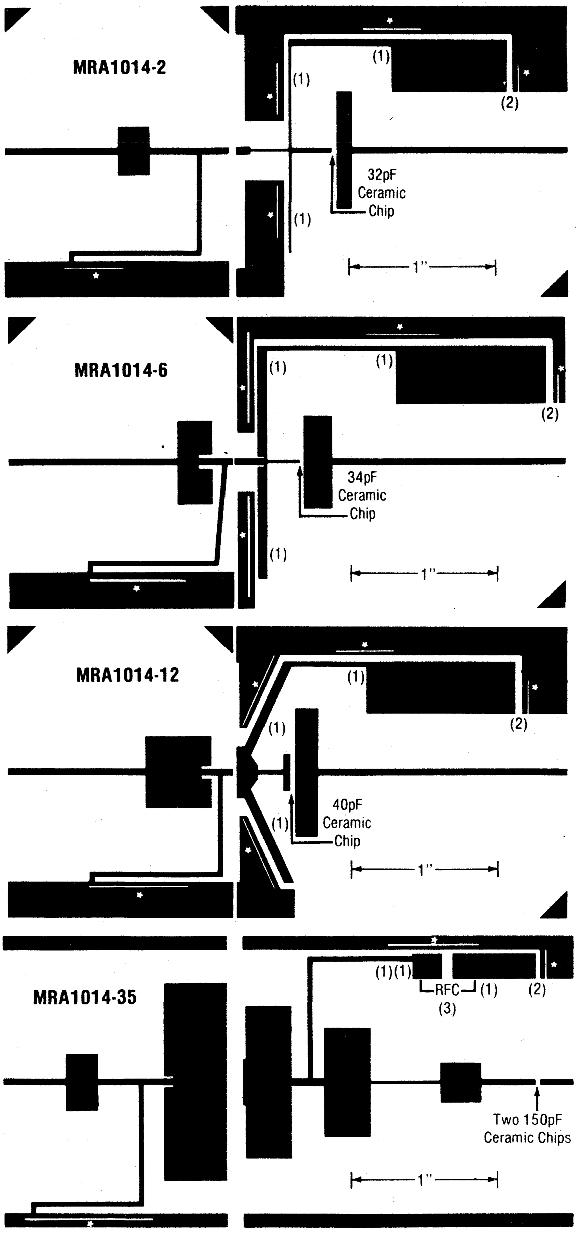


Typical Return Loss vs Frequency



TEST CIRCUIT BOARDS FOR MRA1014 SERIES

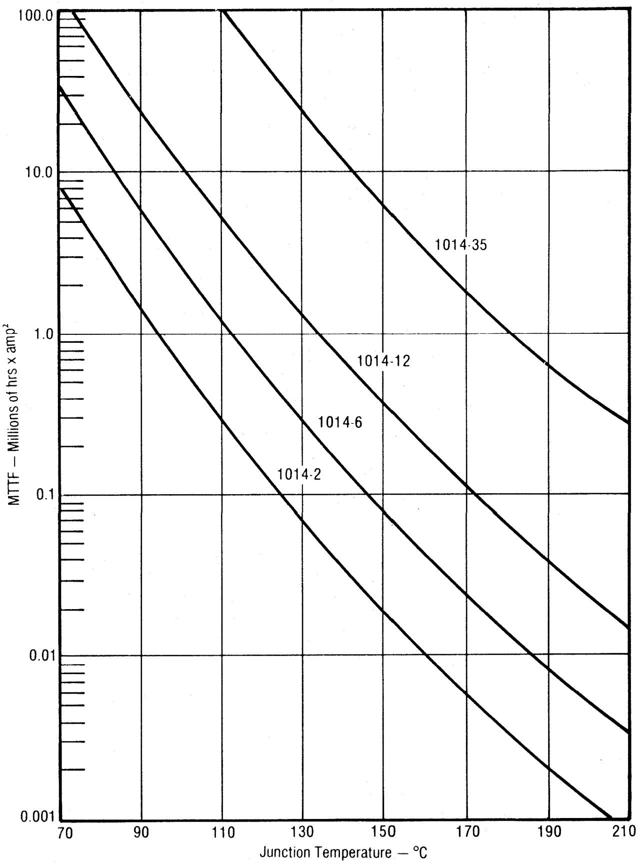
NOTE: Scale is not 1:1.



*Foil wrap or plate around to ground plane. Board material 0.020 inch glass-teflon $\varepsilon_r = 2.55$.
(1) Bypass capacitor to ground (150pF chip).
(2) Use B+ bypass of 0.01 and 1μF capacitors at this point.
(3) 10 turns #20 enamel close wound on 0.040 mandril.

MTTF FACTOR (Normalized to 1 Ampere^2 Continuous Duty)

The graph shown below displays MTTF in hours x ampere^2 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 MRA1014-12 Conditions

where:

$P_o = 12W$

$P_{in} = 2W$

$V_{CC} = 28V$

$\eta_C = 50\%$

$T_{flange} = 70°C$

$$I_C \cong I_E = \frac{100\,P_o}{\eta_C \times V_{CC}} = 0.857A$$

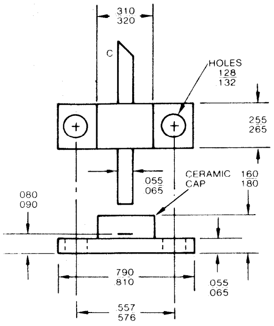
$$P_{diss} = P_{in} + V_{CC}\,I_C - P_o = 14.0W$$

$$T_{junc} = T_{flange} + \theta_{jF} \times P_{diss} = 133°C$$

$$MTTF = \frac{1.2 \times 10^6 \text{ hrs amp}^2}{I_C^2} = 1{,}400{,}200 \text{ hrs}$$

$$= 159 \text{ yrs}$$

MRA Series Package



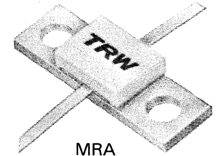
TRW® *SEMICONDUCTORS*

MRA 1417 Series

MICroAMP

MRA 1417-2
MRA 1417-6
MRA 1417-11
MRA 1417-25

- **2-6-11-25 Watts**
- **Broadband 1400-1700 MHz**
- **Internally Compensated***
- **Gold Metalized**
- **Diffused Ballast Resistors**
- **MTTF Data**



Electrical Characteristics at T_{flange} = 25 °C

Symbol	Characteristic	MRA1417-2	MRA1417-6	MRA1417-11	MRA1417-25
BV_{CER}	Collector-Base Breakdown Voltage R_{BE} = 10 Ω	I_C = 20 mA 50 V Min	I_C = 40 mA 50 V Min	I_C = 80 mA 50 V Min	I_C = 160 mA 50 V Min
BV_{EBO}	Emitter-Base Breakdown Voltage	I_E = 0.25 mA 3.5 V Min	I_E = 0.5 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} = 28 V 0.5 mA	V_{CB} = 28 V 1.0 mA	V_{CB} = 28 V 2.0 mA	V_{CB} = 28 V 4.0 mA
		V_{CB} = 45 V 1.0 mA	V_{CB} = 45 V 2.0 mA	V_{CB} = 45 V 4.0 mA	V_{CB} = 45 V 8.0 mA
I_C	Max Continuous Collector Current V_{CE} = 4 V	0.5 A	1.0 A	4.0 A	8.0 A
h_{FE}	Forward Current Transfer Ratio V_{CE} = 5 V	I_C = 0.1 A 10-100	I_C = 0.2 A 10-100	I_C = 0.4 A 10-100	I_C = 0.8 A 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	2.0 W	6.0 W	11.0 W	25.0 W
C_{ob}	Max Collector-Base Capacitance V_{CB} = 28 V, f = 1 MHz	4.5 pF	8 pF	12 pF	24 pF
$P_{G(dB)}$	Min Power Gain in dB V_{CB} = 28 V	P_o = 2.0 W 8.0 dB	P_o = 6.0 W 7.4 dB	P_o = 11.0 W 7.4 dB	P_o = 25.0 W 7.0 dB
η_c	Min Broadband Collector Efficiency	P_o = 2.0 W 40 %	P_o = 6.0 W 45 %	P_o = 11.0 W 45 %	P_o = 25.0 W 45 %
T_j & T_{STG}	Maximum Junction and Storage Temperatures : — 65 to + 200 °C				

* Based on Black's Equation and using $\varphi = 0.96$ 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, Inc. (US ≠ 3,713,006).

The TRW MRA1417 series offers a complete family of broadband, high-gain transistors for applications in the 1.4-1.7GHz band.

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The smooth, broadband transfer characteristics of the MRA1417 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 2, 6, 11 and 25 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.

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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.

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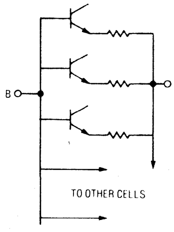

Figure 1. Elementary Method of Cell Combining

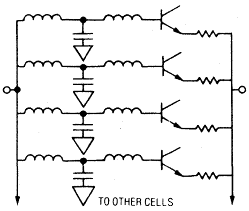

Figure 2. Cells Combined with Transformers

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.

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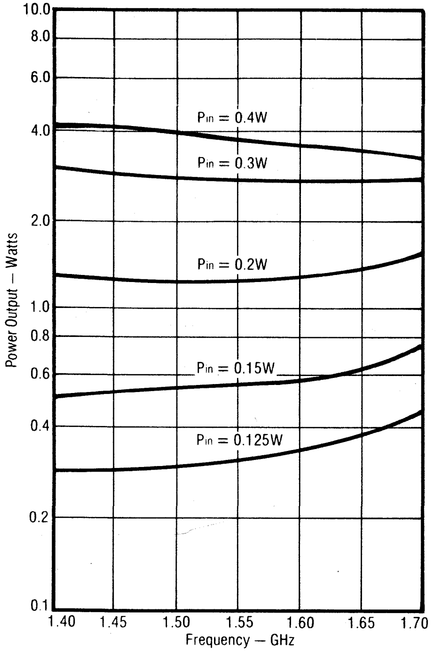
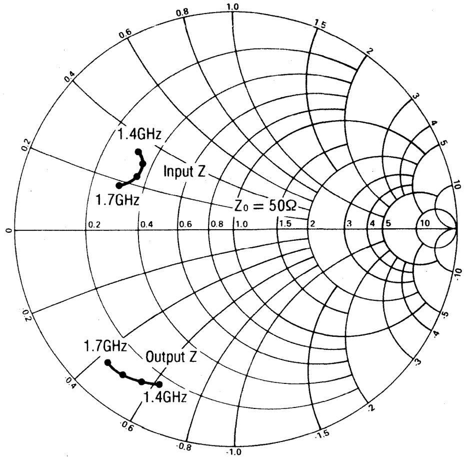
*TRW U.S. Patent #3,713,006

MRA1417-2 — 2 WATTS BROADBAND

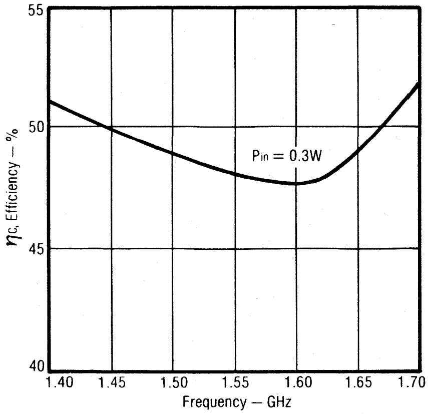
Typical Power Output vs Frequency



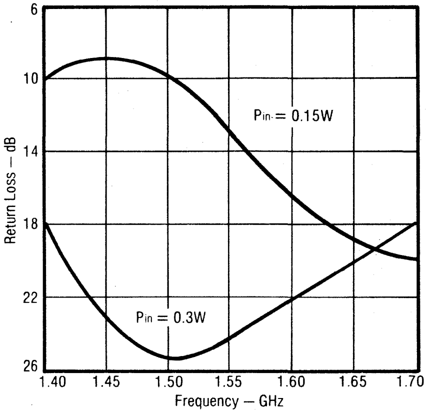
Impedance Data
Vcc = 28V



Typical Efficiency vs Frequency

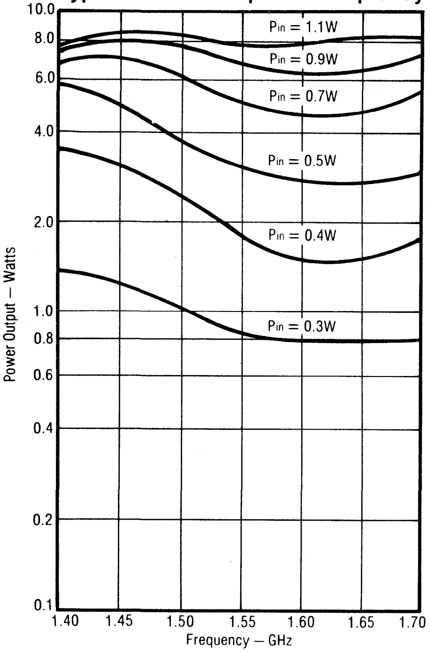


Typical Return Loss vs Frequency

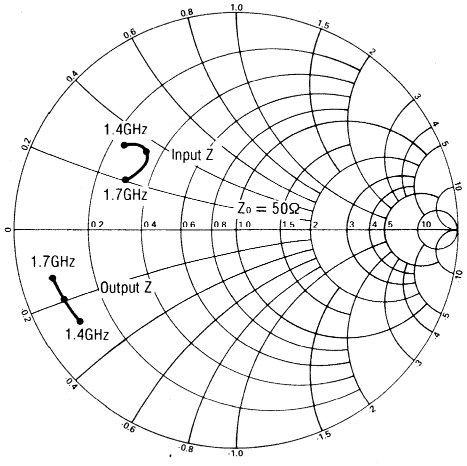


MRA1417-6 — 6 WATTS BROADBAND

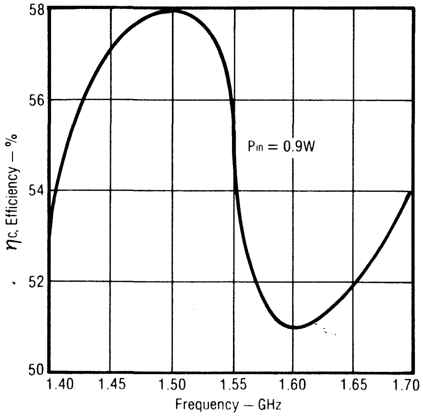
Typical Power Output vs Frequency



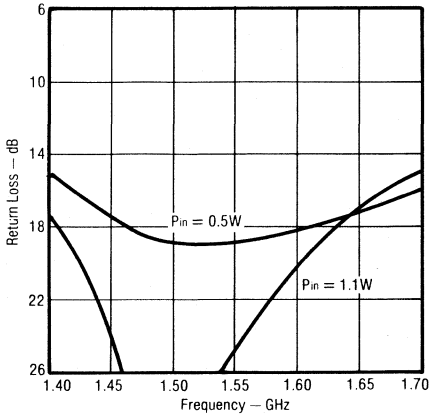
Impedance Data
Vcc = 28V



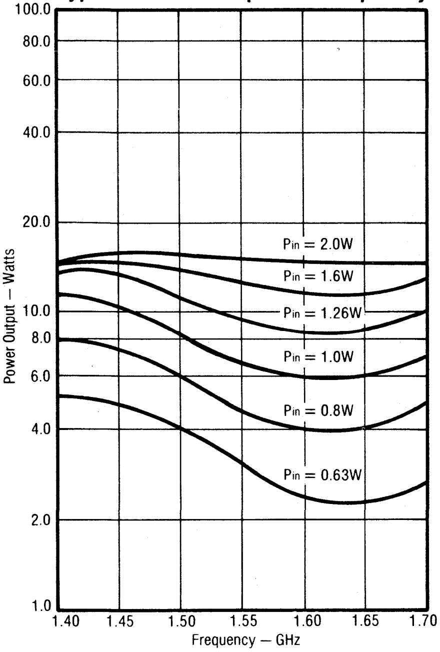
Typical Efficiency vs Frequency

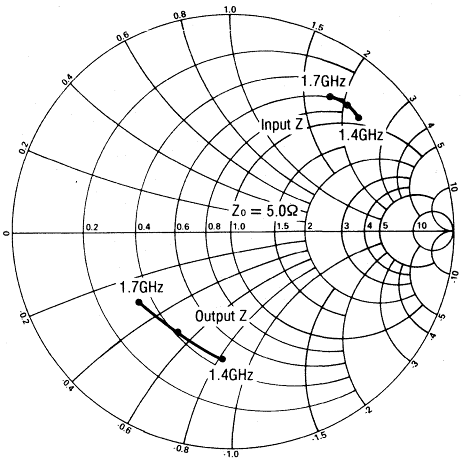


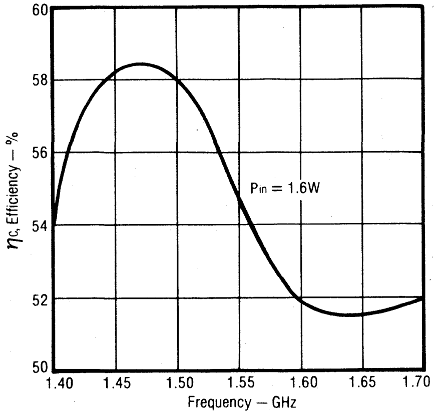
Typical Return Loss vs Frequency

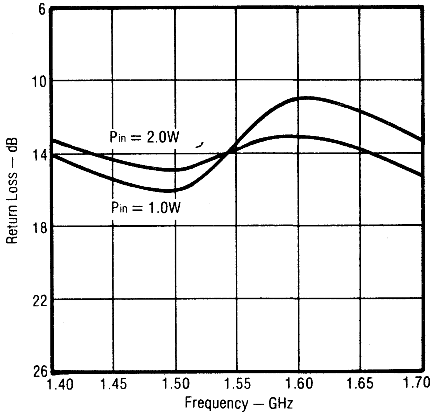


MRA1417-11 — 11 WATTS BROADBAND


Typical Power Output vs Frequency

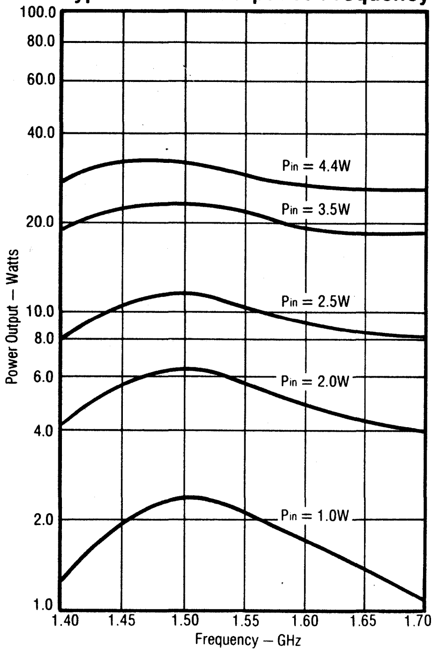

Impedance Data
Vcc = 28V


Typical Efficiency vs Frequency

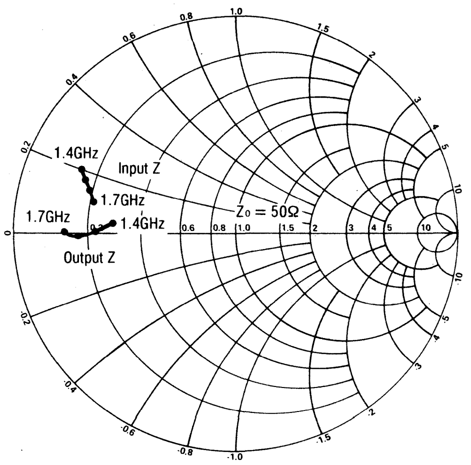

Typical Return Loss vs Frequency

MRA1417-25 — 25 WATTS BROADBAND

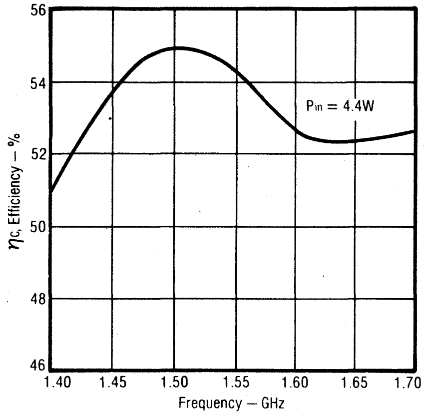
Typical Power Output vs Frequency



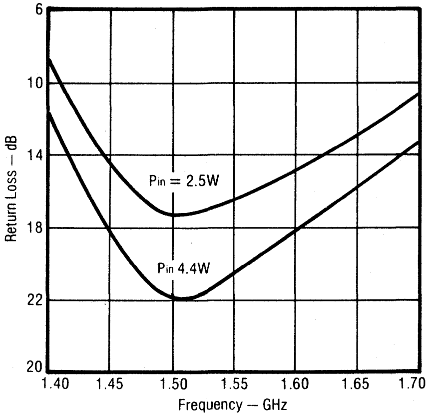
Impedance Data
Vcc = 28V



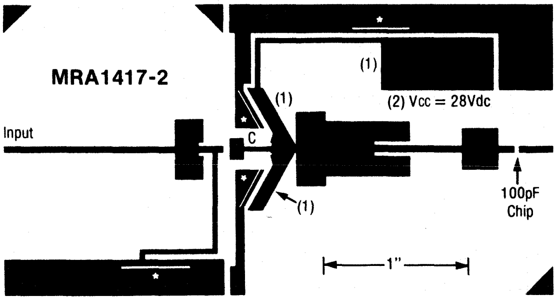
Typical Efficiency vs Frequency

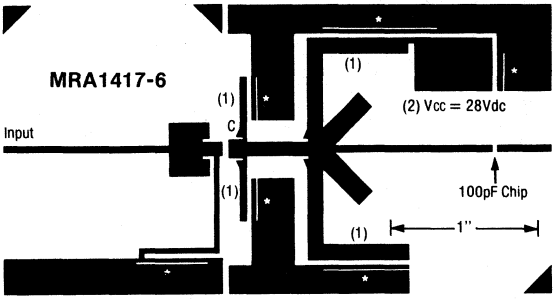


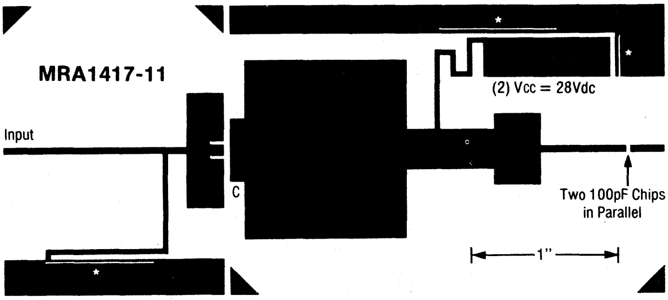
Typical Return Loss vs Frequency

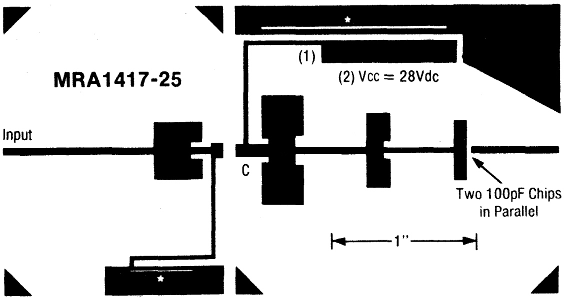


TEST CIRCUIT BOARDS FOR MRA1417 SERIES





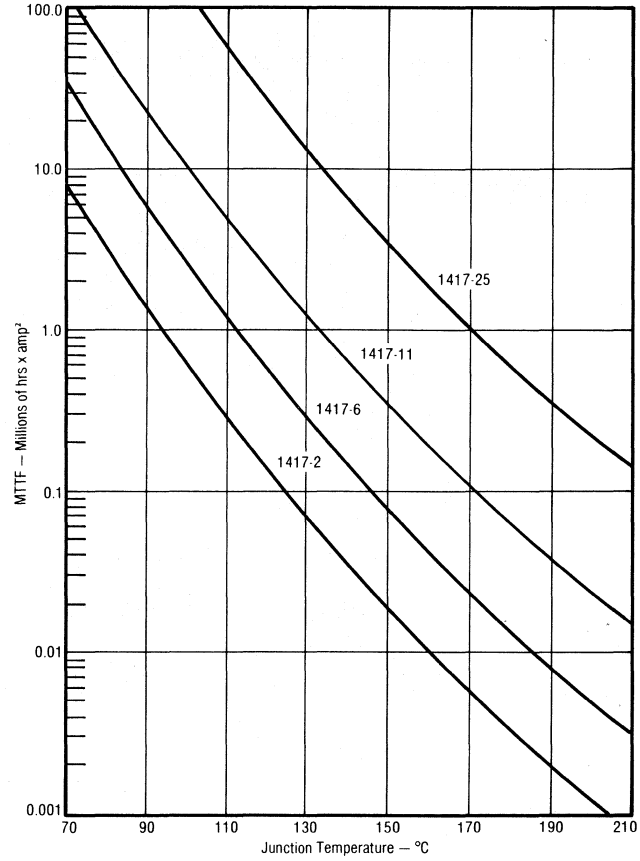




*Foil wrap or plate around to ground plane.
(1) Bypass capacitor to ground (220pF chip).
(2) Use Vcc bypass of 220pF chip, 0.1μF chip and 5μF.
Board material 0.020 inch glass-teflon $\mathcal{E}r = 2.55$.

MTTF FACTOR (Normalized to 1 Ampere^2 Continuous Duty)

The graph shown below displays MTTF in hours x ampere^2 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.

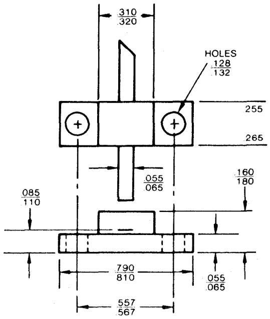


Example of MTTF for MRA1417-11 Conditions

where:

$$P_o = 11W$$
$$P_{in} = 2W$$
$$V_{CC} = 28V$$
$$\eta_C = 45\%$$
$$T_{flange} = 70°C$$
$$I_C \cong I_E = \frac{P_o}{\eta_C \times V_{CC}} = 0.873A$$
$$P_{diss} = P_{in} + V_{CC}\ I_C - P_o = 15.4W$$
$$T_{junc} = T_{flange} + \theta_{jF} \times P_{diss} = 132°C$$
$$MTTF = \frac{1.1 \times 10^6 \text{ hrs amp}^2}{I_C^2} = 1{,}443{,}328 \text{ hrs}$$
$$= 164 \text{ yrs}$$

MRA Series Package



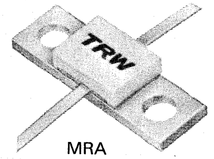
TRW® SEMICONDUCTORS

MRA 1720 Series

MICroAMP

MRA 1720-2
MRA 1720-5
MRA 1720-9
MRA 1720-20

- **2-5-9-20 Watts**
- **Broadband 1700-2000 MHz**
- **Internally Compensated***
- **Gold Metalized**
- **Diffused Ballast Resistors**
- **MTTF Data**



MRA

Electrical Characteristics at T_{flange} = 25 °C

Symbol	Characteristic	MRA1720-2	MRA1720-5	MRA1720-9	MRA1720-20
BV_{CER}	Collector-Base Breakdown Voltage R_{BE} = 10 Ω	I_C = 20 mA 50 V Min	I_C = 40 mA 50 V Min	I_C = 80 mA 50 V Min	I_C = 160 mA 50 V Min
BV_{EBO}	Emitter-Base Breakdown Voltage	I_E = 0.25 mA 3.5 V Min	I_E = 0.5 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} = 28 V 0.5 mA	V_{CB} = 28 V 1.0 mA	V_{CB} = 28 V 2.0 mA	V_{CB} = 28 V 4.0 mA
		V_{CB} = 45 V 1.0 mA	V_{CB} = 45 V 2.0 mA	V_{CB} = 45 V 4.0 mA	V_{CB} = 45 V 8.0 mA
I_C	Max Continuous Collector Current V_{CE} = 4 V	0.5 A	1.0 A	4.0 A	8.0 A
h_{FE}	Forward Current Transfer Ratio V_{CE} = 5 V	I_C = 0.1 A 10-100	I_C = 0.2 A 10-100	I_C = 0.4 A 10-100	I_C = 0.8 A 10-100
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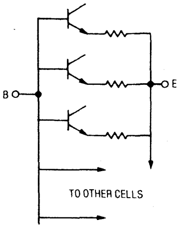

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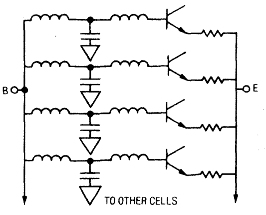

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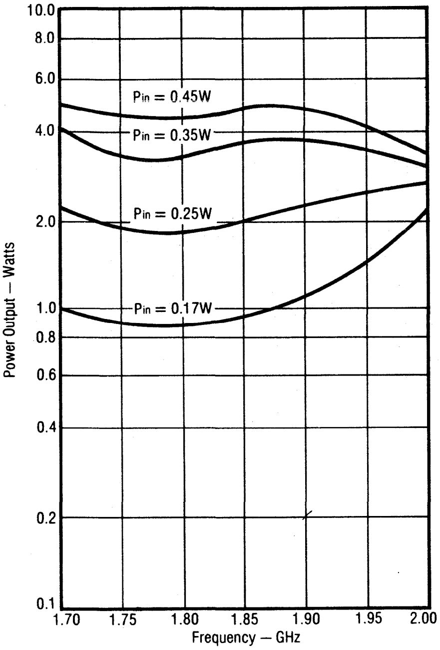
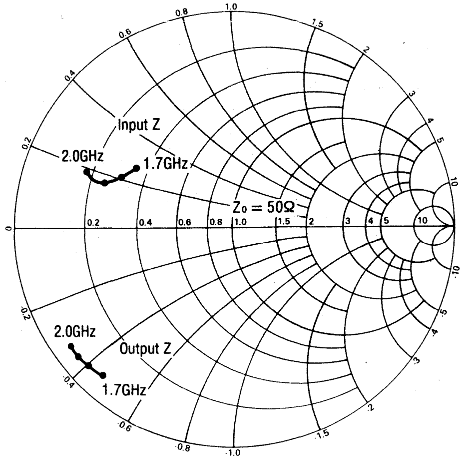
*TRW U.S. Patent #3,713,006

MRA 1720-2 WATTS BROADBAND

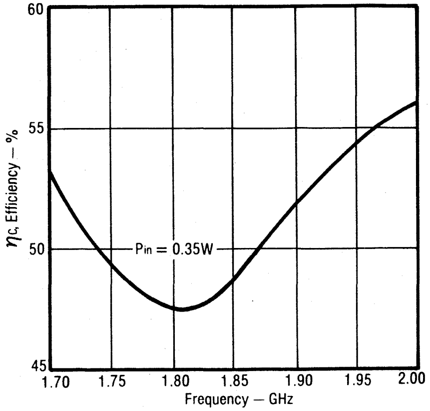
Typical Power Output vs Frequency



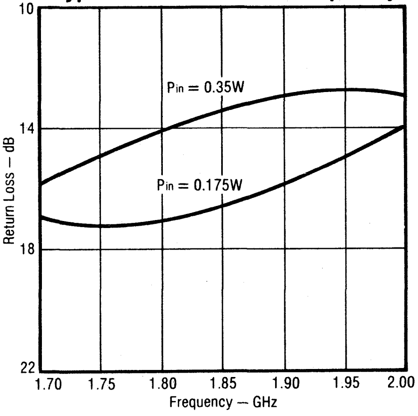
Impedance Data
Vcc = 28V



Typical Efficiency vs Frequency

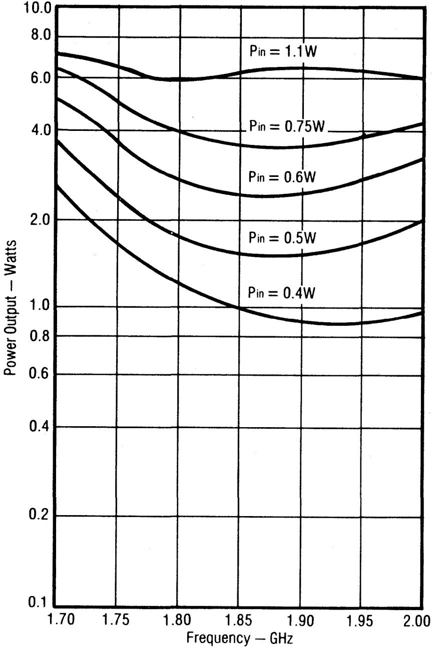


Typical Return Loss vs Frequency

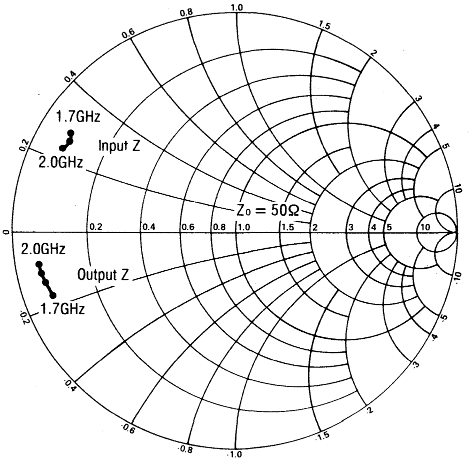


MRA 1720-5 — 5 WATTS BROADBAND

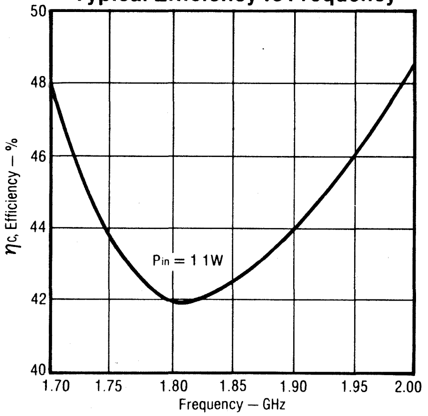
Typical Power Output vs Frequency



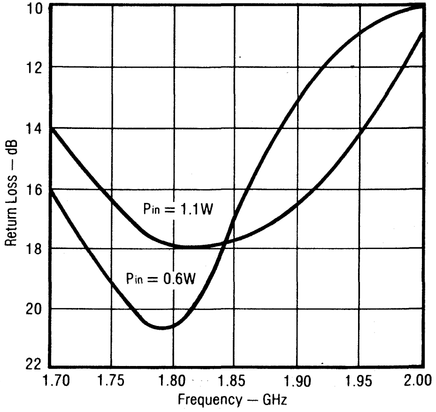
Impedance Data
Vcc = 28V



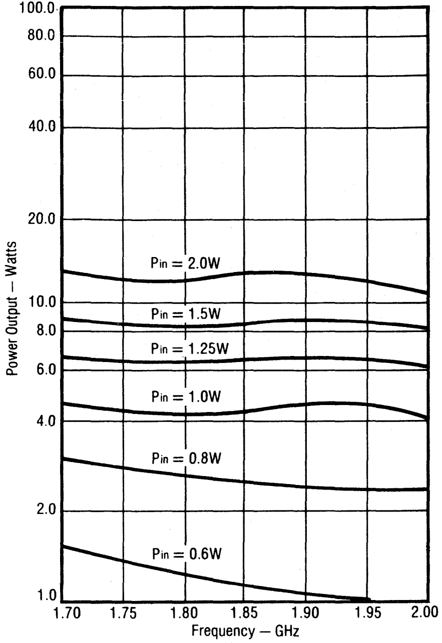
Typical Efficiency vs Frequency

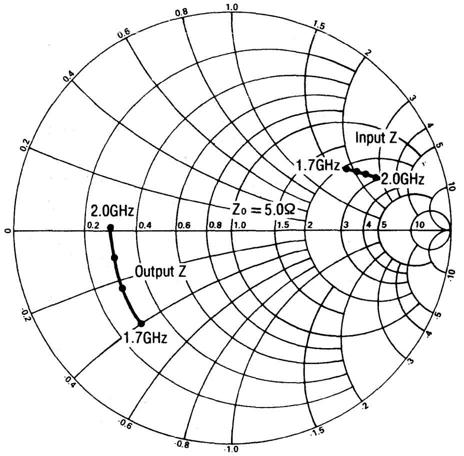


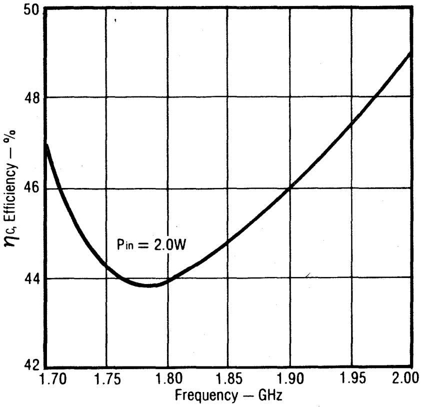
Typical Return Loss vs Frequency

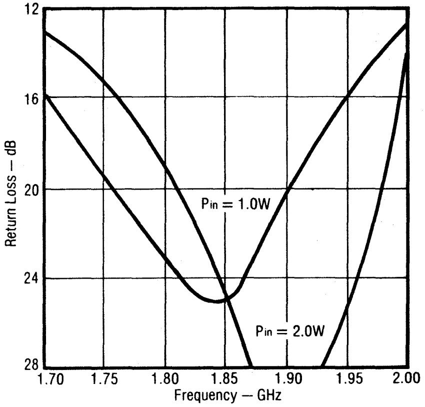


MRA 1720-9 — 9 WATTS BROADBAND

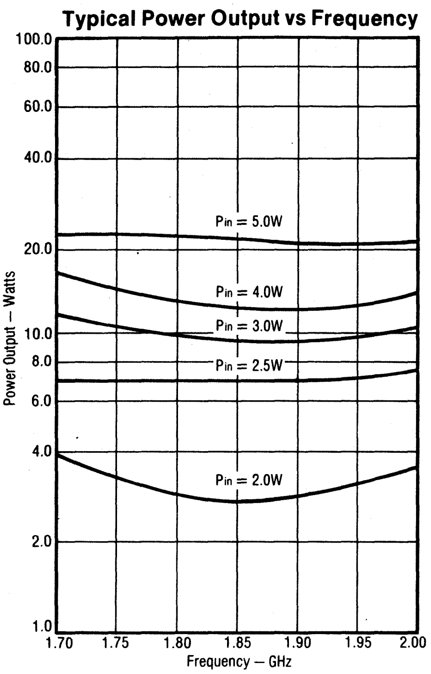

Typical Power Output vs Frequency

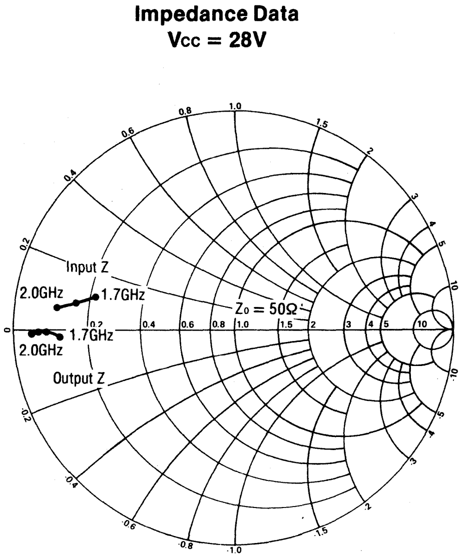

Impedance Data
V_{cc} = 28V

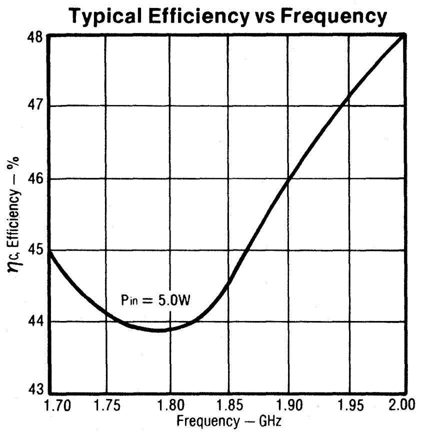

Typical Efficiency vs Frequency

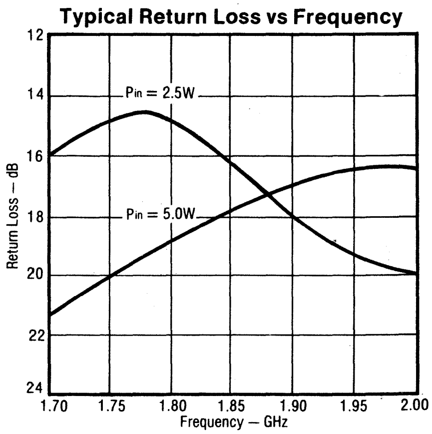

Typical Return Loss vs Frequency

MRA 1720-20 — 20 WATTS BROADBAND

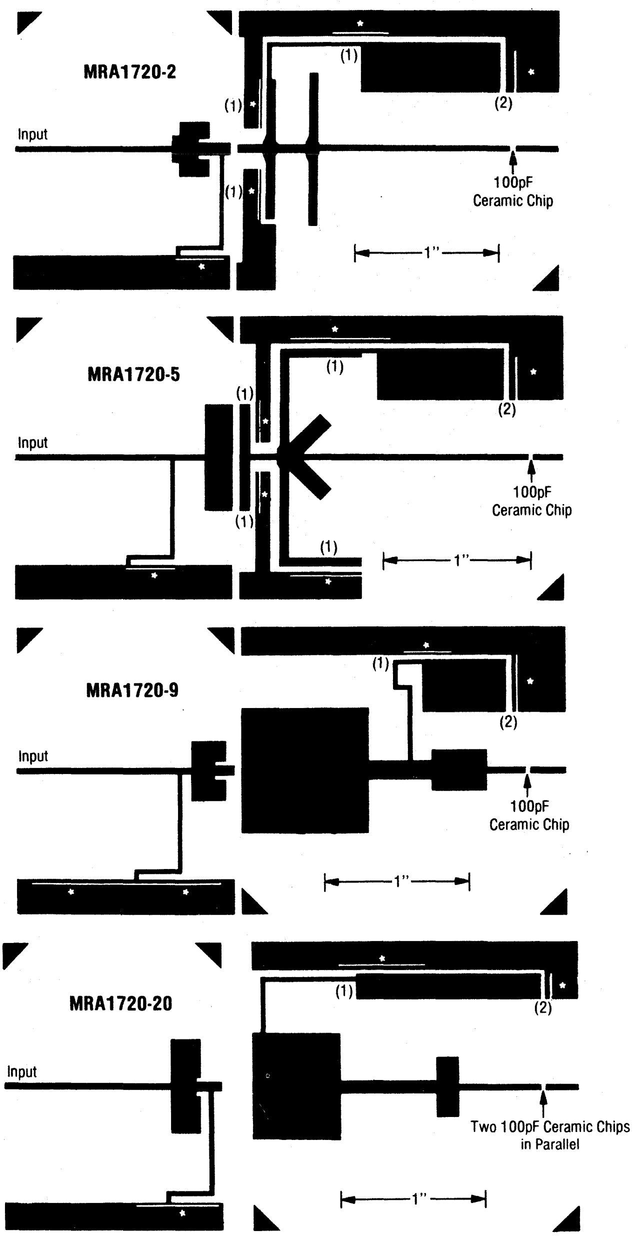

Typical Power Output vs Frequency


Impedance Data
Vcc = 28V


Typical Efficiency vs Frequency


Typical Return Loss vs Frequency

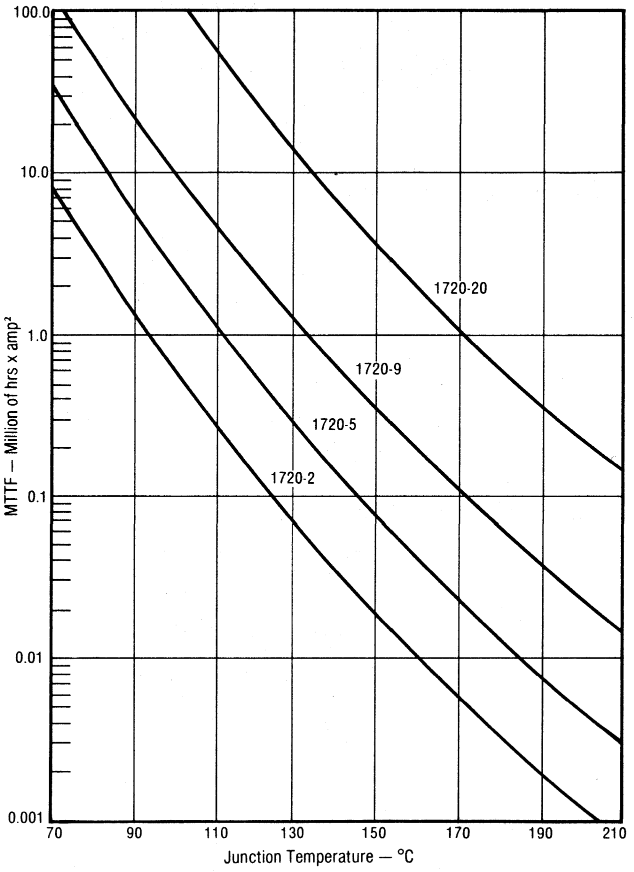
TEST CIRCUIT BOARDS FOR MRA1720 SERIES



*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.
Board material 0.020 inch glass-teflon $\varepsilon_r = 2.55$.

MTTF FACTOR (Normalized to 1 Ampere^2 Continuous Duty)

The graph shown below displays MTTF in hours x ampere^2 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

where:

$P_o = 9W$
$P_{in} = 2W$
$V_{CC} = 28V$
$\eta_C = 40\%$
$T_{flange} = 70°C$

$$I_C \cong I_E = \frac{100\,P_o}{\eta_C \times V_{CC}} = 0.800A$$

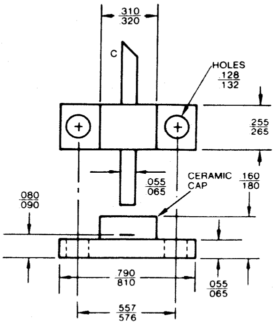
$$P_{diss} = P_{in} + V_{CC}\, I_C - P_o = 15.4W$$

$$T_{junc} = T_{flange} + \theta_{jF} \times P_{diss} = 139.3°C$$

$$\text{MTTF} = \frac{0.7 \times 10^5 \text{ hrs amp}^2}{I_C^2} = 109{,}380 \text{ hrs}$$

$$= 12.46 \text{ yrs}$$

MRA Series Package



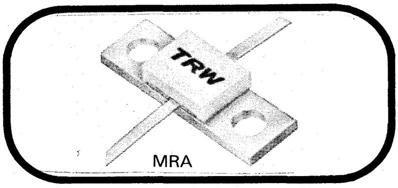
TRW® SEMICONDUCTORS

MRAL 2023 Series

MICROAMP

MRAL 2023-1.5
MRAL 2023-3
MRAL 2023-6
MRAL 2023-12

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



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(R_{bb}) 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.

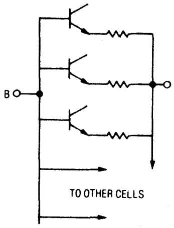


Figure 1. Elementary Method of Cell Combining

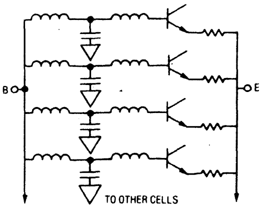


Figure 2. Cells Combined with Transformers

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.

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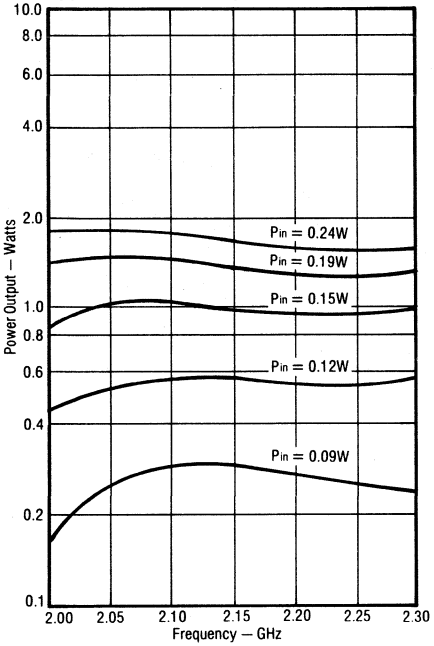
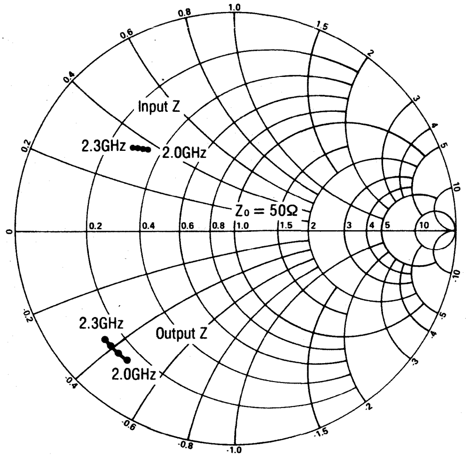
*TRW U.S. Patent #3,713,006

MRAL2023-1.5 WATTS BROADBAND

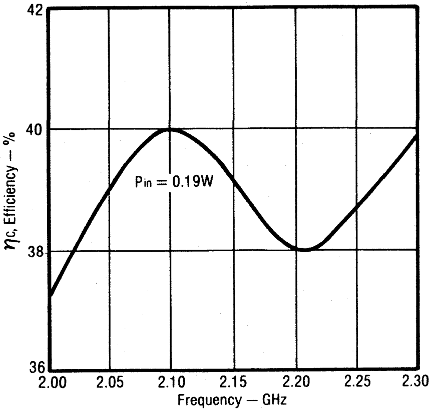
Typical Power Output vs. Frequency



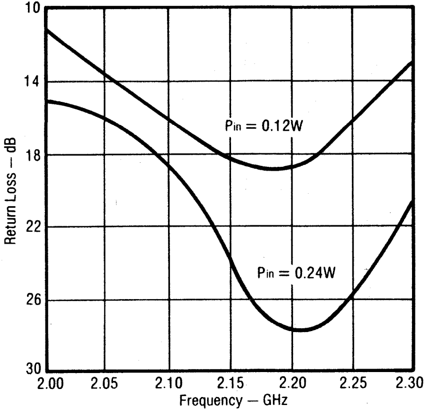
Impedance Data
Vcc = 22V



Typical Efficiency vs. Frequency

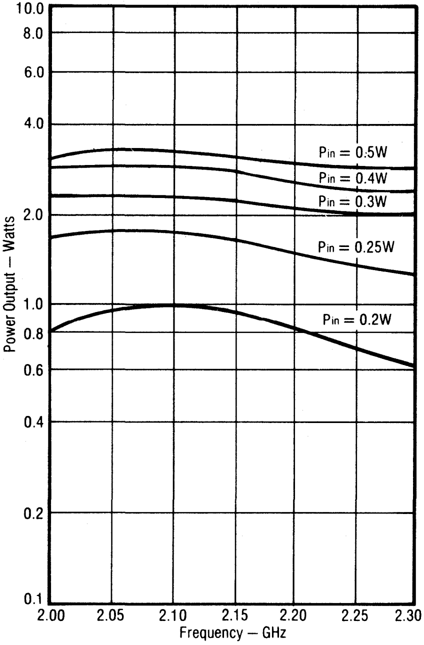


Typical Return Loss vs. Frequency



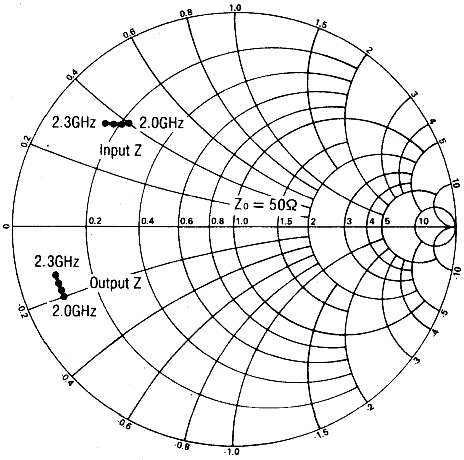
MRAL2023-3 — 3 WATTS BROADBAND

Typical Power Output vs. Frequency

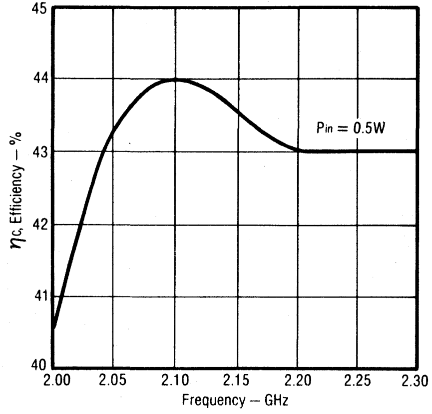


Impedance Data

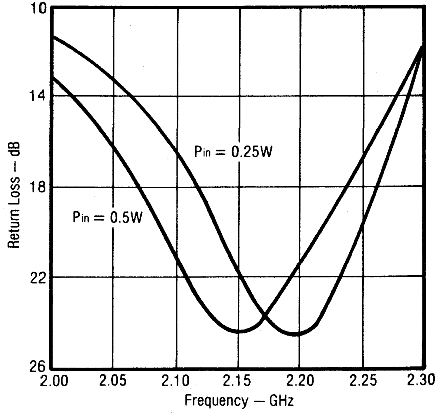
Vcc = 22V



Typical Efficiency vs. Frequency

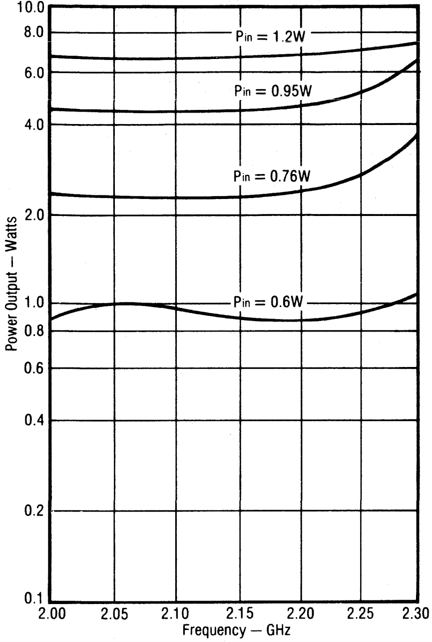


Typical Return Loss vs. Frequency

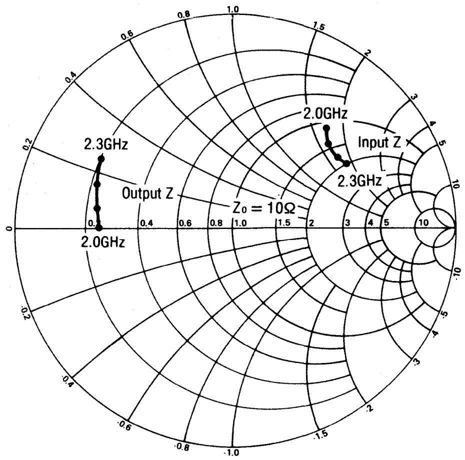


MRAL2023-6 — 6 WATTS BROADBAND

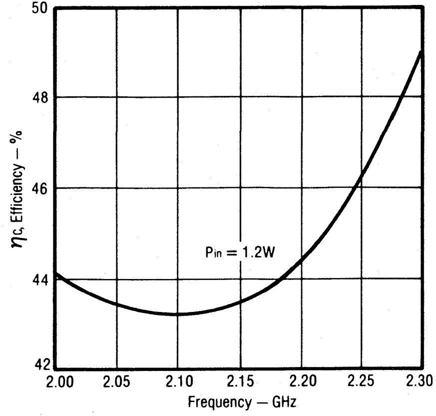
Typical Power Output vs. Frequency



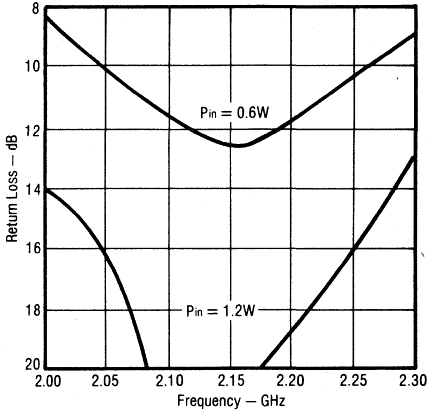
Impedance Data
Vcc = 22V



Typical Efficiency vs. Frequency

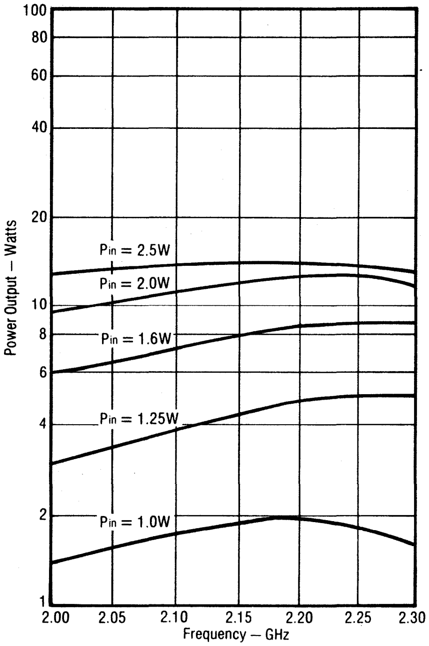


Typical Return Loss vs. Frequency

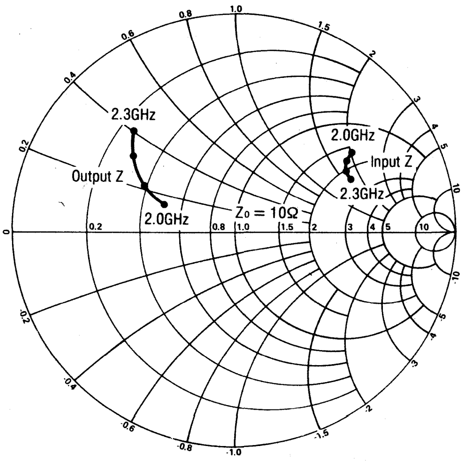


MRAL2023-12 — 12 WATTS BROADBAND

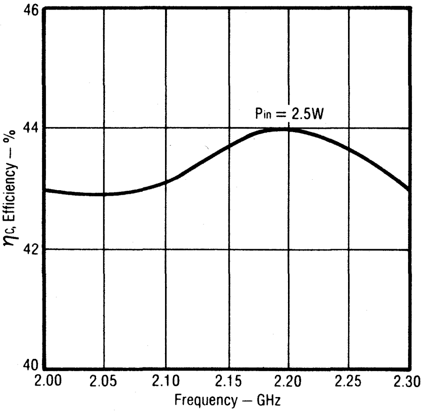
Typical Power Output vs. Frequency



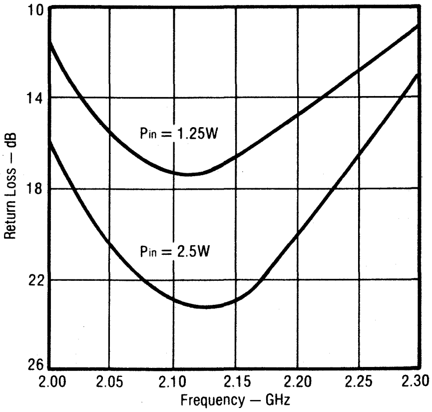
Impedance Data
Vcc = 22V



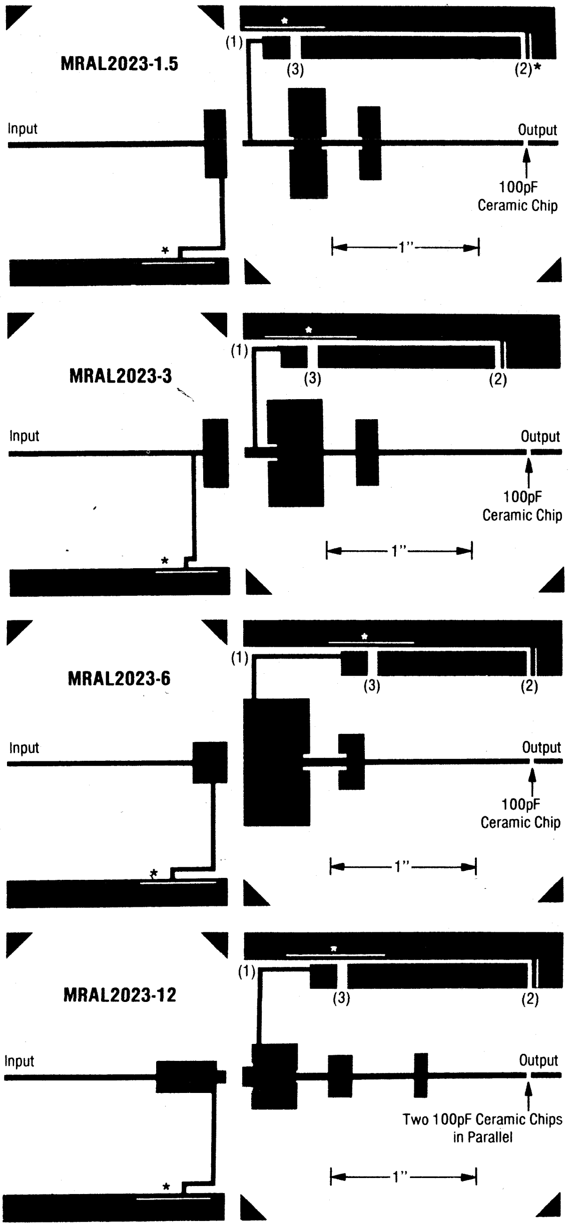
Typical Efficiency vs. Frequency



Typical Return Loss vs. Frequency



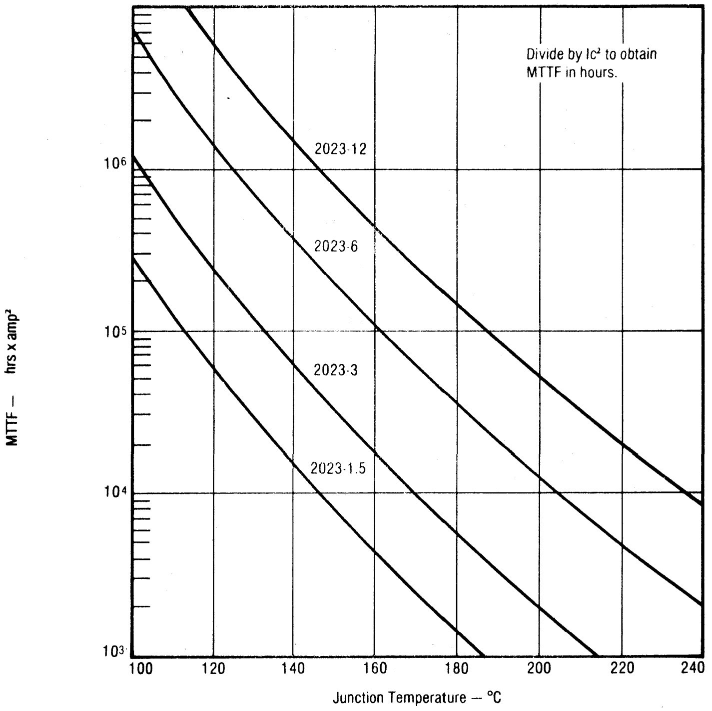
TEST CIRCUIT BOARDS FOR MRAL2023 SERIES



*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:

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

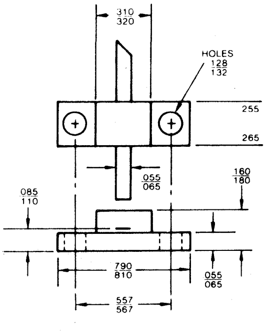
$$I_C \cong I_E = \frac{100\ P_o}{\eta_C \times V_{CC}} = 1.36A$$

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

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

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

MRA Series Package



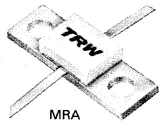
TRW® SEMICONDUCTORS **MRP 0912 - 50**

PRELIMINARY

The MRP 0912 series offers a complete family of broadband high power devices for pulsed application in the 0.9 - 1.2 GHz band. Using internal compensation, the MRP 0912 series is intended for use in IFF, DME, TACAN and transponder applications.

All units are gold metallized for longevity and resistance to metal migrations. They are emitter balasted with diffused silicon resistors for reliability and ruggedness.

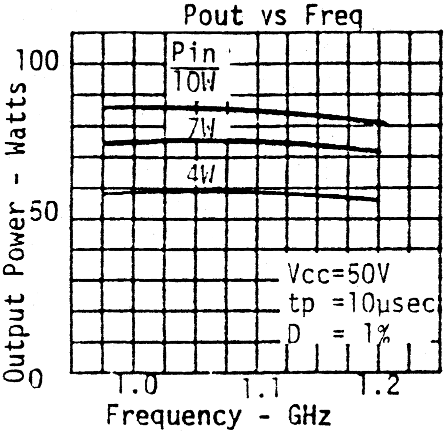
960 - 1215 MHz
50 W PULSE POWER
50 V
GOLD RELIABILITY

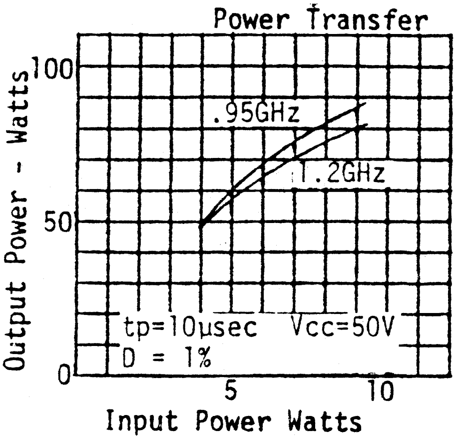


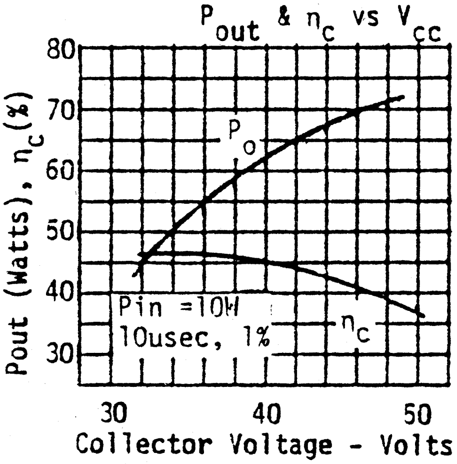
Electrical Characteristics (T_{case} = 25 °C)

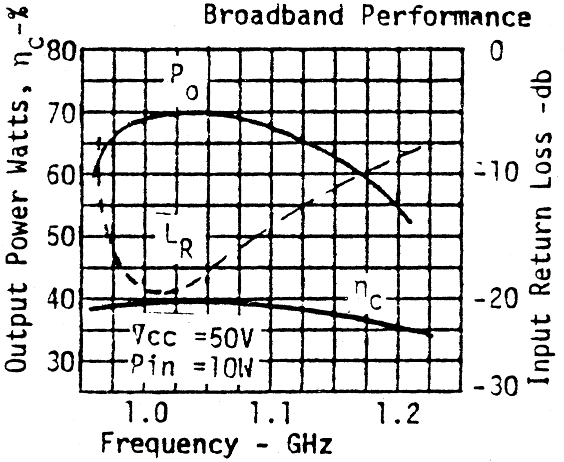
	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC TEST	BV_{CES}	Collector - Emitter Breakdown Voltage	I_C = 10 mA	65			V
	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 5 mA	3.5			V
	H_{FE}	D.C. Current Gain	V_{CE} = 5 V I_C = 1 A	15		100	—
RF TEST	P_{out}	Output Power	V_{CB} = 50 V RF Pulse : 10 µsec 1 % D.C. P_{in} = 10 W F = 960-1 215 MHz	50			W
	I_C	Collector Current	V_{CB} = 50 V RF Pulse : 10 µsec 1 % D.C. P_{in} = 10 W F = 960-1 215 MHz			2,85	A
DESIGN RATINGS	P_T	Power Dissipation				31	W
	I_C	Continuous Collector Current				4	A
	θ_{JC}	Thermal Resistance			5.7		°C/W
	T_{STG}	Storage Temperature		— 65		+ 200	°C

TYPICAL CHARACTERISTICS

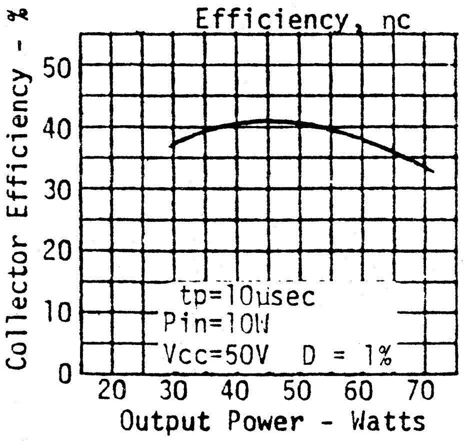


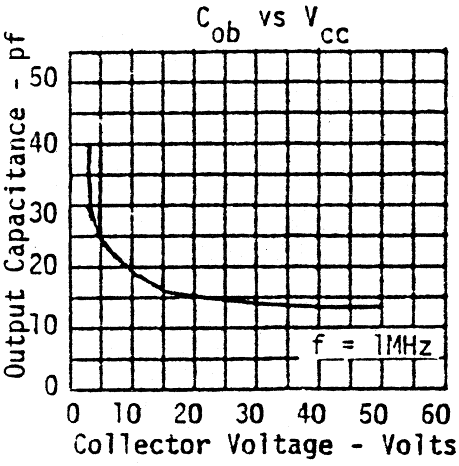


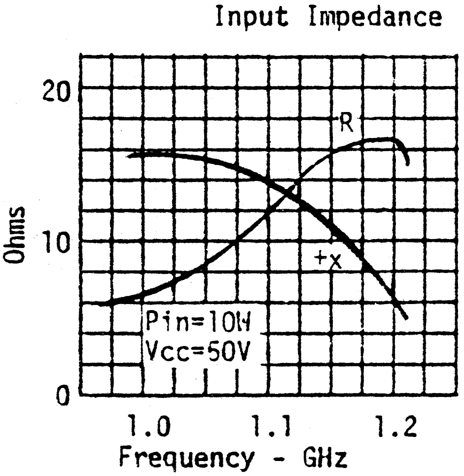


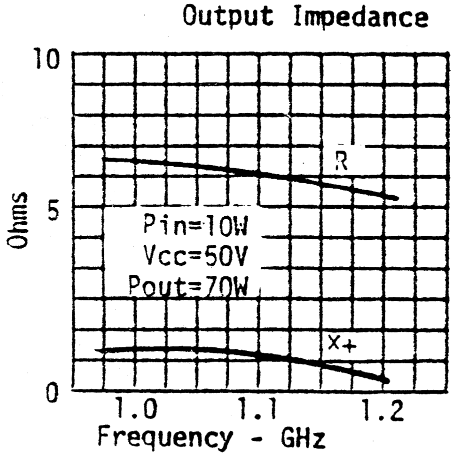


TYPICAL CHARACTERISTICS









DESIGN RATINGS

MTTF (typ) (See Note # 1)

2.41×10^5 hr-amp^2

NOTE # 1 : Based on Metal Migration Theory,

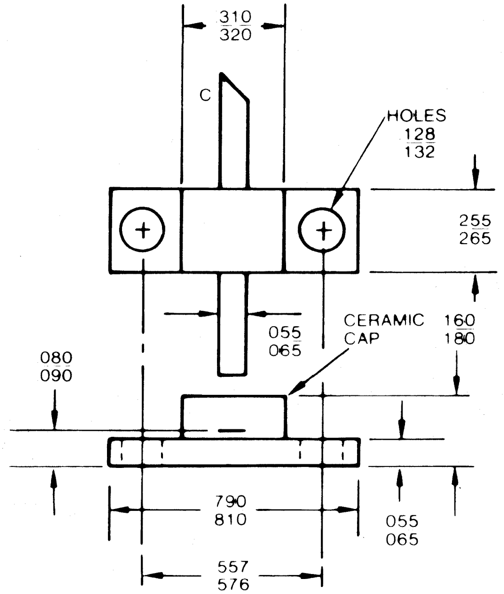
$$\text{MTTF} = (8.65 \times 10^{-6/I})\ \text{EXP}\,[11376/T_j\ (^\circ\text{K})]$$

TABLE I

TRANSIENT θ_{JF}

τon μsec	θ_{JF} °C/W
10^{-1}	.0825
10^0	.244
10^1	.607
10^2	1.40
10^3	2.39
10^4	3.83
10^5	5.01
$\geqslant 10^6$	5.70

MRA



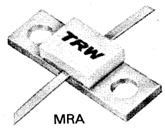
TRW® SEMICONDUCTORS MRP 0912 - 75

PRELIMINARY

The MRP 0912 series offers a complete family of broadband high power devices for pulsed application in the 0.9 - 1.2 GHz band. Using internal compensation, the MRP 0912 series is intended for use in IFF, DME, TACAN and transponder applications.

All units are gold metallized for longevity and resistance to metal migrations. They are emitter balasted with diffused silicon resistors for reliability and ruggedness.

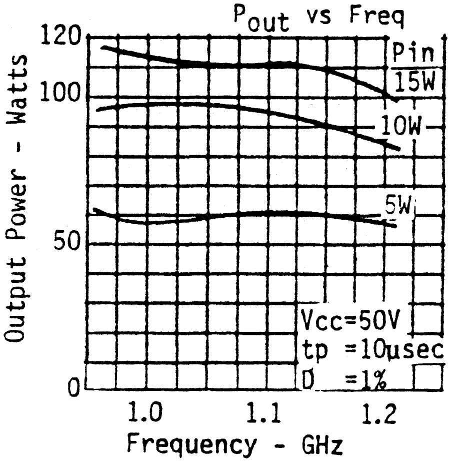
960 - 1215 MHz
250 W PULSE POWER
50 V
GOLD RELIABILITY

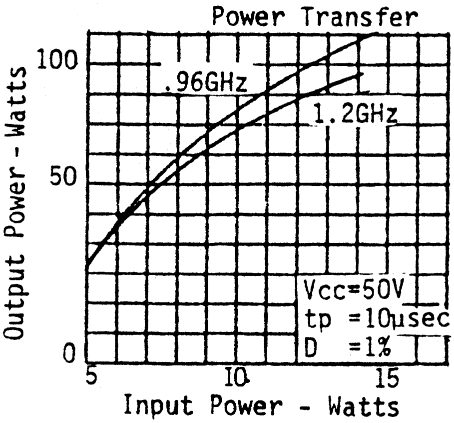


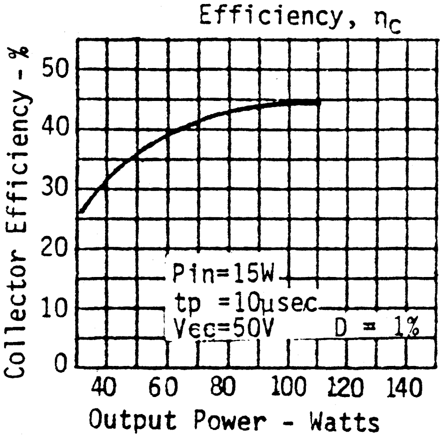
Electrical Characteristics (T_{case} = 25 °C)

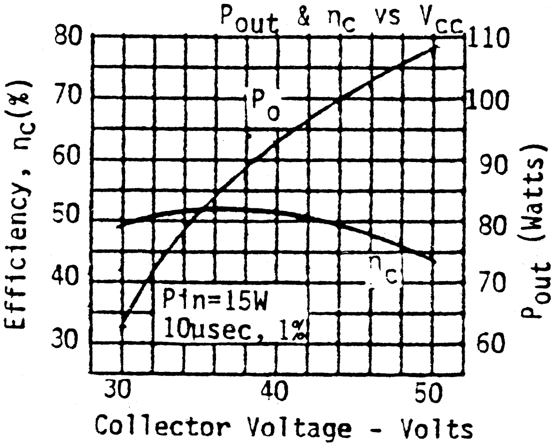
	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC TEST	BV_{CES}	Collector - Emitter Breakdown Voltage	I_C = 20 mA	65			V
	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 5 mA	3.5			V
	H_{FE}	D.C. Current Gain	V_{CE} = 5 V I_C = 1 A	15		100	—
RF TEST	P_{out}	Output Power	V_{CB} = 50 V RF Pulse : 10 µsec 1 % D.C. P_{in} = 15 W F = 960-1 215 MHz	75			W
	I_C	Collector Current	V_{CB} = 50 V RF Pulse : 10 µsec 1 % D.C. P_{in} = 15 W F = 960-1 215 MHz			4,28	A
DESIGN RATINGS	P_T	Power Dissipation				56	W
	I_C	Continuous Collector Current				8	A
	θ_{JC}	Thermal Resistance			3.1		°C/W
	T_{STG}	Storage Temperature		— 65		+ 200	°C

TYPICAL CHARACTERISTICS

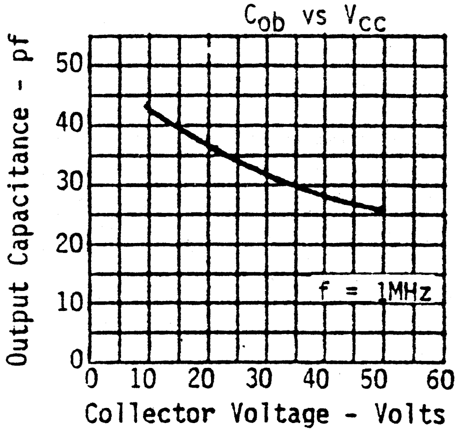




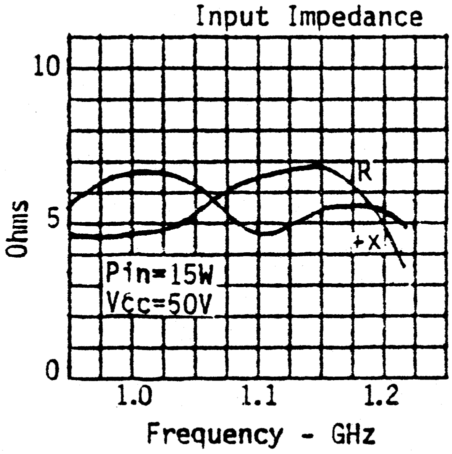




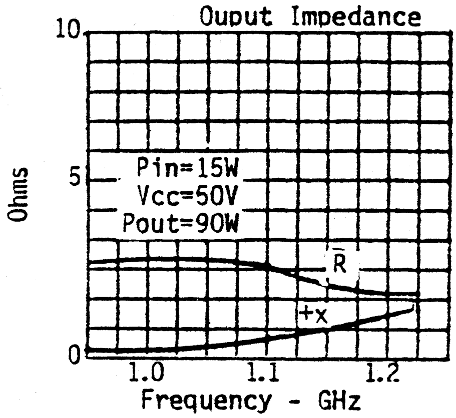
TYPICAL CHARACTERISTICS



C_{ob} vs V_{CC}



Input Impedance



Ouput Impedance

DESIGN RATINGS

MTTF (typ) (See Note # 1)

9.64×10^5 hr-amp^2

NOTE # 1 : Based on Metal Migration Theory,

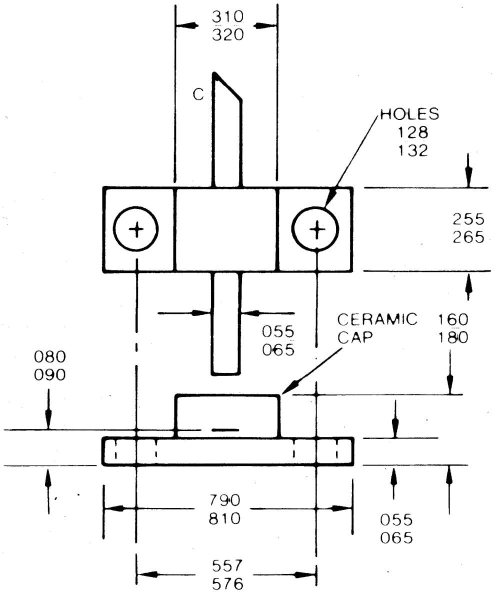
MTTF = $(3.46 \times 10^{-5/12})$ EXP $[11376/T_j$ (°K)]

TABLE I

TRANSIENT θ_{JF}

τon μsec	θ_{JF} °C/W
10^{-1}	.0413
10^0	.127
10^1	.321
10^2	.750
10^3	1.30
10^4	2.09
10^5	2.75
$\geqslant 10^6$	3.12

MRA



TRW® SEMICONDUCTORS

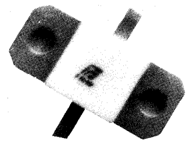
MRP 0912 - 150

PRELIMINARY

The MRP 0912 series offers a complete family of broadband high power devices for pulsed application in the 0.9 - 1.2 GHz band. Using internal compensation, the MRP 0912 series is intended for use in IFF, DME, TACAN and transponder applications.

All units are gold metallized for longevity and resistance to metal migrations. They are emitter balasted with diffused silicon resistors for reliability and ruggedness.

960 - 1215 MHz
150 W PULSE POWER
50 V
GOLD RELIABILITY

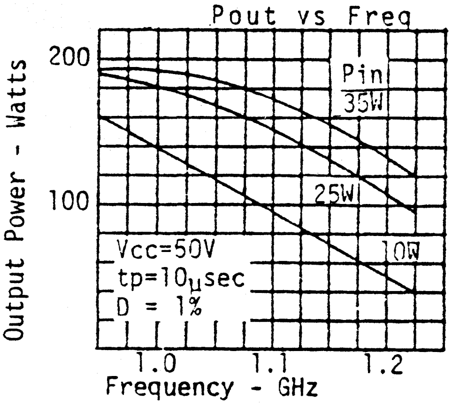


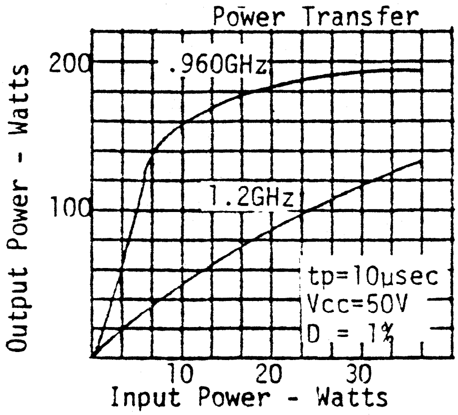
MRP

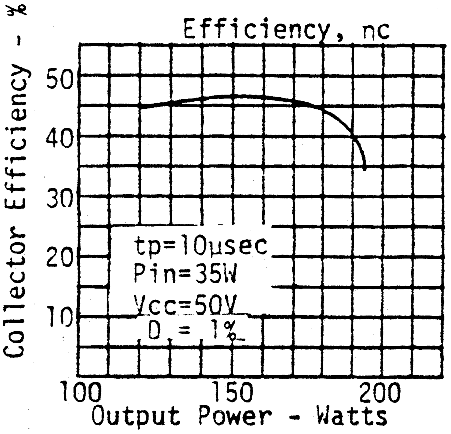
Electrical Characteristics (T_{case} = 25 °C)

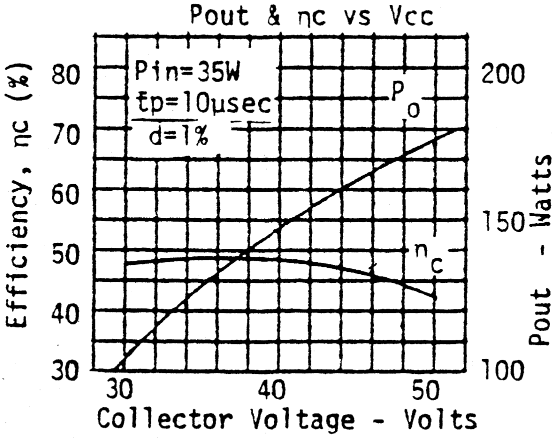
	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC TEST	BV_{CES}	Collector - Emitter Breakdown Voltage	I_C = 30 mA	65			V
	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 5 mA	3.5			V
	H_{FE}	D.C. Current Gain	V_{CE} = 10 V I_C = 1 A	15		100	—
RF TEST	P_{out}	Output Power	V_{CB} = 50 V RF Pulse : 10 µsec 1 % D.C. $P_{in} \doteq 35$ W f = 1 150 MHz	150			W
	I_C	Collector Current	V_{CB} = 50 V RF Pulse : 10 µsec 1 % D.C. P_{in} = 35 W f = 1 150 MHz			10	A
DESIGN RATINGS	P_T	Power Dissipation				77	W
	I_C	Continuous Collector Current				15	A
	θ_{JC}	Thermal Resistance			2.3		°C/W
	T_{STG}	Storage Temperature		— 65		+ 200	°C

TYPICAL CHARACTERISTICS

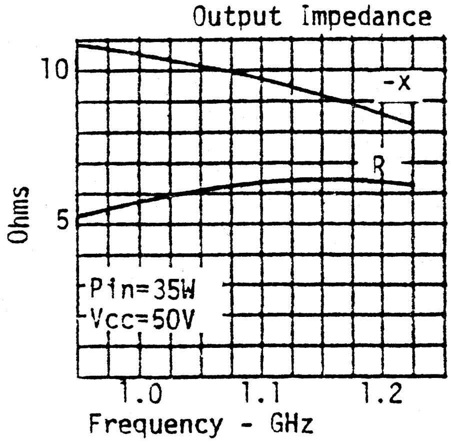

Pout vs Freq

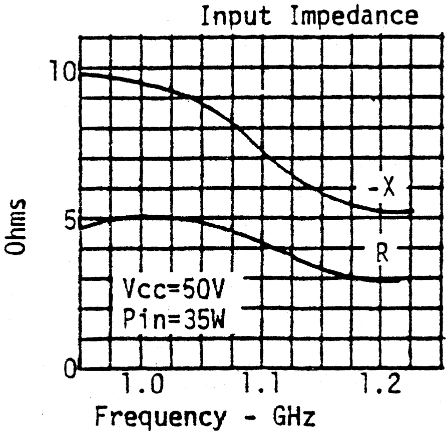

Power Transfer


Efficiency, ηc


Pout & ηc vs Vcc

TYPICAL CHARACTERISTICS





DESIGN RATINGS

MTTF (typ) (See Note # 1)

2.17×10^6 hr-amp^2

NOTE # 1 : Based on Metal Migration Theory,

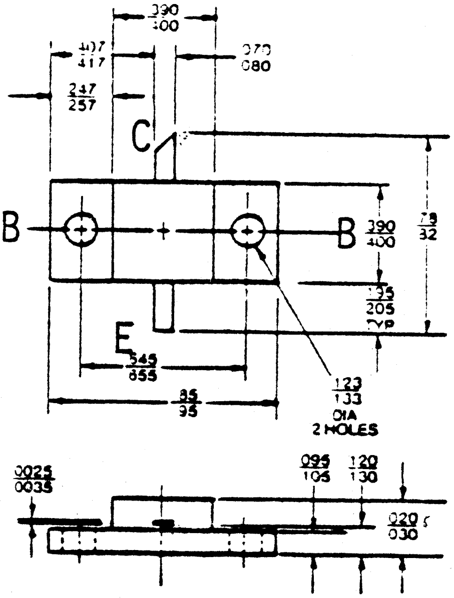
$\mathrm{MTTF} = (7.79 \times 10^{-5/I^2})\ \mathrm{EXP}\,[11376/T_j\ (°K)]$

TABLE I

TRANSIENT θ_{JF}

τon µsec	θ_{JF} °C/W
10^{-1}	.0275
10^{0}	.089
10^{1}	.231
10^{2}	.547
10^{3}	.95
10^{4}	1.52
10^{5}	2.01
$\geqslant 10^{6}$	2.28

MRP



TRW® SEMICONDUCTORS

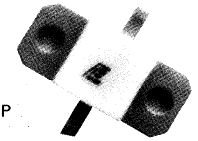
MRP 0912 - 250

PRELIMINARY

The MRP 0912 series offers a complete family of broadband high power devices for pulsed application in the 0.9 - 1.2 GHz band. Using internal compensation, the MRP 0912 series is intended for use in IFF, DME, TACAN and transponder applications.

All units are gold metallized for longevity and resistance to metal migrations. They are emitter balasted with diffused silicon resistors for reliability and ruggedness.

960 - 1215 MHz
75 W PULSE POWER
50 V
GOLD RELIABILITY

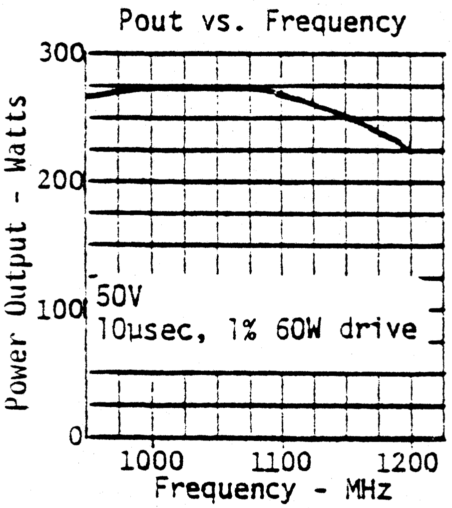


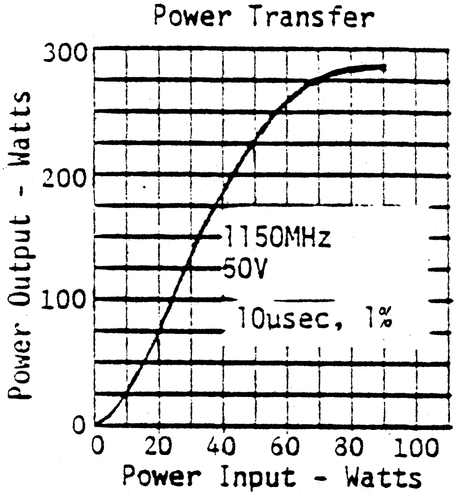
MRP

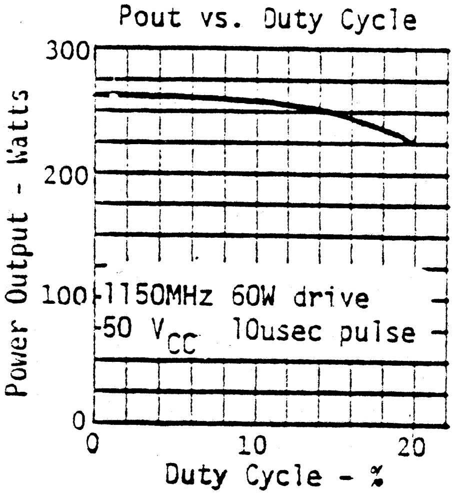
Electrical Characteristics (T_{case} = 25 °C)

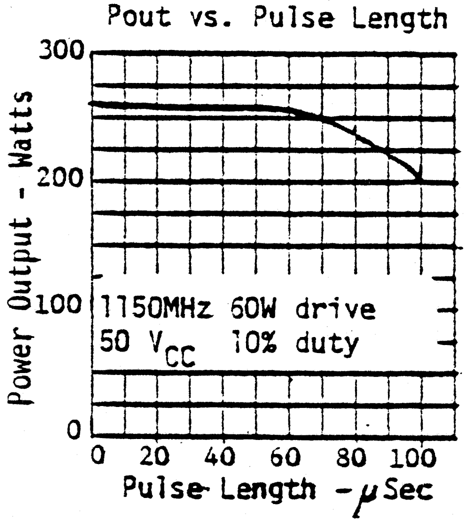
	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC TEST	BV_{CES}	Collector - Emitter Breakdown Voltage	I_C = 50 mA	65			V
	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 10 mA	3.5			V
	H_{FE}	D.C. Current Gain	V_{CE} = 10 V I_C = 1 A	15		100	—
RF TEST	P_{out}	Output Power	V_{CB} = 50 V RF Pulse : 10 µsec 1 % D.C. P_{in} = 65 W F = 1 150 MHz	250			W
	I_C	Collector Current	V_{CB} = 50 V RF Pulse : 10 µsec 1 % D.C. P_{in} = 65 W F = 1 150 MHz			16,6	A
DESIGN RATINGS	P_T	Power Dissipation				117	W
	I_C	Continuous Collector Current				20	A
	θ_{JC}	Thermal Resistance			1.5		°C/W
	T_{STG}	Storage Temperature		— 65		+ 200	°C

TYPICAL CHARACTERISTICS

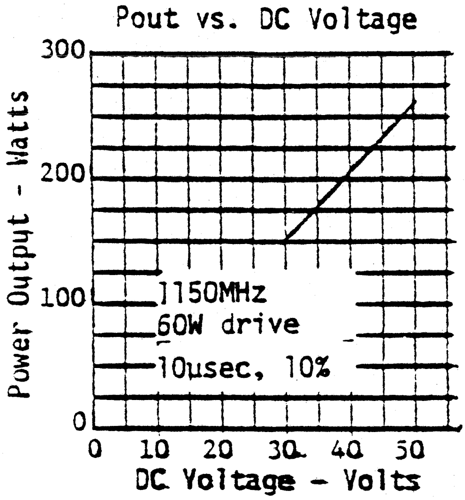


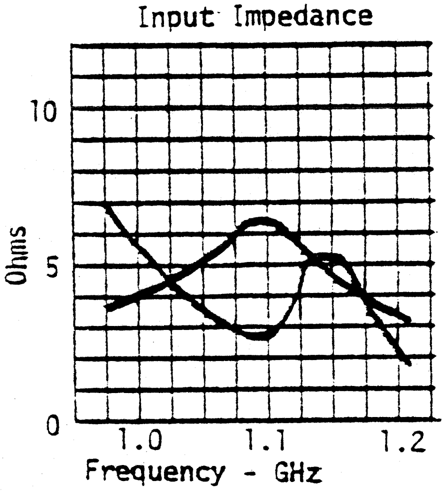


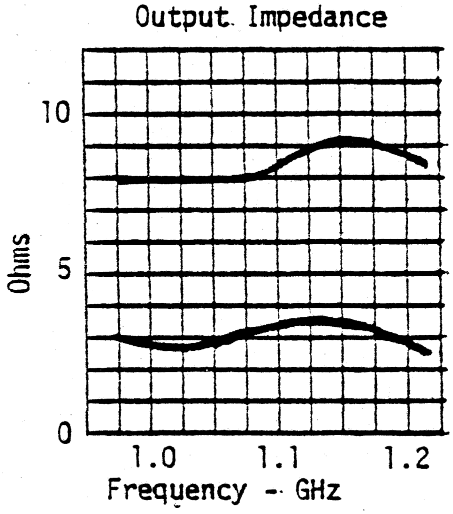




TYPICAL CHARACTERISTICS


Pout vs. DC Voltage


Input Impedance


Output Impedance

DESIGN RATINGS

MTTF (typ) (See Note # 1)

6.03×10^6 hr-amp^2

NOTE # 1 : Based on Metal Migration Theory,

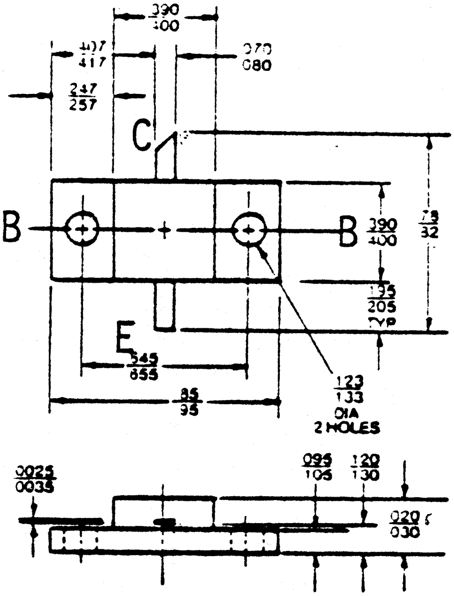
$\mathrm{MTTF} = (2.16 \times 10^{-4/I^2})\ \mathrm{EXP}\,[11376/T_j\ (°K)]$

TABLE I

TRANSIENT θ_{JF}

τon μsec	θ_{JF} °C/W
10^{-1}	.0165
10^{0}	.056
10^{1}	.156
10^{2}	.36
10^{3}	.63
10^{4}	1.02
10^{5}	1.35
$\geqslant 10^{6}$	1.53

MRP



TRW SEMICONDUCTORS

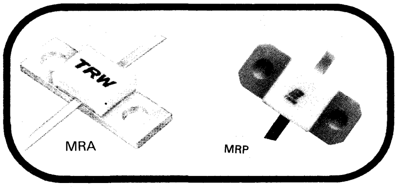
MRP 1115 - 1 . 5 E
MRP 1214 - 8
MRP 1214 - 30
MRP 1214 - 60

PRELIMINARY

1.2 - 1.4 GHz
PULSE POWER UP TO 60 W
GOLD RELIABILITY

The TRW MRP 1115 and 1214 series offers a complete family of broadband high power devices for pulsed application in the 1.2 - 1.4 GHz band.

Using internal compensation, the MRP 1115 and 1214 series is intended for use in phased array radar applications. All units are gold metallized for longevity and resistance to metal migrations. They are emitter balasted with diffused silicon resistors for reliability and ruggedness.



Electrical Characteristics (T_{case} = 25 °C)

SYMBOL	CHARACTERISTICS	MRP1115-1.5 E	MRP 1214-8	MRP 1214-30	MRP 1214-60
BV_{CES}	Collector - Base Breakdown Voltage	I_C = 20 mA 50 V min	I_C = 20 mA 60 V min	I_C = 60 mA 60 V min	I_C = 120 mA 60 V min
BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 0.5 mA 3.5 V min	I_E = 0.5 mA 3.5 V min	I_E = 1.5 mA 3.5 V min	I_E = 3.0 mA 3.5 V min
P_K	Peak Power Out 1.0 m sec PW, 15 % Duty Cycle				
	V_{CB} = 28 V	1.5 W	8.0 W	30.0 W	60.0 W
	V_{CE} = 18 V, I_C = 230 mA	1.5 W			
P_G	Typical Power Gain				
	V_{CB} = 28 V	9.0 dB	7.0 dB	7.0 dB	7.0 dB
	V_{CE} = 18 V, I_C = 230 mA	9.0 dB			
η_C	Typical Broadband Collector Efficiency	N/A	50 %	50 %	50 %
VSWR	Mismatch all Phase Angles	3 : 1	3 : 1	3 : 1	3 : 1
T_J	Max Junction Temperature	200 °C	200 °C	200 °C	200 °C

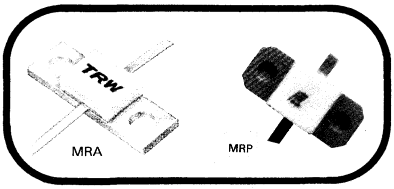
TRW SEMICONDUCTORS

MRP 1214 - 12 A
MRP 1214 - 40 A
MRP 1214 - 85 A

PRELIMINARY

The TRW MRP 1214 series offers a complete family of broadband high power devices for pulsed application in the 1.2 - 1.4 GHz band. Using internal compensation, the MRP 1214 series is intended for use in phased array radar applications. All units are gold metallized for longevity and resistance to metal migrations. They are emitter balasted with diffused silicon resistors for reliability and ruggedness.

1.2 - 1.4 GHz
PULSE POWER UP TO 85 W
GOLD RELIABILITY



Electrical Characteristics (T_{case} = 25 °C)

SYMBOL	CHARACTERISTICS	MRP 1214-12A	MRP 1214-40A	MRP 1214-85A
BV_{CES}	Collector - Base Breakdown Voltage	I_C = 20 mA 60 V min	I_C = 60 mA 60 V min	I_C = 120 mA 60 V min
BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 0.5 mA 3.5 V min	I_E = 1.5 mA 3.5 V min	I_E = 3.0 mA 3.5 V min
P_K	Peak Power Out 100 µsec PW, 10 % Duty, Cycle V_{CB} = 32 V	12.0 W	40.0 W	85.0 W
P_G	Typical Power Gain V_{CB} = 32 V	6.5 dB	6.5 dB	6.5 dB
η_C	Typical Broadband Collector Efficiency	50 %	50 %	50 %
VSWR	Mismatch all Phase Angle	2 : 1	2 : 1	2 : 1
T_J	Max Junction Temperature	200 °C	200 °C	200 °C

TRW *SEMICONDUCTORS*

SUPER 2 GHz Series

Microwave Power Transistors

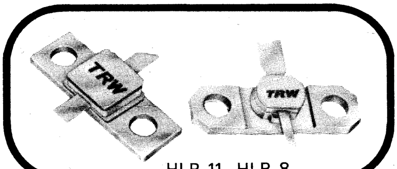
The TRW « Super 2 GHz » series is the first group of 2 GHz, common base devices offering unqualified tolerance of **complete mismatch** (∞ VSWR, any phase) conditions. This feature is particularly desirable in military and space applications where multi-million dollar investments (and even human lives) can be jeopardized by device failure.

The « Super 2 GHz » series is characterized to 2.3 GHz and is priced to be attractive in industrial service. All units are **gold metalized** for longevity and resistance to metal migration. They are emitter ballasted with heat sinked, diffused, rather than deposited metal resistors. This series is housed in TRW's true hermetic, MIL acceptable, HLP package. The package is available with or without flange.

The « Super 2 GHz » series can be adapted readily to circuits designed around older, less reliable devices with a minimum of circuit adjustment. They are mechanically interchangeable with other similar 2 GHz devices.

TRW 2001	1 W, 9 dB	
TRW 2003	3 W, 8 dB	
TRW 2005	5 W, 8 dB	
TRW 2010	10 W, 6 dB	
TRW 2015	15 W, 6 dB	
TRW 2020	20 W, 5.2 dB	

∞ VSWR


HLP-11 HLP-8

Electrical Characteristics (T_{CASE} = 25 °C)

Mechanical Specifications

The following are mechanical specifications for this transistor.

Dimensions : Per outline drawing.

Solderability : Per MIL-STD-750.

Marking : Per MIL-S-19500, « TRW », 4-digit date code, type number.

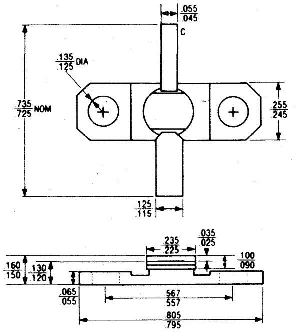
Hermeticity : Per MIL-STD-750, 10^{-7} atmospheres gross and fine leak. (Available on special order screened to 10^{-8} atmospheres.)

Acceleration : Per MIL-STD-750, 20.000 G in any plane.

Bond Pull : Per MIL-STD-750, 3 grams min.

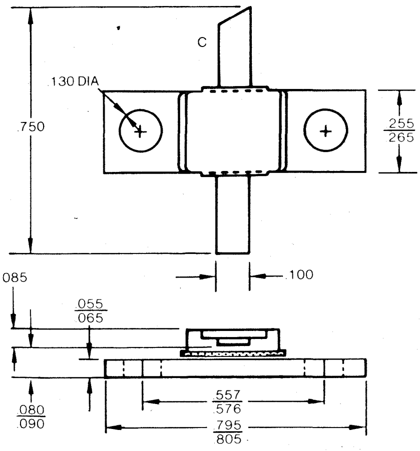
Package HLP-11 HLP-8 : A glass-free, brazed ceramic package assuring long-term integrity of hermetic seals. Leads of KOVAR base material with minimum 60 micro-inches of gold plating.

HLP-8 Normal Package



Flangeless HLP-8
Specify « F » Suffix

HLP-11 Package



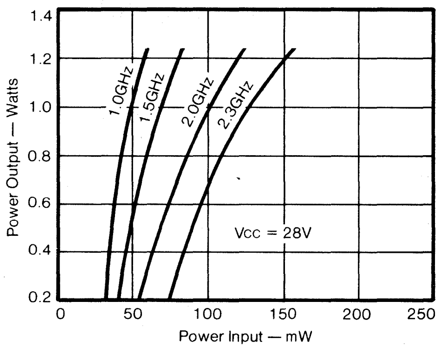
Flangeless HLP-11
Specify « F » Suffix

TRW 2001

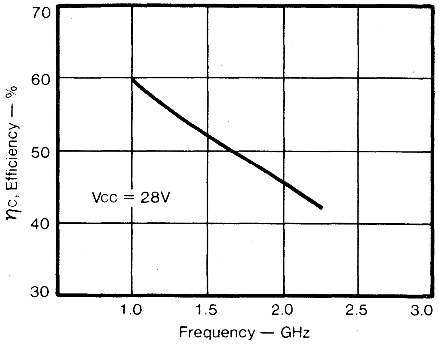
Electrical Characteristics (T_{flange} = 25°C)

Symbol	Characteristic	Conditon	Value
BV_{CER}	Collector-Base Breakdown Voltage $R_{BE} = 10\Omega$	$I_C = 10mA$	50V Min
BV_{EBO}	Emitter-Base Breakdown Voltage	$I_E = 1mA$ $I_C = 0$	4.0V Min
I_{CBO}	Collector Cutoff Current	$V_{CB} = 28V$ $I_E = 0$ $V_{CB} = 45V$	500μA 1mA
I_C	Continuous Collector Current (Max)	$V_{CE} = 4V$	0.250A
h_{FE}	Forward Current Transfer Ratio	$V_{CE} = 5V$ $I_C = 100mA$	10-120
θ_{JF}	Thermal Resistance (Junction to Flange)	—	28°C/W
C_{OB}	Collector-Base Capacitance (Max)	$V_{CB} = 28V$	3.0pF
P_o	Power Output @ 2000MHz	$P_{in} = 0.125W$	1W Min
$P_{o(sat)}$	Power Output @ 2300MHz	$V_{CE} = 28Vdc$	1.0W (Typ)
	Power Output @ 1500MHz		1.2W (Typ)
	Power Output @ 1000MHz		1.3W (Typ)
P_{gain}	Power Gain (dB) @ 2000MHz	$P_o = 1.0W$	9dB Min
VSWR	Mismatch Tolerance @ $V_{CC} = 28V$	$P_o = 1.0W$ f = 2.0GHz	∞
MTTF	Mean-Time-to-Metal Failure (Hrs x Amps²)	$T_j = 150°C$	4,661
η_C	Collector Efficiency (Min)	$P_o = 1.0W$ f = 2.0GHz	40%
T_j & T_{stg}	Max Junction and Storage Temperatures	-65 to 200°C	

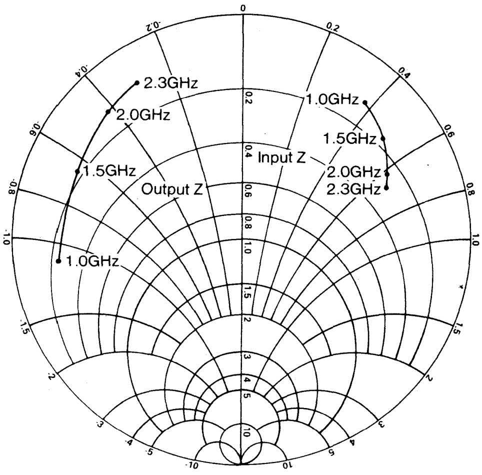
Typical Transfer Characteristics Versus Frequency



Typical ηc Versus Frequency



Impedance Data Vcc = 28V

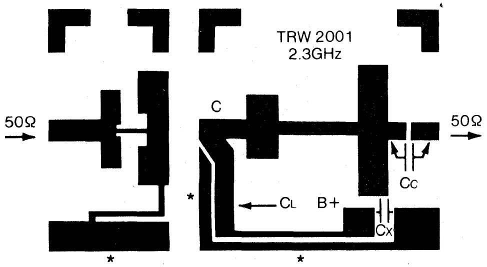


PC BOARD LAYOUT FOR TRW 2001 TEST CIRCUITS

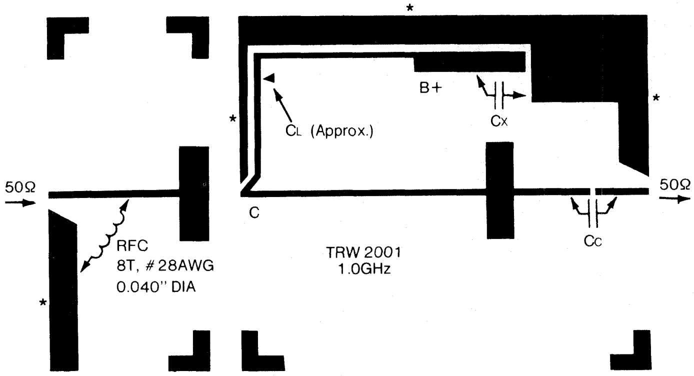
PART DETAILS

* = Foil-wrap asterisked edge to ground plane
C_C = 220pF chip on all circuits
C_X = A combination of two 220pF chips, one 0.1 chip and a 25μF tantalum capacitor (35V min)
C_L = Used as an AC bypass on the shunt inductor line (220pF chip) whose position can be varied

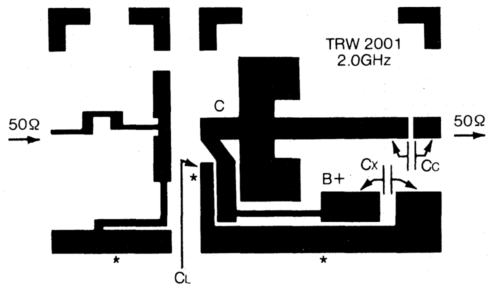
RFC = 1000MHz . . . . 8 turns, #28AWG, 0.040 dia
RFC = 1500MHz . . . . 6 turns, #28AWG, 0.040 dia
RFC = 2000 and 2300MHz . . . . 4 turns, #28AWG, 0.040 dia



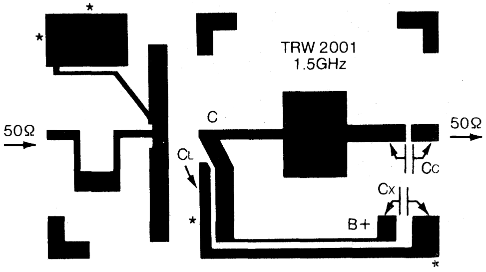
Board Material = 0.062" Glass-Teflon ε_r = 2.55



Board Material = 0.020" Glass-Teflon ε_r = 2.55



Board Material = 0.062" Glass-Teflon ε_r = 2.55

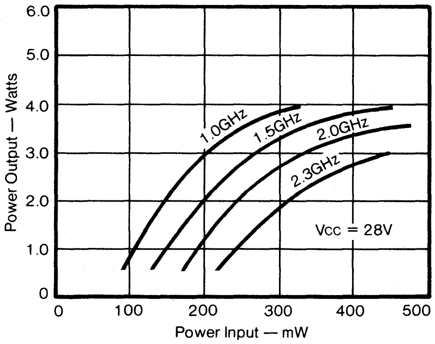


Board Material = 0.062" Glass-Teflon ε_r = 2.55

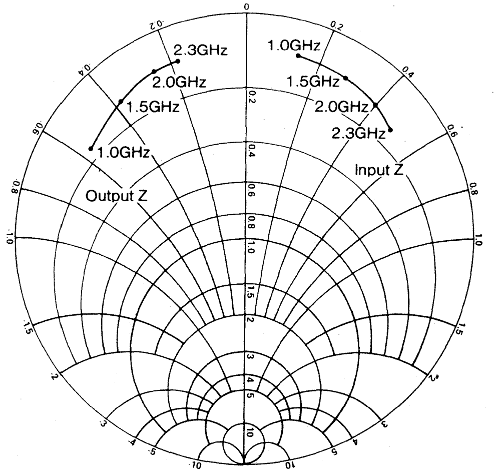
TRW 2003

Electrical Characteristics ($T_{flange} = 25°C$)

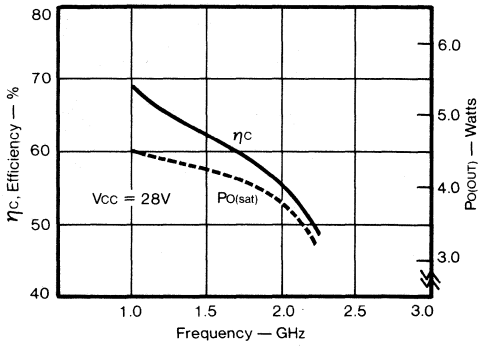
Symbol	Characteristic	Conditon	Value
BV_{CER}	Collector-Base Breakdown Voltage $R_{BE} = 10\Omega$	$I_C = 20mA$	50V Min
BV_{EBO}	Emitter-Base Breakdown Voltage	$I_E = 0.25mA$ $I_C = 0$	3.5V Min
I_{CBO}	Collector Cutoff Current	$V_{CB} = 28V$ $I_E = 0$ $V_{CB} = 45V$	500μA 1mA
I_C	Continuous Collector Current (Max)	$V_{CE} = 4V$	0.50A
h_{FE}	Forward Current Transfer Ratio	$V_{CE} = 5V$ $I_C = 100mA$	10-100
θ_{jF}	Thermal Resistance (Junction to Flange)	—	15°C/W
C_{OB}	Collector-Base Capacitance (Max)	$V_{CB} = 28V$	5.0pF
P_o	Power Output @ 2000MHz	$P_{in} = 0.47W$	3.0W Min
$P_{o(sat)}$	Power Output @ 2300MHz	$V_{CE} = 28Vdc$	3.0W (Typ)
	Power Output @ 1500MHz		3.7W (Typ)
	Power Output @ 1000MHz		4.0W (Typ)
P_{gain}	Power Gain (dB) @ 2000MHz	$P_o = 3.0W$	8dB Min
VSWR	Mismatch Tolerance @ $V_{CC} = 28V$	$P_o = 3.0W$ $f = 2.0GHz$	∞
MTTF	Mean-Time-to-Metal Failure (Hrs x Amps²)	$T_j = 150°C$	20,300
η_C	Collector Efficiency (Min)	$P_o = 3.0W$ $f = 2.0GHz$	40%
T_j & T_{stg}	Max Junction and Storage Temperatures	-65 to 200°C	



Typical Transfer Characterics
Versus Frequency

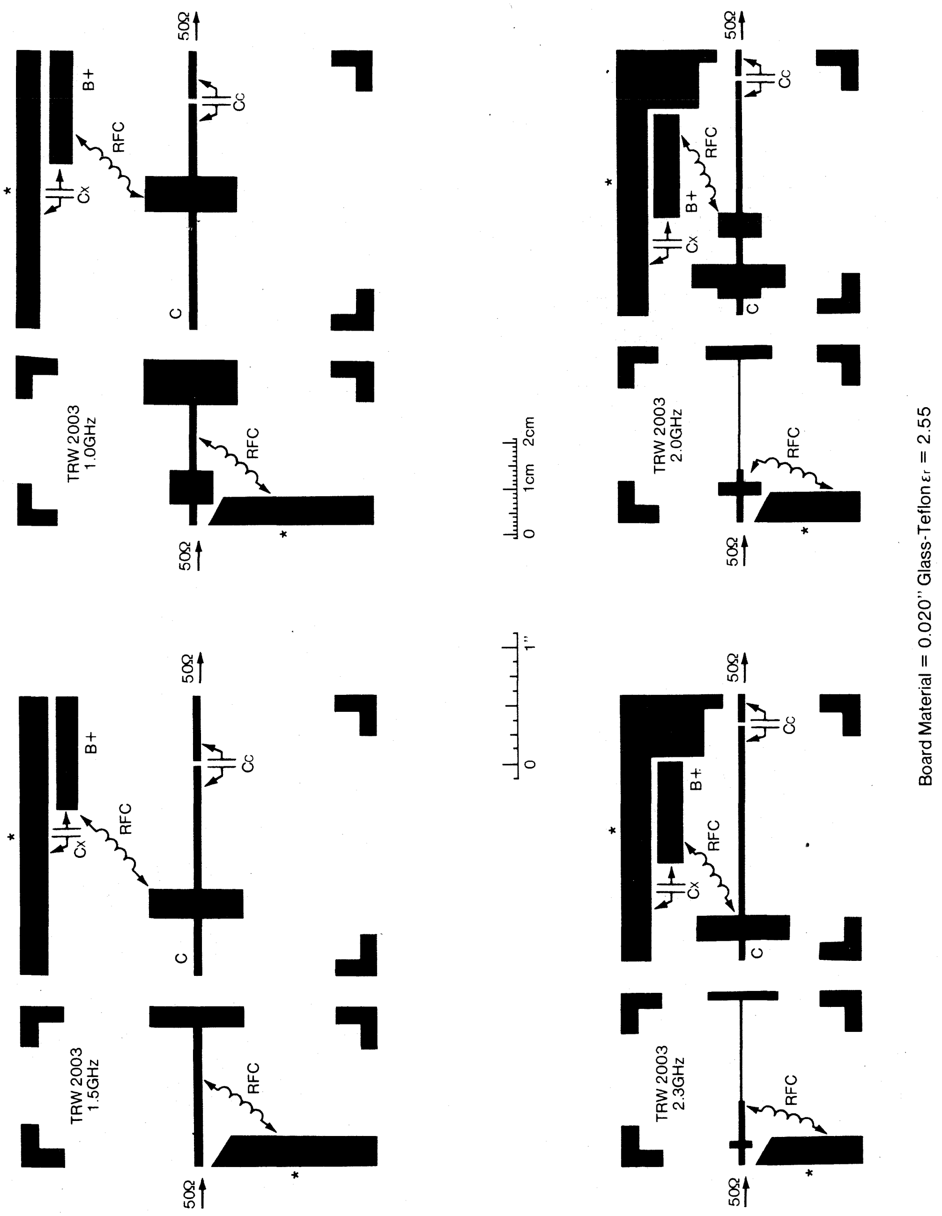


Impedance Data
Vcc = 28V



Typical ηc, Power Output
Versus Frequency

PC BOARD LAYOUT FOR TRW 2003
TEST CIRCUITS



Board Material = 0.020" Glass-Teflon εr = 2.55

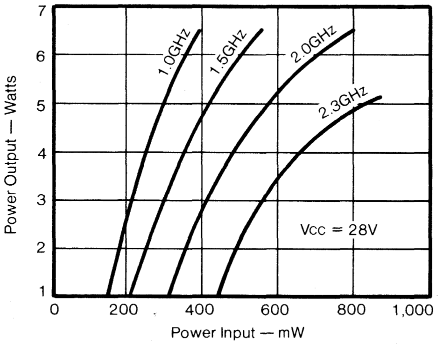
See page 3 for parts details

TRW 2005

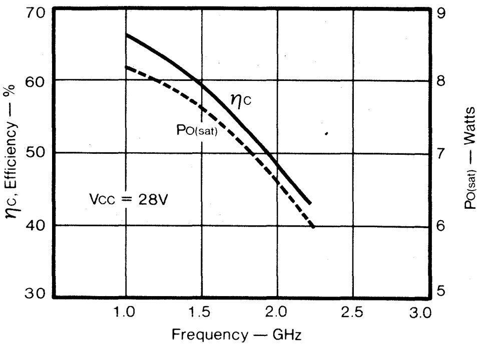
Electrical Characteristics ($T_{flange} = 25°C$)

Symbol	Characteristic	Conditon	Value
BV_{CER}	Collector-Base Breakdown Voltage $R_{BE} = 10\Omega$	$I_C = 40mA$	50V Min
BV_{EBO}	Emitter-Base Breakdown Voltage	$I_E = 0.5mA$ $I_C = 0$	3.5V Min
I_{CBO}	Collector Cutoff Current	$V_{CB} = 28V$ $I_E = 0$ $V_{CB} = 45V$	500μA 2mA
I_C	Continuous Collector Current (Max)	$V_{CE} = 4V$	1.0A
h_{FE}	Forward Current Transfer Ratio	$V_{CE} = 5V$ $I_C = 200mA$	10-100
θ_{JF}	Thermal Resistance (Junction to Flange)	—	8.5°C/W
C_{OB}	Collector-Base Capacitance (Max)	$V_{CB} = 28V$	7.0pF
P_O	Power Output @ 2000MHz	$P_{in} = 0.80W$	5W Min
$P_{O(sat)}$	Power Output @ 2300MHz	$V_{CE} = 28Vdc$	5.0W (Typ)
	Power Output @ 1500MHz		6.5W (Typ)
	Power Output @ 1000MHz		7.5W (Typ)
P_{gain}	Power Gain (dB) @ 2000MHz	$P_O = 5.0W$	8dB Min
VSWR	Mismatch Tolerance @ $V_{CC} = 28V$	$P_O = 5.0W$ $f = 2.0GHz$	∞
MTTF	Mean-Time-to-Metal Failure (Hrs x Amps²)	$T_j = 150°C$	81,200
η_C	Collector Efficiency (Min)	$P_O = 5.0W$ $f = 2.0GHz$	40%
T_j & T_{stg}	Max Junction and Storage Temperatures	-65 to 200°C	

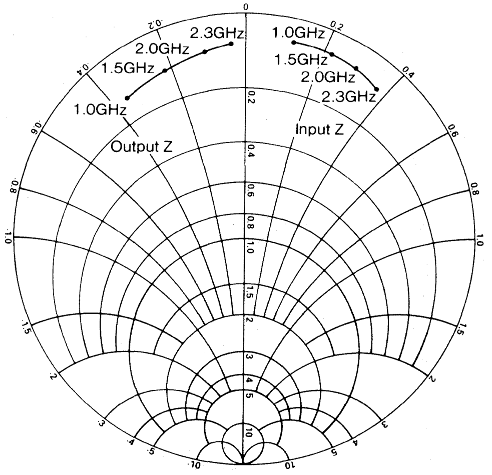
Typical Transfer Characteristics Versus Frequency



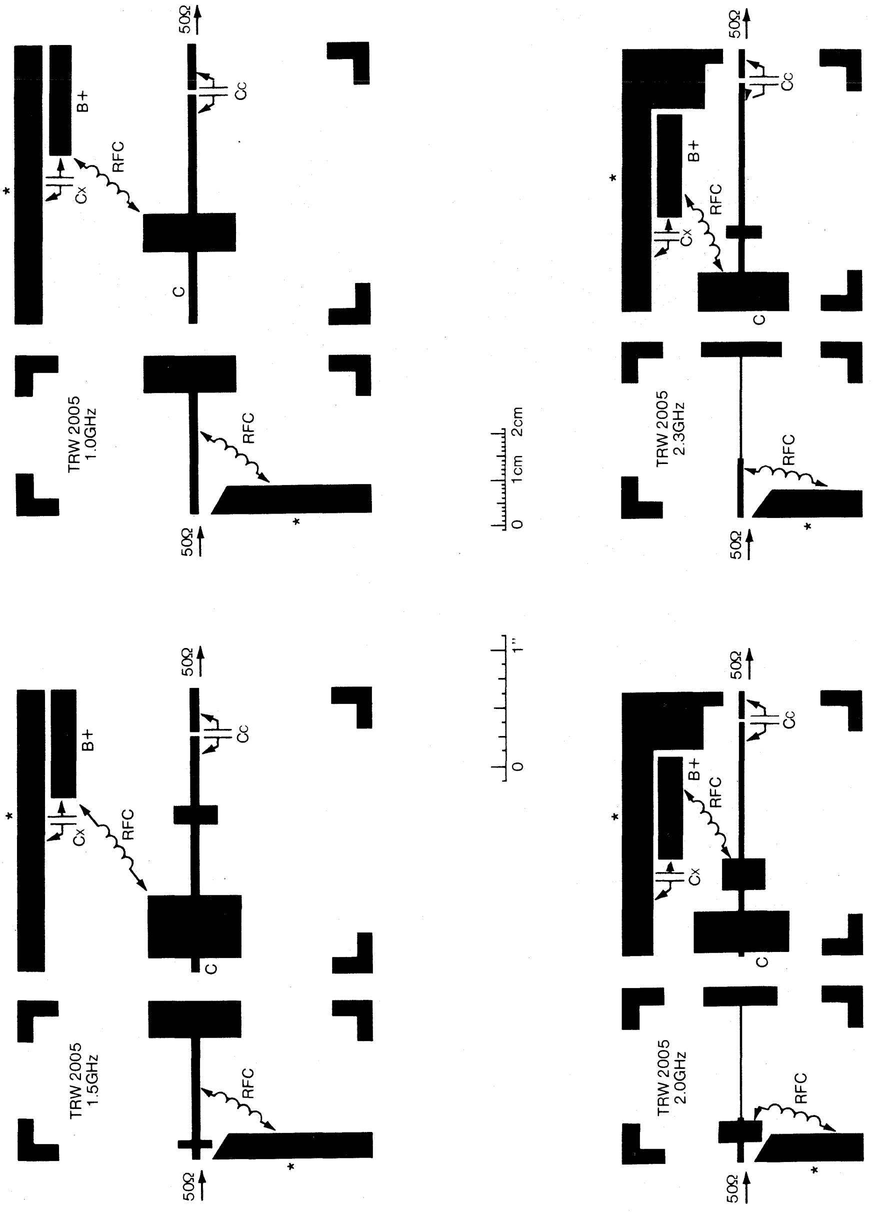
Typical η_C, Power Output Versus Frequency



Impedance Data
$V_{CC} = 28V$



PC BOARD LAYOUT FOR TRW 2005 TEST CIRCUITS



Board Material = 0.020" Glass-Teflon ε_r = 2.55

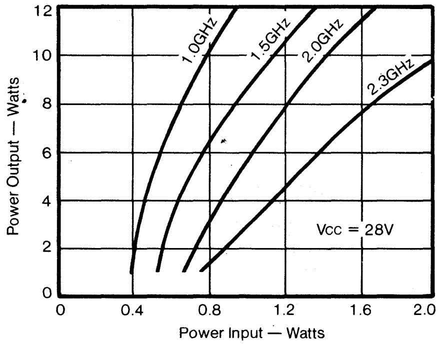
See page 3 for parts details

TRW 2010

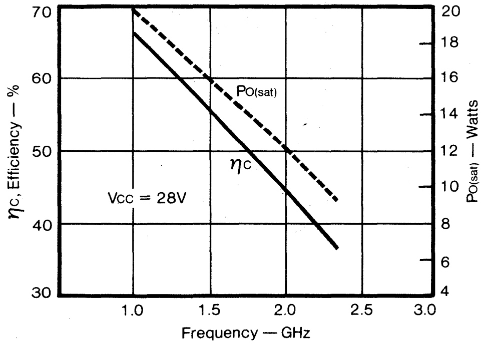
Electrical Characteristics (T_{flange} = 25°C)

Symbol	Characteristic	Conditon	Value
BV_{CER}	Collector-Base Breakdown Voltage R_{BE} = 10Ω	I_C = 80mA	50V Min
BV_{EBO}	Emitter-Base Breakdown Voltage	I_E = 1.0mA I_C = 0	3.5V Min
I_{CBO}	Collector Cutoff Current	V_{CB} = 28V I_E = 0 V_{CB} = 45V	500μA 4mA
I_C	Continuous Collector Current (Max)	V_{CE} = 4V	2.0A
h_{FE}	Forward Current Transfer Ratio	V_{CE} = 5V I_C = 400mA	10-100
θ_{jF}	Thermal Resistance (Junction to Flange)	—	6°C/W
C_{OB}	Collector-Base Capacitance (Max)	V_{CB} = 28V	12.0pF
P_o	Power Output @ 2000MHz	P_{in} = 2.5W	10.0W Min
$P_{o(sat)}$	Power Output @ 2300MHz	V_{CE} = 28Vdc	10.0W (Typ)
	Power Output @ 1500MHz		13.0W (Typ)
	Power Output @ 1000MHz		15.0W (Typ)
P_{gain}	Power Gain (dB) @ 2000MHz	P_o = 10W	6dB Min
VSWR	Mismatch Tolerance @ V_{CC} = 28V	P_o = 10.0W f = 2.0GHz	∞
MTTF	Mean-Time-to-Metal Failure (Hrs x Amps²)	T_j = 150°C	324,800
η_C	Collector Efficiency (Min)	P_o =10.0W f = 2.0GHz	40%
T_j & T_{stg}	Max Junction and Storage Temperatures	-65 to 200°C	

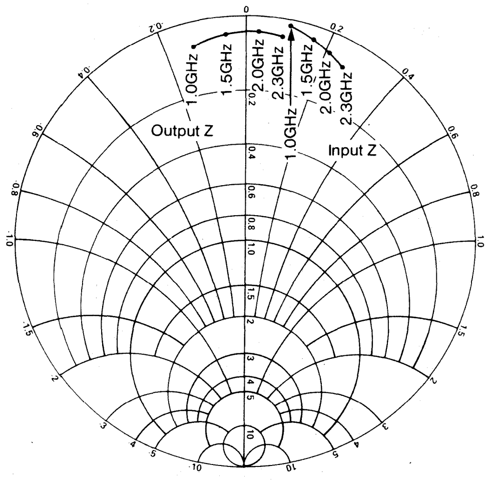
Typical Transfer Characteristics Versus Frequency



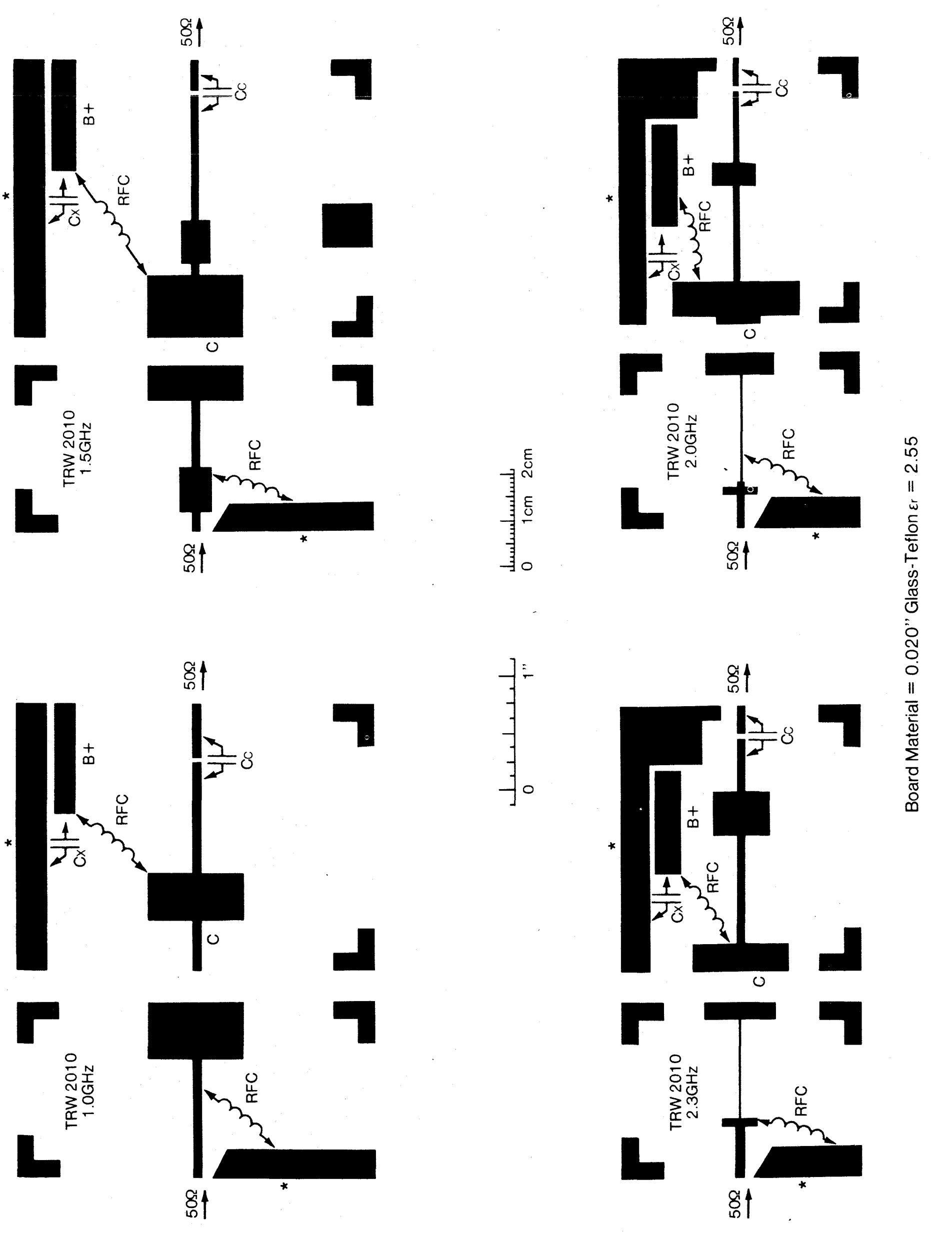
Typical η_C, Power Output Versus Frequency



Impedance Data
V_{CC} = 28V



PC BOARD LAYOUT FOR TRW 2010
TEST CIRCUITS



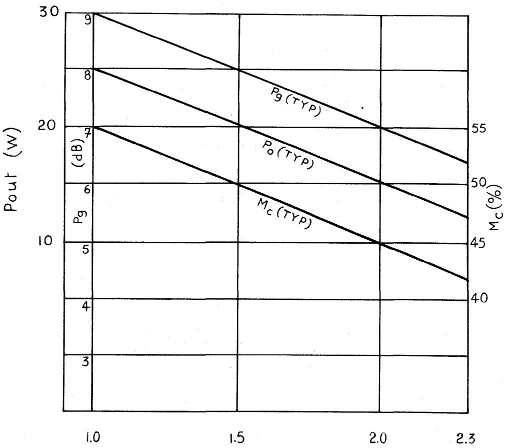
See page 3 for parts details

TRW 2015

Electrical Characteristics (T_{FLANGE} = 25°C)

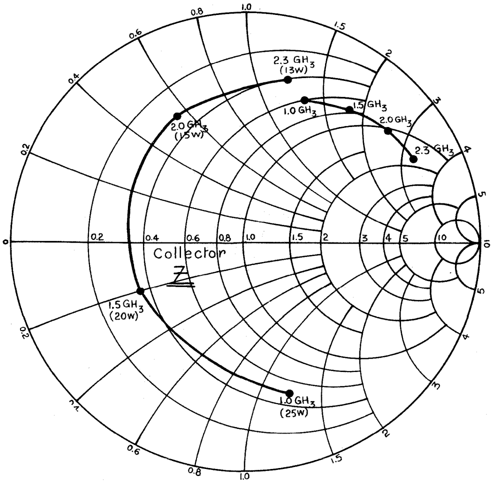
Symbol	Characteristic	Condition	Value
BV_{CER}	Collector-Base Breakdown Voltage R_{BF} = 10 Ω	I_C = 120 mA	50 V Min
BV_{EBO}	Emitter-Base Breakdown Voltage	I_E = 1,5 mA I_C = 0	3.5 V Min
I_{CBO}	Collector Cutoff Current	V_{CB} = 28 V I_E = 0	1.0 mA Max
I_C	Continuous Collector Current (Max)	V_{CE} = 4 V	3.0 A
h_{FE}	Forward Current Transfer Ratio	V_{CE} = 5 V I_C = 600 mA	10-100
θ_{jF}	Thermal Resistance (Junction to Flange)	—	4 °C/W
C_{OB}	Collector-Base Capacitance (Max)	V_{CB} = 28 V	21 pF
P_o	Power Output 2000 MHz	P_{in} = 3.75 W	15.0 W Min
$P_{o(sat)}$	Power Output 1500 MHz	V_{CE} = 28 V	22 W Typ
	Power Output 1000 MHz		30 W Typ
P_{gain}	Power Gain (dB) 2000 MHz	P_o = 15 W	6 dB Min
VSWR	Mismatch Tolerance V_{CC} = 28 V	P_o = 15 W f = 2 GHz	∞
MTTF	Mean Time-to-Metal Failure (Hrs × Amps^2)	T_j = 150 °C	780,000
η_C	Collector Efficiency (Min)	P_o = 15 W f = 2 GHz	40 %
T_j & T_{stg}	Max Junction and Storage Temperature	— 65 °C to + 200 °C	

Typical Performance Characteristics



Impedance Data

Vcc = 28V Zo = 5.0Ω

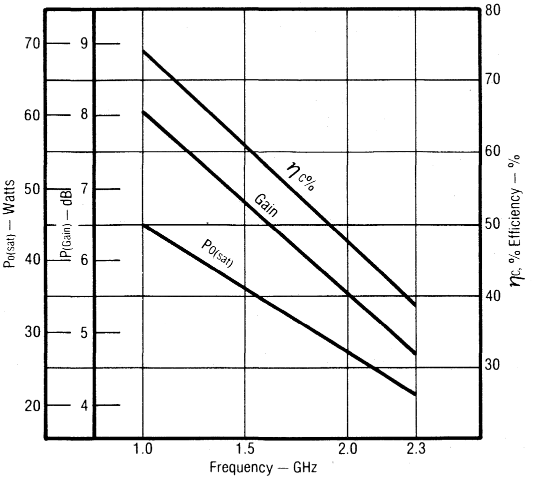


TRW 2020

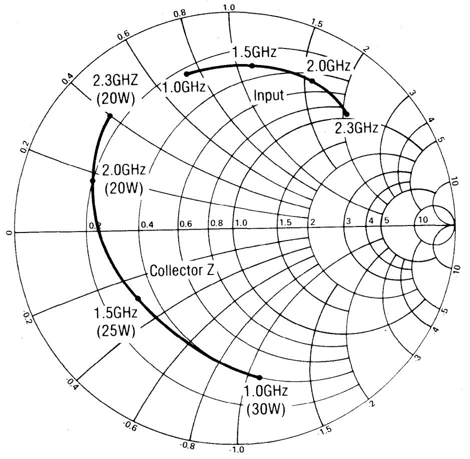
Electrical Characteristics (T_{FLANGE} = 25°C)

Symbol	Characteristic	Condition	Value
BV_{CER}	Collector-Base Breakdown Voltage R_{BE} = 10Ω	I_C = 160mA	50V Min
BV_{EBO}	Emitter-Base Breakdown Voltage	I_E = 2.0mA I_C = 0	3.5V Min
I_{CBO}	Collector Cutoff Current	V_{CB} = 28V I_E = 0 V_{CB} = 45V	1.0mA 8mA
I_C	Continuous Collector Current (Max)	V_{CE} = 4V	4.0A
h_{FE}	Forward Current Transfer Ratio	V_{CE} = 5V I_C = 800mA	10-100
θ_{jF}	Thermal Resistance (Junction to Flange)	—	3°C/W
C_{OB}	Collector-Base Capacitance (Max)	V_{CB} = 28V	24.0pF
P_O	Power Output @ 2000MHz	P_{in} = 6.0W	20.0W Min
$P_{O(sat)}$	Power Output @ 1500MHz	V_{CE} = 28Vdc	30.0W (Typ)
	Power Output @ 1000MHz		40.0W (Typ)
P_{gain}	Power Gain (dB) @ 2000MHz	P_O = 20W	5.2dB Min
VSWR	Mismatch Tolerance @ V_{CC} = 28V	P_O = 20.0W f = 2.0GHz	∞
MTTF	Mean-Time-to-Metal Failure (Hrs x Amps²)	T_j = 150°C	1,588,000
η_C	Collector Efficiency (Min)	P_O = 20.0W f = 2.0GHz	40%
T_j & T_{stg}	Max Junction and Storage Temperature	-65 to 200°C	

Typical Performance Characteristics

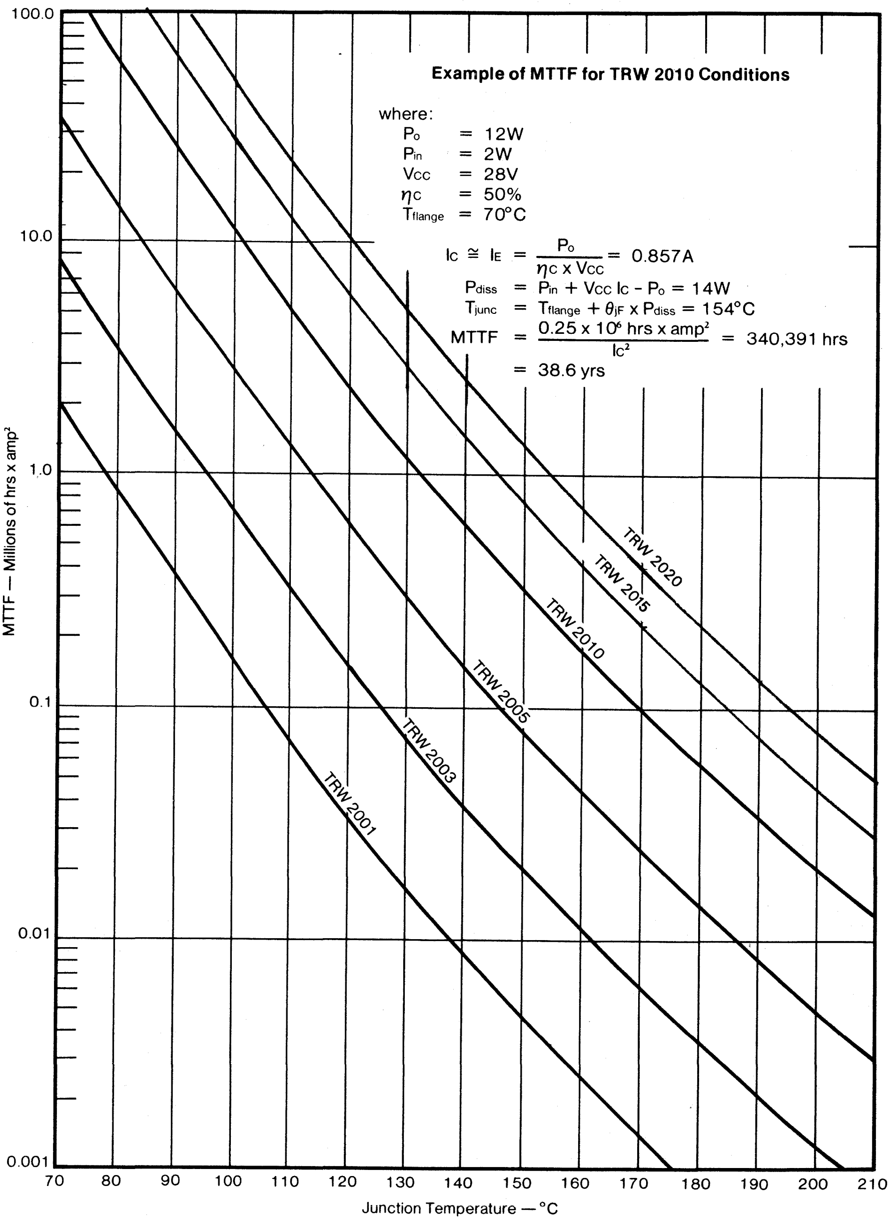


Impedance Data
V_{CC} = 28V Z_O = 5.0Ω



MTTF FACTOR (Normalized to 1 ampere² Continuous Duty)

The graph shown below displays MTTF in hours x ampere² emitter current for each of the "Super 2GHz" 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 on the graph.



Example of MTTF for TRW 2010 Conditions

where:

$P_o = 12W$

$P_{in} = 2W$

$V_{CC} = 28V$

$\eta_C = 50\%$

$T_{flange} = 70°C$

$$I_C \cong I_E = \frac{P_o}{\eta_C \times V_{CC}} = 0.857A$$

$$P_{diss} = P_{in} + V_{CC}\, I_C - P_o = 14W$$

$$T_{junc} = T_{flange} + \theta_{jF} \times P_{diss} = 154°C$$

$$MTTF = \frac{0.25 \times 10^6 \text{ hrs x amp}^2}{I_C^2} = 340{,}391 \text{ hrs}$$

$$= 38.6 \text{ yrs}$$

TRW® **SEMICONDUCTORS**

TRW 2301

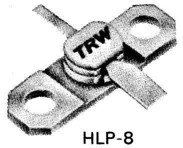
Microwave Power Transistor

2.3 GHz
1.5 W - 20 V
∞ VSWR

Latest in the TRW « Super 2 GHz » Series, the TRW 2301 offers a sturdy transistor which is ideally suited to space, military, radio relay and other applications in the 1 to 3.0 GHz region.

The device is capable of withstanding any mismatch load condition at any phase angle up to, and including, open and short circuit (∞ **VSWR**) under full rated conditions. The unit is **gold metalized,** thereby eliminating metal migration problems common with aluminum parts (metal failure predictions are included herein). Further, the transistor is emitter ballasted with **diffused silicon resistors** rather than deposited metal film resistors for reliability and ruggedness.

The TRW 2301 is housed in the HLP-8, glass-free, **full hermetic** package which is available with or without mouning flange. Full mechanical specifications are guaranteed.



HLP-8

Electrical Characteristics (T_{flange} = 25 °C)

	Symbol	Characteristics	Condition	Value
D C Tests	BV_{CER}	Collector-Base Breakdown Voltage R_{BE} = 10 Ω	I_C = 50 mA	42 V Min
	BV_{EBO}	Emitter-Base Breakdown Voltage	I_E = 1.0 mA I_c = 0	3.5 V Min
	I_{CBO}	Collector Cutoff Current	V_{CB} = 22 V I_E = 0	0.5 mA
	h_{FE}	Forward Current Transfer Ratio	V_{CE} = 5 V I_C = 100 mA	10-120
R F Tests	C_{OB}	Collector-Base Capacitance (Max)	V_{CB} = 20 V	4 pF
	P_o	Power Output	f = 2.3 GHz V_{CE} = 20 V V_{CE} = 24 V	1.5 W Min 2 W Typ
	P_{gain}	Power Gain (dB)	f = 2.3 GHz P_o = 1.5 W V_{CE} = 20 V	8.0 dB Min
	VSWR	Mismatch Tolerance	P_o = 1.5 W f = 2.3 GHz V_{CE} = 20 V	∞
	η_C	Collector Efficiency	P_o = 1.5 W f = 2.3 GHz V_{CE} = 20 V	40 % Min
Operating	T_j & T_{stg}	Max Junction and Storage Temperature	— 65 to + 200 °C	
	θ_{jF}	Thermal Resistance		35 °C/W
	I_C	Continuous Collector Current	V_{CE} = 5 V	0.5 A Max

TRW® SEMICONDUCTORS

TRW 2304

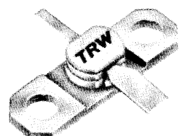
Transistor Microwave Power

Latest in the TRW « Super 2 GHz » Series, the TRW 2304 offers a sturdy transistor which is ideally suited to space, military, radio relay and other applications in the 1 to 3.0 GHz region.

The device is capable of withstanding any mismatch load condition at any phase angle up to, and including, open and short circuit (∞ **VSWR**) under full rated conditions. The unit is **gold metalized,** thereby eliminating metal migration problems common with aluminum parts (metal failure predictions are included herein). Further, the transistor is emitter ballasted with **diffused silicon resistors** rather than deposited metal film resistors for reliability and ruggedness.

The TRW 2304 is housed in the HLP-8, glass-free, **full hermetic** package which is available with or without mounting flange. Full mechanical specifications are guaranteed.

2.3 GHz
4 W - 20 V
∞ VSWR



HLP-8

Electrical Characteristics (T_{flange} = 25 °C)

	Symbol	Characteristics	Condition	Value
D C Tests	BV_{CER}	Collector-Base Breakdown Voltage $R_{BE} = 10\ \Omega$	$I_C = 50$ mA	42 V Min
	BV_{EBO}	Emitter-Base Breakdown Voltage	$I_E = 1.0$ mA $I_C = 0$	3.5 V Min
	I_{CBO}	Collector Cutoff Current	$V_{CB} = 22$ V $I_E = 0$	0.75 mA
	h_{FE}	Forward Current Transfer Ratio	$V_{CE} = 5$ V $I_C = 250$ mA	10-120
R F Tests	C_{OB}	Collector-Base Capacitance (Max)	$V_{CB} = 20$ V	7 pF
	P_o	Power Output	f = 2.3 GHz $V_{CE} = 20$ V $V_{CE} = 24$ V	4 W Min 5 W Typ
	P_{gain}	Power Gain (dB)	f = 2.3 GHz $P_o = 4$ W $V_{CE} = 20$ V	8.0 dB Min
	VSWR	Mismatch Tolerance	$P_o = 4$ W f = 2.3 GHz $V_{CE} = 20$ V	∞
	η_C	Collector Efficiency	$P_o = 4$ W f = 2.3 GHz $V_{CE} = 20$ V	40 % Min
Operating	T_j & T_{stg}	Max Junction and Storage Temperature	— 65 to + 200 °C	
	θ_{jF}	Thermal Resistance		17 °C/W
	I_C	Continuous Collector Current	$V_{CE} = 5$ V	1.5 A Max

TRW SEMICONDUCTORS

TRW 2307

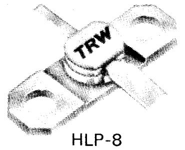
Microwave Power Transistor

Latest in the TRW « Super 2 GHz » Series, the TRW 2307 offers a sturdy transistor which is ideally suited to space, military, radio relay and other applications in the 1 to 3.0 GHz region.

The device is capable of withstanding any mismatch load condition at any phase angle up to, and including, open and short circuit (∞**VSWR**) under full rated conditions. The unit is **gold metalized,** thereby eliminating metal migration problems common with aluminum parts (metal failure predictions are included herein). Further, the transistor is emitter ballasted with **diffused silicon resistors** rather than deposited metal film resistors for reliability and ruggedness.

The TRW 2307 is housed in the HLP-8, glass free, **full hermetic** package which is available with or without mounting flange. Full mechanical specifications are guaranteed.

2.3 GHz
7 W - 20 V
∞ VSWR

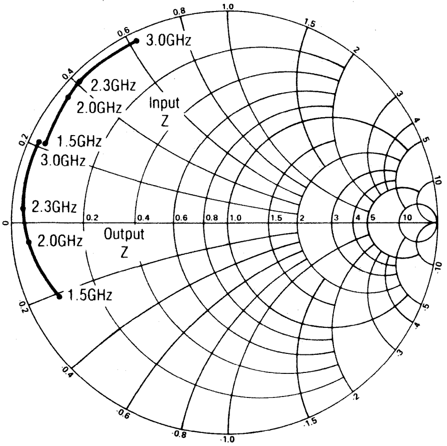


HLP-8

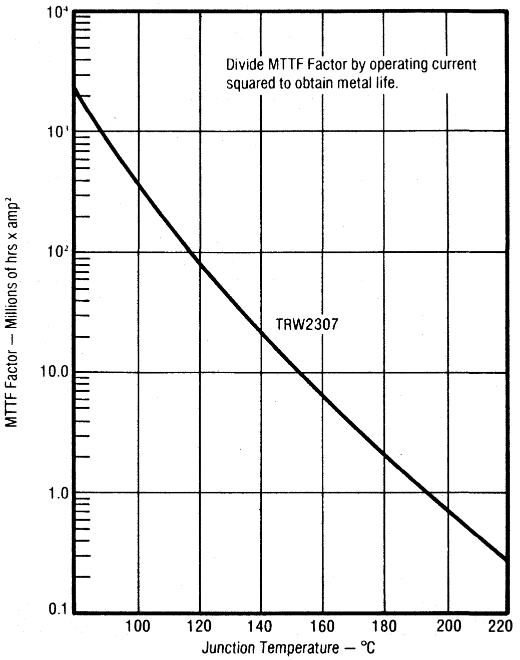
Electrical Characteristics (T_{flange} = 25 °C)

	Symbol	Characteristics	Condition	Value
D C Tests	BV_{CER}	Collector-Base Breakdown Voltage $R_{BE} = 10\ \Omega$	$I_C = 50$ mA	42 V Min
	BV_{EBO}	Emitter-Base Breakdown Voltage	$I_E = 1.0$ mA $I_C = 0$	3.5 V Min
	I_{CBO}	Collector Cutoff Current	$V_{CB} = 22$ V $I_E = 0$ $V_{CB} = 38$ V	1.25 mA 2.5 mA
	h_{FE}	Forward Current Transfer Ratio	$V_{CE} = 5$ V $I_C = 500$ mA	10-120
R F Tests	C_{OB}	Collector-Base Capacitance (Max)	$V_{CB} = 20$ V	10 pF
	P_o	Power Output	f = 2.3 GHz $V_{CE} = 20$ V $V_{CE} = 24$ V	7.0 W Min 9.0 W Min
	P_{gain}	Power Gain (dB)	f = 2.3 GHz $P_o = 7.0$ W $V_{CE} = 20$ V	8.4 dB Min
	VSWR	Mismatch Tolerance	$P_o = 7.0$ W f = 2.3 GHz $V_{CE} = 20$ V	∞
	η_C	Collector Efficiency	$P_o = 7.0$ W f = 2.3 GHz $V_{CE} = 20$ V	40 % Min
Operating	T & T_{stg}	Max Junction and Storage Temperature	— 65 to + 200 °C	
	θ_{jF}	Thermal Resistance		8.5 °C/W
	I_C	Continuous Collector Current	$V_{CE} = 5$ V	2.5 A Max

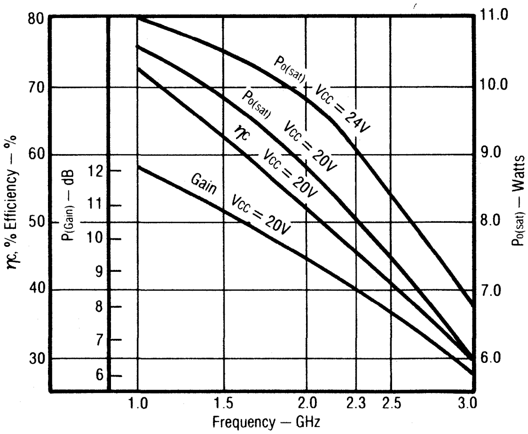
Impedance Data
Vcc = 20V



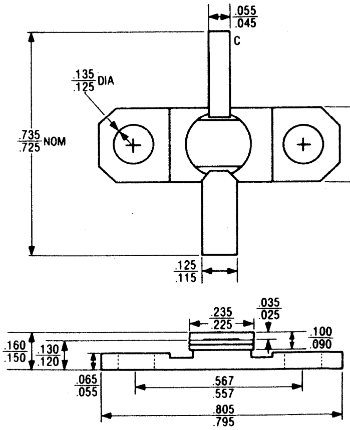
Metal Failure



Typical Performance Characteristics



HLP-8 Package



Mechanical Specifications

The following are mechanical specifications for this transistor.

Dimensions: Per outline drawing.

Solderability: Per MIL-STD-750.

Marking: Per MIL-S-19500, "TRW," 4-digit date code, type number.

Hermaticity: Per MIL-STD-750, 10^{-7} atmospheres gross and fine leak. (Available on special order screened to 10^{-8} atmospheres.)

Acceleration: Per MIL-STD-750, 20,000G in any plane.

Bond Pull: Per MIL-STD-750, 3 grams min.

Package: A glass-free, brazed ceramic package assuring long-term integrity of hermetic seals. Leads of HLP-8, KOVAR base material with minimum 60 microinches of gold plating.

TRW® SEMICONDUCTORS

SUPER 3 GHz SERIES

This data describes TRW's SUPER 3GHz transistors. The etchless gold die metallization, the diffused ballast resistors, and the avalanche protection are available exclusively from TRW.

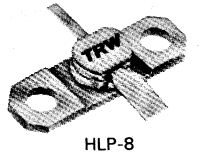
∞ VSWR Tolerance. A TRW first. Every SUPER 3GHz transistor is tested to guarantee each device is capable of withstanding all mismatch conditions (any magnitude, any phase angle). This guarantee precludes costly failures due to an inadvertent impedance mismatch in the laboratory, on the production line or in the field. A 100% production line test for ∞ VSWR capability also assures the die mount integrity. This is not possible with less rugged transistors.

Diffused Ballast Resistors. Another TRW first. Only TRW offers this major technological advance in microwave transistors (patents pending). High resistance ballast resistors are diffused directly into the silicon die totally avoiding the primary failure mechanism of peeling and microcracking associated with conventional thin film, metal ballast resistors. Also, diffused ballasting safely allows much higher resistance values to be achieved (25Ω-100Ω) than does thin film metal ballasting (8Ω-10Ω). Higher ballast levels preclude "hot spotting" since near perfect finger-to-finger and cell-to-cell current sharing is realized. The positive temperature coefficient of the diffused resistor further equalizes uneven temperature distribution.

Avalanche Protection. Yet another TRW first. TRW's exclusive avalanche protection mechanism (patent pending) precludes the failure mode not handled by ballasting alone — secondary breakdown. The voltage across the transistor junction is never allowed to reach breakdown. The P-N diode of the ballast resistor is diffused to avalanche several volts less than the transistor junctions. Under severe mismatch conditions when voltages in excess of breakdown occur, the diode conducts the full avalanche current, thus, protecting the transistor junction. True "full-circle" VSWR protection is achieved with these devices.

Gold Die Metallization. One more TRW first. TRW's etchless, gold metallization process (patent pending) provides exact finger definition. This process is capable of defining sub-micron finger spacing in the interdigitated geometry even though the cross sectional dimension of each gold finger is deeper than it is wide. The etchless process precludes finger scalloping characteristic of all etching processes and eliminates resultant current crowding where metal fingers are necked down. With TRW's gold die metallization original design values are not compromised in the manufacturing process for the primary wear-out mechanism in RF transistors — metal migration. Thus, TRW's etchless, gold metallization system not only capitalizes on the vast improvement in electromigration properties of gold over aluminum but it also assures that the metal lifetime design criteria is retained in the manufacturing process. This achievement cannot be accomplished with any etch-dependent metal system.

TRW 3001 - 1 W
TRW 3003 - 3 W
TRW 3005 - 5 W
∞ VSWR

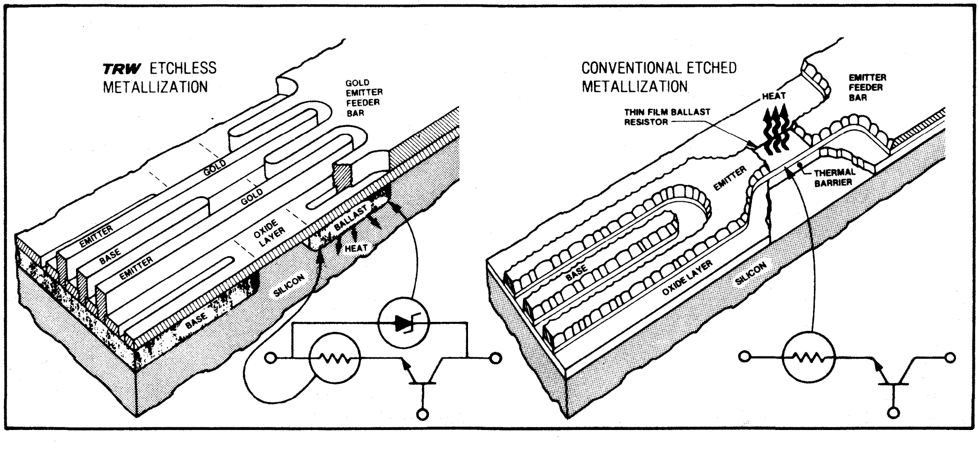


HLP-8

Mono-Metal System. TRW's use of gold metallized die, gold wire bonds, and gold package metal on all SUPER 3GHz transistors precludes intermetallic formations and resultant failures. Gold bonding wire does not work-harden and is thousands of times more resistant to fatigue than is the more brittle aluminum wire alternative. Fatigue tests have verified that TRW's thermal-compression bonding technique provides bond-to-pad mechanical integrity, not possible with aluminum, ultra-sonic bonding systems.

Mil-Package. The Space Qualified HLP-8 is a fully hermetic, glass-free, co-fired ceramic package. It is available with or without a flange.

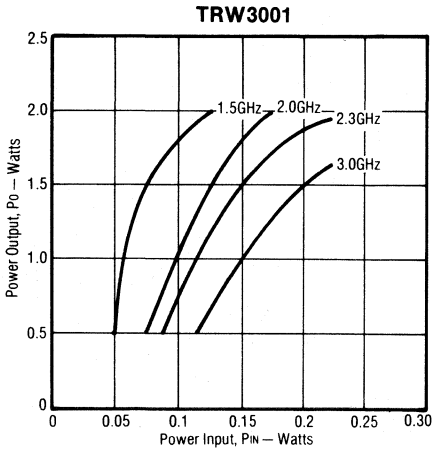
TRW DIFFUSED BALLAST RESISTORS WITH ETCHLESS GOLD METALLIZATION VS. CONVENTIONAL THIN FILM BALLAST RESISTORS WITH ETCHED METALLIZATION

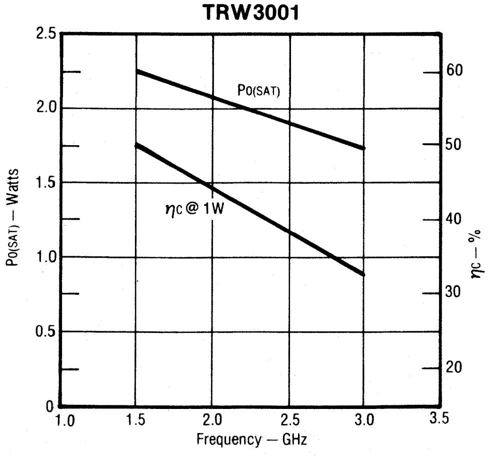


Electrical Characteristics (T_{case} = 25 °C)

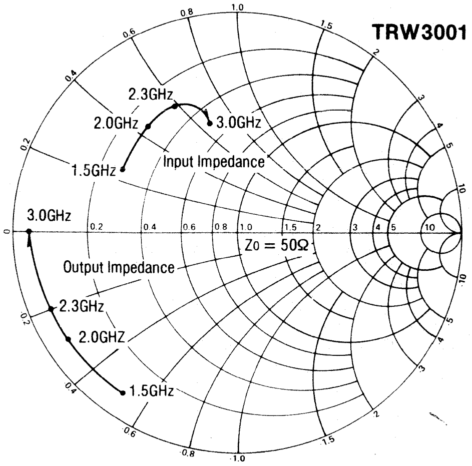
	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC TEST	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 1.0 mA I_C = 0	3.5			V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 1.0 mA b	45			V
	BV_{CES}	Collector - Emitter Breakdown Voltage (EB Shorted)	I_C = 10 mA	50			V
	I_{CBO}	Collector - Base Leakage	V_{CB} = 28 V			0.5	mA
	H_{FE}	DC Current Gain	V_{CE} = 5.0 V I_C = 100 mA	10		120	
RF TEST	P_{gain}	Power Gain	F_O = 3 GHz P_O = 1.0 W V_{CC} = 28 V	7.0			dB
	η_C	Collector Efficiency	F_O = 3 GHz P_O = 1.0 W V_{CC} = 28 V	30			%
	VSWR	Mismatch Tolerance (Without Damage)	F_O = 3 GHz P_O = 1.0 W V_{CC} = 28 V	∞			
	C_{OB}	Collector - Base Capacitance	V_{CB} = 28 V F_O = 1 MHz		3.5	4.0	pF
THERMAL	θ_{JC}	Thermal Impedance Junction to Case	—			35	°C/W
	T_{STG} & T_J	Junction & Storage Temperature Range	—	— 65		+ 200	°C

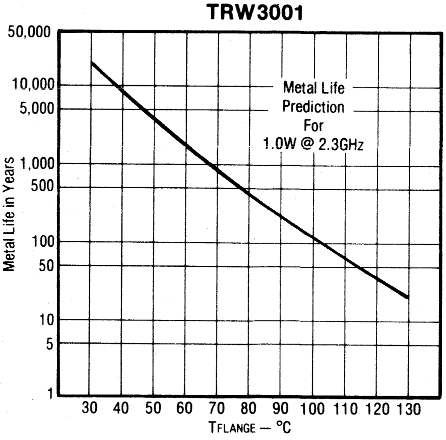
TYPICAL CHARACTERISTICS



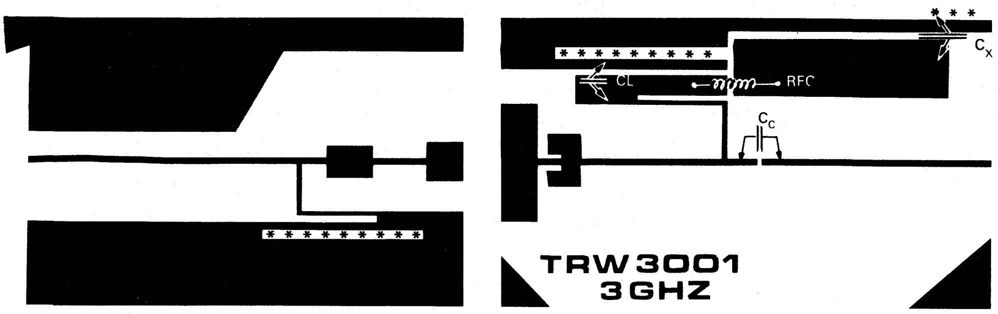


TYPICAL CHARACTERISTICS





PC BOARD LAYOUT F = 3 GHz



PARTS DETAILS

Board material ≃ 0.020″ Glass teflon (ε_r = 2.55).

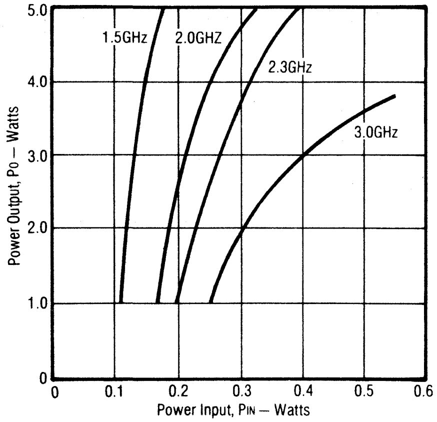
* = Foil wrap asterisked edge to ground plane.
C_C = 100 pF chip.
C_X = 100 pF, 1 nF, 10 nF chip capacitors and 10 μF.
C_L = 100 pF chip capacitor. The capacitor position can be tuned.
R_{FC} = 8 turns # 28AWG, 0.010 dia.

Electrical Characteristics (T_{case} = 25 °C)

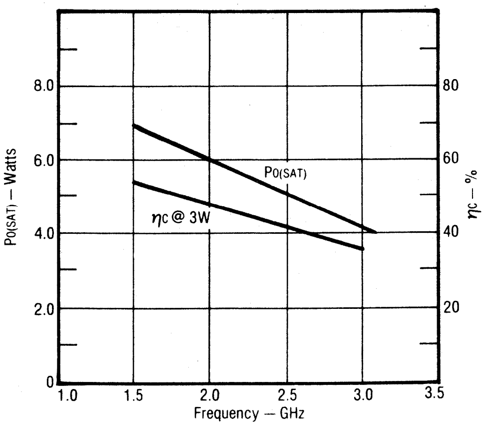
	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC TEST	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 1.0 mA I_C = 0	3.5			V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 3.0 mA	45			V
	BV_{CES}	Collector - Emitter Breakdown Voltage (EB Shorted)	I_C = 30.0 mA	50			V
	I_{CBO}	Collector - Base Leakage	V_{CB} = 28 V			0.75	mA
RF TEST	H_{FE}	DC Current Gain	V_{CE} = 5.0 V I_C = 300 mA	10		120	
	P_{Gain}	Power Gain	F_O = 3 GHz P_O = 3.0 W V_{CC} = 28 V	6.0			dB
	η_C	Collector Efficiency	F_O = 3 GHz P_O = 3.0 W V_{CC} = 28 V	30			%
	VSWR	Mismatch Tolerance (Without Damage)	F_O = 3 GHz P_O = 3.0 W V_{CC} = 28 V	∞			
	C_{OB}	Collector - Base Capacitance	V_{CB} = 28 V F_O = 1 MHz		5.7	7.0	pF
THERMAL	θ_{JC}	Thermal Impedance Junction to Case	—			17	°C/W
	T_{STG} & T_J	Junction & Storage Temperature Range	—	— 65		+ 200	°C

TYPICAL CHARACTERISTICS

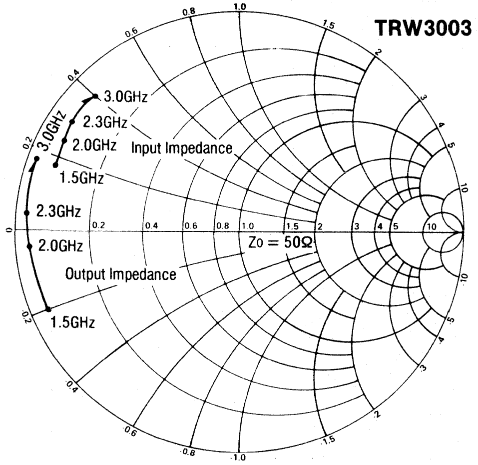
TRW3003

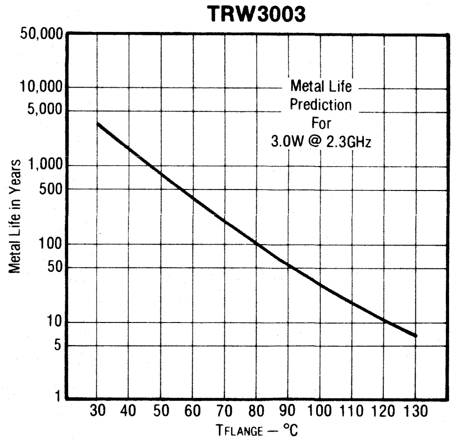


TRW3003

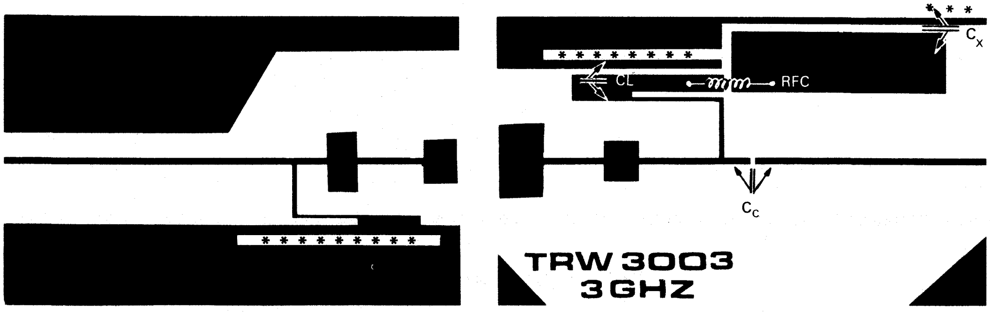


TYPICAL CHARACTERISTICS


TRW3003


TRW3003

PC BOARD LAYOUT F = 3 GHz



PARTS DETAILS

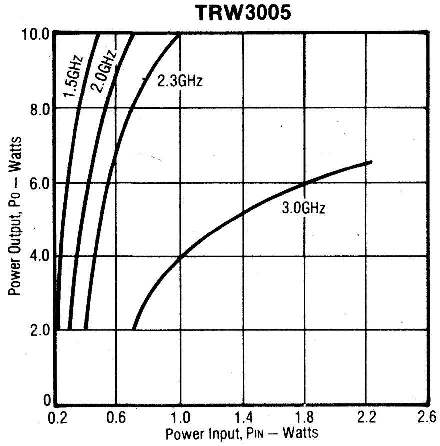
Board material : 0.020″ Glass Teflon (ε_r = 2.55)

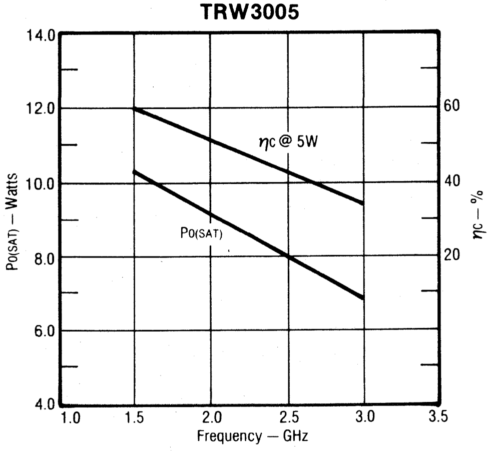
* = Foil wrap asterisked edge to ground plane.
C_C = 100 pF chip.
C_X = 100 pF, 1 nF, 10 nF chip capacitors and 10 μF.
C_L = 100 pF chip capacitor. The capacitor position can be tuned.
R_{FC} = 8 turns # 28AWG, 0.010 dia.

Electrical Characteristics (T_{case} = 25 °C)

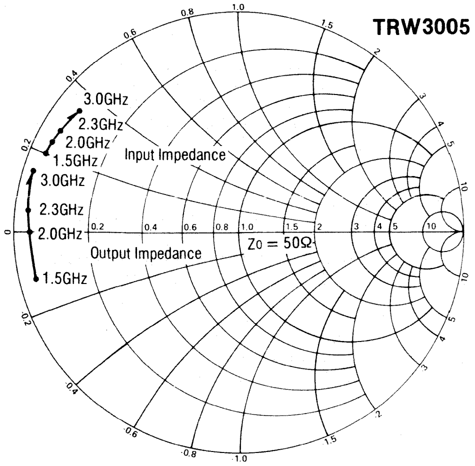
	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC TEST	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 1.0 mA I_C = 0	3.5			V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 5.0 mA	45			V
	BV_{CES}	Collector - Emitter Breakdown Voltage (EB Shorted)	I_C = 50.0 mA	50			V
	I_{CBO}	Collector - Base Leakage	V_{CB} = 28 V			1.25	mA
RF TEST	H_{FE}	DG Current Gain	V_{CE} = 5.0 V I_C = 500 mA	10		120	
	P_{Gain}	Power Gain	F_O = 3 GHz P_O = 5 W V_{CC} = 28 V	5.0			dB
	η_C	Collector Efficiency	F_O = 3 GHz P_O = 5 W V_{CC} = 28 V	30			%
	VSWR	Mismatch Tolerance (Without Damage)	F_O = 3 GHz P_O = 5 W V_{CC} = 28 V	∞			
	C_{OB}	Collector - Base Capacitance	V_{CB} = 28 V F_O = 1 MHz	8.4		10	pF
THERMAL	θ_{JC}	Thermal Impedance Junction to Case	—			8.5	°C/W
	T_{STG} & T_J	Junction & Storage Temperature Range	—	— 65		+ 200	°C

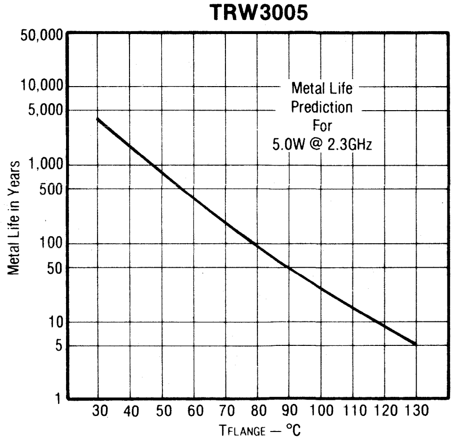
TYPICAL CHARACTERISTICS



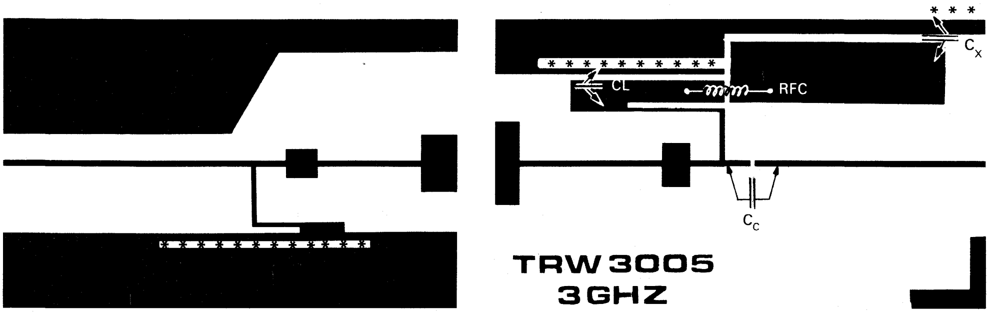


TYPICAL CHARACTERISTICS





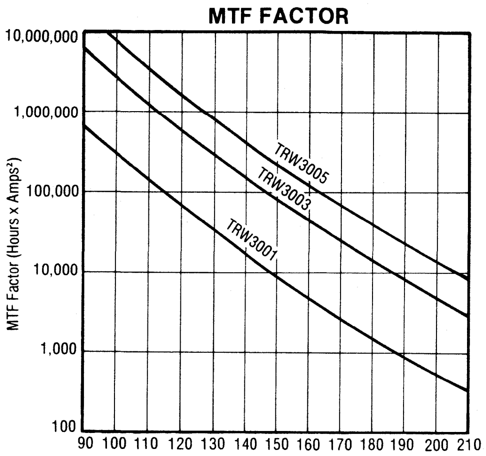
PC BOARD LAYOUT F = 3 GHz



PARTS DETAILS

Board material : 0.020″ Glass Teflon (ε_r = 2.55)

- * = Foil wrap asterisked edge to ground plane.
- C_C = 100 pF chip.
- C_X = 100 pF, 1 nF, 10 nF chip capacitors and 10 μF.
- C_L = 100 pF chip capacitor. The capacitor position can be tuned.
- R_{FC} = 8 turns # 28AWG, 0.010 dia.



MTTF FACTOR

(Normalized to 1 ampere^2 Continuous Duty)

The graph shown displays MTTF in hours x ampere^2 emitter current for each of the 3 GHz devices. Life tests at elevated temperatures have correlated to better than ± 10 % to the theoretical prediction for metal failure. **CAUTION** ε A calculation is required to obtain actual metal life. Sample MTTF calculations based on operating conditions are shown below.

To calculate metal lifetime under any set of conditions, obtain actual data or estimate from typical performance curves. Solve for T_J (°C):

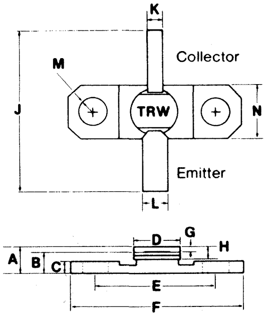
(1)
$$T_j = \theta_{jF}\left(\frac{P_{OUT} \times 100}{\eta c\,\%} + P_{IN} - P_{OUT}\right) + T_{FLANGE}$$

Enter graph of MTF factor vs. T_j. Obtain MTF factor. Calculate metal life by:

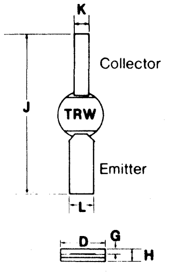
(2)
$$\text{Metal Life in Hours} = \frac{\text{MTF Factor}}{I_c^2\,(\text{Amps})}$$

Mechanical Dimensions

HLP-8 Normal Package



Flangeless HLP-8 (Specify « F » Suffix)



Dimension	U.S. (Inches ± 0.005)	Metric (Centimeters ± 0.0127)
A	0.155	0.3937
B	0.125	0.3175
C	0.060	0.1524
D	0.230	0.5842
E	0.562	1.4270
F	0.800	2.030
G	0.030	0.0762
H	0.095	0.2413
J	0.730 nom	1.85 nom
K	0.050	0.127
L	0.120	0.3048
M	0.130 dia	0.3302 dia
N	0.250	0.6350

TRW 52601

Microwave Linear Transistors

1.5 W
2 GHz
CLASS "A"

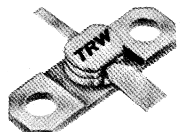
The TRW linear devices described herein are medium signal (1.5 watt), common emitter, diffused ballasted, **gold metalized** microwave transistors characterized for Class « A » service.

Because of TRW's proprietary ballasting and other protection techniques, no special techniques are required to protect these devices from arbitrary terminations up to infinite VSWR (any phase) so long as the transistors are attached properly to an adequate heat sink.

These transistors are useful for a variety of Military and industrial applications. They are available in TRW's HLP-8 flange package (TRW 52601), the HLP-8 flangeless (TRW 52101) and the new TW-200 symmetrically opposed emitter stripline package (TRW 52001).

Particular attention is directed to the ultralinear properties of these transistors and the guaranteed specification in accordance with DIN-45004.

Complete mechanical and electrical data are contained herein.



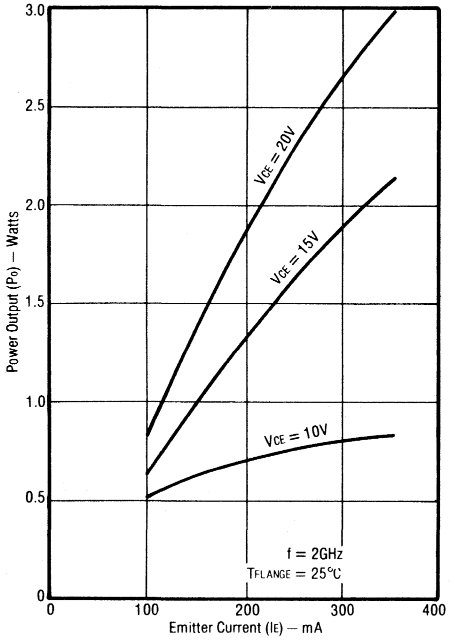
HLP-8

Electrical Characteristics (T_{flange} = 25 °C)

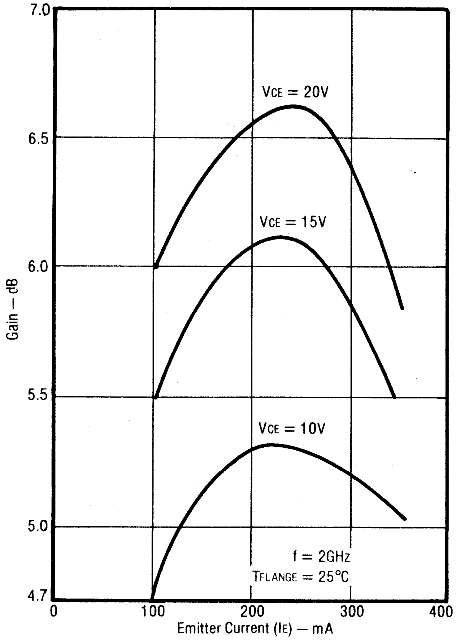
	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	°UNIT
D C Tests	BV_{CEO}	Collector-Emitter Breakdown Voltage	I_C = 20 mA	24			V
	BV_{CER}	Collector-Emitter Breakdown Voltage	R_{BE} = 10 Ω, I_C = 20 mA	50			V
	BV_{EBO}	Emitter-Base Breakdown Voltage	I_E = 0.25 mA	3.5			V
	BV_{CBO}	Collector-Base Breakdown Voltage	I_C = 1.0 mA	45			V
	I_{CBO}	Collector Cutoff Current	V_{CB} = 28 V			0.125	mA
	h_{FE}	Forward Current Transfer Ratio	V_{CE} = 5.0 V, I_C = 100 mA	20		120	—
R F Tests	C_{ob}	Collector-Base Capacitance	V_{CB} = 28 V, f = 1 MHz			5	pF
	P_o	Power Output	V_{CE} = 20 V, I_E = 220 mA f = 2.0 GHz, P_{in} = 0.375 W	1.5			W
	f_t	Frequency Cutoff	V_{CE} = 20 V, I_E = 220 mA	2.7	3.0		GHz
	VSWR	Mismatch Tolerance	P_o = 1.5 W, I_E = 220 mA, V_{CE} = 20 V	∞			
	IMD	Third Order intermodulation Distortion (Reference to Either Tone)	V_{CE} = 20 V, I_E = 220 mA f = 2.0 GHz, $P_{o(PEP)}$ = 1.5 W Tones at 2.05 GHz and 2.1 GHz			— 30	dB
	$IMD_{(TV)}$	Intermodulation per DIN-45004/K	V_{CE} = 20 V, I_E = 150 mA f = 1.0 GHz, P_{REF} = 0.5 W			— 60	dB
Opérating	T_j & T_{stg}	Max Junction and Storage Temperature		— 65		+ 200	°C
	θ_{jC}	Thermal Resistance	T_C = 25 °C			15	°C/W

ELECTRICAL CHARACTERISTICS
TRW52001, TRW52101, TRW52601

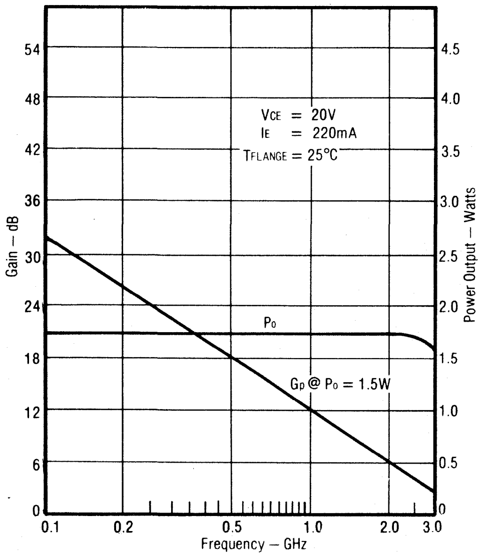
1dB Compression Point vs. Emitter Current



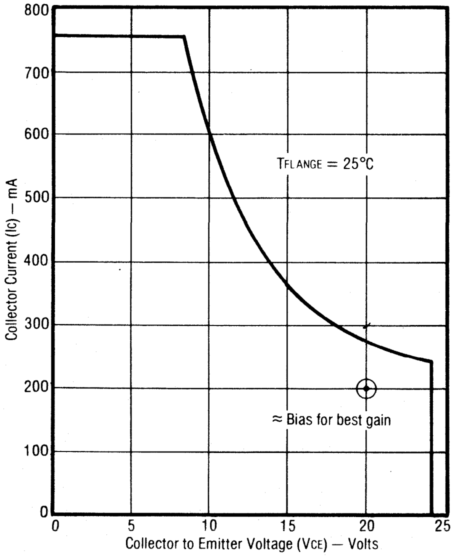
Gain vs. Emitter Current



Gain and 1dB Compressed Power vs. Frequency



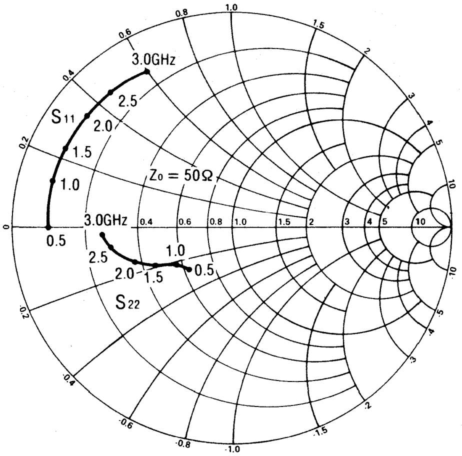
Safe Operating Area

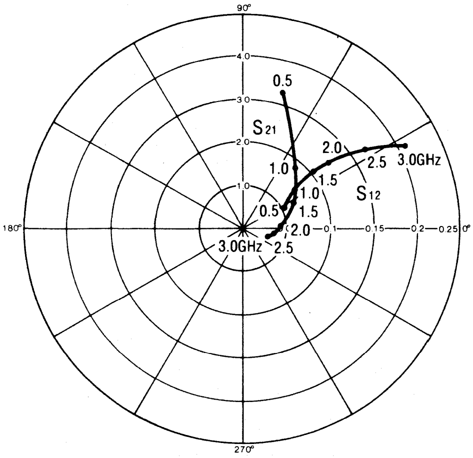


S-PARAMETERS

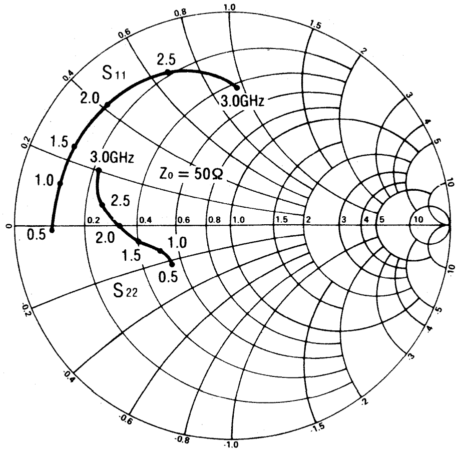
$V_{CE} = 20V$, $I_E = 220mA$, $T_{FLANGE} = 25°C$

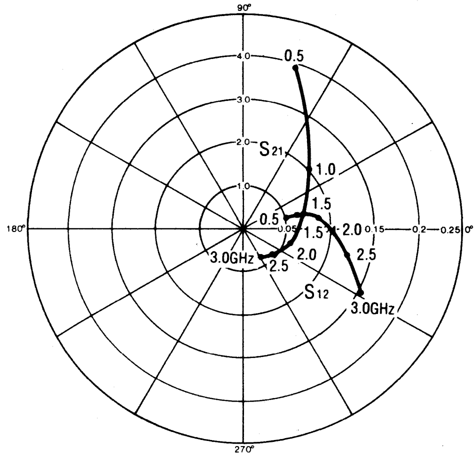
TRW52001





TRW52101, TRW52601

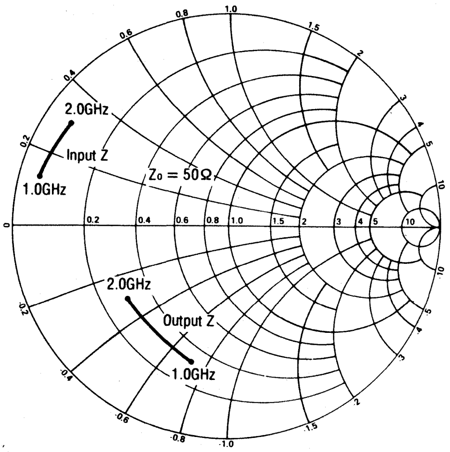




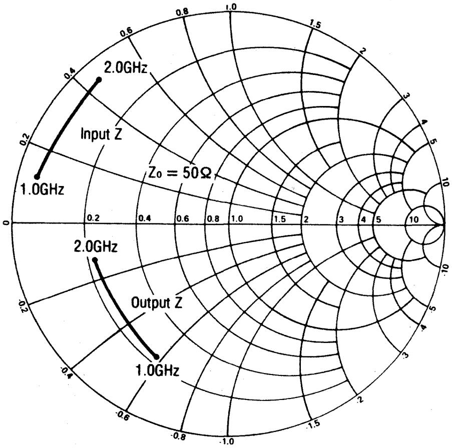
LARGE SIGNAL IMPEDANCE DATA

$V_{CE} = 20V$, $I_E = 220mA$, $T_{FLANGE} = 25°C$

TRW52001

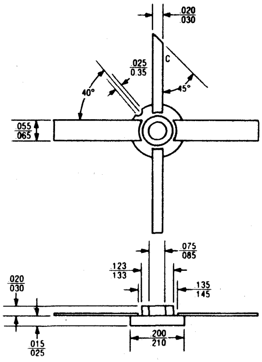


TRW52101, TRW52601

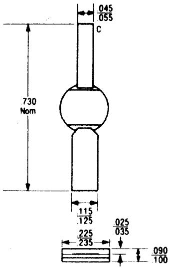


Package Outlines

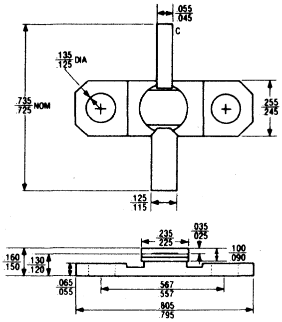
TRW52001



TRW52101



TRW52601



Mechanical Specifications

The following are mechanical specifications for this transistor series.

Dimensions:	Per outline drawing.
Solderability:	Per MIL-STD-750.
Marking:	Per MIL-S-19500, "TRW," 4-digit date code, type number.
Hermaticity:	Per MIL-STD-750, 10^{-7} atmospheres gross and fine leak. (Available on special order screened to 10^{-8} atmospheres.)
Acceleration:	Per MIL-STD-750, 20,000G in any plane.
Lead Pull:	Per MIL-STD-750, 3 grams min.
Package:	A brazed ceramic package assuring long-term integrity of hermetic seals. Leads of KOVAR base material with minimum 60 microinches of gold plating.

TRW® SEMICONDUCTORS

TRW 52602

Microwave Linear Transistors

The TRW linear devices described herein are medium signal (3.0 watt), common emitter, diffused ballasted **gold metalized** microwave transistors characterized for Class « A » service.

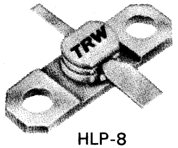
Because of TRW's proprietary ballasting and other protection techniques, no special techniques are required to protect these devices from arbitrary terminations up to infinite VSWR (any phase) so long as the transistors are attached properly to an adequate heat sink.

These transistors are useful for a variety of Military and industrial applications. They are available in TRW's HLP-8 flange package (TRW 52602), the HLP-8 flangeless (TRW 52102).

Particular attention is directed to the ultralinear properties of these transistors and the guaranteed specification in accordance with DIN-45004.

Complete mechanical and electrical data are contained herein.

3 W
2 GHz
CLASS "A"



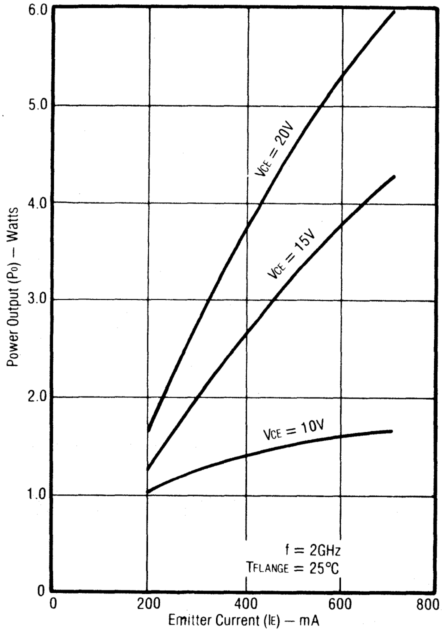
HLP-8

Electrical Characteristics (T_{flange} = 25 °C)

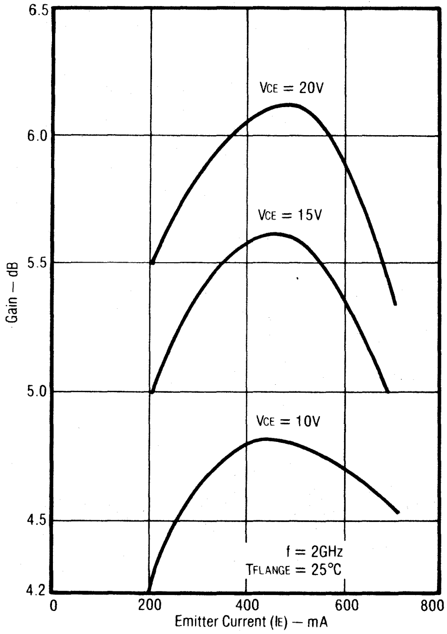
	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC Tests	BV_{CEO}	Collector-Emitter Breakdown Voltage	$I_C = 40$ mA	24			V
	BV_{CER}	Collector-Emitter Breakdown Voltage	$R_{BE} = 10\ \Omega$, $I_C = 40$ mA	50			V
	BV_{EBO}	Emitter-Base Breakdown Voltage	$I_E = 0.50$ mA	3.5			V
	BV_{CBO}	Collector-Base Breakdown Voltage	$I_C = 2.0$ mA	45			V
	I_{CBO}	Collector Cutoff Current	$V_{CB} = 28$ V			0.25	mA
	h_{FE}	Forward Current Transfer Ratio	$V_{CE} = 5.0$ V, $I_C = 200$ mA	20		120	—
R F Tests	C_{ob}	Collector-Base Capacitance	$V_{CB} = 28$ V, f = 1 MHz			7	pF
	P_o	Power Output	$V_{CE} = 20$ V, $I_E = 440$ mA f = 2.0 GHz, $P_{in} = 0.75$ W	3.0			W
	f_t	Frequency Cutoff	$V_{CE} = 20$ V, $I_E = 440$ mA	2.7	3.0		GHz
	VSWR	Mismatch Tolerance	$P_o = 3.0$ W, $I_E = 440$ mA, $V_{CE} = 20$ V	∞			
	IMD	Third Order Intermodulation Distortion	$V_{CE} = 20$ V, $I_E = 440$ mA $P_{o(PEP)} = 3.0$ W Tones at 2.000 GHz and 2.005 GHz			— 30	dB
	$IMD_{(TV)}$	Intermodulation per DIN-45004/K	$V_{CE} = 20$ V, $I_E = 300$ mA f = 1.0 GHz, $P_{REF} = 1.0$ W			— 60	dB
Operating	T_j & T_{stg}	Max Junction and Storage Temperature		— 65		+ 200	°C
	θ_{j-C}	Thermal Resistance	25 °C			8.5	°C/W

ELECTRICAL CHARACTERISTICS

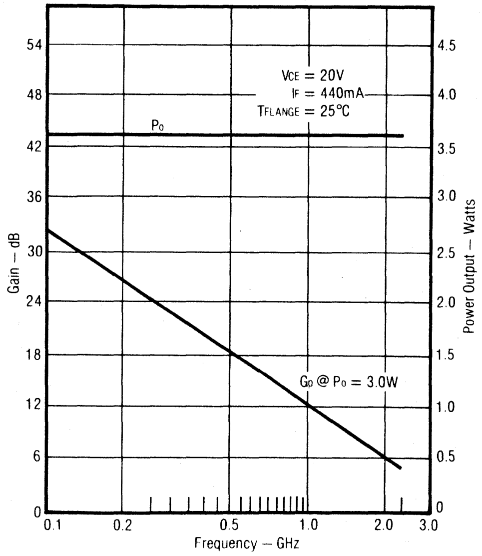
1dB Compression Point vs. Emitter Current



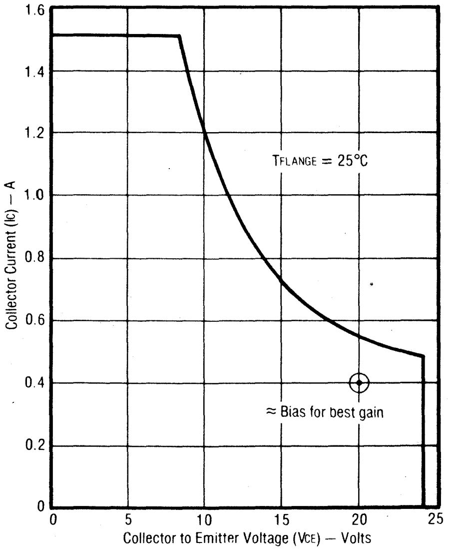
Gain vs. Emitter Current



Gain and 1dB Compressed Power vs. Frequency

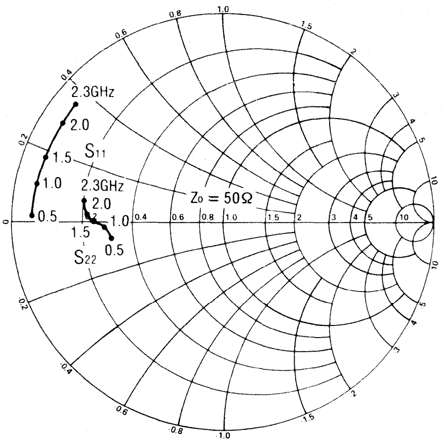


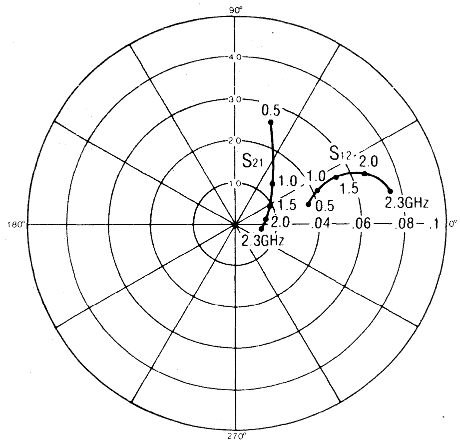
D.C. Safe Operating Area



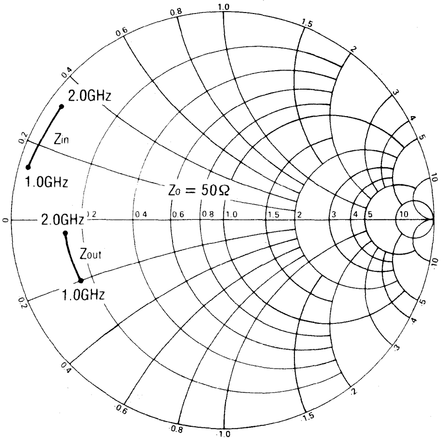
S-PARAMETERS

$V_{CE} = 20V$, $I_E = 440mA$, $T_{FLANGE} = 25°C$

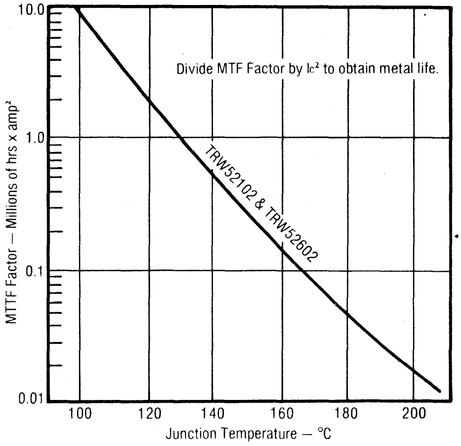




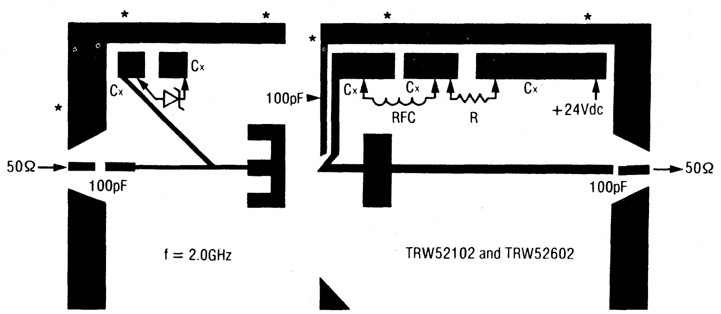
Large Signal Impedance Data



MTTF Factor vs. Junction Temperature



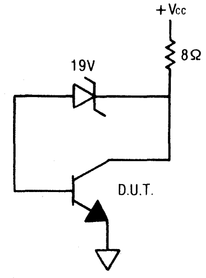
TEST CIRCUIT BOARD FOR TRW52102 AND TRW52602



Parts Details

* = Foil-wrap asterisked edge to ground plane. Board material 0.020 inch glass-teflon $\varepsilon_r = 2.55$.
C_x = 100pF and 0.1pF chip
Zener Diode = 19V, 1W
RFC = 8 turns, #28A.W.G., 0.040 diameter
R = 8Ω, 2W

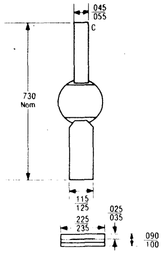
Self-Regulating Bias Circuit



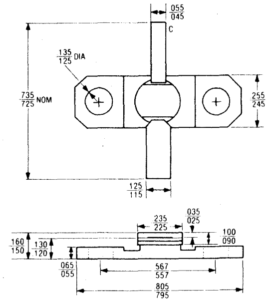
Set V_{CC} for desired I_E
$V_{CE} \approx V_Z + 1$

Package Outlines

TRW52102



TRW52602



Mechanical Specifications

The following are mechanical specifications for this transistor series.

Dimensions:	Per outline drawing.
Solderability:	Per MIL-STD-750.
Marking:	Per MIL-S-19500, "TRW," 4-digit date code, type number.
Hermaticity:	Per MIL-STD-750, 10^{-7} atmospheres gross and fine leak. (Available on special order screened to 10^{-8} atmospheres.)
Acceleration:	Per MIL-STD-750, 20,000G in any plane.
Bond Pull:	Per MIL-STD-750, 3 grams min.
Package:	A brazed ceramic package assuring long-term integrity of hermetic seals. Leads of KOVAR base material with minimum 60 microinches of gold plating.

TRW® SEMICONDUCTORS

TRW 52604

Microwave Linear Transistors

6 W
2 GHz
CLASS "A"

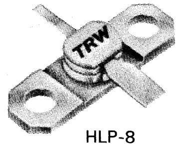
The TRW linear devices described herein are medium signal (6.0 watt), common emitter, diffused ballasted, **gold metalized** microwave transistors characterized for Class « A » service.

Because of TRW's proprietary ballasting and other protection techniques, no special techniques are required to protect these devices from arbitrary terminations up to infinite VSWR (any phase) so long as the transistors are attached properly to an adequate heat sink.

These transistors are useful for a variety of Military and industrial applications. They are available in TRW's HLP-8 flange package (TRW 52604), the HLP-8 flangeless (TRW 52104).

Particular attention is directed to the ultralinear properties of these transistors and the guaranteed specification in accordance with DIN-45004.

Complete mechanical and electrical data are contained herein.



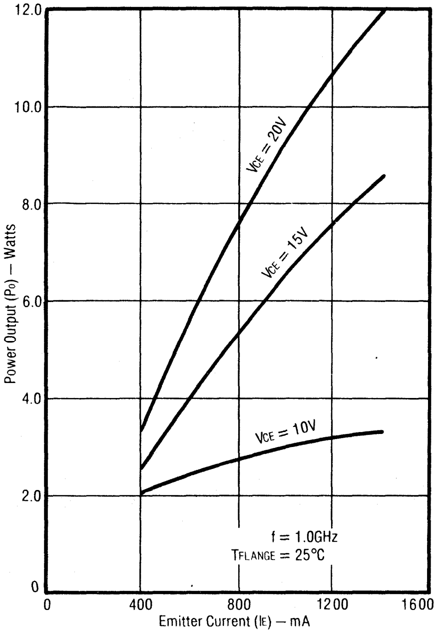
HLP-8

Electrical Characteristics (T_{flange} = 25 °C)

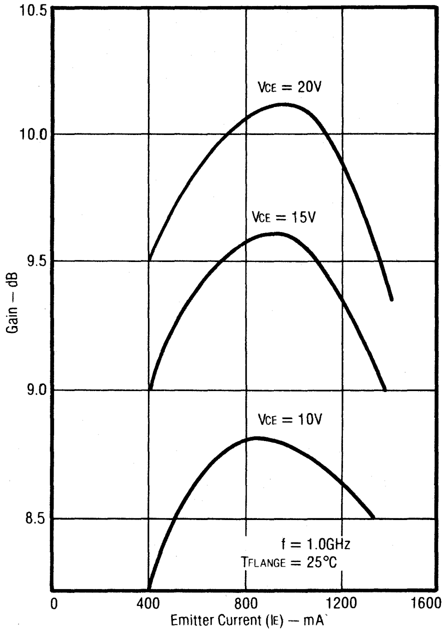
	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
D C Tests	BV_{CEO}	Collector-Emitter Breakdown Voltage	I_C = 80 mA	24			V
	BV_{CER}	Collector-Emitter Breakdown Voltage	R_{BE} = 10 Ω, I_C = 80 mA	50			V
	BV_{EBO}	Emitter-Base Breakdown Voltage	I_E = 1.0 mA	3.5			V
	BV_{CBO}	Collector-Base Breakdown Voltage	I_C = 4.0 mA	45			V
	I_{CBO}	Collector Cutoff Current	V_{CB} = 28 V			0.5	mA
	h_{FE}	Forward Current Transfer Ratio	V_{CE} = 5.0 V, I_C = 400 mA	20		120	—
R F Tests	C_{ob}	Collector-Base Capacitance	V_{CB} = 28 V, f = 1 MHz			12	pF
	P_o	Power Output	V_{CE} = 20 V, I_E = 880 mA f = 1.0 GHz, P_{in} = 0.600 W	6.0			W
	f_t	Frequency Cutoff	V_{CE} = 20 V, I_E = 880 mA	2.4	2.6		GHz
	VSWR	Mismatch Tolerance	P_o = 5.0 W, I_E = 600 mA, V_{CE} = 20 V	3:1			
	IMD	Third Order Intermodulation Distortion	V_{CE} = 20 V, I_E = 880 mA $P_{o(PEP)}$ = 6.0 W Tones at 1.000 GHz and 1.005 GHz			— 30	dB
	$IMD_{(TV)}$	Intermodulation per DIN-45004/K	V_{CE} = 20 V, I_E = 600 mA f = 1.0 GHz, P_{REF} = 2.0 W			— 60	dB
Operating	T_j & T_{stg}	Max Junction and Storage Temperature		— 65		+ 200	°C
	θ_{j-C}	Thermal Resistance	P_o = 5 W, V_{CE} = 20 V, I_E = 880 mA			6.0	°C/W

ELECTRICAL CHARACTERISTICS

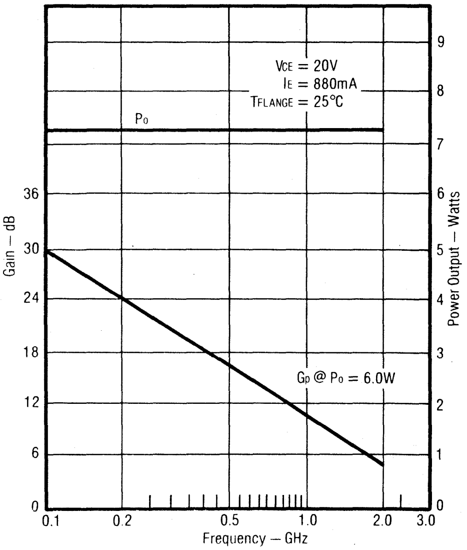
1dB Compression Point vs. Emitter Current



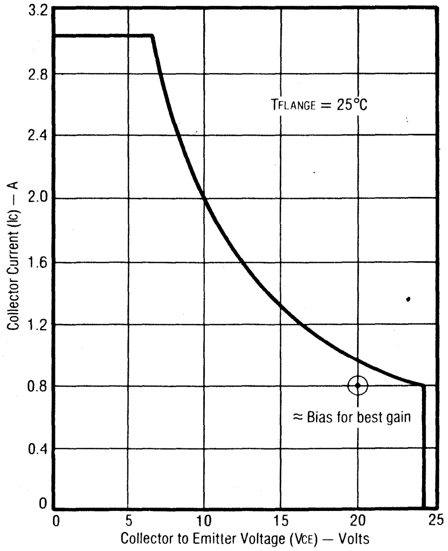
Gain vs. Emitter Current



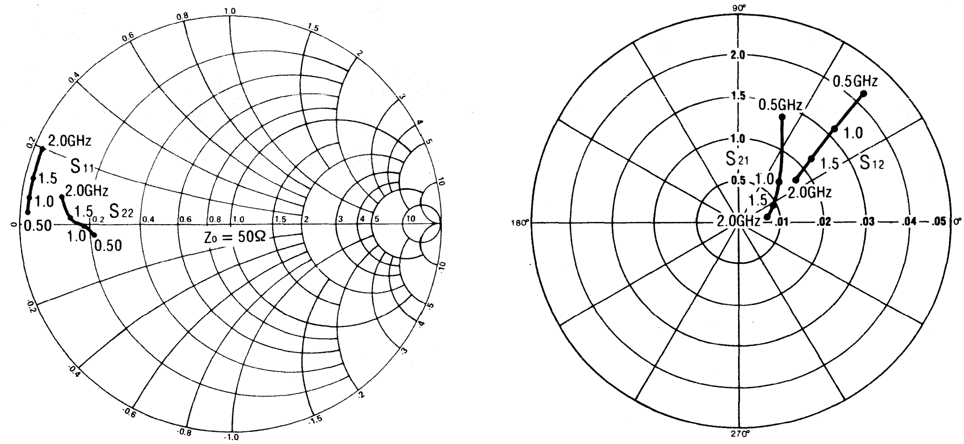
Gain and 1dB Compressed Power vs. Frequency



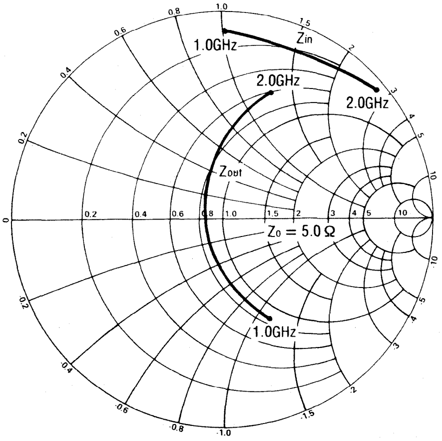
D.C. Safe Operating Area



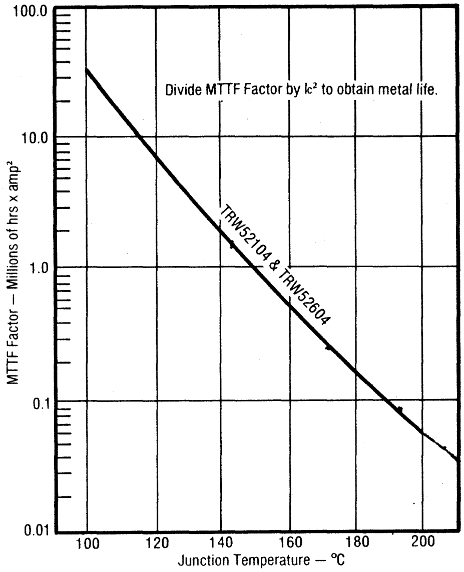
S-Parameters
VCE = 20V, IE = 880mA, TFLANGE = 25°C



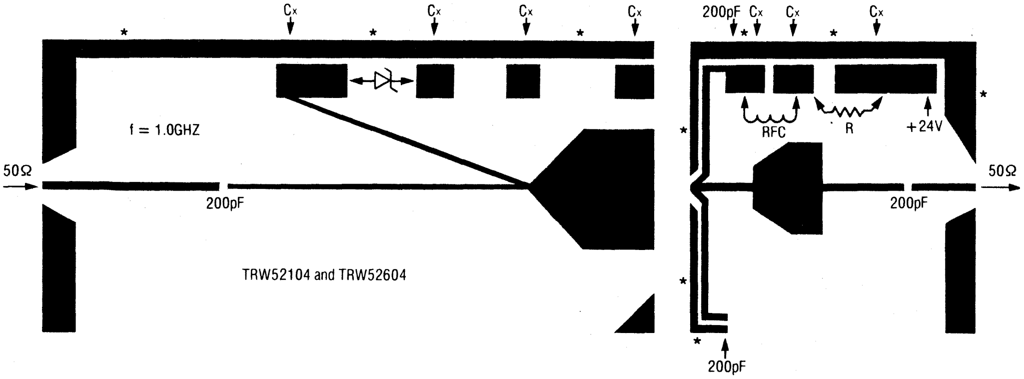
Large Signal Impedance Data



MTTF Factor vs. Junction Temperature



TEST CIRCUIT BOARD FOR TRW52104 AND TRW52604



Parts Details

* = Foil-wrap asterisked edge to ground plane. Board material 0.020 inch glass-teflon $\varepsilon_r = 2.55$.

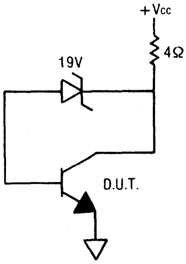
C_x = 100pF and 0.1μF chip

Zener Diode = 19V, 1W

RFC = 8 turns, #28A.W.G., 0.040 diameter

R = 4Ω, 4W

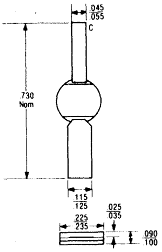
Self-Regulating Bias Circuit



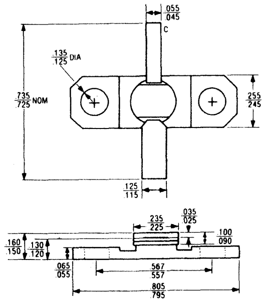
Set Vcc for desired I_E
$V_{CE} \approx V_Z + 1$

Package Outlines

TRW52104



TRW52604



Mechanical Specifications

The following are mechanical specifications for this transistor series.

Dimensions: Per outline drawing.

Solderability: Per MIL-STD-750.

Marking: Per MIL-S-19500, "TRW," 4-digit date code, type number.

Hermaticity: Per MIL-STD-750, 10^{-7} atmospheres gross and fine leak. (Available on special order screened to 10^{-8} atmospheres.)

Acceleration: Per MIL-STD-750, 20,000G in any plane.

Bond Pull: Per MIL-STD-750, 3 grams min.

Package: A brazed ceramic package assuring long-term integrity of hermetic seals. Leads of KOVAR base material with minimum 60 microinches of gold plating.

TRW® SEMICONDUCTORS **TRW 53601**

Microwave Linear Transistors

The TRW linear devices described herein are medium signal (0.8 watt), common emitter, diffused ballasted, **gold metalized** microwave transistors characterized for Class « A » service.

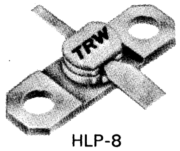
Because of TRW's proprietary ballasting and other protection techniques, no special techniques are required to protect these devices from arbitrary terminations up to infinite VSWR (any phase) so long as the transistors are attached properly to an adequate heat sink.

These transistors are useful for a variety of Military and industrial applications. They are available in TRW's HLP-8 flange package (TRW 53601), the HLP-8 flangeless (TRW 53101) and the new TW-200 symmetrically opposed emitter stripline package (TRW 53001).

Particular attention is directed to the ultralinear properties of these transistors and the guaranteed specification in accordance with DIN-45004.

Complete mechanical and electrical data are contained herein.

0.8 W
3 GHz
CLASS "A"

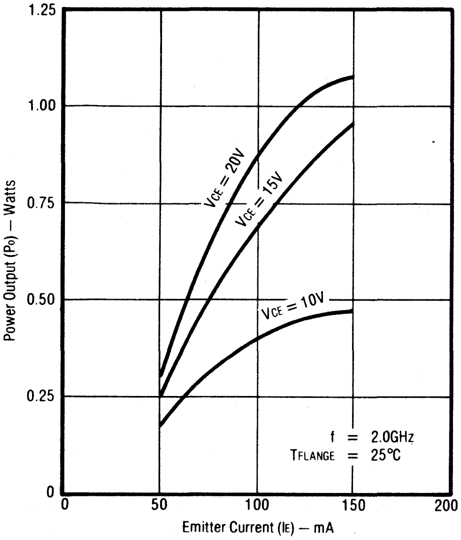


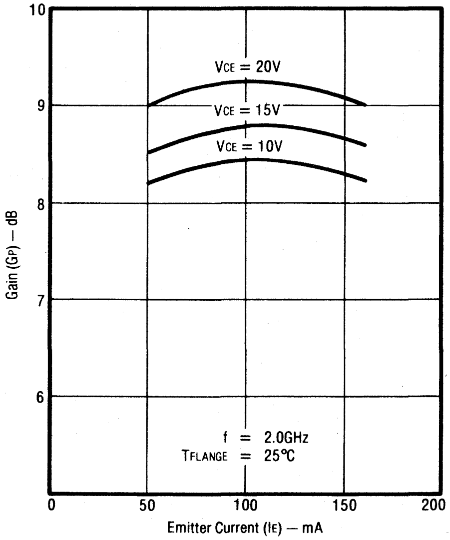
HLP-8

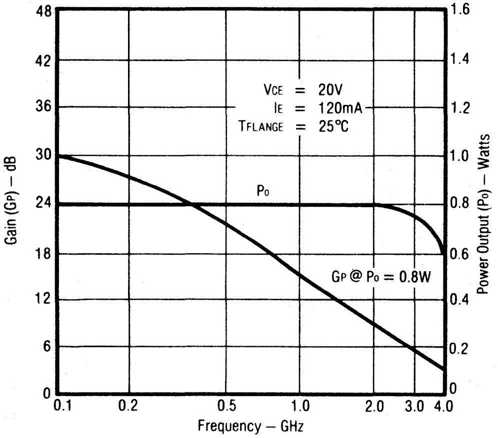
Electrical Characteristics (T_{flange} = 25 °C)

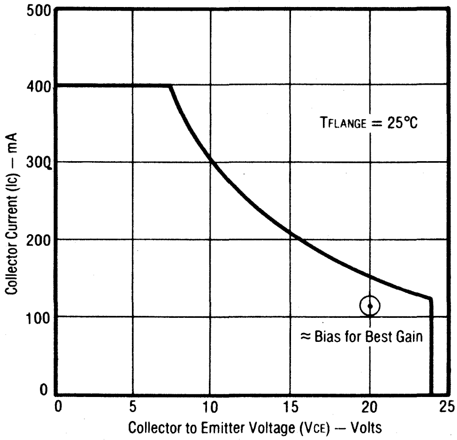
	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
D C Tests	BV_{CEO}	Collector-Emitter Breakdown Voltage	I_C = 10 mA	24			V
	BV_{CER}	Collector-Emitter Breakdown Voltage	R_{BE} = 10 Ω, I_C = 10 mA	50			V
	BV_{EBO}	Emitter-Base Breakdown Voltage	I_E = 0.25 mA	3.5			V
	BV_{CBO}	Collector-Base Breakdown Voltage	I_C = 1.0 mA	45			V
	I_{CBO}	Collector Cutoff Current	V_{CB} = 28 V			0.25	mA
	h_{FE}	Forward Current Transfer Ratio	V_{CE} = 5.0 V, I_C = 100 mA	20		120	—
R F Tests	C_{ob}	Collector-Base Capacitance	V_{CB} = 28 V, f = 1 MHz			3.5	pF
	P_o	Power Output	V_{CE} = 20 V, I_E = 120 mA f = 2.0 GHz, P_{in} = 0.113 W	0.8			W
	f_t	Frequency Cutoff	V_{CE} = 20 V, I_E = 120 mA	3.0	3.3		GHz
	VSWR	Mismatch Tolerance	P_o = 0.8 W, I_E = 120 mA, V_{CE} = 20 V	∞			
	IMD	Third Order Intermodulation Distortion (Reference to Either Tone)	V_{CE} = 20 V, I_E = 120 mA $P_{o(PEP)}$ = 0.8 W Tones at 2.000 GHz and 2.005 GHz			— 30	dB
	$IMD_{(TV)}$	Intermodulation per DIN-45004/K	V_{CE} = 20 V, I_E = 75 mA f = 1.0 GHz, P_{REF} = 0.25 W			— 60	dB
Opérating	T_j & T_{stg}	Max Junction and Storage Temperature		— 65		+ 200	°C
	θ_{jF}	Thermal Resistance	T_C = 25 °C			31	°C/W

Electrical Characteristics
TRW53001, TRW53101, TRW53601


1dB Compression Point vs. Emitter Current


Gain vs. Emitter Current


Gain and 1dB Compressed Power vs. Frequency


D.C. Safe Operating Area

Mechanical Specifications

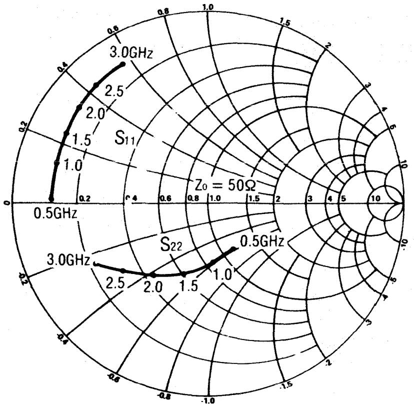
The following are mechanical specifications for this transistor series.

Dimensions:	Per outline drawing.
Solderability:	Per MIL-STD-750.
Marking:	Per MIL-S-19500, "TRW," 4-digit date code, type number.
Hermeticity:	Per MIL-STD-750, 10^{-7} atmospheres gross and fine leak. (Available on special order screened to 10^{-8} atmospheres.)
Acceleration:	Per MIL-STD-750, 20,000G in any plane.
Bond Pull:	Per MIL-STD-750, 3 grams min.
Package:	A brazed ceramic package assuring long-term integrity of hermetic seals. Leads of KOVAR base material with minimum 60 microinches of gold plating.

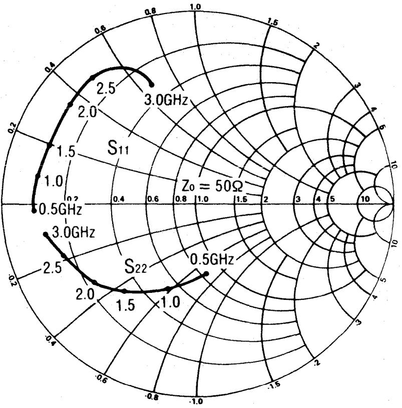
S-Parameters

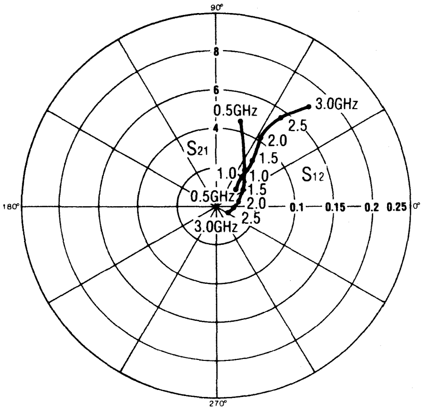
V_{CE} = 20V, I_E = 120mA, T_{FLANGE} = 25°C

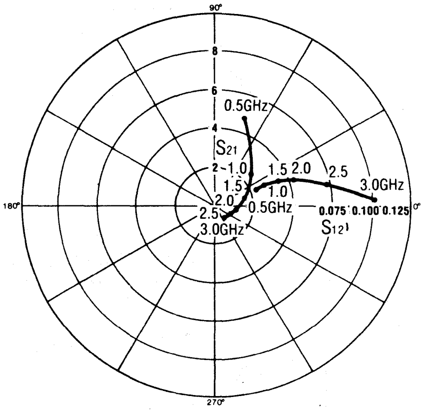
TRW53001



TRW53101, TRW53601

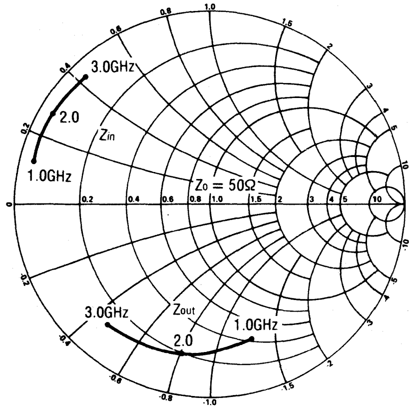


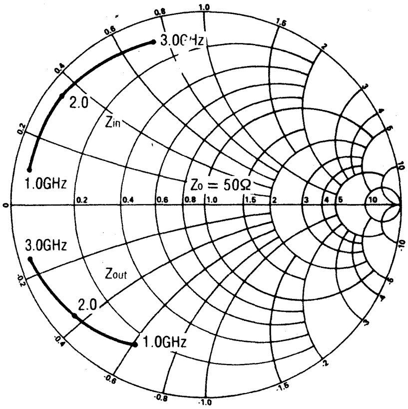




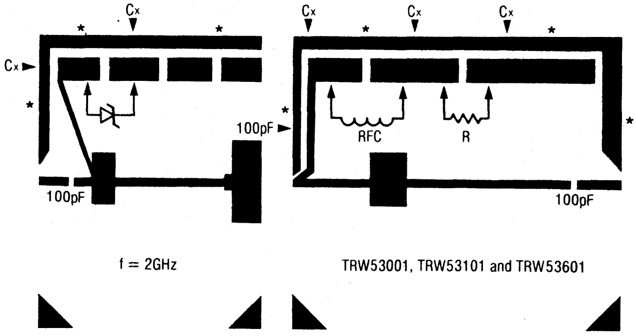
Large Signal Impedance Data

V_{CE} = 20V, I_E = 120mA, T_{FLANGE} = 25°C





Test Circuit Board For TRW53001, TRW53101 AND TRW53601

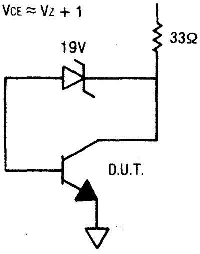


Parts Details

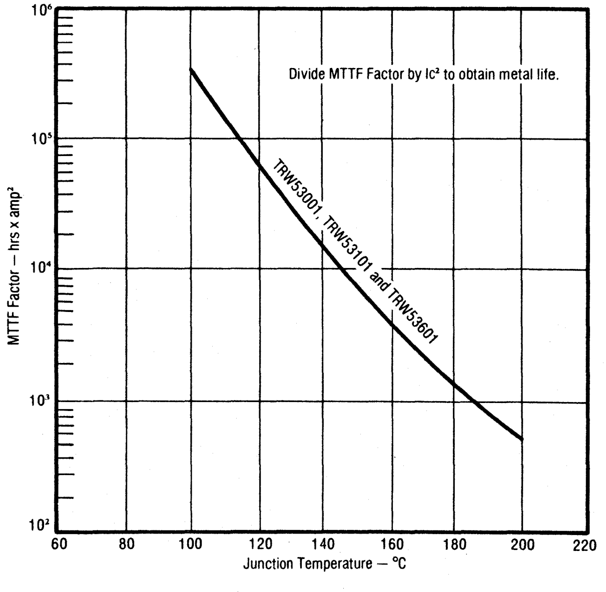
* = Foil-wrap asterisked edge to ground plane. Board material 0.020 inch glass-teflon $\varepsilon_r = 2.55$.
C_x = 100pF and 0.1µF chip
Zener Diode = 19V, 1W
RFC = 8 turns, #28A.W.G., 0.040 diameter
R = 33Ω, 1W

Self-Regulating Bias Circuit

Set V_{CC} for desired I_E
$V_{CE} \approx V_Z + 1$

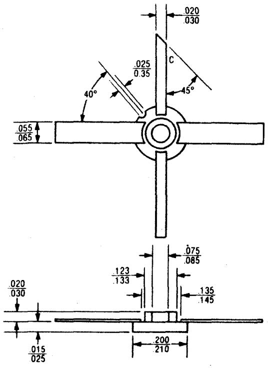


MTTF Factor vs. Junction Temperature

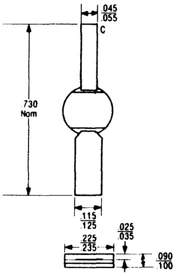


Package Outlines

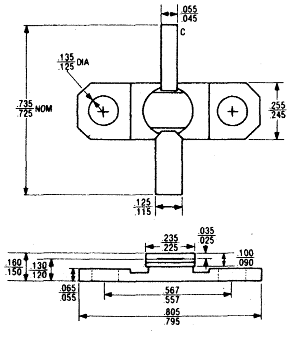
TRW53001



TRW53101



TRW53601



TRW® SEMICONDUCTORS

TRW 53602

Microwave Linear Transistors

The TRW linear devices described herein are medium signal (1.6 watt), common emitter, diffused ballasted, **gold metalized** microwave transistors characterized for Class « A » service.

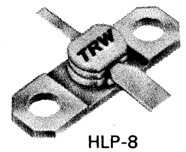
Because of TRW's proprietary ballasting and other protection techniques, no special techniques are required to protect these devices from arbitrary terminations up to infinite VSWR (any phase) so long as the transistors are attached properly to an adequate heat sink.

These transistors are useful for a variety of Military and industrial applications. They are available in TRW's HLP-8 flange package (TRW 53602), the HLP-8 flangeless (TRW 53102).

Particular attention is directed to the ultralinear properties of these transistors and the guaranteed specification in accordance with DIN-45004.

Complete mechanical and electrical data are contained herein.

1.6 W
3 GHz
CLASS "A"



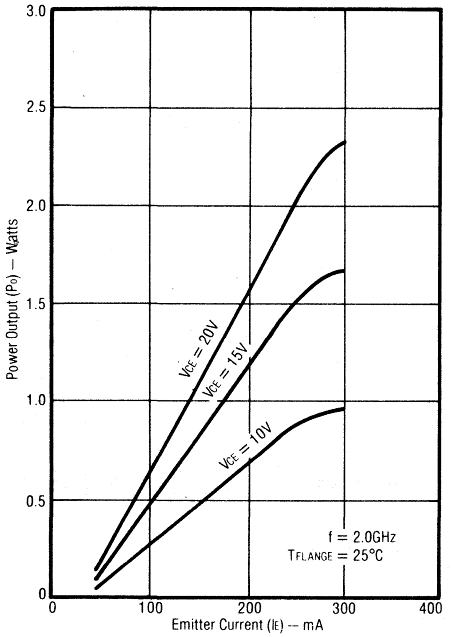
HLP-8

Electrical Characteristics (T_{flange} = 25 °C)

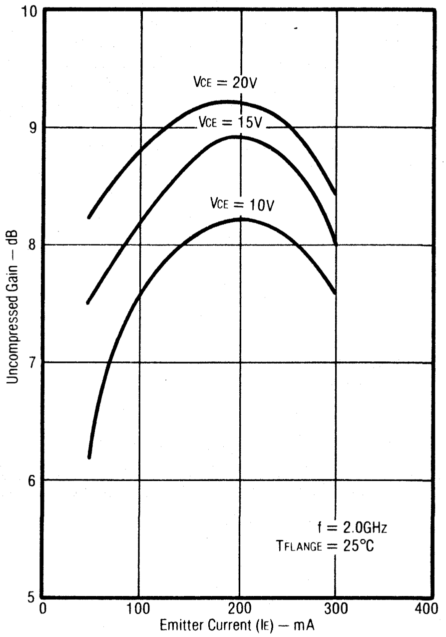
	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
D C Tests	BV_{CEO}	Collector-Emitter Breakdown Voltage	$I_C = 20$ mA	24			V
	BV_{CER}	Collector-Emitter Breakdown Voltage	$R_{BE} = 10\ \Omega$, $I_C = 20$ mA	50			V
	BV_{EBO}	Emitter-Base Breakdown Voltage	$I_E = 0.50$ mA	3.5			V
	BV_{CBO}	Collector-Base Breakdown Voltage	$I_C = 2.0$ mA	45			V
	I_{CBO}	Collector Cutoff Current	$V_{CB} = 28$ V			0.5	mA
	h_{FE}	Forward Current Transfer Ratio	$V_{CE} = 5.0$ V, $I_C = 200$ mA	20		120	—
R F Tests	C_{ob}	Collector-Base Capacitance	$V_{CB} = 28$ V, f = 1 MHz			5.5	pF
	P_o	Power Output	$V_{CE} = 20$ V, $I_E = 230$ mA f = 2.0 GHz, $P_{in} = 0.253$ W	1.6			W
	f_t	Frequency Cutoff	$V_{CE} = 20$ V, $I_E = 230$ mA	3.0	3.3		GHz
	VSWR	Mismatch Tolerance	$P_o = 1.6$ W, $I_E = 230$ mA, $V_{CE} = 20$ V	∞			
	IMD	Third Order Intermodulation Distortion (Reference to Either Tone)	$V_{CE} = 20$ V, $I_E = 230$ mA $P_{o(PEP)} = 1.6$ W Tones at 2.000 GHz and 2.005 GHz			— 30	dB
	$IMD_{(TV)}$	Intermodulation per DIN-45004/K	$V_{CE} = 20$ V, $I_E = 150$ mA f = 1.0 GHz, $P_{REF} = 0.5$ W			— 60	dB
Operating	T_j & T_{stg}	Max Junction and Storage Temperature		— 65		+ 200	°C
	θ_{j-C}	Thermal Resistance	$T_C = 25$ °C			17	°C/W

ELECTRICAL CHARACTERISTICS

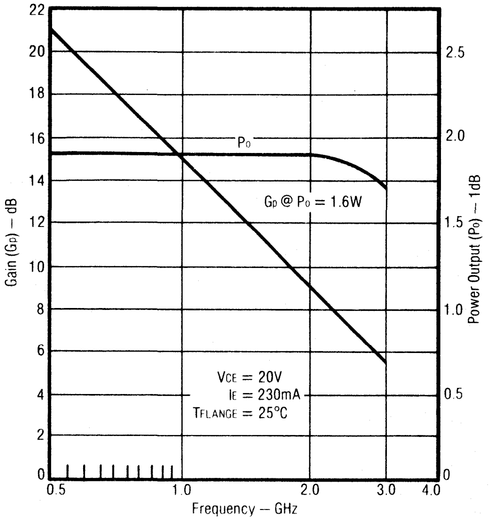
1dB Compression Point vs. Emitter Current



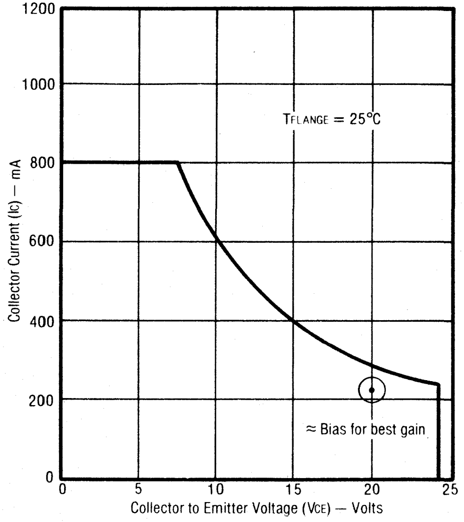
Gain vs. Emitter Current



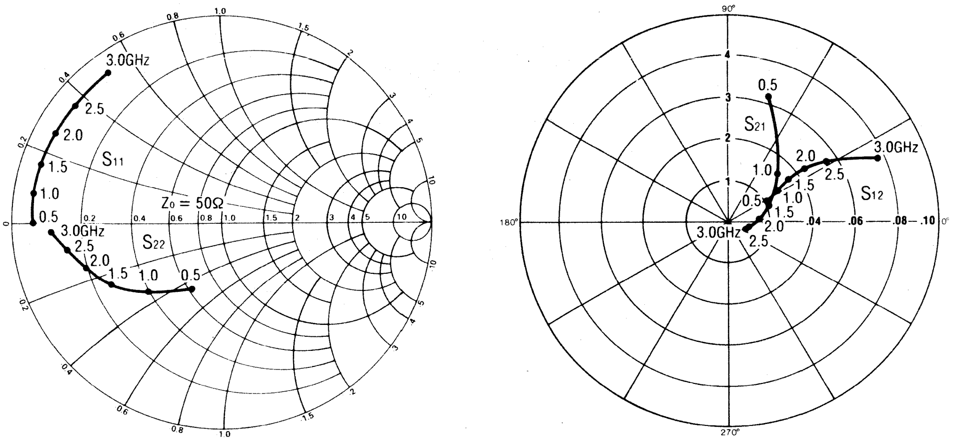
Gain and 1dB Compressed Power vs. Frequency



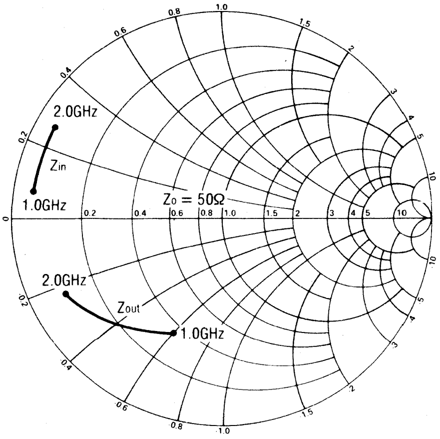
D.C. Safe Operating Area



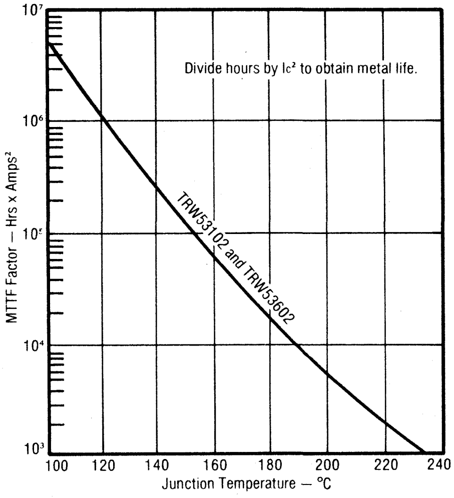
S-PARAMETERS
V_{CE} = 20V, I_E = 230mA, T_{FLANGE} = 25°C



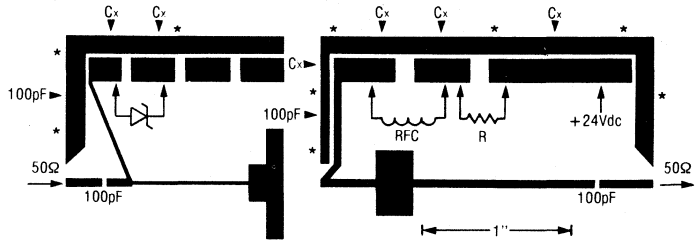
Large Signal Impedance Data



MTTF Factor vs. Junction Temperature



TEST CIRCUIT BOARD FOR TRW53102 AND TRW53602



TRW53102 and TRW53602 ·

f = 2.0GHz

Parts Details

* = Foil-wrap asterisked edge to ground plane. Board material 0.020 inch glass-teflon $\varepsilon_r = 2.55$.

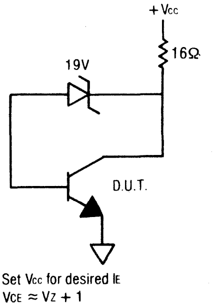
C_x = 100pF and 0.1μF chip

Zener Diode = 19V, 1W

RFC = 8 turns, #28A.W.G., 0.040 diameter

R = 16Ω, 2W

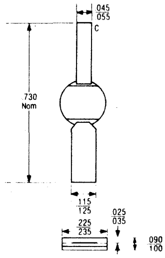
Self-Regulating Bias Circuit



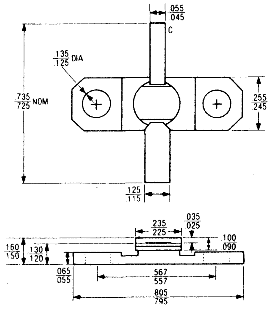
Set V_{CC} for desired I_E
$V_{CE} \approx V_Z + 1$

Package Outlines

TRW53102



TRW53602



Mechanical Specifications

The following are mechanical specifications for this transistor series.

Dimensions: Per outline drawing.

Solderability: Per MIL-STD-750.

Marking: Per MIL-S-19500, "TRW," 4-digit date code, type number.

Hermaticity: Per MIL-STD-750, 10^{-7} atmospheres gross and fine leak. (Available on special order screened to 10^{-8} atmospheres.)

Acceleration: Per MIL-STD-750, 20,000G in any plane.

Bond Pull: Per MIL-STD-750, 3 grams min.

Package: A brazed ceramic package assuring long-term integrity of hermetic seals. Leads of KOVAR base material with minimum 60 microinches of gold plating.

TRW® SEMICONDUCTORS **TRW 54601**

Microwave Linear Transistors

The TRW linear devices described herein are medium signal (0.5 watt), common emitter, diffused ballasted, **gold metalized** microwave transistors characterized for Class « A » service.

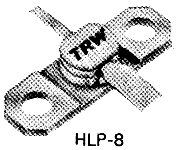
Because of TRW's proprietary ballasting and other protection techniques, no special techniques are required to protect these devices from arbitrary terminations up to infinite VSWR (any phase) so long as the transistors are attached properly to an adequate heat sink.

These transistors are useful for a variety of Military and industrial applications. They are available in TRW's HLP-8 flange package (TRW 54601), the HLP-8 flangeless (TRW 54101) and the new TW-200 symmetrically opposed emitter stripline package (TRW 54001).

Particular attention is directed to the ultralinear properties of these transistors and the guaranteed specification in accordance with DIN-45004.

Complete mechanical and electrical data are contained herein.

0.5 W
4 GHz
CLASS "A"



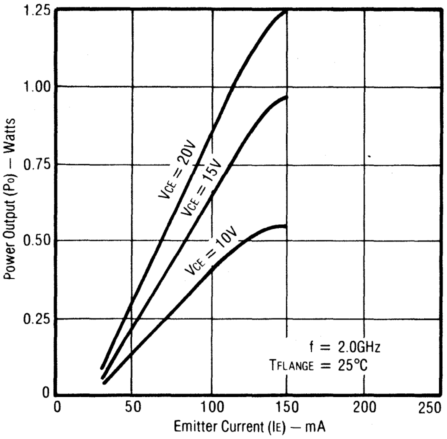
HLP-8

Electrical Characteristics (T_{flange} = 25 °C)

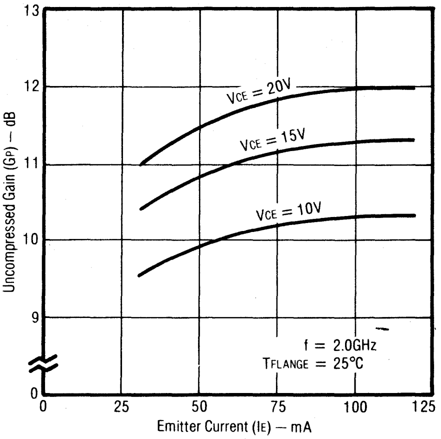
	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
D C Tests	BV_{CEO}	Collector-Emitter Breakdown Voltage	I_C = 10 mA	24			V
	BV_{CER}	Collector-Emitter Brekdown Voltage	R_{BE} = 10 Ω, I_C = 10 mA	50			V
	BV_{EBO}	Emitter-Base Breakdown Voltage	I_E = 0.25 mA	3.5			V
	BV_{CBO}	Collector-Base Breakdown Voltage	I_C = 1.0 mA	45			V
	I_{CBO}	Collector Cutoff Current	V_{CB} = 28 V			0.25	mA
	h_{FE}	Forward Current Transfer Ratio	V_{CE} = 5.0 V, I_C = 100 mA	20		120	—
R F Tests	C_{ob}	Collector-Base Capacitance	V_{CB} = 28 V, f = 1 MHz			3.5	pF
	P_o	Power Output, V_{CE} = 20 V, I_E = 120 mA	TRW 54101, 54601				
			f = 2.0 GHz, P_{in} = 0.032 W	0.5			W
			f = 4.0 GHz, P_{in} = 0.125 W		0.5		W
			TRW 54001				
			f = 2.0 GHz, P_{in} = 0.050 W	0.5			W
			f = 4.0 GHz, P_{in} = 0.158 W		0.5		W
	f_t	Frequency Cutoff	V_{CE} = 20 V, I_C = 120 mA	4.0	4.5		GHz
	VSWR	Mismatch Tolerance	P_o = 0.5 W, I_E = 120 mA, V_{CE} = 20 V	∞			
	IMD	Third Order Intermodulation Distortion (Reference to Either Tone)	V_{CE} = 20 V, I_E = 120 mA $P_{o(PEP)}$ = 0.5 W Tones at 2.000 GHz and 2.005 GHz			— 30	dB
	$IMD_{(TV)}$	Intermodulation per DIN-45004/K	V_{CE} = 20 V, I_E = 75 mA f = 1.0 GHz, P_{REF} = 0.15 W			— 60	dB
Opérating	T_j & T_{stg}	Max Junction and Storage Temperature		— 65		+ 200	°C
	θ_{J-C}	Thermal Resistance	T_C = 25 °C			40	°C/W

Electrical Characteristics
TRW54001, TRW54101, TRW54601

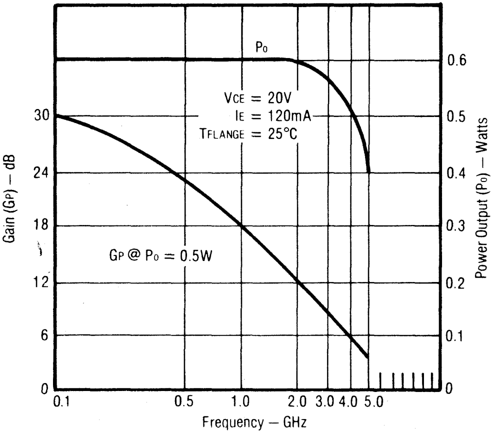
1dB Compression Point vs. Emitter Current



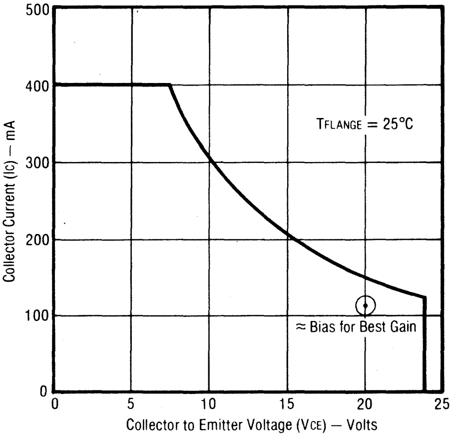
Gain vs. Emitter Current



Gain and 1dB Compressed Power vs. Frequency



D.C. Safe Operating Area



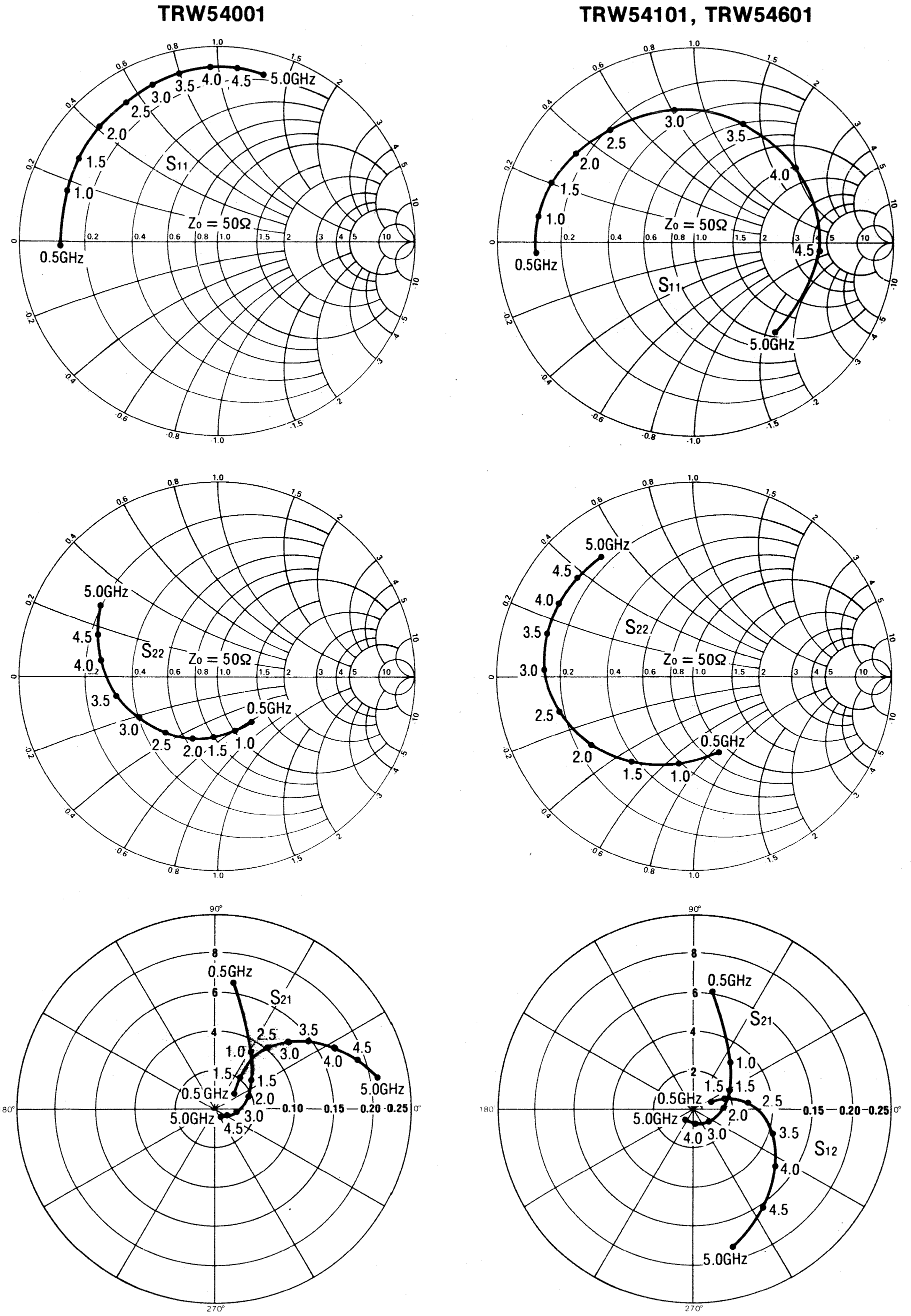
Mechanical Specifications

The following are mechanical specifications for this transistor series.

Dimensions:	Per outline drawing.
Solderability:	Per MIL-STD-750.
Marking:	Per MIL-S-19500, "TRW," 4-digit date code, type number.
Hermeticity:	Per MIL-STD-750, 10^{-7} atmospheres gross and fine leak. (Available on special order screened to 10^{-8} atmospheres.)
Acceleration:	Per MIL-STD-750, 20,000G in any plane.
Bond Pull:	Per MIL-STD-750, 3 grams min.
Package:	A brazed ceramic package assuring long-term integrity of hermetic seals. Leads of KOVAR base material with minimum 60 microinches of gold plating.

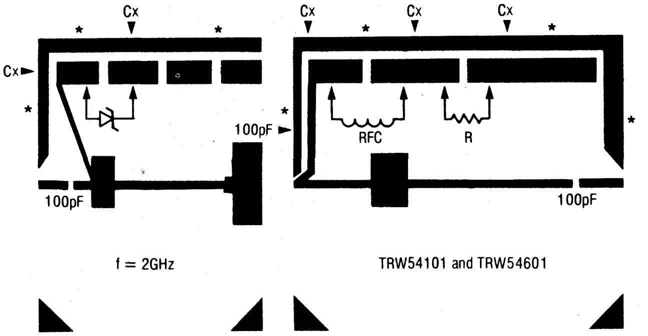
S-Parameters

V_{CE} = 20V, I_E = 120mA, T_{FLANGE} = 25°C



TRW54001 **TRW54101, TRW54601**

Test Circuit Board For TRW54101 and TRW54601



Parts Details

* = Foil-wrap asterisked edge to ground plane. Board material 0.020 inch glass-teflon $\varepsilon_r = 2.55$.

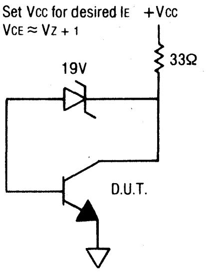
C_x = 100pF and 0.1μF chip

Zener Diode = 19V, 1W

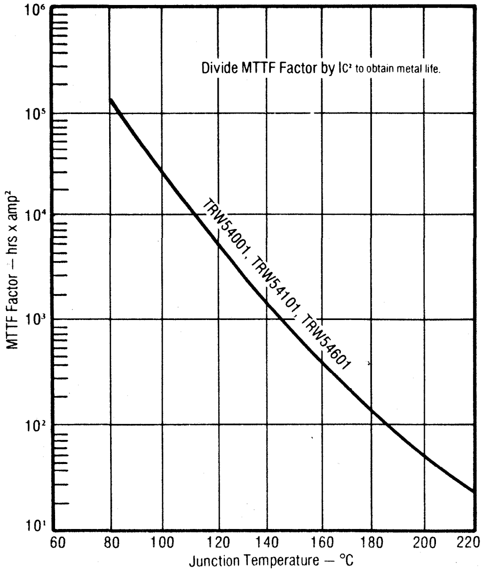
RFC = 8 turns, #28A.W.G., 0.040 diameter

R = 33Ω, 1W

Self-Regulating Bias Circuit

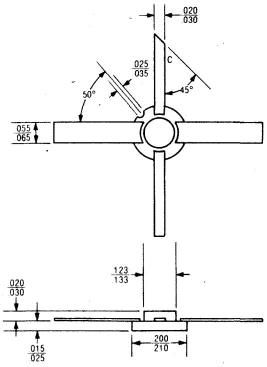


MTTF Factor vs. Junction Temperature

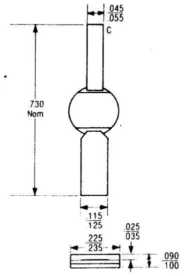


Package Outlines

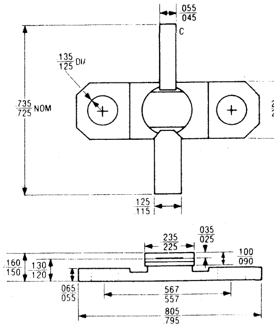
TRW54001



TRW54101



TRW54601



TRW® SEMICONDUCTORS

TRW 62601

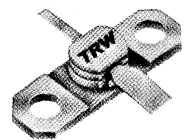
Microwave Power oscillators Transistors

Up to 3 GHz
1.2 W at 2.5 GHz
∞ VSWR

The TRW 62601 is designed for use up to 3 GHz with a typical Pout of 1.2 W at 2.5 GHz.

TRW oscillator devices are commun collector, diffused ballasted, gold metalized microwave transistors characterized for Power oscillator applications.

Their construction enables these devices to be able to withstand an infinite VSWR at any phase and at operating conditions.

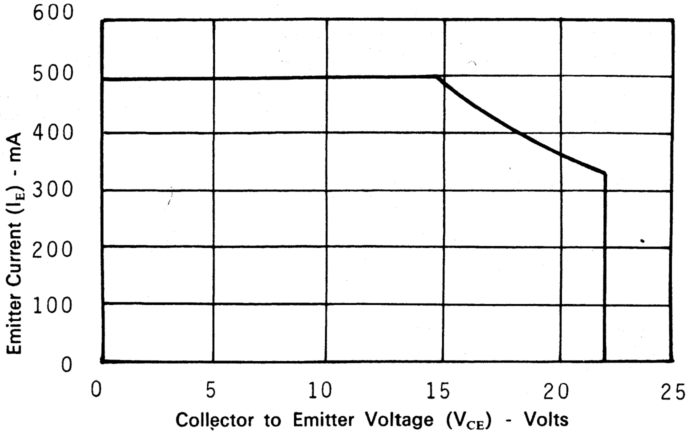


HLP-8

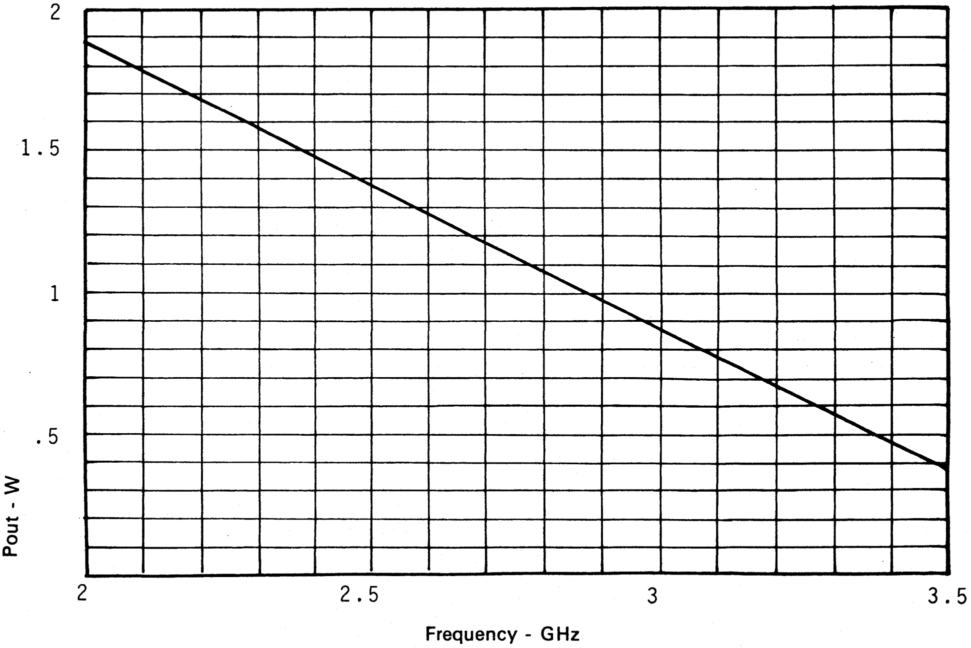
Electrical Characteristics (T_{flange} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
D C Test	BV_{CEO}	Collector - Emitter Breakdown Voltage	I_C = 20 mA	22			V
	BV_{CER}	Collector - Emitter Breakdown Voltage	R_{BE} = 10 Ω I_C = 20 mA	50			V
	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 0.25 mA	3.5			V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 1.0 mA	45			V
	I_{CBO}	Collector Cutoff Current	V_{CB} = 28			0.125	mA
	h_{FE}	Forward Current Transfer Ratio	V_{CE} = 5.0 V I_C = 100 mA	20		120	
R F Test	C_{ob}	Collector Base Capacitance	V_{CB} = 28 V F = 1 MHz			5.0	pF
	F_T	Frequency Cutoff	V_{CE} = 20 V I_E = 220 mA	2.7	3.0		GHz
	P_o	Power output	F = 2.0 GHz V_{CE} = 20 V I_E = 220 mA	1.25			W
	VSWR	Mismatch Tolerance	P_o = 1.25 W V_{CE} = 20 V I_E = 220 mA		∞ : 1		
Operating	θ_{jF}	Thermal Resistance (junction to Flange)				15	°C/W
	T_{STG}	Max Junction and Storage Temperature		— 65		200	°C

D.C. Safe Operating Area

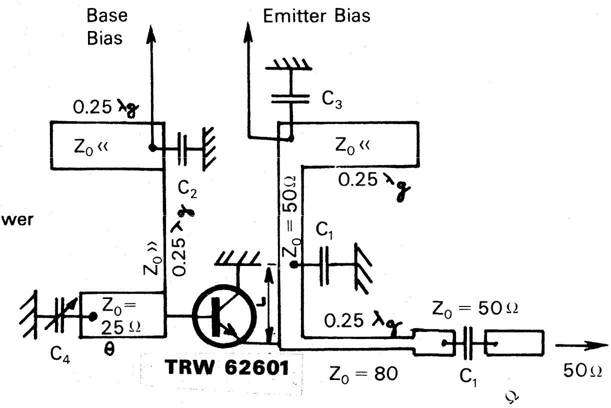


Output Power vs. Frequency
(V_{CE} = 20 V, I_E = 220 mA)

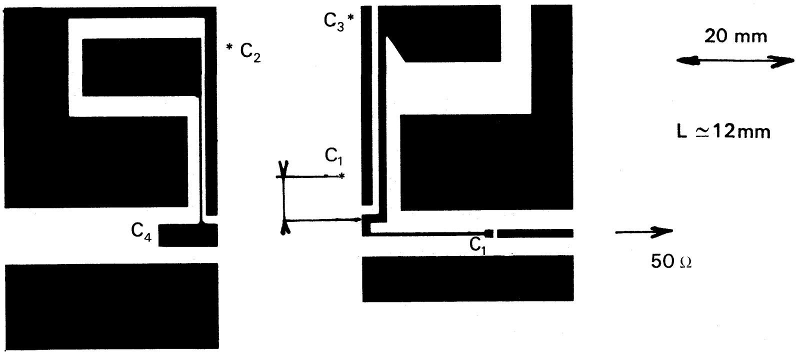


TEST CIRCUIT

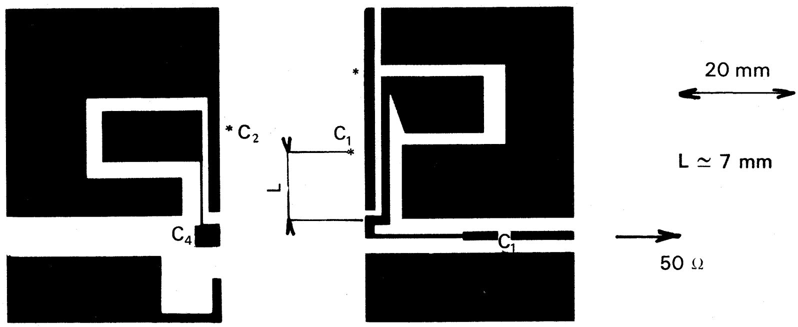
C_1: 220 pF (chip)
C_2: 220 pF (chip) + 10 nF
C_3: 220 pF (chip) + 10 nF + 10 μF
C_4: 0.6-4.5 pF (Frequency tuning)
L : adjust to obtain the maximum output power
$\theta = 0.115\ \lambda g$ for Fo = 2.3 GHz
$\theta = 0.06\ \lambda g$ for Fo = 3 GHz



PC Board Layout for Fo = 2.3 GHz (BW = 500 MHz)



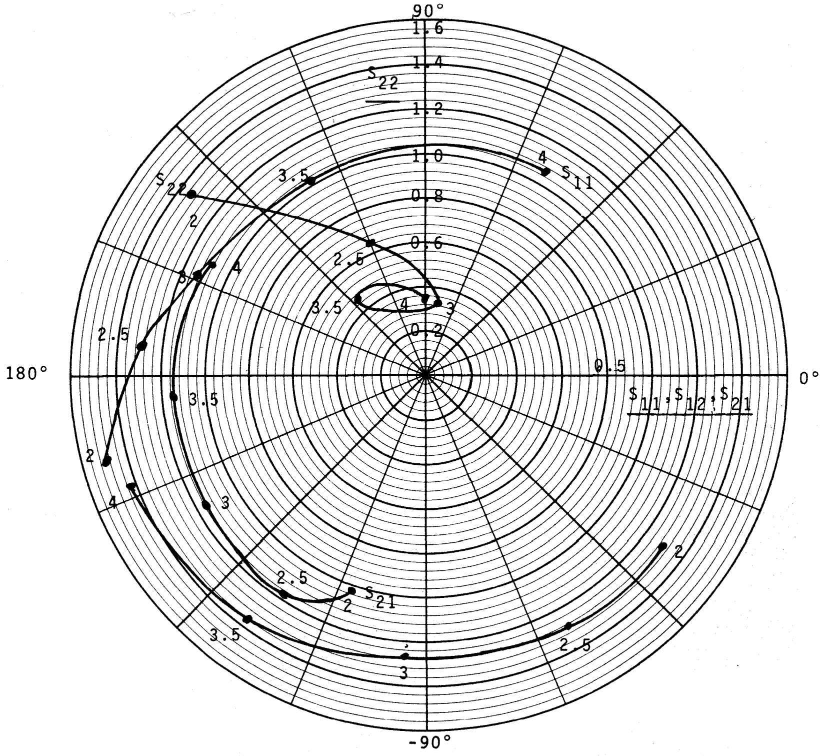
PC Board Layout for Fo = 3 GHz (BW = 500 MHz)



* Foil-wrap asterisked edge to ground plane.
Board material :- 0.020" Glass teflon (Er = 2.55)
Adjust L to obtain the maximum output power

Small Signal S-Parameters

(V_{CE} = 20 V, I_E = 220 mA)

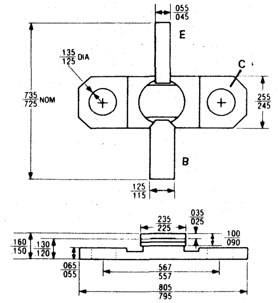


Mechanical Specifications

The following are mechanical specifications for this transistor series.

Dimensions:	Per outline drawing.
Solderability:	Per MIL-STD-750.
Marking:	Per MIL-S-19500, "TRW," 4-digit date code, type number.
Hermaticity:	Per MIL-STD-750, 10^{-7} atmospheres gross and fine leak. (Available on special order screened to 10^{-8} atmospheres.)
Acceleration:	Per MIL-STD-750, 20,000G in any plane.
Bond Pull:	Per MIL-STD-750, 3 grams min.
Package:	A brazed ceramic package assuring long-term integrity of hermetic seals. Leads of KOVAR base material with minimum 60 microinches of gold plating.

Package Outlines



TRW® SEMICONDUCTORS

TRW 62602

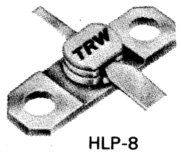
Microwave Power oscillator Transistors

Up to 3 GHz
2 W at 2.5 GHz
∞ VSWR

The TRW 62602 is designed for use upt to 3 GHz with a typical Pout of 2 W at 2.5 GHz.

TRW oscillator devices are commun collector, diffused ballasted, gold metalized microwave transistors characterized for Power oscillator applications.

Their construction enables these devices to be able to withstand an infinite VSWR at any phase and at operating conditions.

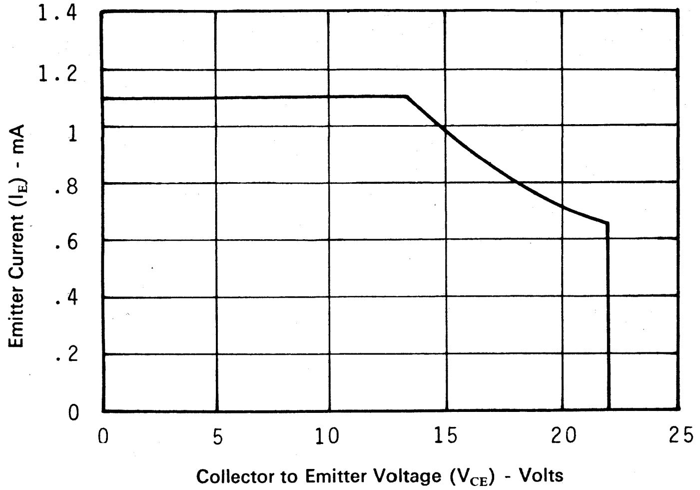


HLP-8

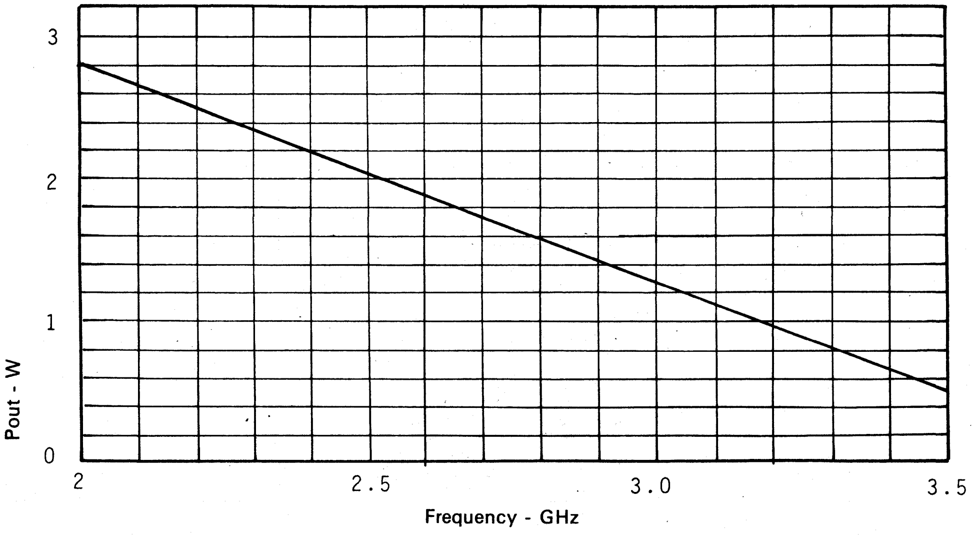
Electrical Characteristics (T_{CASE} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC Test	BV_{CEO}	Collector - Emitter Breakdown Voltage	$I_C = 40$ mA	22			V
	BV_{CER}	Collector - Emitter Breakdown Voltage	$R_{BE} = 10\ \Omega$ $I_C = 40$ mA	50			V
	BV_{EBO}	Emitter - Base Breakdown Voltage	$I_E = 0.5$ mA	3.5			V
	BV_{CBO}	Collector - Base Breakdown Voltage	$I_C = 2.0$ mA	45			V
	I_{CBO}	Collector Cutoff Current	$V_{CB} = 28$ V			0.25	mA
	h_{FE}	Forward Current Transfer Ratio	$V_{CE} = 5.0$ V $I_C = 200$ mA	20		120	
RF Test	C_{ob}	Collector Base Capacitance	$V_{CB} = 28$ V F = 1 MHz			7.0	pF
	F_T	Frequency Cutoff	$V_{CE} = 2.0$ GHz $I_E = 440$ mA	2.7	3.0		GHz
	P_o	Power output	F = 2.00 GHz $V_{CE} = 20$ V $I_E = 440$ mA	2.5			W
	VSWR	Mismutch Tolerance	$P_o = 2.5$ W $V_{CE} = 20$ V $I_E = 440$ mA		∞ : 1		
Operating	θ_{jF}	Thermal Resistance (junction to Flange)				8.5	°C/W
	T_{STG}	Max Junction and Storage Temperature		— 65		200	°C

D.C. Safe Operating Area

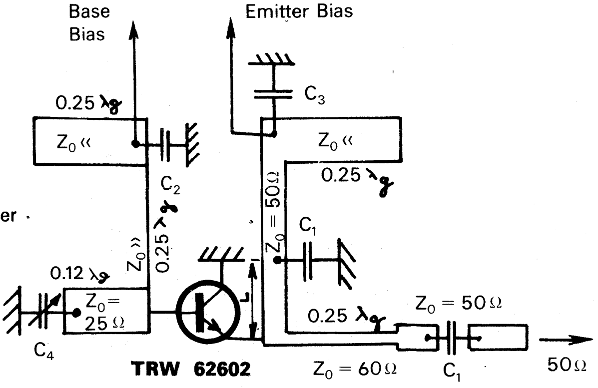


Output Power vs. Frequency
(V_{CE} = 20 V, I_E = 440 mA)

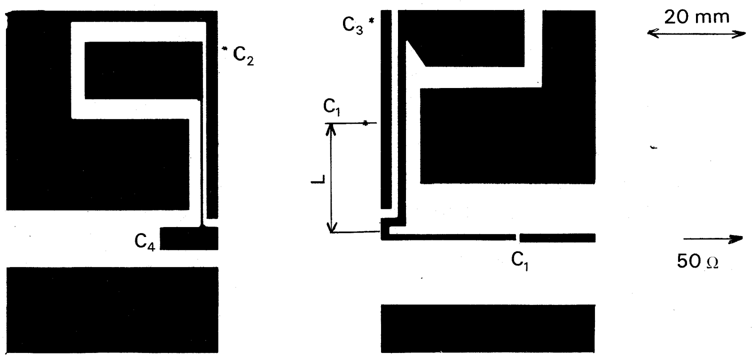


TEST CIRCUIT

C_1: 220 pF (chip)
C_2: 220 pF (chip) + 10 nF
C_3: 220 pF (chip) + 10 nF + 10 μF
C_4: 0.6-4.5 pF (Frequency tuning)
L : adjust to obtain the maximum output power



PC Board Layout for Fo = 2.3 GHz (BW = 500 MHz)

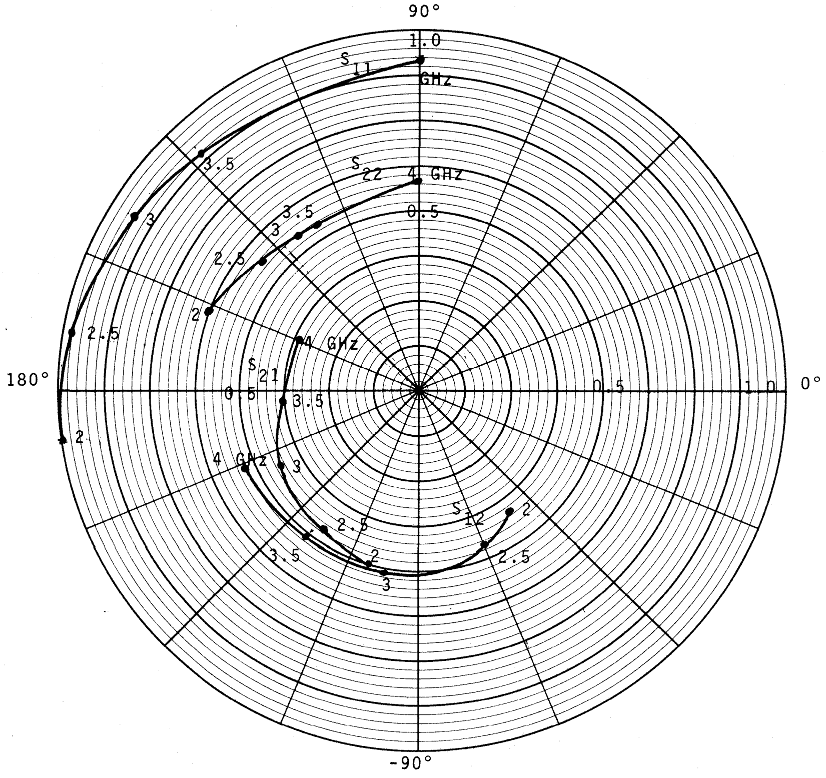


* Foil-wrap asterisked edge to ground plane.
Board material :- 0.020" Glass teflon (Er = 2.55)
Adjust L to obtain the maximum output power

For F = 2 GHz	L = 24 mm
F = 2.3 GHz	L = 19 mm
F = 2.5 GHz	L = 14 mm

Small Signal S-Parameters

(V_{CE} = 20 V, I_E = 440 mA)

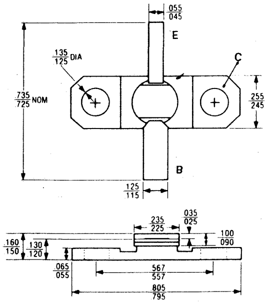


Mechanical Specifications

The following are mechanical specifications for this transistor series.

Dimensions:	Per outline drawing.
Solderability:	Per MIL-STD-750.
Marking:	Per MIL-S-19500, "TRW," 4-digit date code, type number.
Hermaticity:	Per MIL-STD-750, 10^{-7} atmospheres gross and fine leak. (Available on special order screened to 10^{-8} atmospheres.)
Acceleration:	Per MIL-STD-750, 20,000G in any plane.
Bond Pull:	Per MIL-STD-750, 3 grams min.
Package:	A brazed ceramic package assuring long-term integrity of hermetic seals. Leads of KOVAR base material with minimum 60 microinches of gold plating.

PACKAGE OUTLINE



TRW SEMICONDUCTORS

TRW 63601

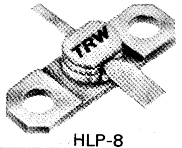
Microwave Power oscillator Transistors

Up to 3.5 GHz
430 mW at 3 GHz
∞ VSWR

The TRW 63601 is designed for use up to 3.5 GHz with a typical Pout of 430 mW at 3 GHz.

TRW oscillator devices are commun collector, diffused ballasted, gold metalized microwave transistors characterized for Power oscillator applications.

Their construction enables these devices to be able to withstand an infinite VSWR at any phase and at operating conditions.



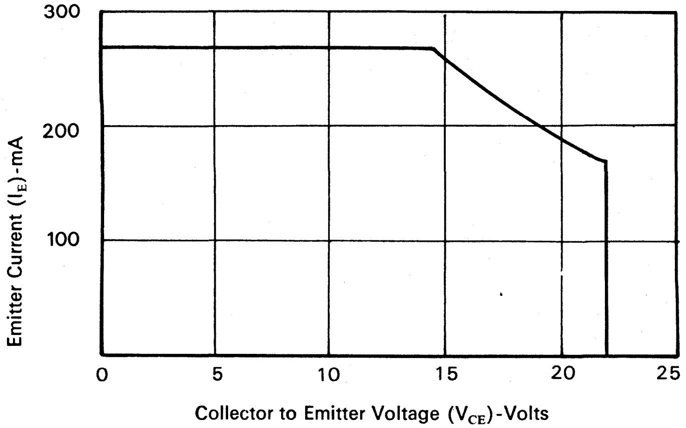
HLP-8

Electrical Characteristics (T_{flange} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
D C Test	BV_{CEO}	Collector - Emitter Breakdown Voltage	I_C = 10 mA	22			V
	BV_{CER}	Collector - Emitter Breakdown Voltage	R_{BE} = 10 Ω I_C = 10 mA	50			V
	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 0.25 mA	3.5			V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 1.0 mA	45			V
	I_{CBO}	Collector Cutoff Current	V_{CB} = 28 V			0.250	mA
	h_{FE}	Forward Current Transfer Ratio	V_{CE} = 5.0 V I_C = 100 mA	20		120	
R F Test	C_{ob}	Collector Base Capacitance	V_{CB} = 28 V F = 1 MHz			3.5	pF
	F_T	Frequency Cutoff	V_{CE} = 20 V I_E = 120 mA	3.0	3.3		GHz
	P_o	Power output	F = 2.3 GHz V_{CE} = 20 V I_E = 120 mA	0.6			W
	VSWR	Mismatch Tolerance	P_o = 0.6 W V_{CE} = 20 V I_E = 120 mA		∞ : 1		
Operating	θ_{jF}	Thermal Resistance (junction to Flange)				32	°C/W
	T_{STG}	Max Junction and Storage Temperature		— 65		200	°C

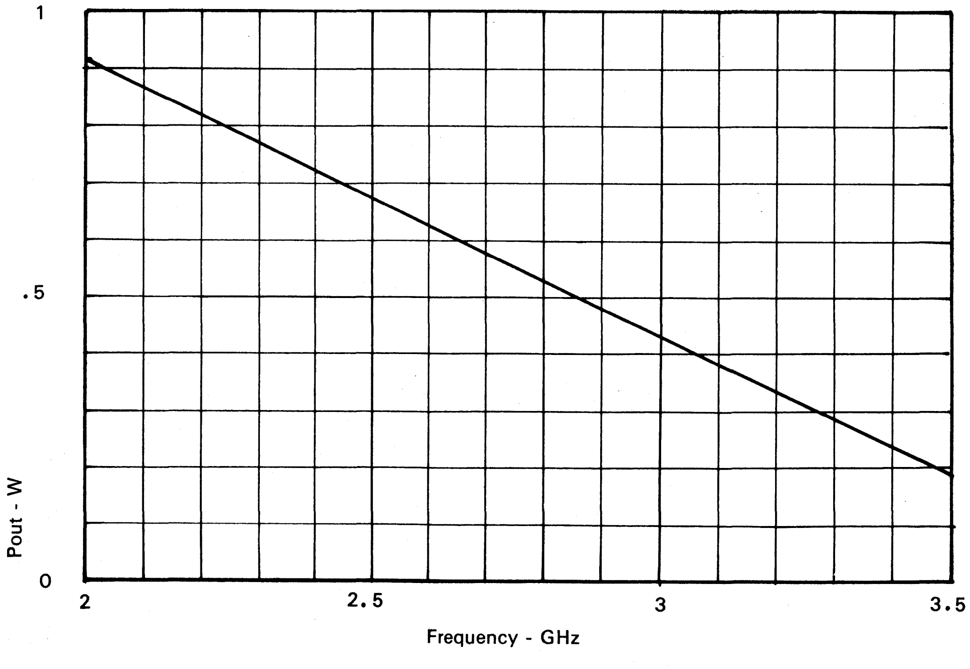
D.C. Safe Operating Area

T_{flange} = **75** °C



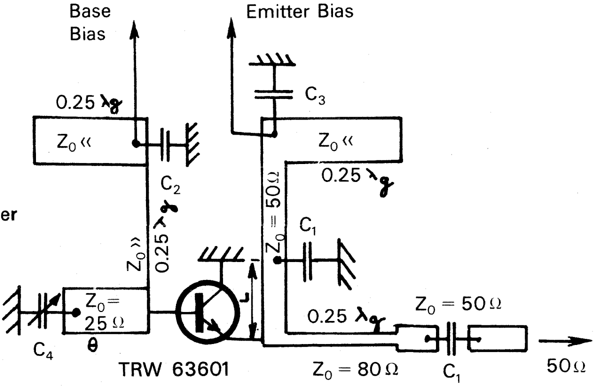
Output Power vs. Frequency

(V_{CE} = 20 V, I_E = 120 mA)

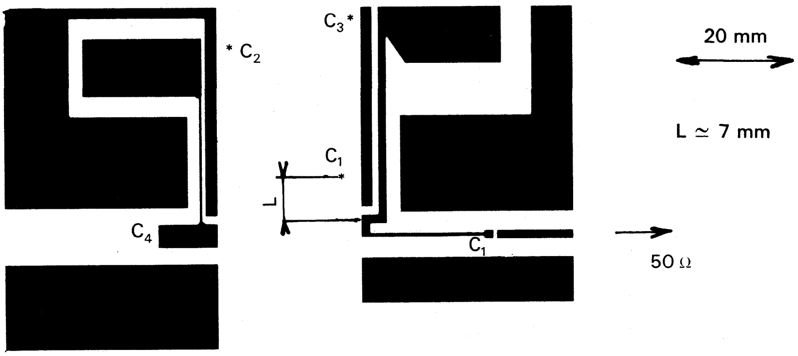


TEST CIRCUIT

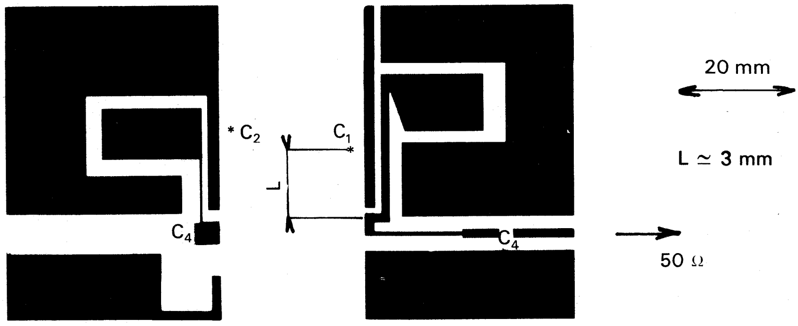
C_1: 220 pF (chip)
C_2: 220 pF (chip) + 10 nF
C_3: 220 pF (chip) + 10 nF + 10 μF
C_4: 0.6-4.5 pF (Frequency tuning)
L : adjust to obtain the maximum output power
θ = 0.115 λg for Fo = 2.3 GHz
θ = 0.06 λg for Fo = 3 GHz



PC Board Layout for Fo = 2.3 GHz (BW = 500 MHz)



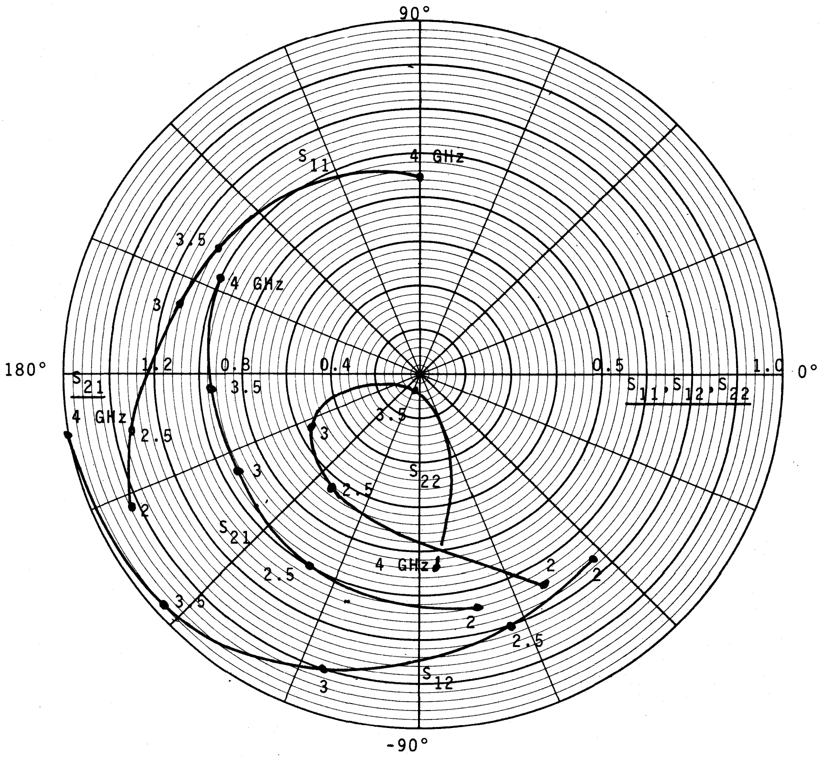
PC Board Layout for Fo = 3 GHz (BW = 500 MHz)



* Foil-wrap asterisked edge to ground plane.
Board material :– 0.020" Glass teflon (Er = 2.55)
Adjust L to obtain the maximum output power

Small Signal S-Parameters

(V_{CE} = 20 V, I_E = 120 mA)



Mechanical Specifications

The following are mechanical specifications for this transistor series.

Dimensions: Per outline drawing.

Solderability: Per MIL-STD-750.

Marking: Per MIL-S-19500, "TRW," 4-digit date code, type number.

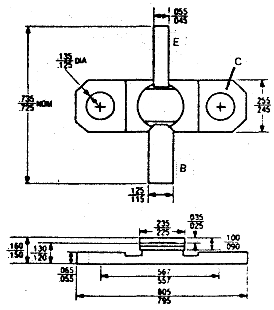
Hermaticity: Per MIL-STD-750, 10^{-7} atmospheres gross and fine leak. (Available on special order screened to 10^{-8} atmospheres.)

Acceleration: Per MIL-STD-750, 20,000G in any plane.

Bond Pull: Per MIL-STD-750, 3 grams min.

Package: A brazed ceramic package assuring long-term integrity of hermetic seals. Leads of KOVAR base material with minimum 60 microinches of gold plating.

Package Outlines



TRW® SEMICONDUCTORS **TRW 63602**

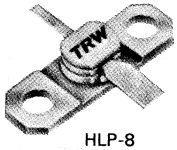
Microwave Power Transistors

Up to 3.5 GHz
850 mW at 3 GHz
∞ VSWR

The TRW 63602 is designed for use up to 3.5 GHz with a typical Pout of 850 mW at 3 GHz.

TRW oscillator devices are commun collector, diffused ballasted, gold metalized microwave transistors characterized for Power oscillator applications.

Their construction enables these devices to be able to withstand an infinite VSWR at any phase and at operating conditions.

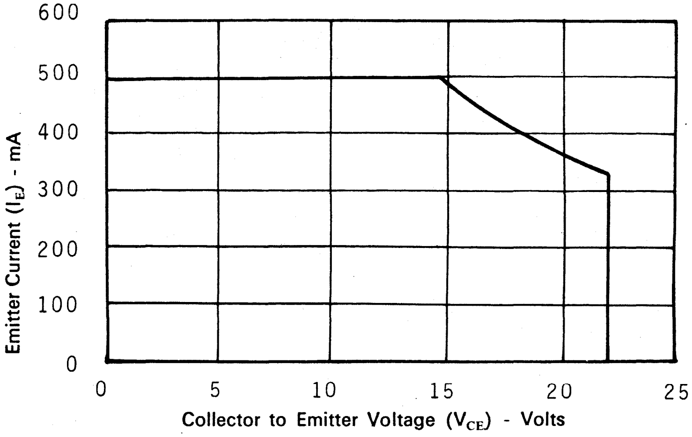


HLP-8

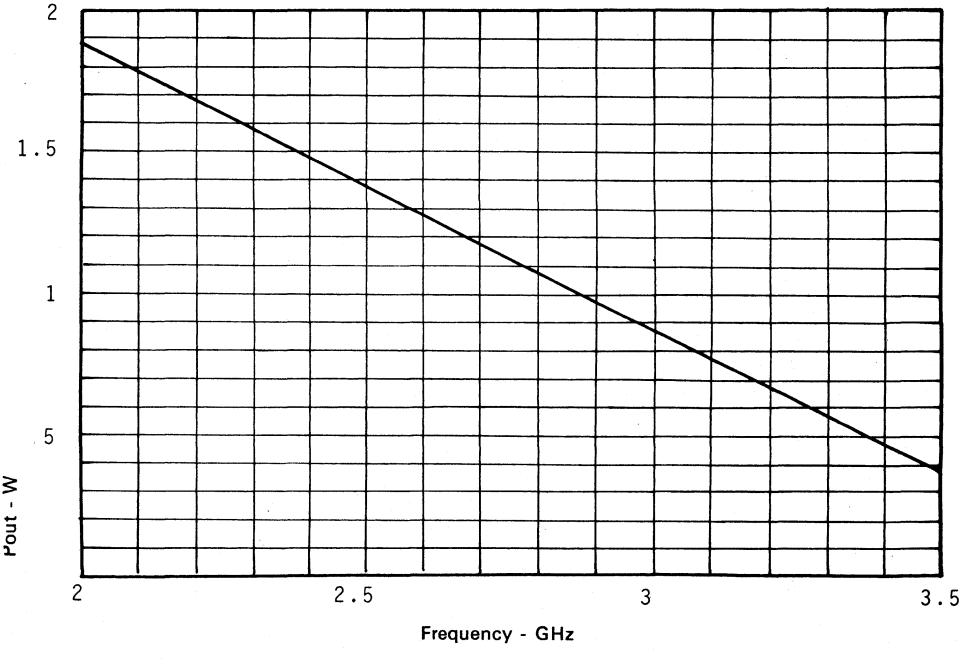
Electrical Characteristics (T_{flange} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
D C Test	BV_{CEO}	Collector - Emitter Breakdown Voltage	I_C = 20 mA	22			V
	BV_{CER}	Collector - Emitter Breakdwon Voltage	R_{BE} = 10 Ω I_C = 20 mA	50			V
	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 0.5 mA	3.5			V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 2.0 mA	45			V
	I_{CBO}	Collector Cutoff Current	V_{CB} = 28 V			0.5	mA
	h_{FE}	Forward Current Transfer Ratio	V_{CE} = 5.0 V I_C = 200 mA	20		120	
R F Test	C_{ob}	Collector Base Capacitance	V_{CB} = 28 V F = 1 MHz			5.5	pF
	F_T	Frequency Cutoff	V_{CE} = 20 V I_E = 230 mA	3	3.3		GHz
	P_o	Power output	F = 2.3 GHz V_{CE} = 20 V I_E = 230 mA	1.2			W
	VSWR	Mismatch Tolerance	P_o = 1.2 W V_{CE} = 20 V I_E = 230 mA			∞ : 1	
Operating	θ_{jF}	Thermal Resistance (junction to Flange)				17	°C/W
	T_{STG}	Max Junction and Storage Temperature		— 65		200	°C

D.C. Safe Operating Area

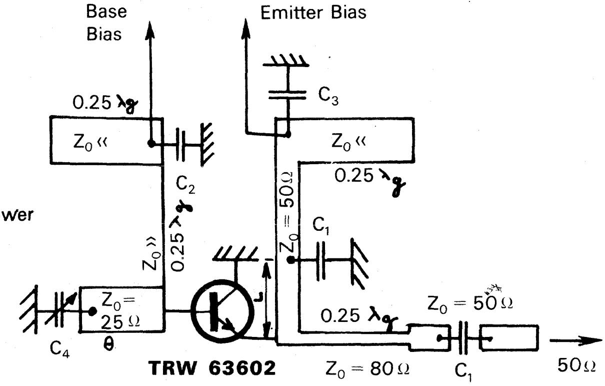


Output Power vs. Frequency
(V_{CE} = 20 V, I_E = 230 mA)

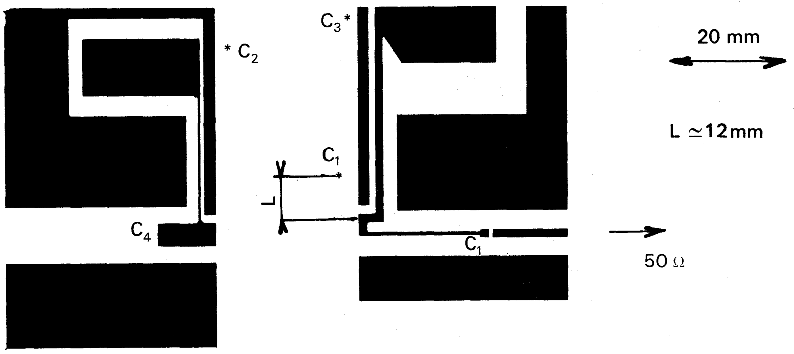


TEST CIRCUIT

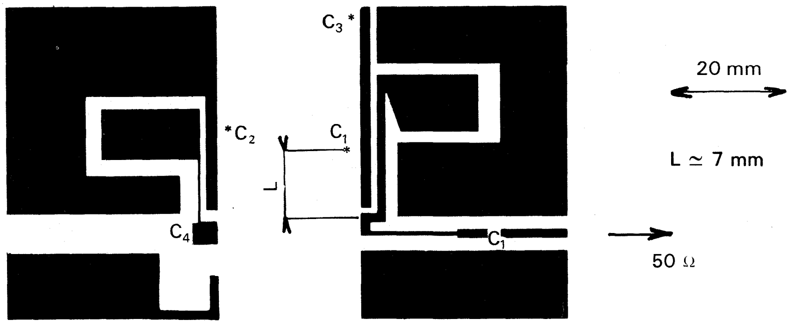
C_1: 220 pF (chip)
C_2: 220 pF (chip) + 10 nF
C_3: 220 pF (chip) + 10 nF + 10 μF
C_4: 0.6-4.5 pF (Frequency tuning)
L : adjust to obtain the maximum output power
$\theta = 0.115\ \lambda g$ for Fo = 2.3 GHz
$\theta = 0.06\ \lambda g$ for Fo = 3 GHz



PC Board Layout for Fo = 2.3 GHz (BW = 500 MHz)



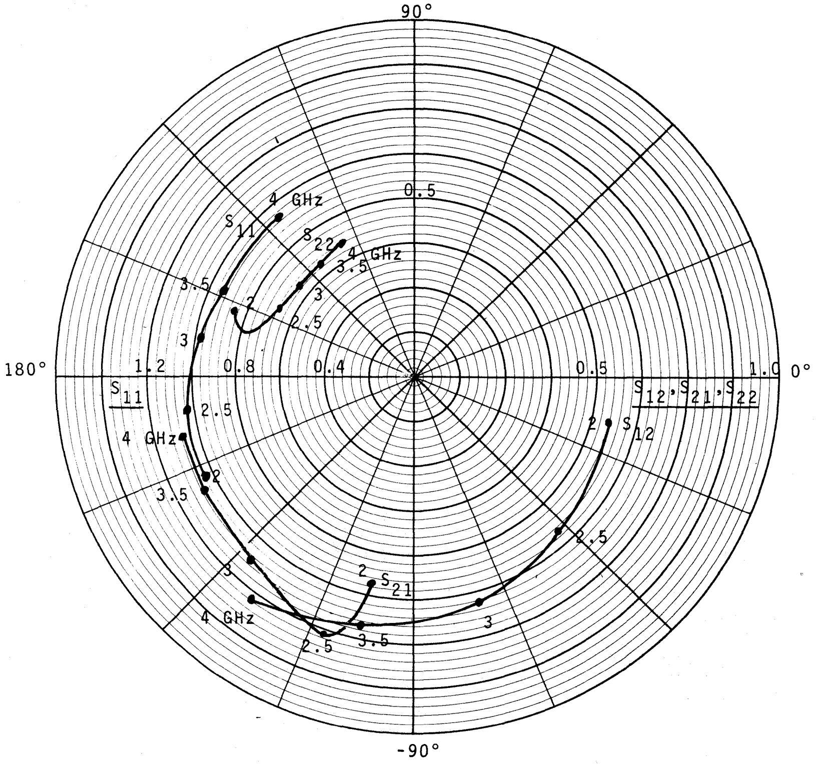
PC Board Layout for Fo = 3 GHz (BW = 500 MHz)



* Foil-wrap asterisked edge to ground plane.
Board material :- 0.020" Glass teflon (Er = 2.55)
Adjust L to obtain the maximum output power

Small Signal S-Parameters

(V_{CE} = 20 V, I_E = 230 mA)

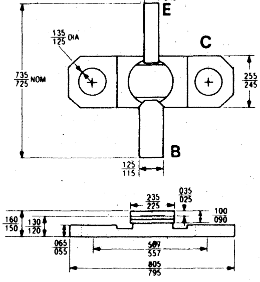


Mechanical Specifications

The following are mechanical specifications for this transistor series.

Dimensions:	Per outline drawing.
Solderability:	Per MIL-STD-750.
Marking:	Per MIL-S-19500, "TRW," 4-digit date code, type number.
Hermaticity:	Per MIL-STD-750, 10^{-7} atmospheres gross and fine leak. (Available on special order screened to 10^{-8} atmospheres.)
Acceleration:	Per MIL-STD-750, 20,000G in any plane.
Bond Pull:	Per MIL-STD-750, 3 grams min.
Package:	A brazed ceramic package assuring long-term integrity of hermetic seals. Leads of KOVAR base material with minimum 60 microinches of gold plating.

Package Outlines



TRW® **SEMICONDUCTORS**

TRW 64601

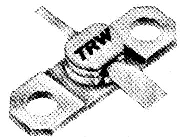
Microwave Power oscillator Transistors

Up to 5 GHz
350 mW at 4 GHz
∞ VSWR

The TRW 64601 is designed for use up to 5 GHz with a typical Pout of 350 mW at 4 GHz.

TRW oscillator devices are commun collector, diffused ballasted, gold metalized microwave transistors characterized for Power oscillator applications.

Their construction enables these devices to be able to withstand an infinite VSWR at any phase and at operating conditions.



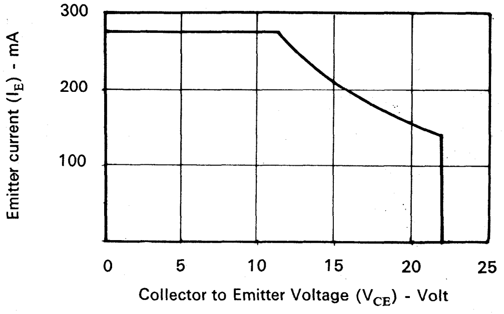
HLP-8

Electrical Characteristics (T_{CASE} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
D C Test	BV_{CEO}	Collector - Emitter Breakdown Voltage	I_C = 10 mA	22			V
	BV_{CER}	Collector - Emitter Breakdown Voltage	R_{BE} = 10 Ω I_C = 10 mA	50			V
	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 0.25 mA	3.5			V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 1.0 mA	45			V
	I_{CBO}	Collector Cutoff Current	V_{CB} = 28			0.25	mA
	h_{FE}	Forward Current Transfer Ratio	V_{CE} = 5.0 V I_C = 100 mA	20		120	
R F Test	C_{ob}	Collector Base Capacitance	V_{CB} = 28 V F = 1 MHz			3.5	pF
	F_T	Frequency Cutoff	V_{CE} = 20 V I_E = 120 mA	4.0	4.5		GHz
	P_o	Power output	F = 4 GHz V_{CE} = 20 V I_E = 120 mA	0.300	0.350		W
	VSWR	Mismatch Tolerance	P_o = 0.300 W V_{CE} = 20 V I_E = 120 mA		∞ : 1		
Operating	θ_{JF}	Thermal Resistance (junction to Flange)				40	°C/W
	T_{STG}	Max Junction and Storage Temperature		— 65		100	°C

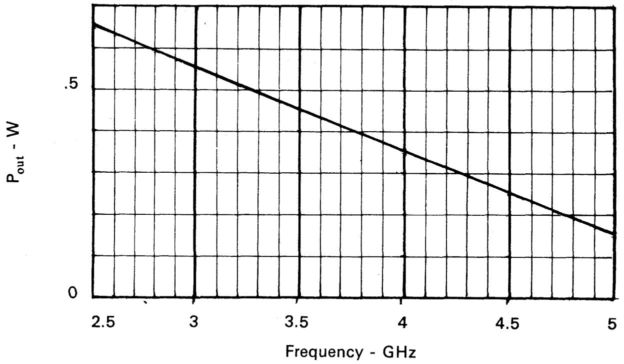
DC Safe Operating Area

$T_{Flange} = 75\ °C$



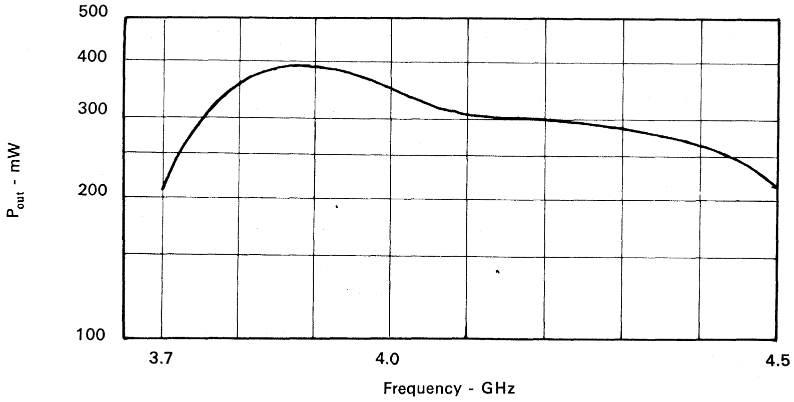
Output Power V_S Frequency

(V_{CE} = 20 V, I_E = 120 mA)



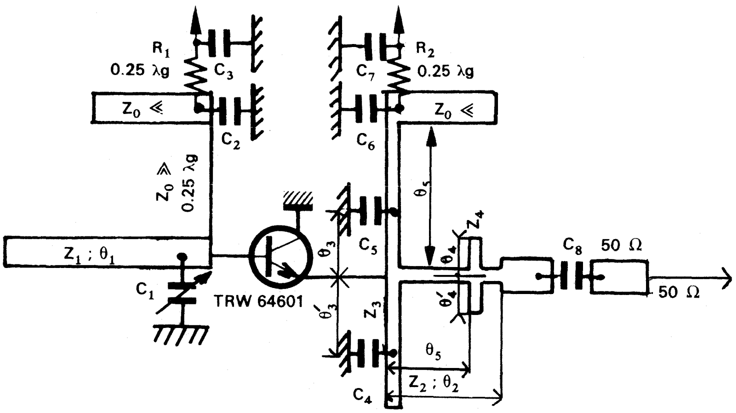
P_{out} V_S Frequency with a Fixed tuned output circuit

Oscillator circuit : TF; V_{CE} = 20 V; I_E = 120 mA



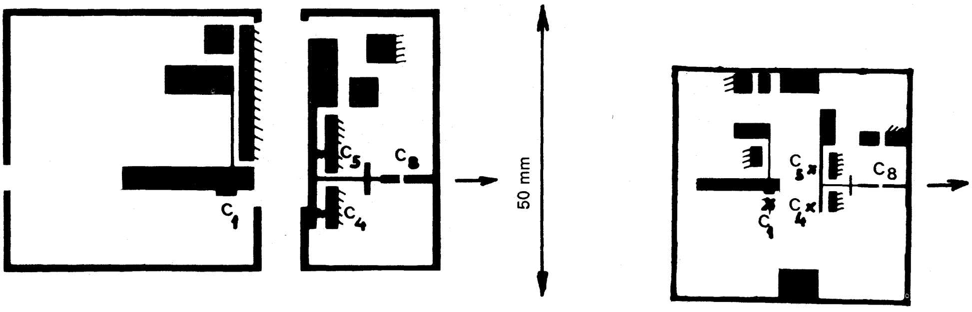
Test circuit

$F_0 = 4$ GHz



$Z_1 = 23.5\ \Omega$ $\theta_1 = 0.52\ \lambda g$
$Z_2 = 80/67\ \Omega$ $\theta_2 = 0.25\ \lambda g$
$Z_3 = 50\ \Omega$ $\theta_3 = 0.095\ \lambda g$; $\theta'_3 = 0.140\ \lambda g$
Adjust θ_3 and θ_3 to obtain the maximum output power
$Z_4 = 62\ \Omega$ $\theta_4 = 0.05\ \lambda g$
$\theta_5 = 0.18\ \lambda g$
$R_1 = 160\ \Omega$
$R_2 = 1\ \Omega$
$C_1 = 0.4 - 2.5$ pF
$C_2 = C_6 = 100$ pF (chip) + 10 nF
$C_3 = C_7 = 10$ nF
$C_4 = C_5 = C_8 = 33$ pF (chip)

P_C Board layout For $F_0 = 4$ GHz (BW = 700 MHz)

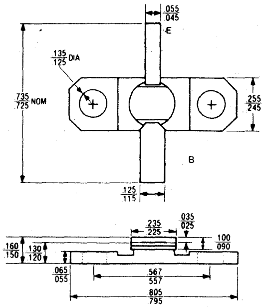


//// Foil wrap edge to ground plane

Board Material : 0.020″ Glass teflon; $E_r = 2.55$

Board Material : 0.025″ Epsilan 10 ; $E_r = 10.2$

Package Outlines



Mechanical Specifications

The following are mechanical specifications for this transistor series.

Dimensions:	Per outline drawing.
Solderability:	Per MIL-STD-750.
Marking:	Per MIL-S-19500, "TRW," 4-digit date code, type number.
Hermaticity:	Per MIL-STD-750, 10^{-7} atmospheres gross and fine leak. (Available on special order screened to 10^{-8} atmospheres.)
Acceleration:	Per MIL-STD-750, 20,000G in any plane.
Bond Pull:	Per MIL-STD-750, 3 grams min.
Package:	A brazed ceramic package assuring long-term integrity of hermetic seals. Leads of KOVAR base material with minimum 60 microinches of gold plating.

TRW® SEMICONDUCTORS

TRW 64602

Microwave Power Oscillator Transistor

PRELIMINARY

UP TO 4 GHz

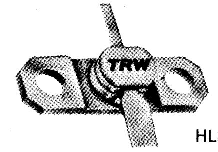
650 mW AT 4 GHz

∞ VSWR

The TRW 64602 is designed for use up to 5 GHz with a typical P_{out} of 650 mW at 4 GHz.

TRW oscillator devices are commun collector, diffused ballasted, gold metalized microwave transistors characterized for Power oscillator applications.

Their construction enables these devices to be able to withstand an infinite VSWR at any phase and at operating conditions.



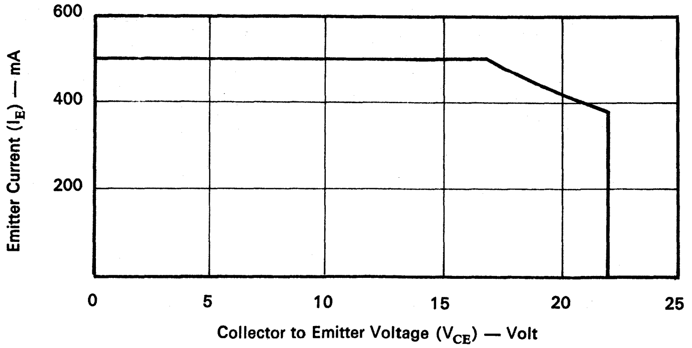
HLP-8

Electrical Characteristics (T_{case} = 25 °C)

	SYMBOL	CHARACTERISTICS	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
DC TEST	BV_{CEO}	Collector - Emitter Breakdown Voltage	I_C = 20 mA	22			V
	BV_{CER}	Collector - Emitter Breakdown Voltage	I_C = 20 mA R_{BE} = 10 Ω	50			V
	BV_{EBO}	Emitter - Base Breakdown Voltage	I_E = 0.5 V	3.5			V
	BV_{CBO}	Collector - Base Breakdown Voltage	I_C = 2 mA	45			V
	I_{CBO}	Collector Cutoff Current	V_{CE} = 28 V			0.5	mA
RF TEST	H_{FE}	Forward Current Transfer Ratio	V_{CE} = 5 V I_C = 200 mA	20		120	
	C_{OB}	Collector Base Capacitance	V_{CB} = 28 V F = 1 MHz			5.5	pF
	P_O	Power output	V_{CE} = 20 V I_C = 240 mA F = 4 GHz	550	650		mW
	VSWR	Mismatch Tolerance	V_{CE} = 20 V I_C = 240 mA F = 4 GHz		∞ : 1		
THERMAL	θ_{JF}	Thermal Resistance Junction to Flange				20	°C/W
	T_{STG} & T_J	Max Junction & Storage Temperature		— 65		+ 200	°C

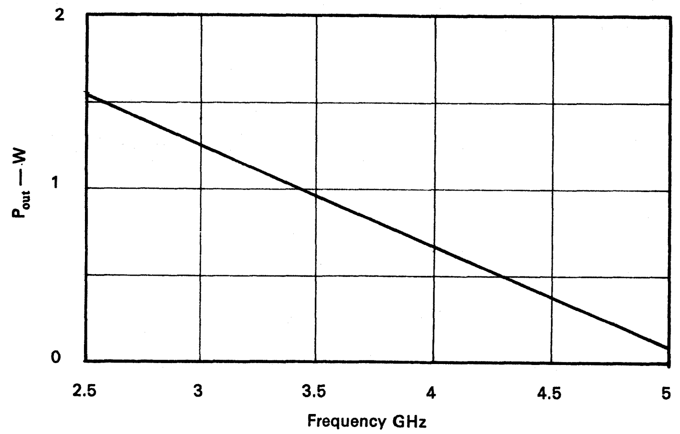
DC Safe Operating Area

$T_{flange} = 75\ °C$

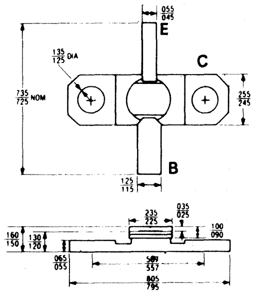


Output Power vs Frequency

(V_{CE} = 20 V, I_E = 240 mA)



Package Outlines



Mechanical Specifications

The following are mechanical specifications for this transistor series.

Dimensions	: Per outline drawing.
Solderability	: Per MIL-STD-750.
Marking	: Per MIL-S-19500, « TRW », 4-digit date code, type number.
Hermaticity	: Per MIL-STD-750, 10^{-7} atmospheres gross and fine leak (Available on special order screened to 10^{-8} atmospheres.)
Acceleration	: Per MIL-STD-750, 20.000G in any plane.
Bond Pull	: Per MIL-STD-750, 3 grams min.
Package	: A brazed ceramic package assuring long-term integrity of hermetic seals. Leads of KOVAR base material with minimum 60 microinches of gold plating.

APPLICATION NOTES

APPLICATION NOTE No 1

Reliability and MTF -- The Long and Short of It

Mean Time for Failure in microwave power transistors is increasing by the introduction of new designs and improved metallization systems. Here is a review of both long-term and short-term reliability problems and how they can be dealt with.

ALONG with the development of high power microwave transistors has been a determined effort by the major transistor houses to improve device short and long-term reliability. Short-term reliability allows a device to withstand electrical or environmental abuse for brief periods of time, such as infinite VSWR. Long-term reliability on the other hand is the ability of a device to take adverse conditions for an extended period of time, such as elevated ambience or non-optimum load conditions.

Several factors enter into the determination of microwave transistor reliability. Among the most important are

- a device design that minimizes thermal stresses and current densities (both conductive to premature and long-term failure modes).
- silicon and junction passivation integrity.
- metallization ruggedness as to thermal, electrochemical corrosion, silicon dissolution, oxide reduction, and electromigration effects.
- and a package design that provides a hermetic, low parasitic, and maximum heat dissipation environment.

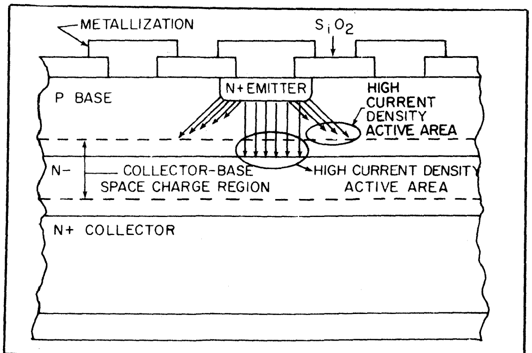
Short-term failure—forward bias

When a microwave power transistor fails under short-term stress conditions, it is invariably caused by intense localized heating at the emitter-base or collector-base junction. This heating culminates in a localized melting of the contacting metallization and the silicon crystal, resulting in catastrophic failure. These stress conditions usually occur from a high VSWR presented to the device by non-optimum load conditions.

Either low voltage and high current, high voltage and low current, or intermediate current-voltage combinations can occur, depending on the magnitude and phase angle of the VSWR. Most high power microwave transistors are operated in a common-base, class C mode. When a voltage swing exceeds specific voltage ratings, large avalanche currents flow in the device causing high power dissipation and localized heating. If the load termination allows a low-voltage, high-current state to occur, equally destructive localized heating results.

Forward-bias secondary breakdown occurs whenever a device is heavily biased into the active region and large emitter and collector currents flow (Fig. 1a). Under these conditions, a large transverse voltage drop occurs in the base region under the emitter. As a result large base current components de-bias the emitter-base junctions in their central portions such that only the periphery of these junctions are active, causing high amounts of heat to be generated. Should the load termination be such that avalanche conditions prevail, the multiplication further aggravates the already present current and power density stresses.

The severity of localized heating depends both on the current drive and applied voltage. For a given current level, increases in V_{CE} cause higher power densities in the collector-base junction, resulting in higher temperatures. Increases in current drive cause equally deleterious effects for a given V_{CE} bias level, since higher current levels further diminish the useful emitter-base active area due to base-current de-biasing effects. As a result, localized power densities are increased and with the available areas decreased, the local thermal impedances cause inordinate temperature



1(a). Cross section of a typical epitaxial, planar diffused junction transistor shows current flow under hard forward bias conditions at corners of emitter-base junction. **(b) Collector-base forward-bias,** or emitter-base reverse bias causes emitter-collector current to be localized in the center of the emitter-base junction (color tint).

Mike Flahie, Microwave Engineer, TRW Semiconductor Division, Lawndale, Calif.

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rises to occur. Unfortunately, these temperature rises are degenerative: i.e., as a particular junction becomes hot, the more current it will draw; as it draws more current the hotter it becomes.

Emitter-base junction de-biasing is directly proportional to the frequency and power of a transistor. High frequency devices demand narrow basewidths, relatively high base-sheet resistances, and high collector-base voltages.

Saturated secondary breakdown

Reverse-bias can be equally fatal to a device. Here current flows through the device under either emitter-base reverse-bias conditions, or hard, high-current, collector-base forward-bias conditions. Under either condition, base current direction is reversed causing emitter-collector current to be localized in the central portion of the emitter-base junction (Fig. 1b). Reduced area and periphery result in high local impedances.

When both conditions exist, the effect can be even more disastrous. Hard avalanche reverse-bias of an emitter-base junction results in a temporary emitter-collector current gain degradation.[1] A doubly-fatal condition results: current gain is reduced; hence, the next current-drive cycle faces deteriorated gain—the cycle is clearly degenerative. The degeneration of junction properties can be avoided via internal device current-limiting techniques.

Packaging integrity important

Long-term failure modes are characterized by gradual deterioration of device performance levels due to junction, contacting metallization (including wire and die bonds), or package degradation effects. The processes are both degenerative and cumulative, and lead to eventual catastrophic failure.

A transistor package provides a protective environment, low thermal impedance, low parasitic and a mechanically rugged housing for a chip. It should only minimally detract from the intrinsic device capability. Compromises are usually the case: i.e., device performance is usually sacrificed in order to provide reliable performance. Package integrity, such as the quality of the isolating dielectric (e.g. BeO), lead connection layout, and overall package construction usually result in a 1-2 dB power degradation. This results from both high thermal impedances and high parasitic losses presented by the housing.

Major reliability problems involved in the package assembly process are

- die bonding of the chip to the package
- wire bond leads from the package to the chip
- hermeticity of the assembled package
- voids between the header and die
- voids in the heat sinking base of the header
- and cracking of the die during both the die and wire bonding operations.

Assuming total package integrity, two critical variables that influence both the short and long term reliability of a microwave power transistor are the quality of the die bond to the header and the external lead bonding. Faulty die bonding leads to voids between the die and its heat sink. These voids in turn lead to poor thermal conductance areas, creating local device "hot spots." This leads to localized thermal runaway, causing eventual destruction of the device.

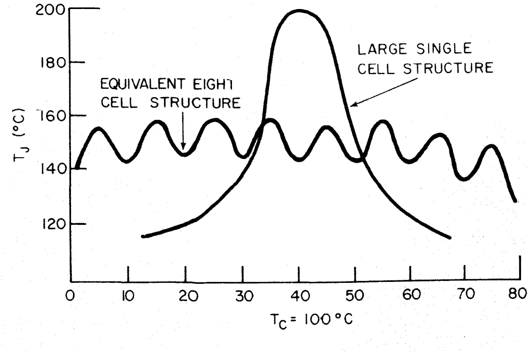
Faulty lead bonding can have a similar result If a lead is shorter or longer than the other corresponding leads, or presents a localized high impedance due to poor contact, phase differences result in non-uniform rf current distribution.

Hot spots and multi-cell design

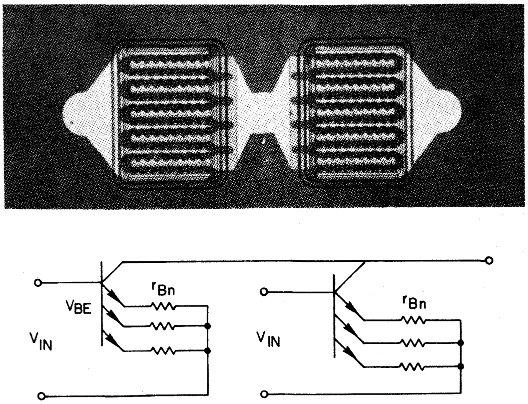
Microwave power transistor design is predicted on two main criteria:

- sufficient collector-base junction area and periphery to manage the heat generated; dc to rf conversion efficiencies are only 30-60%.
- and, extremely fine geometries to maximize emitter-periphery to base-area ratios.

(continued on next page)



2. The temperature profile across the surface of a large area microwave transistor can be distributed by using a multi-cell construction.



3. Cell-pair of an emitter ballasted, TRW 5 W, 3 GHz transistor and schematic. Darker areas are the refractory ballast resistor material.

RELIABILITY AND MTF

To attain higher power at microwave frequencies by using larger collector-base junction areas has historically ended in a situation of diminishing returns. Less output power is observed as the collector-base junction area is increased above a critical level, although the device emitter periphery/base area ratio, f_t, and base periphery figure of merits are maintained. Further, large collector-base area devices are more prone to premature failure than their lower power, scaled down "equivalents." This results because large area devices exhibit grossly non-uniform current and temperature distributions (Fig. 2) where a temperature gradient of approximately 4°C/mil exists from the center of the die to the edge.[2] As a result only a small fraction of the available active device area is used for power conversion. Cooler portions receive less drive current, for a fixed emitter-base voltage bias level, due to the exponential relationship between current, voltage, and temperature of a forward biased junction:

$$I_E \doteq \mathrm{C}T^{1.4}\, e^{(-1/KT)(E_g - qV_{BE})} \qquad (1)$$

where

E_g = Energy gap for silicon doping.
q = charge electron.
V_{BE} = base emitter bias voltage.
C = constant.
T = temperature – °K.

The percentage increase in emitter current per °C is obtained by the differentiating Eq. 1 with respect to temperature, holding V_{BE} constant:

$$\frac{1}{I_E}\left(\frac{dI_E}{dT}\right) = \frac{1}{T}\,[1.4 + (E_g - q\,V_{BE})/KT] \qquad (2)$$

When operating near 300°K (room temperature), and a forward bias V_{BE} = 1 V, Eq. 2 predicts

$$\frac{1}{I_E}\left(\frac{dI_E}{d\,T}\right) = 1.75\%/°\mathrm{C} \qquad (3)$$

Hence, a difference in temperature of 20°C can result in a percentage current difference of nearly 35%. Further, since

$$\frac{1}{I_E}\left(\frac{dI_E}{dT}\right) = \frac{1}{I_E}\left(\frac{dI_E}{dx}\right)\left(\frac{dx}{dT}\right) \qquad (4)$$

then

$$\frac{1}{I_E}\left(\frac{dI_E}{dx}\right) = \frac{1}{T}\left(\frac{dT}{dx}\right)[1.4 + (E_g - q\,V_{BE})/KT] \qquad (5)$$

Equation 5 means that large percentage thermal gradients are accompanied by large percentage current gradients.

To avoid hot spots the collector-base junction area is usually divided into paralleled "cells," (Fig. 2). However, paralleling multiple cells presents difficulties. Phase differences associated with package parasitics and physical die dimensions cause major problems at gigahertz frequencies. These phase differences can result in unequal power drive to the individual cells resulting in situations equally as dangerous to device reliability as poor device area layout.

Emitter ballasting, where discrete resistive elements are introduced in series with the emitter contact metallization, greatly reduces these drive input non-uniformities, and increases the device ruggedness to secondary breakdown effects. Emitter ballasting works as follows: If a given emitter-base junction site becomes excessively heated and tries to draw more than its proportionate share of drive current, the series resistance will divide the input voltage in accordance with the IR drop demanded by the relative impedance levels of both the series resistance and the emitter-base junction site involved (Fig. 3).

For a dual-celled, emitter-ballasted device, the emitter current at any site is

$$I_E = I_S\,(e^{qV_{BE}/KT} - 1) \qquad (6)$$

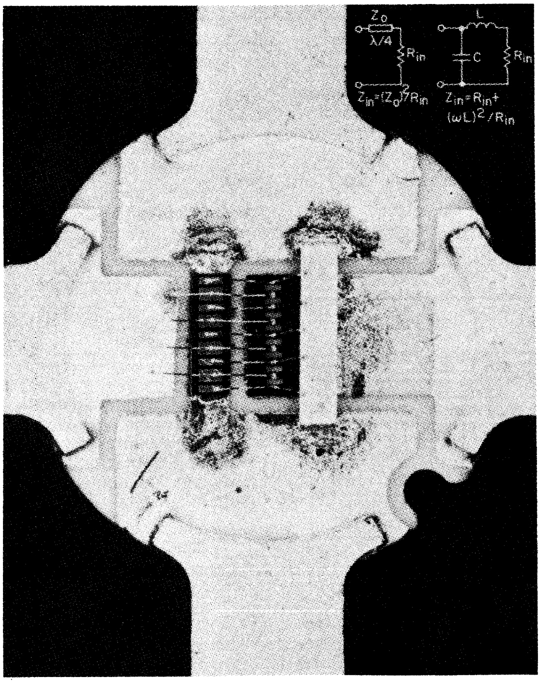
But

$$V_{BE} = V_{IN} - I_E r_B \qquad (7)$$

Hence

$$I_E = I_S\,(e^{q(V_{in} - I_E r_B/KT)} - 1) \qquad (8)$$

In other words, for a constant V_{IN} applied across the emitter-base junction and ballast network, local increases in I_E due to temperature cause a rise in the local $I_E r_B$ drop, resulting in less V_{BE} voltage drive. The ballast resistor thus stabilizes any endangered site. Although the ballast resistors are in series with the load, their effect on the rf performance of the device can be minimized. The resultant total value is $R_T = 1/\sum_n (1/r_{Bn})$ which is usually small. Further, increases in



4. Matching sections given by $\mathbf{Z_{in} = R_{in} + (\omega L)^2/R_{in}}$ consist of lead wire inductances and discrete SiO$_2$/Si capacitance elements.

saturation voltage for the paralleled ballast resistors are also minimal, since the $I_E R_T$ drop is on the order of a few hundreds of millivolts. One additional advantage of multicellular construction is it increases the total amount of collector-base junction periphery for a given total-required base area. This increase in periphery decreases the total thermal impedance of the device, since θ_{jc} is inversely proportional to base periphery.

Further improvements in device reliability and performance are obtainable with in-package, discrete element, impedance matching schemes (Fig. 4). Should for any reason an emitter-ballasted transistor present a low input impedance not controlled by emitter-ballasting at any given cell, an impedance inverting network can be provided to reflect this low impedance input into a high impedance input. Should R_{in} decrease due to either phase differences in the input drive, or localized heating, Z_{in} inrceases inversely (Fig. 4) limiting the amount of power delivered to the misbehaving site.

Transistor equivalent circuit

Transistor unilateral gain (that gain obtained when a device is designed with a lossless network and matched at both ports) can be approximated by:[2]

$$G(f) \approx \frac{G(0)}{[1 + G^2(0)\ (f/f_{\max})^4]^{1/2}} \qquad (9)$$

For $G^2(0)\ (f/f_{\max})^4 >> 1, G(f) \approx (f_{\max}/f)^2$.

The maximum frequency of oscillation of a transistor, $f_{\max}$, is the frequency for which power gain drops to unity. For the simplified transistor equivalent circuit of (Fig. 5) the real part of the input conductance is $1/r_b'$; the real part of the output conductance is approximately $\omega_T C_C$, and current gain $|h_f e| = \omega_T/\omega$. The gain of the equivalent circuit given by (Fig. 5) is then

$$G(f) = \frac{P_{out}}{P_{IN}} \approx \frac{I^2_{OUT}\ (1/Re(Y_{OUT}))}{4\, I^2_{IN}\ (1/Re(Y_{IN})} \qquad (10)$$

Hence,

$$G(f) \approx \frac{f_T}{8\,\pi\, f^2\, r_b\, C_C} \qquad (11)$$

For $f = f_{\max}$, $G(f) = 1$, hence

$$f_{\max} = \frac{f_T}{8\,\pi\, r_b'\, C_C} \qquad (12)$$

To achieve high gain at a particular frequency, f_T must be maximized, and the $r_b' C_C$ product minimized. For a simple interdigitated device, r_b, the base spreading resistance is approximated by

$$r_b' \approx \frac{R_{BS}}{2 L_E N_E} \qquad (13)$$

where

R_B = base sheet resistivity, in $\Omega/\square$
S = emitter to base contact spacing
L_E = emitter contact length
N_E = total number of emitter contacts

and

$2 L_E N_E$ = total emitter periphery, E_P.

C_C is the collector- base junction capacitance (neglecting fringing and other parasitic capacitances), and its magnitude is given by

$$C_C = \frac{\epsilon_o\, \epsilon\, A_B}{X_D} \qquad (14)$$

where

ϵ_o = permittivity to free space
ϵ = relative dielectric constant of silicon
A_B = collector-base junction area
X_D = depletion width at a given value of V_{CE} or V_{CB}.

Therefore the $r_b' C_C$ product is approximately

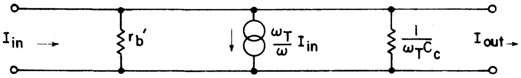
$$r_b' C_C \approx \frac{\epsilon\, \epsilon_o\, R_B\, S A_B}{X_D\, E_P} \qquad (15)$$

For a fixed frequency, base sheet resistivity, and voltage, transistor gain depends on

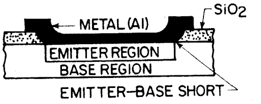
$$G \approx \frac{f_T}{S}\left(\frac{E_P}{B_A}\right) \qquad (16)$$

Hence most transistor geometries are designed to maximize the E_P/B_A (emitter-periphery to base area) ratio, and minimize the emitter to base contact spacings. f_T is given by the following

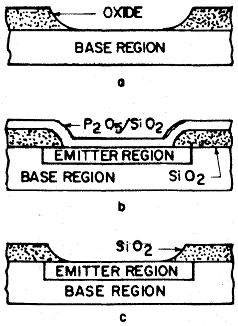
$$f_T = \Big[\ 2\,\pi\, [r_E(C_E + C_C + C_X) + W^2/2.43D + X_D/2\, V_S + r_C'\, C_C]\ \Big]^{-1} \qquad (17)$$



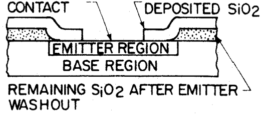
5. Simplified equivalent circuit of a transistor—$r_b C_C$ is minimized for maximum frequency.



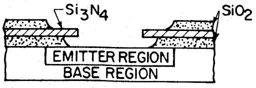
7. Metal-oxide reduction effects result in emitter-base shortening.



6. "Emitter-washout" effects are shown in (a) before emitter diffusion, (b) after, and (c) after emitter diffusion and emitter-washout.



8. By disposition an additional layer onto the wafer, secondary contacts, narrower in width may be defined over the emitter diffusion sites.



9. A silicon-nitride shelf technique diminishes the "emitter-washout" hazard.

where

$$r_E = \frac{KT}{qI_E}$$

C_E = emitter-base junction capacitance given by $\epsilon \epsilon_o A_E/X_E$
C_C = collector-base junction capacitance
C_X = parasitic capacitances
W = metallurgical basewidth
D = diffusion constant of minority carriers in the base
X_D = collector-base junction depletion width
V_S = saturated limiting velocity of majority carriers in the collector-base depletion region
r_C = parasitic collector region resistance
K = Boltzmann's constant
T = temperature in °K
I_E = emitter current
A_E = emitter area
X_E = emitter base, junction depletion width.

To maximize f_T, consistent with the highest operating emitter current the following must be minimized:

- emitter-base junction de-biasing and base-widening effects (which cause gain degradation)
- emitter-base and collector-base junction areas
- metallurgical basewidths
- collector-base junction voltage, and
- parasitic series collector resistance.

The capacitances are minimized by device geometries that maximize the E_P/B_A ratios, and minimize the emitter and base contact areas. Base widths are minimized by using the shallowest feasible collector-base and emitter-base junction depths. Emitter current capability is extended by minimal r_b' and maximal emitter periphery.

Contact geometries and emitter washout

Three distinct transistor contact geometries to meet these requirements are presently used: interdigitated, overlay, and mesh, or matrix types. (These are discussed in a subsequent article; pp. 46-51). Due to the requirements of shallow-diffused junctions, a high integrity passivation and contact definition scheme is required. Some contact geometries employ "emitter-washout" to define the final contact to the emitter-base junction sites.

"Emitter-washout is the practice of chemically removing the resultant thin P_2O_5/SiO_2 layer over the emitter contact sites after the emitter diffusion step (Fig. 6). The thin SiO_2 layer that remains can present a reliability hazard if the metallization used reduces this oxide layer under high temperature. A classic example is the aluminum-silicon oxide reaction that leads to emitter-base junction degradation and eventual failure (Fig. 7).[4] "Second-contact" schemes can minimize this hazard by replacing the oxide removed during the washout process with an additional layer of SiO_2, (Fig. 8).

Silicon-nitride layer can also diminish the "emitter-washout" hazard because it is more immune to metallization reduction effects. Since it also has a lower etch rate than silicon oxide in the silicon-oxide etchant, its thickness is relatively unaltered and a protective silicon nitride "shelf" remains over the emitter-base junction site (Fig. 9).

All three emitter-base junction site contacting techniques are used in interdigitated, overlay, and mesh geometry transistor. Their ultimate reliability depends both on the shallowness of the emitter-base junction sites, and the metallization system employed.

Metal migration—how and why[5]

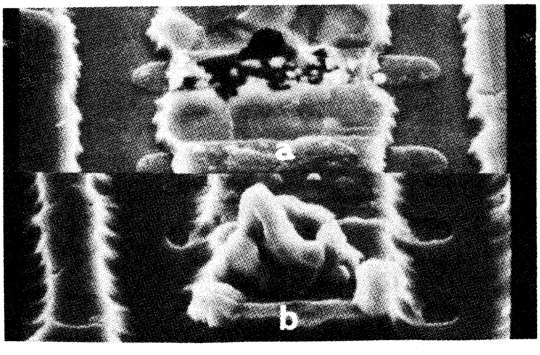
Aluminum has long been used for semiconductor devices because of its distinct advantages and properties:

- low bulk resistivity ($\rho \approx 2.7\ \mu\ \Omega$-cm)
- excellent adherence to Si and SiO_2
- ease of evaporation
- low cost
- low resistance ohmic contact to heavily doped n and p-type Si
- amenability to chemical pattern delineation.

However, it has several limitations:

- susceptibility to current induced electromigration forming voids and hillocks.
- Interactions with both Si and SiO_2 lead to contact embrittlement, loss of adhesion, dissolution of Si into Al in the active areas, void formation, and contact opens and shorts.
- Intermetallic compound formation with gold lead wires leading to poor adhesion, high contact resistance, and eventual contact failure.
- Difficulty in delineating fine line geometries due to its non-isotropic etch characteristics and crystalline structure.
- Oxide step coverage problems.
- Severe electroylic-corrosion susceptibility.

The most stringent requirement to be met by an alternate metallization system is it be highly resistant to current induced metal mass migration. This phenomena poses the most severe hazard to long term reliability, as it is the pre-



10(a) Void formation is accelerated by high temperatures which actlvate metal ions and high current densities. Hence, more electrons are available to collide with the activated ions and impart momentum to them. **(b) Hillocks** are the result of a net mass transport and build-up toward the anodics end of the film (RCA photo).

dominant failure mechanism even when operating within safe-area regimes. The next most stringent requirement is short term ruggedness under junction high temperature conditions. It must not interact with either the SiO_2 passivation layers or the Si contact areas to cause junction degradation.

At a given temperature, a certain equilibrium concentration of vacancies exists in all metal films. Self diffusion of metal ions throughout the film arise due to the metal ions being thermally activated into adjacent vacancies from their normal lattice sites. In the absence of external forces, the metal in diffusion is isotropic and results in no net accumulation or depletion of mass in any given site. With an electric field, however, the thermally activated metal ions experience a force due to their charge resulting in an ion flux toward the cathodic end of the film (Fig. 10). In addition the electric field will cause electron scattering off the activated ions and impart momentum to them, inducing an ion flux toward the anodic end of the film. In good conductors, the momentum exchange force dominates the electrostatic force and results in a net mass transport toward the anodic end of the film. Voids can also be formed at the negative terminals, eventually resulting in contact opens. Void formation is accelerated by high temperatures and high current densities, i.e., above 150°C and $10^6 A/cm^2$.

Although more detailed analyses of electromigration effects are available,[5,6,7,8,9] Black's simplified theory describes this phenomena and provides insight into the main variables influencing the Median Time to Failure (MTF).[3]

$$\mathrm{MTF} = \left(\frac{W \cdot t}{CJ^2} \right) e^{\phi/KT} \tag{18}$$

where

W = stripe width of the metallization
t = stripe thickness of the metallization
J = current density
ϕ = activation energy for diffusion of the metal
K = Boltzmann's constant
T = temperature in °K
C = constant depending on degree of film crystallinity, resistivity, ion mass, density, and stripe geometry.

Figure 11 (in color tint) shows the expected best case MTF for a small grained aluminum stripe 1 μ thick × 2.54 μ wide, with a current density of 10^6 Amps/cm^2. Other expected MTF's for various current densities, temperatures, and a 10^{-7} cm^2 cross sectional area are also shown.

To increase the MTF of devices, three options exist:

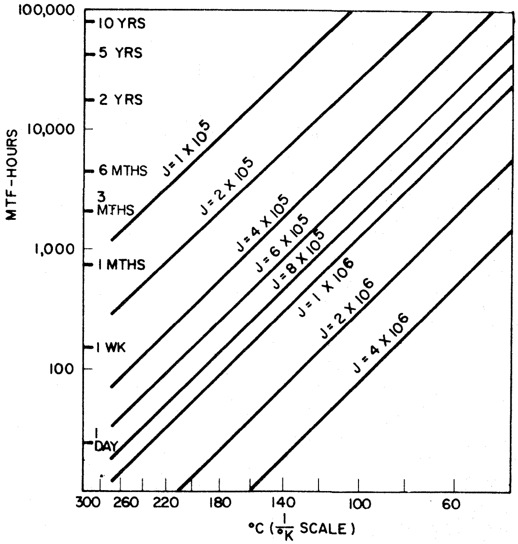
- Reduce the current density and temperature.
- Select a metal system with a higher activation energy and higher mass.
- Alter a basic aluminum system to increase the activation energy and decrease the pre-exponential constant.

Utilization of a new metal system, or altering of the basic aluminum system has been the option generally exercised by the industry (see pp. 54 through 58). However, a system providing higher resistance to electromigration effects may not satisfy temperature, corrosion resistance, oxide step coverage, adhesion, and production capability criteria previously discussed.

Three basic techniques have shown to retard electromigration effects in aluminum: (1) the addition of a small percentage of Cu (~ 4% by wt), (2) the use of a glass passivation layer over large grained aluminum, and (3) the addition of a small amount of Si (~ 0.3%).

The addition of a small percentage of Cu to Al results in an activation energy of approximately 0.6 eV (essentially the same as pure Al) but at current densities of 4 × 10^6 Amps/cm^2 and at temperatures from 100°C to 200°C, the improvement in MTF was found to be approximately 100. This increase in MTF is attributed to a change of the pre-exponential constant in Eq. 18.[9] However, copper junction poisoning presents a reliability risk. Silicon diodes and NPN transistors, power aged at temperatures of 100-200°C, and at current densities of 10^4 to 10^5 Amps/cm^2 degrade in less than 24 hours due to softening of the emitter base junction. Similar units stored at the same temperature but without power dissipation remained intact. This may be explained in terms of Cu atoms drifting to the junction under the influence of an electric field.[10]

The addition of a glass passivation layer over large grained aluminum has been reported to result in an activation energy of approximately 0.56 eV, and a J^2 MTF factor of approximately



11. MFT decreases rapidly as temperature and current density increase as shown on this log scale.

9×10^{14} hours $(A/cm^2)^2$ at 200°C, as contrasted to a J^2 MTF product of 6×10^{13} hours $(A/cm^2)^2$ for unpassivated, small grained Al (activation energy $= 0.48$ eV) at 200°C. This represents a factor of 15 lifetime improvement.[11]

The addition of a small percentage of Si ($\sim 0.3\%$ by wt.) has also been reported to result in a lower activation energy than Al, i.e., 0.32 eV versus 0.55 eV, but with a times-ten improvement in lifetime, at 180°C and a current density of 2×10^6 A/cm^2.[12]

Gold metallization systems

Refractory-gold metallization systems provide the most drastic increase in electromigration resistance, as well as interfacial layer metallurgical stability.[11,15,16] In these systems, the gold layer serves as the primary conductive layer, and the refractory layers provide adhesion and a barrier layer to prevent Au-Si eutectic formation (which occurs at $\sim 370°C$). Several composite systems are presently used: Ni-Cr/W/Au, PtSi/Ti/Pt/Au, PtSi/Mo/Au, PtSi/W/Au, and PtSi/Ti/W/Au.

PtSi primary layers provide low ohmic contact resistance[20] and are formed in excess of 500°C without evidence of emitter-base junction degradation effects. Even in extremely shallow junctions, i.e. $\leq 0.2\ \mu$, the $Pt + Si \rightarrow PtSi$ reaction is limited. The refractory layers exhibit minimal SiO_2 reduction effects and almost no silicon dissolution effects. Refractory layers are efficient barriers to Au-Si reactions due to the absences of refractory-gold intermetallics.

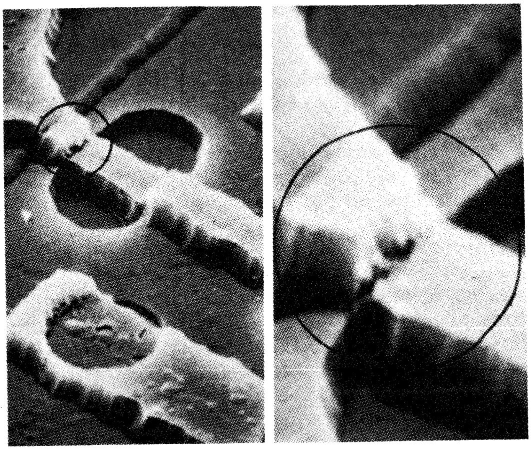
Due to the extreme melting temperatures of refractory metals, evaporation techniques are not usually used. Instead, rf sputter deposition methods are used which allow precise deposition control as well as excellent oxide step coverage. Reliability problems presented by thin metallization over oxide steps are eliminated (Fig. 13).

The corrosion resistance properties of Al-Au, Al-Al, Mo-Au, Ti-Pt-Au, W-Au, and Ti: W-Au are summarized in the Table.[14] ●●

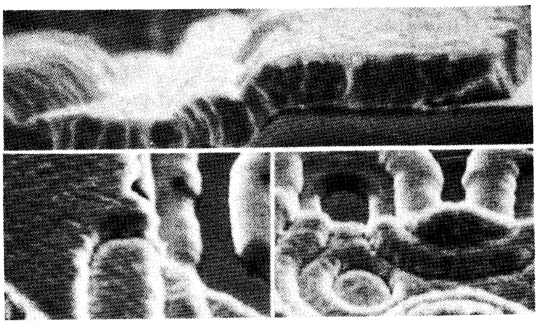
Table: Temperature/Humidity/Bias testing of various metal systems of unencapsulated test transistors*

Metal System	% Cumulative Failure/ in no. hours
Al-(Au wire)	100%/100 hours
Al-(Al wire)	100%/100 hours
Mo-Au-(Au wire)	100%/100 hours
Ti-Pt-Au-(Au wire)	0%/>1000 hours
W-Au-(Au wire)	96%/250 hours
(10%)Ti:w-Au-(Au wire)	93%/1000 hours**

* Test Conditions: 85°C, 85% relative humidity. $V_{CB} = +6$ V, $V_{EB} = +2$ V, grounded base.
**At 55°C/70% relative humidity, 4%/1000 hours.



12. Poor step coverage can result with an evaporated aluminum metallization which gives rise to regions of extremely high current densities and eventually failure.



13. Gold metallization provides good step coverage as shown in these 6000 times photomicrographs. The cross-section of the rf sputtered gold strip has no discontinuities.

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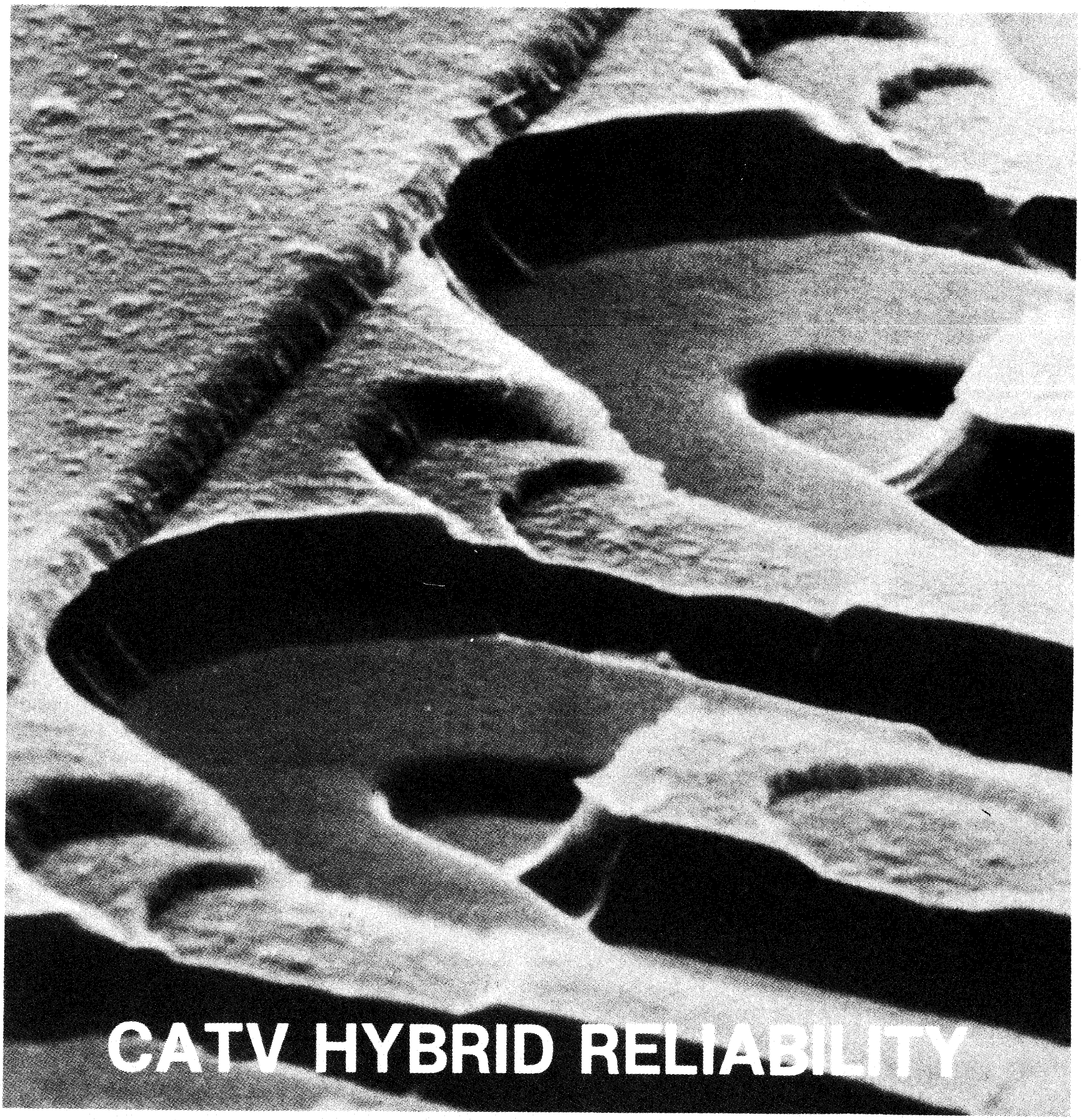


CATV HYBRID RELIABILITY

350,000 Units in the Field with Over 3,000,000,000 Hours

RELIABILITY

Performance is important, so is price. However, if the product is not reliable the equipment manufacturers and the system operator have a lot more to lose than dollars or performance. It costs several times the initial price of a hybrid to replace a failed unit in the field and the downtime is not appreciated by the subscribers. TRW RF Semiconductors understands more than price/performance tradeoffs. We understand reliability.

This brochure briefly outlines some of the reliability considerations in designing and building hybrid amplifiers and describes the ongoing programs that will assure a continuation of what is now the best semiconductor record in the industry.

Through five-years experience building hybrids and 20 years building transistors, TRW RF Semiconductors has built up an expertise that shows. When a problem does arise, we react, we learn and we continually improve the product.

HISTORY OF THE CATV MODULE

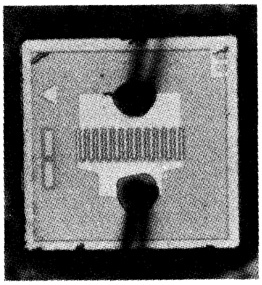
The history of the CATV module at TRW RF Semiconductors has been one of change. Our present products are a result of a well-controlled, evolutionary process. All process changes must be qualified and tested before they are put into production. The original product was a good one, but we are constantly searching for ways to improve the performance and reliability.

We changed to unglazed alumina substrates to improve metal adhesion and resistance to resistor cracking with overvoltage. This also lowered the die temperature (T_j) by 10°C. We instituted a solder reflow process that attaches all components in one step. With the implementation of this more controllable and more reliable system, the pins are soldered directly to the substrate eliminating the swage operation. The die heat spreaders are also reflow soldered instead of the old inductive heating technique. We changed from silver plated pins which were subject to oxidation, to gold-plated copper pins which are stiffer and easier to solder.

Other improvements have followed in quick succession. The aluminum heat sinks were nickel-plated to eliminate long term oxidation at the substrate interface. A copper metallization layer was inserted under the gold surface metal to improve component solderability. We also began securing all transformers to the substrate to better maintain tuned performance.

THE TRANSISTOR DIE

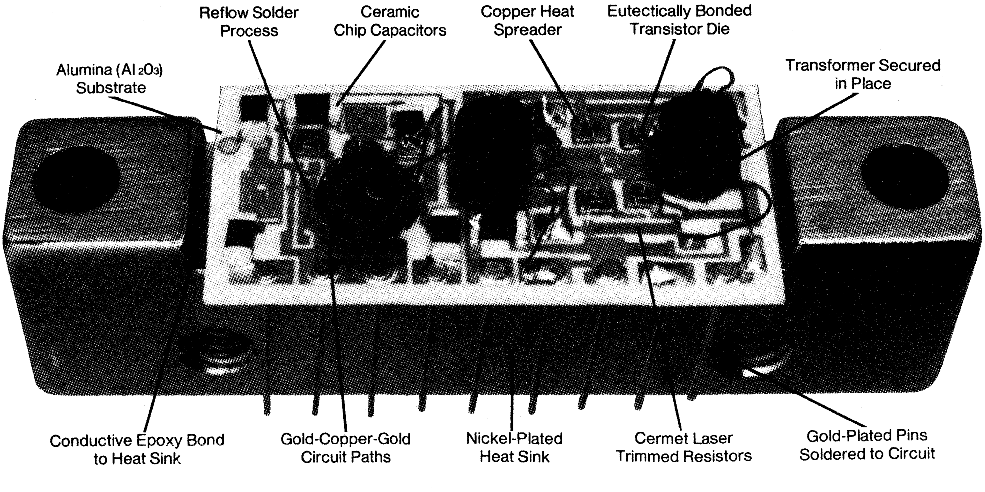
The transistor die is the heart of the hybrid amplifier. With four to eight devices per circuit, the transistor limits performance and is the most critical to proper circuit operation. However, when properly manufactured and surrounded by optimized circuitry, these devices have an MTF in excess of 100 years. Two well known failure mechanisms are metal migration and excessive power.



Transistor die with wire bonds on hybrid

METAL MIGRATION

This phenomenon is the predominant failure mechanism in transistors even when operating within "safe" areas. It is a function of time, temperature and current density.



At a given temperature, an equilibrium concentration of vacancies exist in all metal films. Self diffusion of metal ions throughout the film arise due to the metal ions being thermally activated into adjacent vacancies. In the absence of external forces, this ion diffusion is isotropic and results in no depletion or build-up of mass in any particular area. In the presence of an electric field, however, the metal ions experience a force due to their charge. This results in an ion flux toward the cathodic end of the film. The electric field will also cause electron scattering of the activated ions and impart momentum to them. This induces an ion flux toward the anodic end of the film. The momentum exchange force dominates the electrostatic force and results in a net mass transport toward the anodic end of the film, eventually resulting in open circuits. This void formation is accelerated by high-temperature and high-current densities.

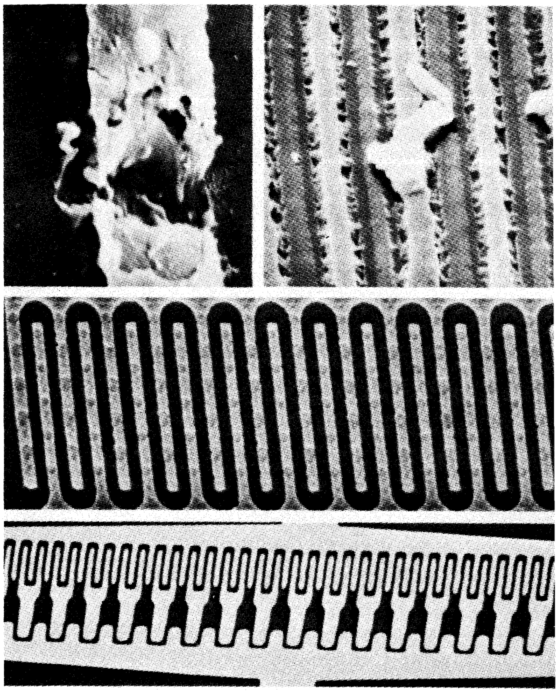
Aluminum possesses certain properties which make it desirable for semiconductor applications such as cost and ease of evaporation. However, aluminum has exhibited a susceptibility to this phenomenon of electromigration above the current densities of 10^6 amps/cm^2. The current density in our present products is $6\text{x}10^4$ amps/cm^2 which is more than an order of magnitude below this danger area.

EXCESSIVE POWER

Power handling capability is the second mechanism and is in many cases not the primary cause. A circuit resistor failure, a power supply failure, improper heat sinking, or a severe transient can cause a transistor failure no matter how ruggedly a device is designed. Any semiconductor device will fail if enough power is supplied. A combination of heat and high-current densities cause thermal runaway. Too much power virtually destroys the device.

The industry standard for the maximum temperature a transistor device can be operated, with a reasonable lifetime, is 200°C at the semiconductor junction. On the TRW RF Semiconductor hybrid circuit the hottest transistor die will be less than 150°C at 90°C sink temperature, thus ensuring a large margin of safety.

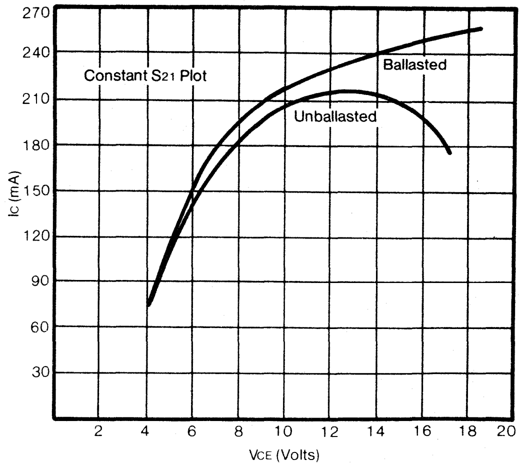
Aluminum metal systems currently used by CATV semiconductor manufacturers have performance limitations because of the nature of the aluminum process. Generally, the higher performance is pushed, the more reliability is sacrificed. To transcend this performance/reliability barrier, TRW RF Semiconductors is introducing a gold metallization technology. This proprietary process has been developed over the past three years. This technique plus diffused emitter ballasting resistors allows improved performance and reliability. The TRW RF Semiconductors gold metallization process achieves finer geometry as shown below. The designer now has the flexibility to use geometries impossible with aluminum devices.



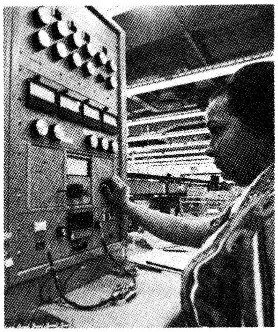
Top left: Circuit break due to migration. Top right: Metal migration. Middle: Aluminum device. Bottom: Gold device.

GOLD METALLIZATION

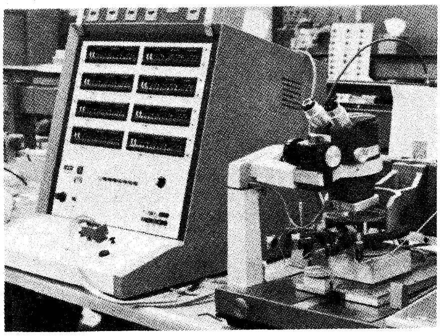
Gold also has a minimum improved lifetime of ten times under severe testing conditions. The diffused emitter ballasting resistors thermally stabilize the device preventing hot spots. These resistors are current limiting; therefore, the device can handle much more power in a smaller area than a non-ballasted device. The graph below shows S_{21} plots on the I-V plane for a ballasted versus non-ballasted device demonstrating the superior power handling of the ballasted device. All this means better performance *and* reliability in CATV equipment.



Gold Transistor Metallization Chamber



Second Order Testing



Autoprobe

DESIGN AND MANUFACTURING

The TRW RF Semiconductors hybrid is designed and manufactured with materials and techniques chosen because of their reliable history in the demanding CATV environment and many years of military/aerospace and commercial usage. All process improvements are thoroughly evaluated in pilot line production and qualification tested before they are released to production.

DESIGN

The design has steadily evolved from a thermal, mechanical and performance aspect. With the help of an infrared-scanning microscope, the thermal profile can be optimized to give best performance at conservative die temperatures. This ensures long transistor life. Mechanical improvements provide protection against thermal and mechanical shock as well as environmental elements such as moisture and corrosion. These changes were made while also improving performance.

COMPONENTS

The hybrid circuit is built on an alumina (Al_2O_3) *substrate.* This white, hard substance is ideally suited for the thin-film circuit process. It electrically isolates, is thermally conductive, and can be manufactured smooth enough to allow precision deposition of the resistors (chromium and silicon oxide) and circuit paths (gold and copper).

The heart of the hybrid is the *transistor die* which is manufactured for ruggedness as well as performance. The hybrid transistors are a product of nine years experience in supplying the CATV industry.

The *pins* are gold plated for solderability and corrosion resistance and the chip *capacitors* are an industry standard component. *Transformers* are of a proven design with years of field operation, and the *heat sink* is nickel-plated providing good conductivity and corrosion resistance.

THE MANUFACTURING PROCESS

Thin Film Fabrication

The hybrid amplifier starts in the sputtering chamber where cermet (for the resistors) and then gold (for the conductors) are kinetically deposited on the alumina substrate by bombarding a target of the desired material with an argon plasma. Each of four special sputtering chambers process 850 circuits at a time. After sputtering, the circuits undergo a series of photo-etch and plate-up operations. The resistors and circuit paths are outlined and selectively etched to form the desired conductor-resistor pattern. These circuit paths are then plated with a copper-gold sandwich to provide good solderability and corrosion resistance. The finished circuit is visually inspected and sent to laser trim.

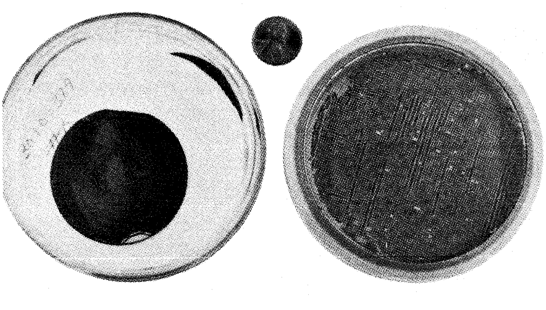
A computer-controlled laser trims the value of each resistor to better than one-percent tolerance. Each circuit, containing up to 27 resistors, can be trimmed in less than three seconds.

Transistor Fabrication

Using the latest diffusion and automatic handling equipment, the transistors take 30 process steps and several weeks to complete. After 100-percent testing for DC parameters and sample RF testing for distortion parameters, the transistors are eutectically bonded to heat spreaders. These spreaders reduce thermal impedance when mounted on the substrate and aid in efficient heat transfer to the heat sink.

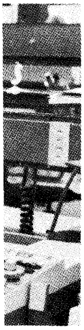
Hybrid Assembly

Solder paste is silk-screened onto the thin film circuit only on the transistor and capacitor bonding pads. These components are mounted and held into place by the paste containing flux and

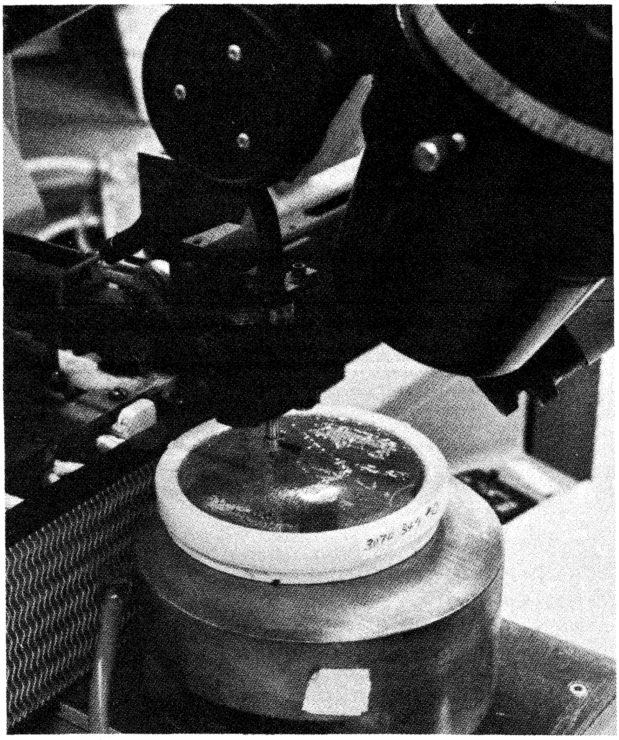


Transistor Wafer: 1) after autoprobe; 2) ready to mount

t: Laser Trimmer



Final Test



Automatic Die Mounting

solder particles in suspension. After the pins are dropped into place the circuit is ready for solder reflow.

The solder reflow process heats the substrate at a precise temperature and for a precise time. The solder particles melt and "reflow" attaching the transistors, capacitors and pins with uniform solder connections. Soldering the pins directly to the circuit paths eliminates up to 18 wire bonds.

After visual inspection the units are wire bonded. One-mil aluminum wires are ultrasonically attached to make the base and emitter connections to the circuit conductors. Other bonds are added for tuning purposes.

The heat sinks are individually numbered for traceability and are attached to the substrate with conductive epoxy. The epoxy is a thermal and electrical conductor between the heat sink and the gold ground plane on the back side of the circuit.

The transformers are secured to the circuit and the leads are soldered to the circuit conductors. The die is given a protective coating to prevent any possible micro particle contamination. The hybrid amplifier is now RF operable and ready to be tuned for response, flatness and match. Response is achieved by pulling combinations of wire bonds which changes the circuit inductance. Match is achieved by positioning the transformer leads. The units are capped, sealed with epoxy and marked.

TEMPERATURE CYCLING AND BURN-IN

A 100-percent temperature cycle and burn-in follow to ensure only the best products go to our customers. Temperature cycling tests the mechanical integrity of the circuit. All parts are cycled six times from +90°C to -10°C allowing 30 minutes soak at each temperature extreme. Power burn-in then follows temperature cycle. All units are mounted in burn-in fixtures and powered at 24V for eight hours at 115°C sink. The amplifiers are retested for changes during burn-in, packaged and then inspected by Quality Control before shipment.

TESTING

A large part of the hybrid construction process is testing which starts with incoming inspection and ends with final Quality Control sampling and inspection.

To assure performance and reliability, the transistor die are subjected to rigorous testing before being mounted on the circuit. The silicon wafer containing about 6000 individual transistors are autoprobed. The autoprobe performs eight DC tests on each transistor and marks out any not meeting the standards. A sample is taken from each wafer and mounted on headers for full DC and RF testing. If the sample passes, 20 hybrid amplifiers are built from this wafer and RF tested for all the distortion parameters (second order, x-modulation, triple beat and noise). If these units pass, the wafer is approved for production. Since each amplifier has its own number stamped on the heat sink, the transistors on each amplifier can be traced back to the original wafer. A sample from this wafer can be examined two years later, if necessary.

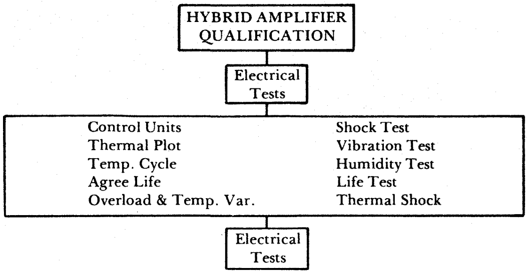
After the transistor die are mounted on the heat spreaders, each one is visually and electrically tested to assure that no damage was done during mounting.

Before the completed amplifiers are tuned for match and response, they are 100 percent tested for second-order distortion and DC current. This test shows whether the circuit is balanced and performing correctly. After temperature cycle and burn-in, this test is repeated on all units. Match and response are rechecked on a sample basis.

Finally the completed hybrid amplifiers are tested by Quality Control on a 0.65 AQL sample for match, response, gain, second-order distortion and DC current. The mechanical configuration is also checked on this sample.

NEW PRODUCT QUALIFICATION

All new designs and significant product variations must be subjected to, and successfully pass, a rigorous reliability qualification program before the device is approved for production. A testing diagram taken from our Reliability Test Plan is shown below. These tests are done according to MIL-STD-883.



PROCESS CONTROLS

HYBRID TRACEABILITY

AT TRW RF Semiconductors a history of all hybrid circuits is kept. This allows a check of all process steps. Traceability is maintained from circuit metallization to final testing and includes the particular die lot which was used for any specific circuit.

In addition to traceability, which is primarily a production and engineering aid, there are several Quality Control steps which help to ensure all products are manufactured in a well-controlled production line.

DIE MOUNT QUALIFICATION

CATV transistors are mounted on heat spreaders with a high-speed automatic machine. To ensure the quality of this high-speed operation, regular quality control checks are made on the quality and strength of the bonds.

REFLOW QUALIFICATION

A daily QC check is made of the solder reflow process which solders the individual components to the circuit. Both a visual inspection and shear-strength test are made to test the process.

LASER QUALIFICATION

All resistors in CATV hybrids are adjusted to value by a YAG-laser resistor trimming system. This system is checked regularly by Quality Control to ensure that the product being generated is within the required specifications. In addition, a continuous production monitor assures proper laser performance.

WIRE-BOND QUALIFICATION

Wire bonding is a process which must be carefully controlled because of the many parameters which affect the quality of the bonds. The Quality Control group at TRW RF Semiconductors performs two separate bonding checks on a periodic basis. The first check is a bondability test to ensure that the metal itself is bondable. This is performed on each lot of material. The second test checks the bonding machines for proper operation. This test is performed every two hours and accomplished by measuring the force necessary to separate a bond from the circuit.

QA AUDITING SYSTEM

There are many Quality Control check points throughout the CATV hybrid process. To ensure complete tests and inspections, the Quality Assurance Department performs a periodic audit of each inspection point and issues a report on that audit.

ENVIRONMENTAL AND RELIABILITY TEST CAPABILITIES

The 100 percent temperature cycling and full-power burn-in is a normal part of the production process. The other tests outlined below are used for qualification of new products or processes.

TEMPERATURE CYCLE

CATV hybrids are temperature cycled from + 90°C to - 10°C for six one-hour cycles.

POWER BURN-IN

CATV hybrids are burned-in at 115°C case for eight hours under normal DC operating conditions.

POWER CYCLING

The power cycling test is one which attempts to duplicate, as closely as possible, the actual operating conditions under which a module should operate. The test fixture consists of a mounting board which can be heated or cooled. One method of operation would be to apply power (DC and RF) to a unit then apply heat for a given time. The power and heat may then be switched off and the part quickly cooled to begin another cycle.

LIQUID-TO-LIQUID THERMAL SHOCK

This test determines the resistance of a circuit to sudden extreme temperature changes. The test is conducted by immersing the unit in a low temperature liquid, then transferring it to a high-temperature liquid. The transfer is kept as short as possible. The immersion time may be any length but is usually 15 minutes.

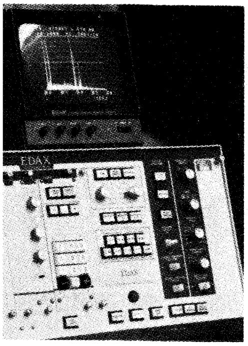
HUMIDITY TESTS

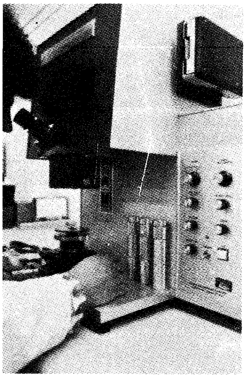
This test is intended to determine the resistance of a unit to a humid environment, and may be conducted with or without power applied. A typical test would subject the unit to a temperature cycle of 25°C to 65°C while exposed to a humidity of 95 percent.

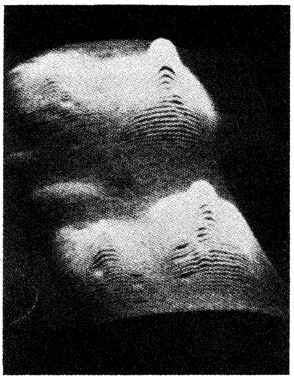
MECHANICAL SHOCK

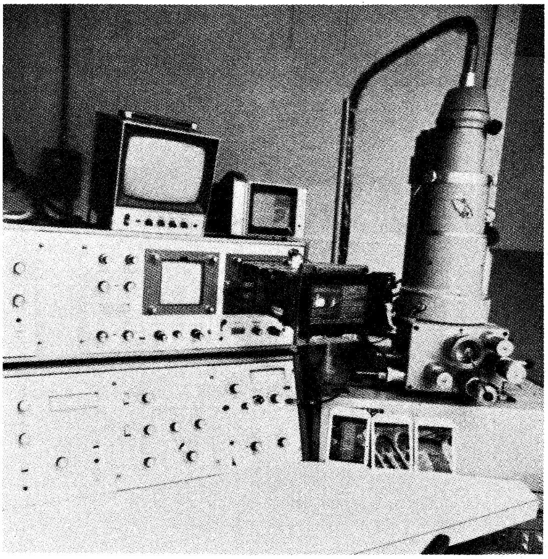
The purpose of this test is to determine the resistance of a unit to severe shock. Our environmental laboratory has the capability of exposing units to a 10,000G shock for a duration of 0.2 microseconds.

Burn-In Racks

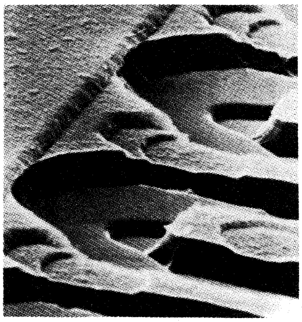








Top left: X-ray Dispersion Analyzer
Top right: X-ray System
Middle left: Infrared Scanning Microscope
Middle right: Scan of Hybrid Push-Pull Section
Directly above: Scanning Electron Microscope
Right: SEM Photograph of Transistor



VARIABLE FREQUENCY VIBRATION

This is a destructive test which is performed for the purpose of determining the effect on component parts of vibration in the specified frequency range. TRW RF Semiconductors has the facilities for performing this test in the 20 to 20,000Hz frequency range.

X-RAY

The QA laboratory has the capability of taking and developing X-ray exposures of hybrid circuits and discrete transistors. This is a very valuable tool for detecting voids in solder or eutectic bonds.

INFRARED MICROSCOPY

The ability to examine a circuit thermally under operating conditions is absolutely necessary when designing a new product or testing a new process. We utilize an infrared microscanner for evaluation of new products from the standpoint of thermal resistance and operating temperature. Resolution of 0.0005 inch can be achieved.

SCANNING ELECTRON MICROSCOPY

The SEM, which is part of the QA Reliability Physics Laboratory, is used in all facets of product analysis at TRW RF Semiconductors. This instrument allows us to closely examine hybrid microcircuits and transistors not possible with optical techniques.

DISPERSIVE X-RAY ANALYSIS

This capability, which is a feature of the SEM, allows us to make a microprobe to determine the chemical composition of a sample. This is accomplished by detection of secondary emission X-rays which possess characteristic energies. The relative quantity and location of elements may then be displayed on the CRT.

TRANSISTOR LIFE TESTING

Each new transistor considered for use in a hybrid amplifier undergoes a series of extensive reliability life tests. The new gold devices are now being subjected to the following tests:

1. Operating Life Test: 20 volts, 150mA, with T_j = 200°C for 1000 HRS.
2. High-Temperature Reverse Bias: V_{CB} = 26 volts, T_A = 100°C for 1000 HRS.
3. High-Temperature Storage: 400°C for 1000 HRS.
4. Humidity Test: 90% relative humidity over temperature excursion at 25°C to 65°C for 1000 HRS.

HYBRID LIFE TESTING

Hybrid life testing plays an important role in hybrid development. These tests, continually run under worst case conditions (95°C ambient), provide valuable data which can be used to identify potential problem areas. All units are inspected and tested after 24, 100, 250, 500, 1000 and then every 1000 hours. Typically, there are always 100 to 300 units of each type under test. Failures are carefully analyzed to determine corrective action needed in the components, process, quality control or design. This program has allowed us to supply a product that has an excellent record in the field.

Since we shipped our first hybrid in 1970, over 350,000 TRW RF Semiconductor hybrids have been put into the field and have accumulated over 3-billion operating hours.* While accurate figures on field failures are difficult to obtain, based on customer inputs we estimate the failure rate to be less than 1% per year.

WARRANTY

Details of the warranty policy are contained in a separate warranty document.

**Based on (1) 4-month delay from time we ship until units are put in field and (2) 720 hours per month.*

APPLICATION NOTE No 3

RELIABILITY CONSIDERATIONS IN DESIGN AND USE OF RF INTEGRATED CIRCUITS

By
JAMES HUMPHREY
and
GEORGE LUETTGENAU
TRW Semiconductors
February 5, 1976

ABSTRACT

Reliability is a major factor in the profitability of CATV Systems.

In spite of its proportionally low cost, the RF integrated circuit figures prominently in the overall reliability picture. This complex and important function is located at strategic points in the system.

Fortunately, modern design and manufacturing technology, which draws extensively from resources generated by military and space activities, assures a degree of reliability which is compatible with the most stringent requirements.

Transistor chips are the most vital elements of the RF integrated circuit. Low noise and distortion require state-of-the-art transistor structures. Gold metallization, thermal equilibrium by means of diffused balancing resistors, as well as automated process control have resulted in transistor lifetimes of over 100 years.

One of the inherent reliability advantages of IC's is the reduced number of interconnects. The full benefit of this characteristic is achieved through the use of gold conduction paths in conjunction with gold wire bonding. Perhaps the single most dangerous enemy of high reliability is excessive heat. Careful, computer-aided circuit design coupled with thermally sound, stress-free mechanical construction guarantee structural integrity and safe operating temperatures under all practical conditions. Infrared scanning helps verify the achievement of design goals.

Abuse or abnormal stresses may counteract the best of reliability. In order to avoid problems, the user must control the electrical, thermal, and mechanical environment surrounding the RF IC. Much progress in this respect has been made by the equipment industry.

INTRODUCTION

Reliability considerations are becoming increasingly important in the operation of CATV Systems, requiring an absorption of military and aerospace reliability technology into the CATV business. Market surveys show a large number of MSO's and consultants consider reliability as a major item in equipment selection.

A definition of major reliability terms is important along with an introduction to microcircuit reliability tools (both hardware and software).

An overview discussion of Physics of Construction involved with the die and interconnects must be presented.

DEFINITIONS

R = Reliability

Reliability is related to the probability that an item will perform a defined task satisfactorily for a specified length of time, when used for the purpose intended, and under conditions for which it was designed to operate.

Failure

Failure is a detected cessation of ability to perform a specified function within previously established limits in the area of interest.

(a) Dead on arrival
(b) Infant mortalities
(c) Lifetime failure rates (random)
(d) End of life (wearout)

MTBF (Mean Time Between Failures)

The total measured operating time of a population of equipment, divided by the total number of failures within the population during the measured period of time.

Average Life

The mean value for a normal distribution of lives, and generally, it applies to failures resulting from wearout.

BASIC RELIABILITY EQUATION

$R = e^{-t/m} = e^{-\lambda t}$

Where: R = Reliability or probability of success

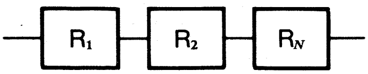
t = Mission time in hours

m = MTBF in hours $= \frac{\text{hours}}{\text{failures}}$

λ = Failure rate $= \frac{1}{\text{MTBF}} = \frac{\text{failures}}{\text{hours}}$

SYSTEM RELIABILITY

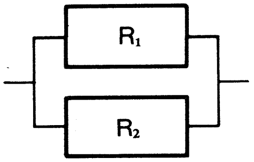
1. When components are in series, failure of any one of the components will result in failure of the system.



Then: $R_{SYSTEM} = R_1 \times R_2 \times R_3 \times --- R_N$

$\lambda_{SYSTEM} = \lambda_1 + \lambda_2 + \lambda_3 + --- \lambda_N$

2. When the same components are in parallel (redundancy) neglecting, for simplicity, the decision-making device, the switchover function and the fail safe requirements:



$R_{SYSTEM} = R_1 + R_2 - (R_1 R_2)$

RELIABILITY CURVE

The following curve represents the typical condition of operational reliability.

RELIABILITY PREDICTION ALGORITHM

The military has put considerable money and time into the study of reliability. One very useful military document is Military Handbook 217B, *Reliability Prediction of Electronic Equipment*. This handbook shows how to develop failure rate predictions by the use of mathematical models based on years of data collection by military agencies. A discussion of the interaction of components in the model is very useful in gaining an understanding of the overall subject.

PART FAILURE RATE MODEL λ_p

$\lambda_p = \lambda_b (\pi_T \times \pi_E \times \pi_Q \times \pi_F \times \pi_M)$

Where: λ_p = Part failures in failures per 10^6 hrs.

λ_b = Base failure rate

π_T = Temperature adjustment factor

π_E = Environmental adjustment factor

π_Q = Adjustment factor based on quality

π_F = Adjustment factor for circuit function

= 0.8 for digital hybrids

= 1.0 for linear hybrids

= 1.1 for combination hybrids

π_M = Adjustment factor for maturity of product

BASE FAILURE RATE MODEL λ_b

$\lambda_b = \lambda_S + A_s\lambda_c + \Sigma\lambda_{RT}N_{RT}$ (Substrate contribution)

$+ \Sigma\lambda_{DC}N_{DC}$ (Attached components contributions)

$+ \lambda_{PF}\pi_{PF}$ (Package contributions)

Where: λ_b = Base failure rate in failures/10^6 hr.

λ_S = Failure rate due to the substrate and film processing

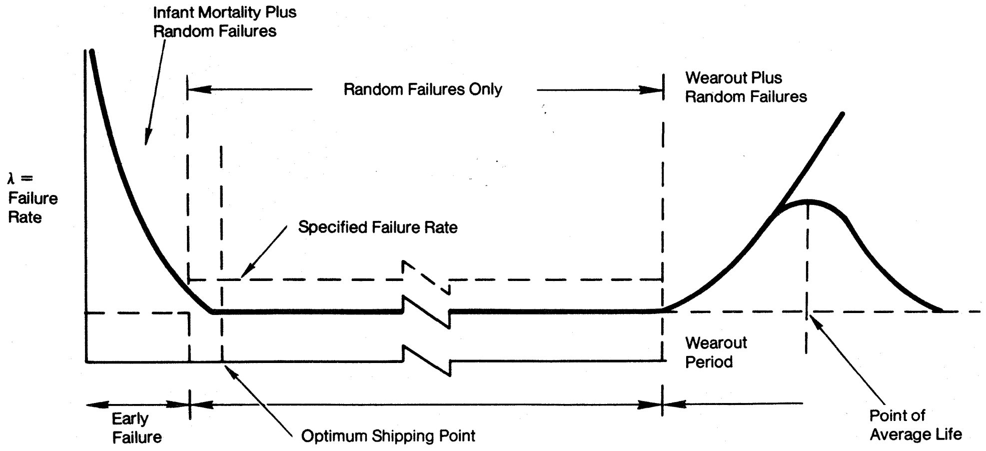
$A_s\lambda_c$ = Failure rate contributions due to network complexity and substrate area which includes:

(a) Number of lead terminations

(b) Number of film resistors

(c) Number of discrete chip devices

(d) Type of film (thin versus thick)



$\Sigma\lambda_{RT}N_{RT}$ = The sum of the failure rates for each resistor as a function of the required resistance tolerance
$\Sigma\lambda_{DC}N_{DC}$ = The sum of the attached device failure rates for semiconductors and capacitors
$\lambda_{PF}\pi_{PF}$ = The hybrid package failure adjusted to include material and style

PHYSICS OF CONSTRUCTION

Following the enumeration and identification of symbols used in reliability algorithms, a discussion of the major microelectronic components with respect to their reliability contributions is in order:

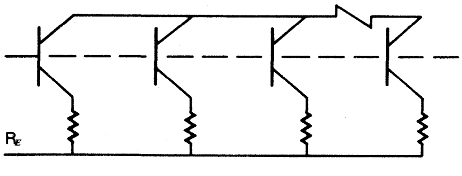
TRANSISTORS

The transistor die is the heart of the hybrid amplifier. With four to eight devices per circuit, the transistor determines performance and is most critical to proper circuit operation.

During the last few years users have witnessed major advances in the performance of linear broadband transistors. Often, efforts to improve one characteristic have adverse effects on other desirable features. For instance, distortion may be bettered by thinning the epitaxial collector region. This, however, leads to sensitivity to voltage transients and other abnormal operating conditions. Therefore, devices with outstanding performance in one area are prone to weakness in others. Computer-aided device design coupled with volume production and tight process controls have resulted in transistors in which all essential features are in proper balance.

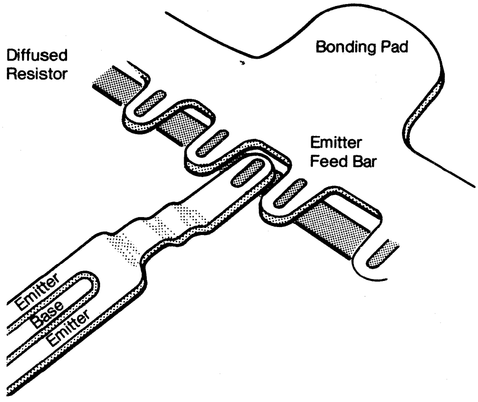
High f_T is generally recognized as an important factor in achieving wide bandwidth and uniform distortion characteristics. Gigahertz transistors, which are now being used, have very delicate patterns, involving micron and submicron tolerances. They also occupy sizable areas on the silicon wafer, since watt-sized powers have to be handled. It is only realistic to expect that all parts of the overall transistor structure are not perfectly alike, but rather resemble the parallel configuration of many, slightly differing, small devices, as shown in the figure.

Ballast Resistors

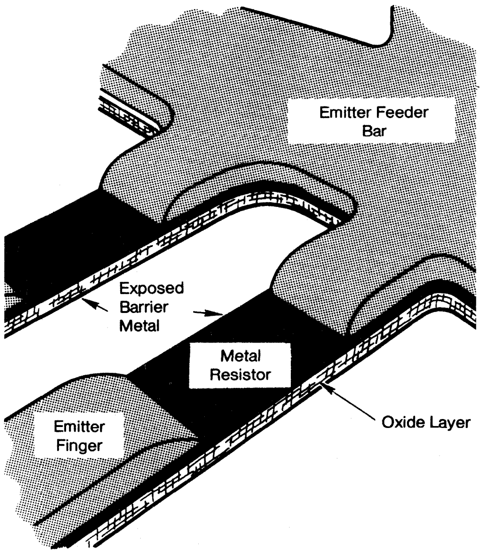


It is also apparent that the entire transistor geometry cannot be tightly thermally coupled within itself, therefore giving rise to the possibility of small sub-areas of the transistor assuming different values of temperature than others. This possible problem can be effectively combatted by adding emitter balancing resistors to the device. Ideally each emitter-site or finger should have its own resistor. This goal is easily realized in interdigitated structures. Film or diffused monolithic resistors may be used. From a process and reliability point of view, diffused resistors are preferred because they avoid the silicon-oxide barrier which has a very high thermal resistance.

Diffused Ballasting System (Only one emitter contact shown)



Metal Film Ballast Resistor



METAL MIGRATION

Some time ago a serious failure mechanism, associated with GHz transistors, was discovered. The metallization stripes of such devices, as mentioned earlier, are only a few microns wide. The metal thickness is, because of fabrication limitations, of similar dimensions. Consequently, the current density in these stripes is quite high, often reading hundreds of thousands of amperes per cm^2 of cross-section. Under these circumstances, metal migration may occur. With such large numbers of electrons flowing in such crowded space, the probability of collisions with thermally activated metal ions is great. The ions are propelled in the direction of electron current flow causing, in the long run, the metal to move, forming hillocks, whiskers and voids. The lifetime of a transistor is a function of three things: the current density, the temperature, and the type and consistency of metallization.

Not much leeway exists in reducing the current density (unless f_T is sacrificed). Changing from aluminum to gold extends the life at least by an order of magnitude. At high temperatures the difference is even more pronounced. At 150°C, the time to metal failure for gold metallization microwave transistors is in excess of 10^6 hours = 114 years. While this number is quite comforting, one is not at liberty to treat the subject of transistor chip heatsinking too lightly. A proven method for removing heat while at the same time obtaining a solid mechanical mount, has been to employ a heatspreader between the silicon chip and the IC substrate. Automatic mounting stations are used to eutectic collet mount the chip to indexed leadframes. Tight contrôl of pressure and scrub sequence result in defect free attachment. Although one may employ other methods of heatsinking, e.g. beryllium oxide substrates for part of the circuit, the added mechanical complexity and the reduced freedom of optimal circuit layout presently outweight the minor advantages resulting from a reduction in transistor temperature.

INTERCONNECTS

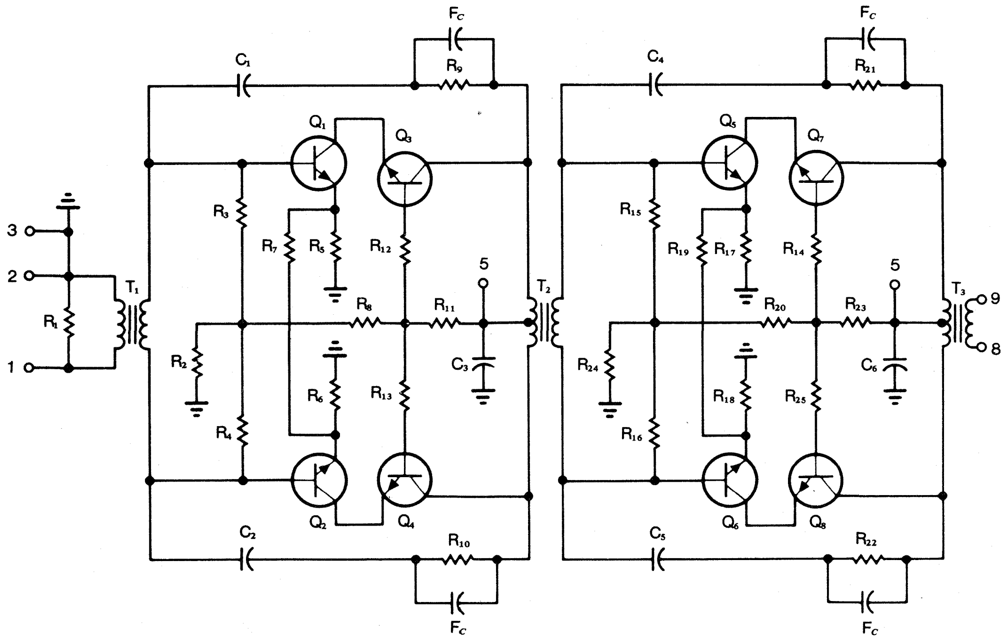
One of the most important parts of hybrid circuits is the interconnect system. The ability to reduce the number, control the quality, and test them by screening complete functions, is one of the major advantages of hybrid circuits over more conventional approaches. Constant improvement in the mechanical and metallurgical systems have drastically improved reliability.

An analysis of the schematic on the standard 33dB Hybrid Amplifier will illustrate the point:

Comparing hybrid versus discrete techniques, one can show the following:

1. For each transistor used, a minimum of three interconnects corresponding to the solder joints at the PC board are eliminated.
2. For each capacitor used, a minimum of two interconnects are eliminated.
3. For each film resistor used, a minimum of four interconnects are eliminated corresponding to the connection to the resistor body and the connection to the PC board.
4. Transformer interconnects will be the same for hybrid or discrete.

33dB Gain Block



The increase in interconnects in building 33dB of gain in discrete form over the same circuit in hybrid form is:

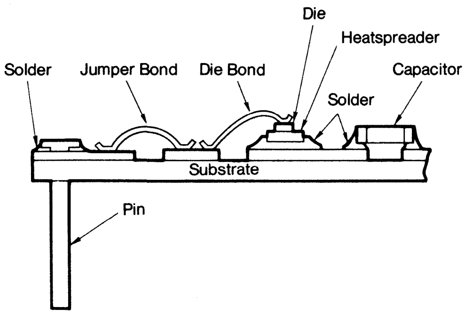
Add due to transistors = 24
Add due to chip capacitors = 12
Add due to resistors = 100
Add due to transformers = 0
Less due to hybrid jumpers = -4
Less due to active pins = -5
127 Additional interconnects per 33dB function

MIL Handbook 217B also discusses the reduction in reliability of printed circuit boards as a direct multiple of the holes required. Eighty-one additional holes are involved in making one discrete amplifier.

Having the interconnects made early in the manufacturing sequence, before the subsequent series of tests and inspections, has beneficial influence on end equipment reliability.

The complete functional system including interconnects is tested, screened and Q.C. sampled many times before it even meets up with the PC board in the manufacturers subsystem.

Interconnects



COMPONENT MOUNT

The transistor heatspreaders, chip capacitors and pin connections are soldered to the metallization pattern on the substrate surface. This process is completed in a tightly controlled solder reflow furnace.

Due to the fact that the units are processed in an inert atmosphere and thoroughly cleaned and inspected early in the production process, workmanship problems are greatly reduced.

BONDS

Wire bonding was a major reliability issue for years.

Aluminum has been one of the most widely used bonding systems in the hybrid industry for many years. The main reason for this is that ultrasonic aluminum systems bond at room temperature and, hence, do not interfere with other hybrid assembly processes.

Gold thermal compression ball bonding has been a reliable standard process in the semiconductor industry for years. However, the requirement for 300°C bonding temperatures have kept this technique out of most hybrids. The recent changeover to all gold hybrids prompted the development of a compatible low temperature gold wire bonding system which by far out-performs aluminum.

Advantages of Aluminum Bonds

Low temperature process
Compatible with Al die metal
Low cost
High speed
Easy to loop (stiff)

Disadvantages of Aluminum Bonds

Degrades with time/temperature
Kirkendall voiding
Intermetallic formation with gold
Brittle and subject to cracks
Difficult to screen
Difficult to control

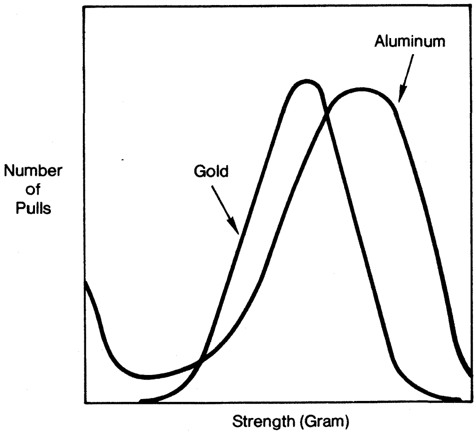
Advantages of Gold Bonding

Compatible with gold die and substrate
Strength stable with time/temperature
Malleable — not subject to cracking
Easier to control process

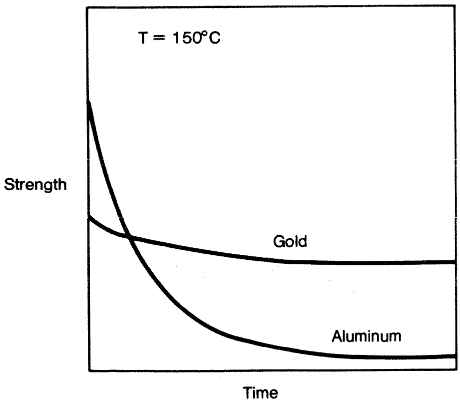
Disadvantages of Gold Bonding

More expensive
More deformation at bond foot
Hard to form loops

Histogram of Gold Versus Aluminum Bond Strengths



Strength Versus Time on Gold Versus Aluminum Wire



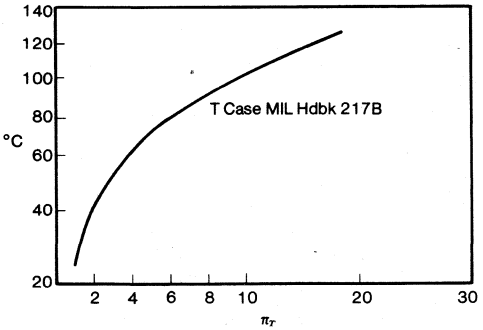
RELIABILITY ADJUSTMENT FACTORS

Following is a discussion of the "π adjustment factors" in MIL Handbook 217B. These relate to the external influences on hybrid circuit reliability.

TEMPERATURE ADJUSTMENT FACTOR π_T

Operating temperature is one of the most important factors in reliability. As can be seen by the curve shown, great reliability improvements can be obtained by lowering the case temperature.

Failure Rate Multiplier Due to Temperature



This curve shows that a hybrid circuit, operating at a case temperature of 100°C, has four times the failure rate as the same circuit run at 50°C.

ENVIRONMENTAL ADJUSTMENT FACTOR π_E

This adjustment factor is based on the service environmental conditions that the part will be exposed to during operation.

π_E, Environmental Factor Based on Environmental Service Conditions

Environment	Symbol	π_E
Ground, Benign	G_B	0.2
Space Flight	S_F	0.2
Ground Fixed	G_F	1.0
Airborne, Inhabited	A_I	4.0
Naval, Sheltered	N_S	4.0
Ground, Mobile	G_M	4.0
Naval, Unsheltered	N_U	5.0
Airborne, Uninhabited	A_U	6.0
Missile, Launch	M_L	10.0

The question is where does CATV fit into this table. Mechanical and thermal casting designs are extremely important in protecting the RF IC from the external environment conditions. Still, wide variations in system placement introduce a swing factor for environmental effects, which will cause π_E for CATV to fall between 1.0 and 5.0.

The user must strive to keep the components as close to laboratory zero as possible.

MATURITY ADJUSTMENT FACTOR π_M

The failure rate predicted by this mechanical model can be expected to increase by a factor of ($\pi_M = 10$) under any one of the following conditions:

(a) New device in initial production.
(b) Where major changes in design or processes have occurred.
(c) Where there has been an extended interruption in production or a change in line personnel (radical expansion).

The factor of 10 can be expected to apply until conditions and controls have stabilized. This period can extend for as much as 6 months of continuous production.

This maturity factor is extremely important. The industry has used over 400,000 CATV modules since the first module was shipped in 1970. Since that time we have constantly improved and refined the IC. Optimum reliability is an evolutionary process depending on time, volume, defect analysis and feedback to fine tune the product and eliminate defects.

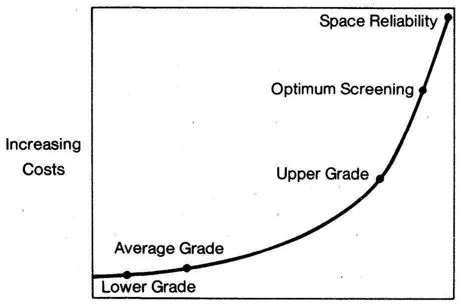
QUALITY ADJUSTMENT FACTOR π_Q

This is the adjustment factor based on the quality grade of the product. This factor modifies the reliability levels by the different quality levels specified in MIL STD 883, *Test Methods and Procedures for Microelectronics.* These levels take into account different screening levels, qualification levels and quality conformance inspection requirements for the specified class.

	π_Q
MIL STD 883 Class A	0.5
MIL STD 883 Class B	1.0
Vendor Equivalent Class B	5.0
MIL STD 883 Class C	30.0
Commercial with Screening	50.0
Commercial (No Screening)	75.0

A study of the MIL STD 883 Quality Requirements allow a very important discussion of cost versus reliability. As could be expected the test, manpower, equipment, time and paperwork go up rapidly as the MIL STD Grade is increased. A relative plot of this relationship is shown below:

Cost Versus Reliability



Many of the MIL Standard Military requirements seem unimportant in influencing CATV reliability. However, the cost versus reliability curve is real and the equipment supplier can make choices as to the type of reliability he is willing to pay for.

EQUIPMENT

It takes a massive capital investment in order to meet the manufacturing requirements for the CATV industry. The volume, quality and performance standards required have caused us to constantly reinvest for the future. Many of the invested dollars are for equipments for which the return on investment is subjective.

SCANNING ELECTRON MICROSCOPE

This instrument allows very high magnification of surface conditions not available with optical methods. Magnifications up to 100,000 times are possible with the SEM.

DISPERSIVE X-RAY ANALYSIS

This capability, which is a feature of the SEM, allows us to make a microprobe to determine the chemical composition of a sample. This is accomplished by detection of secondary emission x-rays which possess characteristic energies. The relative quantity and location of elements may then be displayed on the CRT.

VARIABLE FREQUENCY VIBRATION

This is a destructive test which is performed for the purpose of determining the effect on component parts of vibration in the specified frequency range.

X-RAY

This is a very valuable tool for detecting voids in solder or eutectic bonds.

INFRARED MICROSCOPY

The ability to examine a circuit thermally under operating conditions is absolutely necessary when designing a new product or testing a new process. The infrared microscanner is used for evaluation of new products from the standpoint of thermal resistance and operating temperature. Resolution of 0.0005 inch can be achieved.

CONCLUSIONS

- Many reliability tools are available today both in equipments for evaluation of reliability and in analytical tools such as MIL Handbook 217B for predictions of reliability.
- Hybrid circuits offer massive reliability leverage due to:
  (a) Reduction of Interconnects
  (b) Ability to control quality by screening
  (c) Large volume of complex standard functions are easier to control
- Case temperature is very important for reliability
- A monometallic system, i.e., gold die metallization and gold wire bonding are optimum for reliability.
- Reliability can be improved by adding quality cost to the module process. This increased cost may easily be returned due to the lower failure rate.

ACKNOWLEDGEMENTS

The authors wish to thank Al Bird, TRW Systems Group, Redondo Beach, California, for his technical quidance.

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APPLICATION NOTE No 4

Match impedances in microwave amplifiers

and you're on the way to successful solid-state designs. Here's how to analyze input/output factors and to create a practical design.

The key to successful solid-state microwave power-amplifier design is impedance matching.

In any high-frequency power-amplifier design, improper impedance matching will degrade stability and reduce circuit efficiency. At microwave frequencies, this consideration is even more critical, since the transistor's bond-wire inductance and base-to-collector capacitance become significant elements in input/output impedance network design.

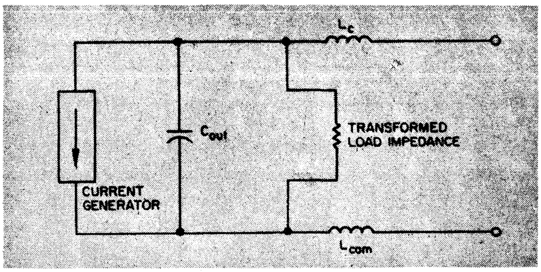
In selecting a suitable transistor, therefore, keep in mind that the input and output impedances are critical along with power output, gain and efficiency.

Unless the selected transistor is used at frequencies that are much lower than the maximum operating frequency, the input impedance is largely inductive with a small real part. The large inductance is due to bond wires that connect the transistor chip to the input lead of the package and to the common-element bond wires. The small real part of the input impedance is due to the large geometries required to generate high power at high frequencies; the base bulk resistance may be the predominant part of the real input impedance.

Use microstrip stubs at input network

The first and most important step in designing the input matching network for the selected device is to provide a shunt capacitance that will resonate the inductive component of the input impedance. This step forms the low-pass matching section of the network and should provide the smallest possible transformed impedance. To minimize the inductive component, the input and common-element lead lengths must be kept short.

The resonating capacitance is generally best provided by a microstrip stub. In some cases the stub producing the required capacitance is so large that a practical circuit size cannot be realized. It is best then to distribute as much of this capacitance as is physically practical and to provide the balance with high-quality chip capacitors.



1. **In this output equivalent circuit,** capacitance C_{OUT} is almost equal to the selected transistor's collector-to-base capacitance C_{ob}.

The first section of the impedance matching network is extremely important because it can degrade the stability of the amplifier if it is not well designed. Depending on the design frequency of the amplifier and the transistor selected, the resonated real impedance can range from less than 50 Ω to much higher. When it is below 50 Ω, an additional low-pass matching section can be conveniently added to achieve the required 50-Ω impedance at the input.

The higher-impedance case presents a special problem if microstrip techniques are used to build the matching network. The problem occurs because the resonated impedance may be as high as 300 Ω. Reducing this to 50 Ω by use of a low-pass network configuration requires a series-transmission line that will behave as an inductor. The rule of thumb is that the characteristic impedance of the transmission line must be at least twice the higher impedance before such behavior results. Examination of the accompanying table shows that characteristic impedance lines of greater than 100 Ω are very narrow. Narrow transmission lines (less than 0.01-inch wide) should be avoided wherever possible, because repeatability of width dimensions is poor. Also, the loss in a narrow line may become excessive. A better solution is to use a quarter-wave transmission-line transformer with a characteristic impedance

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equal to the square root of the 50-Ω impedance product: $Z_o = \sqrt{50\ Z_R}$.

Make output bandwidth wider than input

The output impedance of a microwave power transistor is usually defined as the conjugate of the load impedance required to achieve the device performance. A typical output equivalent circuit is shown in Fig. 1. The capacitance C_{out} is nearly equal to the collector-base capacitance C_{ob} specified for the selected transistor. L_c is the inductance of the bond wires used to bridge from the collector metallization area to the package output lead, and L_{com} represents the inductive effects of the common element bond wires.

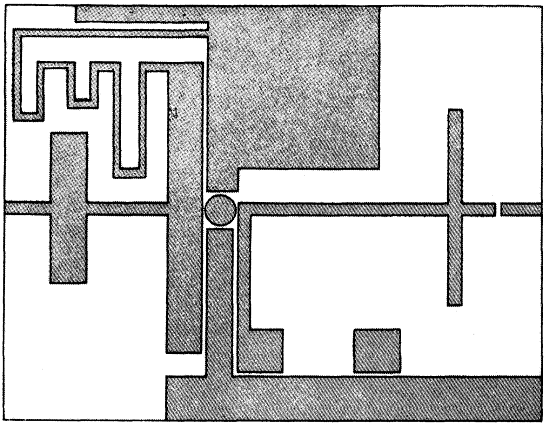
For correct operation of the transistor, the ultimate load impedance must be transformed to a real impedance across the current generator. This real impedance is determined by

$$R_L = \frac{[V_{cc} - V_{ce}\ (sat)]^2}{2P_{out}}.$$

The load impedance presented to the package terminals will contain the real impedance at the current generator, transformed to a lower value by the low-pass L section formed by C_{out} and the parasitic inductances L_c and L_{com}. Usually the reactive part of the load impedance is made inductive to tune out the residual capacitance of the device.

The output matching network should be designed so it has greater bandwidth than the input matching network. Providing a good collector match, both above and below the design frequency, ensures that the input power will be reflected before the collector VSWR rises to values that endanger the transistor. In this way the transistor is protected from off-frequency operation. The amount of additional bandwidth required for protection of the transistor depends on the ruggedness of the transistor used. The manufacturer's specifications for VSWR tolerance and input Q can be a guide for determining the bandwidth requirements of the input matching network.

One technique for obtaining the required bandwidth is to resonate a portion of the capacitive reactance of the transistor output impedance with a shunt inductor. The shunt inductor can also be used to feed the collector supply voltage to the transistor. Additional transformation may be obtained from a low-pass matching section. By adjusting the amount of shunt inductance and rematching with the low-pass section, the designer can create a truly broadband output match.



2. **With this typical microwave amplifier breadboard layout,** the entire board can be soldered to a metal plate to provide a path for thermal cooling.

Don't overlook base and collector paths

In addition to matching the device impedances, direct-current paths must be provided to the base and collector of the transistor. The collector path is provided by the shorted stub in the impedance-matching network. The base path requires the addition of a choke from the base to ground. The choke can be a lumped element or a distributed shorted stub of sufficient impedance to be negligible in the circuit. A quarter-wavelength stub is ideal. The narrowest practical line should be selected. In addition a dc blocking capacitor is required in the collector circuit. Also needed is a bypass capacitor to provide the proper ac shorting point for the inductive stub in the col-

Microstrip Z_0 and velocity factor vs width-to-height (W/H) ratio.

(Prepared by Don Schulz, Applications Engineer, TRW)

W/H	Air K = 1.0		Teflon K = 2.55		Epoxy K = 4.25		Alumina K = 9.6	
	Z_o	V_P	Z_o	V_P	Z_o	V_P	Z_o	V_P
0.630	168.425	1.000	110.683	0.657	87.986	0.522	60.977	0.362
0.695	161.878	1.000	106.258	0.656	84.414	0.521	58.441	0.361
0.766	155.370	1.000	101.865	0.656	80.870	0.521	55.927	0.360
0.844	148.909	1.000	97.509	0.655	77.360	0.520	53.440	0.359
0.931	142.506	1.000	93.199	0.654	73.888	0.518	50.985	0.358
1.026	136.171	1.000	88.941	0.653	70.463	0.517	48.566	0.357
1.131	129.916	1.000	84.745	0.652	67.090	0.516	46.187	0.356
1.247	123.753	1.000	80.616	0.651	63.775	0.515	43.853	0.354
1.375	117.692	1.000	76.565	0.651	60.524	0.514	41.568	0.353
1.516	111.746	1.000	72.597	0.650	57.345	0.513	39.337	0.352
1.672	105.926	1.000	68.721	0.649	54.243	0.512	37.164	0.351
1.843	100.242	1.000	64.944	0.648	51.223	0.511	35.053	0.350
2.032	94.706	1.000	61.273	0.647	48.291	0.510	33.007	0.349
2.240	89.327	1.000	57.714	0.646	45.451	0.509	31.030	0.347
2.470	84.115	1.000	54.271	0.645	42.709	0.508	29.123	0.346
2.723	79.076	1.000	50.951	0.644	40.066	0.507	27.289	0.345
3.002	74.218	1.000	47.757	0.643	37.527	0.506	25.531	0.344
3.310	69.546	1.000	44.692	0.643	35.094	0.505	23.849	0.343
3.649	65.065	1.000	41.759	0.642	32.768	0.504	22.244	0.342
4.023	60.779	1.000	38.959	0.641	30.550	0.503	20.716	0.341
4.435	56.689	1.000	36.292	0.640	28.440	0.502	19.266	0.340
4.890	52.796	1.000	33.760	0.639	26.439	0.501	17.892	0.339
5.391	49.100	1.000	31.360	0.639	24.544	0.500	16.594	0.338
5.944	45.600	1.000	29.091	0.638	22.755	0.499	15.370	0.337
6.553	42.291	1.000	26.952	0.637	21.069	0.498	14.218	0.336
7.224	39.173	1.000	24.938	0.637	19.485	0.497	13.138	0.335
7.965	36.233	1.000	23.047	0.636	17.998	0.497	12.125	0.335
8.781	33.484	1.000	21.275	0.635	16.606	0.496	11.179	0.334
9.681	30.904	1.000	19.618	0.635	15.305	0.495	10.295	0.333
10.674	28.491	1.000	18.071	0.634	14.091	0.495	9.472	0.332
11.768	26.240	1.000	16.629	0.634	12.961	0.494	8.707	0.332
12.974	24.143	1.000	15.288	0.633	11.911	0.493	7.996	0.331
14.304	22.192	1.000	14.043	0.633	10.937	0.493	7.338	0.331
15.770	20.381	1.000	12.888	0.632	10.033	0.492	6.728	0.330
17.387	18.702	1.000	11.818	0.632	9.198	0.492	6.164	0.330
19.169	17.148	1.000	10.830	0.632	8.425	0.491	5.644	0.329
21.133	15.172	1.000	9.917	0.631	7.713	0.491	5.164	0.329
23.300	14.385	1.000	9.074	0.631	7.056	0.490	4.722	0.328
25.688	13.162	1.000	8.299	0.630	6.451	0.490	4.315	0.328

Table continued

W/H	Air K = 1.0		Teflon K = 2.55		Epoxy K = 4.25		Alumina K = 9.6	
	Z_o	V_P	Z_o	V_P	Z_o	V_P	Z_o	V_P
28.321	12.036	1.000	7.585	0.630	5.894	0.490	3.942	0.327
31.224	10.999	1.000	6.929	0.630	5.383	0.489	3.598	0.327
34.424	10.047	1.000	6.326	0.630	4.914	0.489	3.284	0.327
37.953	9.172	1.000	5.773	0.629	4.483	0.489	2.995	0.327
41.843	8.370	1.000	5.266	0.629	4.089	0.489	2.731	0.326
46.132	7.634	1.000	4.801	0.629	3.727	0.488	2.489	0.326
50.860	6.960	1.000	4.376	0.629	3.397	0.488	2.267	0.326
56.073	6.343	1.000	3.987	0.629	3.094	0.488	2.065	0.326
61.821	5.779	1.000	3.632	0.628	2.818	0.488	1.880	0.325
68.157	5.264	1.000	3.307	0.628	2.566	0.487	1.711	0.325
75.144	4.792	1.000	3.010	0.628	2.335	0.487	1.557	0.325
82.846	4.362	1.000	2.739	0.628	2.125	0.487	1.417	0.325
91.337	3.969	1.000	2.492	0.628	1.933	0.487	1.289	0.325
100.700	3.611	1.000	2.267	0.628	1.758	0.487	1.172	0.324

lector-matching network.

Selection of a blocking capacitor is relatively straightforward. The capacitor should be chosen to provide low loss at the operating frequency while maintaining the capacitance at a value that inhibits low-frequency oscillation. The latter is caused by the series capacitor's tendency to display rising reactance with decreasing frequency.

Blocking capacitors must be large enough to preserve coupling characteristics down to a frequency where the shunt-feed chokes can effectively short the respective port to ground. Coupling capacitors should not be excessively large, or they may produce as much as 1-dB loss in gain with a corresponding decrease in efficiency in the case of collector coupling capacitors. The Q of the coupling capacitor determines the acceptable range of capacitance values and is generally inversely related to capacitance.

Bypass capacitors are selected by analysis of the same considerations as those for blocking capacitors. A large bypass capacitor (tantalum or electrolytic), placed from the dc feedpoint to ground, prevents tendencies toward low-frequency oscillation in the circuit. Also, it may be necessary to add smaller bypass capacitors to preserve stability over a wide range of frequencies.

Adjust for bandwidth and physical dimensions

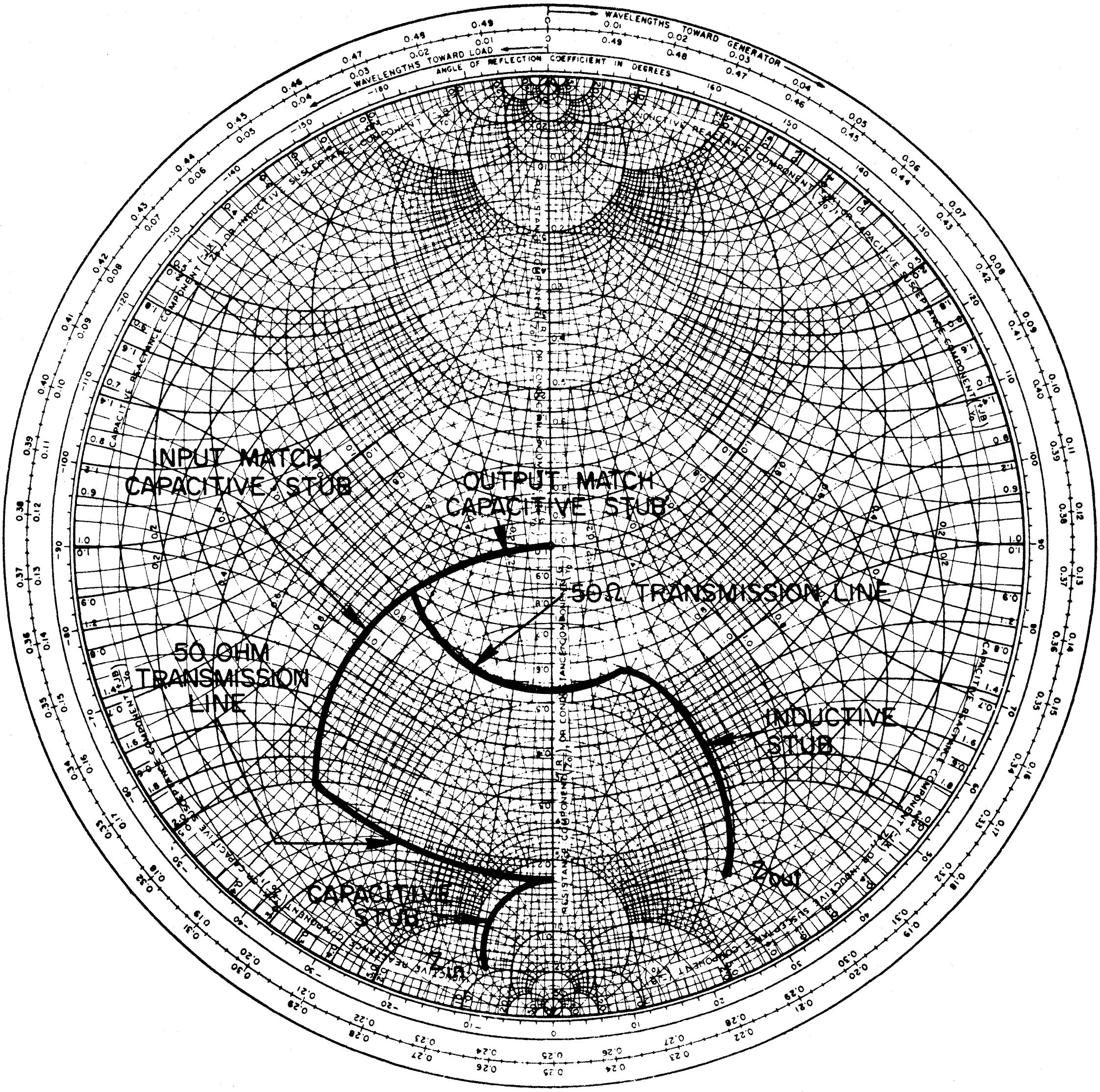
The circuit design may be adjusted quickly for bandwidth requirements through use of a computer optimization program such as Magic, offered by University Computing of Dallas, Tex. When that step is finished, electrical dimensions must be converted to physical dimensions.

At this point in the design sequence, the dielectric material must be chosen. Three commonly used materials are Teflon fiberglass, epoxy fiberglass and alumina. Above 500 MHz, epoxy fiberglass exhibits too many losses to be a good choice. Teflon fiberglass can be used up to several gigahertz; it has reasonable dielectric losses and is easy to process. Alumina, a ceramic, offers a high dielectric constant, good dimensional consistency and small circuit geometry.

When plastic materials are used, it's a good practice to measure the material thickness and dielectric constant, because variations are common. In a recent test the dielectric constant of a sheet of epoxy fiberglass material was measured at 4.55 at 1 MHz and 4.25 at 500 MHz. If the manufacturer's value of 5.5 had been used for the design of matching networks, considerable error would have resulted.

The physical dimensions of the matching circuitry may be calculated from the data in the table. The line lengths are scaled by the velocity factor, which is equal to $Z_o/Z_{o(air)}$ in air for a constant width-to-height ratio, W/H.

The final design of a typical breadboard microwave amplifier is shown in Fig. 2. The ground areas on the top of the board are connected to the microstrip ground plane by 2-mil-thick foil wrapped around the edges of the board and the areas directly under the emitter leads of the transistor. The foil is secured to the top and bot-



3. **The immittance chart,** with values specified for the design example, indicates the necessary inductive and capacitive stubs. Impedance transformations are achieved by 50-Ω series-transmission lines.

tom surfaces with solder. Plating may be used for production units. The entire board can be soldered to a metal plate to allow connector mounting and to provide a thermal path for the heat generated by the transistor.

The initial tune-up of the amplifier matching circuits can be expedited by use of a network analyzer and a precision load on the input or output connector. The circuit can be adjusted to match the nominal impedances supplied by the transistor manufacturer. Distributed stubs are purposely made longer than necessary and are adjusted to the correct length by trimming of the foil on the capacitive stubs. The inductive stub in the output network is adjusted by positioning of the bypass capacitor along the stub and the adjacent ground plane.

This procedure results in a load line that is fairly close to optimum. A transistor can now be inserted in the circuit and the collector matching network readjusted for maximum collector efficiency. Stub tuners are used to match the amplifier input impedance, so that only one variable at a time need be considered. Initially it may be necessary to operate the transistor at reduced collector voltage and power output to avoid excessive stress. When maximum efficiency is obtained, the stub tuner is removed and the input network adjusted for minimum input VSWR.

Now let's design an impedance-matching circuit

Let's consider a practical example of a procedure for the design of impedance-matching circuitry. The sample circuit uses a TRW 2N5596 at 700 MHz as the active device.

Specifications for the completed amplifier are:

$Z_{in} = 50\ \Omega$,
$Z_{out} = 50\ \Omega$,
$P_{out} = 20$ W,
$G_p = 7$ dB,
$\eta = 55\%$ minimum.

Specifications for the TRW 2N5596 are:

$P_{out} = 20$ W at 1 GHz,
$\eta = 55\%$ minimum at 1 GHz,
$G_p = 5$ dB minimum at 1 GHz,
$Z_{in} = 2.5 + J4.0$ at 700 MHz,
$Z_{out} = 6.0 - J12.5$ at 700 MHz.

In practice, the gain of a common-emitter amplifier decreases at a rate of 4 to 5 dB per octave. The 2N5596 at 700 MHz produces about 7 dB of gain. Therefore approximately 4 W of drive will be required to produce 20 W of output power. The collector efficiency can be expected to increase at the lower frequency, but it is difficult to estimate because it is a complex phenomenon. Manufacturers' curves of typical behavior are useful. Output power will not increase significantly with the decreased frequency.

The efficiency-frequency relationship depends on device f_T and ballasting. Heavily ballasted transistors tend to give increased efficiency as frequency is decreased. However, they level out at a lower efficiency than a nonballasted part because of I^2R losses in ballast resistors. The average increase in efficiency as a result of decreasing frequency is about 20% per octave. Values from 10 to 40% per octave have been measured.

The initial phase of the design is best accomplished on an immittance chart. The chart with appropriate values indicated for the sample design is shown in Fig. 3. The input match is achieved when the input impedance is resonated with a capacitive susceptance of 0.18 mhos. This susceptance is realized by use of a pair of capacitive microstrip stubs. Each stub must exhibit a reactance of 2 × 1/0.18 mhos, or 11.1 Ω. The length of the stub may be calculated by

$$\tan\theta = \frac{Z_o}{X_c}.$$

For ease of adjustment, the length of the stubs should be less than 60 degrees. Because capacitive reactance is a tangential function, the reactive variations per unit length become increasingly severe past 60 degrees. It is better to decrease Z_o rather than to use longer stubs to achieve higher capacitance. Therefore $Z_o \leqq 1.732\ X_c \leqq 19.24\ \Omega$. Because it is easier to shorten a microstrip stub than to lengthen it, the Z_o of 15 Ω, for example, provides sufficient adjustment range to accommodate device variations.

The next step is to transform the resonated impedance to 50 Ω. This is accomplished by a series-transmission line with a characteristic impedance of 50 Ω. From Fig. 3, we see that the length of this line can be directly determined to be 0.062 wavelengths, or 22.3 degrees, long. A capacitive susceptance of 0.040 mhos completes the transformation. Again, a pair of capacitive stubs will provide the susceptance. For ease of converting the design to microstrip dimensions, it is convenient to choose a Z_o for the second stub that is equal to that selected for the first. Therefore:

$$\tan\theta = \frac{Z_o}{X_c} = \frac{15}{50} = 0.3,$$
$$\text{or } \theta = 16.7 \text{ degrees.}$$

In this case the length chosen is 20 degrees to allow for some adjustment.

The output match is achieved by partial resonating of the device's output impedance with an inductive susceptance. While the amount of susceptance chosen is arbitrary at this point, the output network bandwidth is affected by the value. From Fig. 3, we can determine that 0.05 mhos is required for the first matching element. This susceptance is achieved by use of a shorted microstrip stub. The length of the stub may be calculated from the equation

$$\tan\theta = \frac{X_L}{Z_o}.$$

If Z_o of the stub is arbitrarily chosen to be 50 Ω,

$$\tan\theta = \frac{20}{50} = 0.4,$$
$$\theta = 21.8 \text{ degrees.}$$

Again, the stub is made somewhat longer because it can be adjusted by sliding the chip capacitor (ac short) up or down the line length. The remaining transformation is achieved by a 50-Ω series-transmission line of 0.15 wavelengths (54 degrees long) and a capacitive susceptance of 0.014 mhos. Selecting a pair of 50-ohm microstrip lines to provide the susceptance requires a stub length of

$$X_c = 2 \times \frac{1}{0.014} = 143\ \Omega.$$
$$\tan = \frac{Z_o}{X_c} = \frac{50}{143} = 0.350 = 19.3 \text{ degrees.}$$

A stub length of 25 degrees will provide an adequate allowance for adjustment of the circuit. ■■

APPLICATION NOTE No 5

MOUNTING OF STUDDED RF POWER TRANSISTORS

I) Preparing of heat-sink

The majority of thermal energy generated in the chip is dissipated downward to the heat sink through the package in a circular cone et 45° from the bottom of the chip (See drawing).

Since efficiency, power gain and life expetency is inversly proportional to the chip temperature, care must be taken in getting the most heat transferred from the package to the heat-sink.

A) The hole in the heat-sink for the transistor stud must not be larger than absolutely necessary, i.e. : Nr 8-32 UNC-2 A stud, Nr. 10-32 UNC-2 A studs, etc.

B) Do not chamfer hole, but remove any burr left by drill with a file — to keep as much of the heat sink as possible in direct contact with the header flange.

C) Keep the heat-sink which is in direct contact with the header flange as flat as possible and clean of any foreign material.

II) Mounting the transistor.

The transistor leads are not made to give mechanical support nor should they be used in holding the transistor when screwing the nut down :

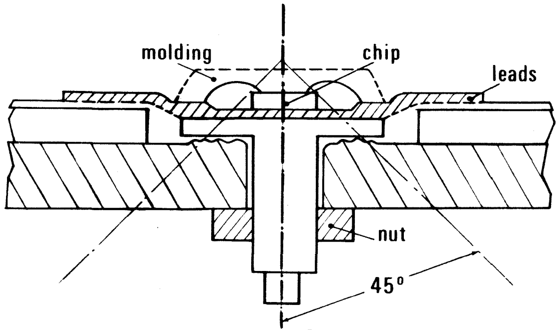
A) Make sure the distance from the flange of the header to the bottom of the electrical leads is observed (See drawing).

B) Coat the heat-sink surface with a small amount of thermal contact grease.

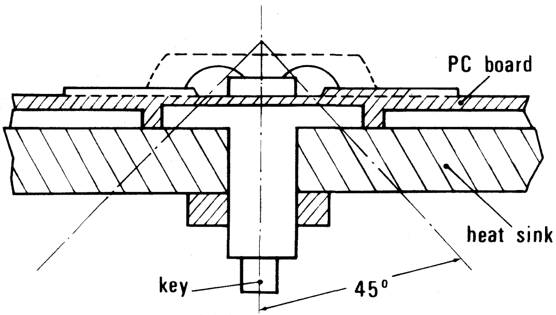
C) Put transistor in place making sure emitter, base and collector are aligned property.

D) Lock the nut into place with 10 in.pound (± 10 %) (9 kg.cm) torque by holding transistor in place with fingers or by gripping the key provided on the studd of the transistor with a tool.

E) The solder leads into place.



BAD MOUNT



GOOD MOUNT

MOUNTING OF FLANGE RF POWER TRANSISTORS

I. Preparation of heat sink

To ensure maximum heat transfer from the transistor to the heat sink it is imperative that the heat sink be made as flat as possible. Ideally one should target for a flatness of the mounting surface to 0.02 mm by careful machining.

It is also important to ensure that the fixing holes do not have any burrs around them, which may prevent the transistor from sitting firmly on the heat sink.

II. Mounting proceedure

A) Prior to mounting, the transistor flange should be lapped to 0.01 mm flatness using a 400 grit carborundum paper on a flat surface, and then cleaned of any small particles.

B) Apply the absolute minimum of thermal grease to the flange base of the transistor and then rub lightly on a flat surface to remove any excess. TOO MUCH THERMAL GREASE IS WORSE THAN USING NONE.

C) Bolt the transistor in place using the appropriate screws plan washers and lock washers.

If at any time it is found necessary to remove the transistor and then replace it once more in the circuit, the device should be lapped again before mounting. This will be necessary since the flange will almost certainly have been distorted by mounting and removal.

MOUNTING OF RF POWER MODULES - (MOBILE MX/MV)

A similar proceedure to that for the mounting of lange transistors should be adhered to. However the degree of flatness to be acheived is as follows.

a) Heat sink - 0.1 mm.

b) Module - This is already delivered to a flatness guaranteed to be better than 0.15 mm.

Again, the absolute minimum of heat sink compound should be used.

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APPLICATION NOTE No 6

TV TRANSPOSERS BAND IV & V
P_0 = 0.5 W/1.0 W

This note describes the performance of a broadband (470-860 MHz) ultra linear amplifier designed for service in band IV and V T.V. transposers.
Device used :

TPV 596.

Basic specs :

I.M.D. — 60 dB max. at Po = 0.5 watts
Vce = 20 volts ; Ic = 200 mA
Pgain = 11.5 dB min.

The approach used is intended to be straight forward and inexpensive as follows.

1) The load line be defined to provide the correct match for peak power (P. sync).
2) The VSWR at the collector be less than 2 : 1.
3) The input match be designed to provide flat gain with decreasing frequency.
4) Use computer aided design.
5) Use a three tone norm
   Pvision = — 8 dB
   Psound = — 7 dB
   Psideband = — 16 dB
6) Circuit realization to be a distributed design built upon teflon glass copper clad circuit boards. However the design will be analized using Er = 1.0.

The input and output impedances were taken from the TPV 596 data sheet and plotted on a smith chart. First consider the input. To have flat gain with an optimum collector load, the basic physics of a class « A » biased device defines a gain slope of — 6 dB/octave which must be compensated for. The band of interest is 470-860 MHz which is .915 octaves which implies that 5.25 dB of gain must be compensated for if the device is perfectly matched at 860 MHz. This means that a transmission loss of 5.25 dB or a VSWR of 11.0 : 1 must be employed at 470 MHz. The input Z is converted to Y on smith chart (I). The point at 860 MHz will intersect the constant conductance line equal to 1.0 (20 m℧) if it is rotated 0.14 λ using a 20 m℧ (50 Ω) transmission line. After this rotation a capacitive stub or chip capacitor is used to resonate the susceptance at 860 MHz ; A capacitive stub or a chip capacitor equal to 16.7 pF can be used, and the result is shown on Smith chart (I). It is interesting to note that the VSWR vs : frequency can be adjusted for gain flatness by selecting an optimum Zo for the capacitive stub. It is also obvious that the locus of impedances at the circuit input can very between the locus of points defined by using a chip capacitor, and the imaginary axis by using a stub with Zo = ∞. Graph (II) is a plot of these results. Because infinite isolation doesn't exist between the output and input of any transistor, and because the required network is very simple, the input circuit will be optimized empirically. A computed aided circuit will be defined for the output only. It is also indicated that a combination chip capacitor and stub may provide the best results.

The output circuit considerations were first determined using a smith chart approach. It must be clearly understood that computer optimization is only as good as the circuit configuration and associated computer instructions.

The approach follows :

Smith Chart (II)

1) The device output impedances are first converted to admittances and plotted as the conjugate (Y load).
2) In order to allow easy collector lead soldering a Zo = 50 Ω, 3 mm long transmission line is used. Since the Smith chart is normalized to 20 m℧ (50 Ω) we can rotate toward the load directly as the chart is configured.
3) Since the balance of the circuit used Yo = 10 m℧ (100 Ω) we next normalize the chart to 10 m℧. 100 Ω transmission line was chosen as a good compromise between physical length requirements and ease of realization on Teflon Glass.
4) The next element, a shorted shunt transmission line less than $\lambda/4$ in length reduces the imaginary part by moving each point of admittance along a line of constant conductance. The length was chosen to locate the lowest frequency point (400 MHz) near the real axis so that the locus of points would be more equally distributed about a 2.0 : 1 VSWR circle.

5) The resultant locus of points are then rotated with a 10 m℧ (100 Ω) transmission line to a degree which locates the admittance point of 860 MHz near the line of constant conductance equal to 2.0 on Smith Chart (II). This conductance is exactely equal to 20 m℧ since the chart is normalized to 10 m℧.

6) The final step is to use a parallel resonant circuit which will reduce the imaginary pacts at both the upper and lower frequencies.

The following approach was used to calculate the element values for the antiresonant circuit.

By observation of the smith chart it was decided to place the 460 and 860 MHz points on or just inside the 2.0 : 1 VSWR circle.

It then follows that

$$\text{at } f_1 = 460 \text{ MHz} \qquad W_1C - \frac{1}{W_1L} = -0.4$$

$$\text{at } f_2 = 860 \text{ MHz} \qquad W_2C - \frac{1}{W_2L} = 1{,}7$$

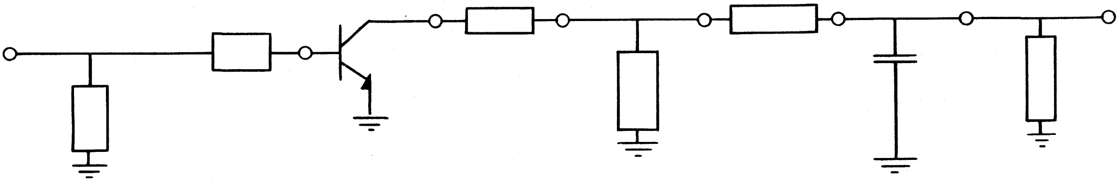
The 2 equations with 2 unknows are solved with the following result.

L = 0,189 nHy
C = 496.11 pFd

since we are normalized to 10 m℧

Lactual = 0.189/.01 nH = 18.9 nHy
Cactual = 496.11 × 0.1 pF = 4.96 pFd

7) The result is normalized to 20 m℧ with the final result shown.



Zo	10 Ω	50 Ω	TPV 596	50 Ω	100 Ω	100 Ω		100 Ω
Calc. Value	45.7 mm	3.78 mm		3 mm	76.1 mm	29,3 mm	4.9 pF	50.4 mm
Empirical Value	8.5 48.8 mm	1.5 mm	Opti-mized Value	3 mm	98.8 mm	39.62	5.5 pF	61.6 mm

Graph (III) shows the various VSWR calculated compared to the theoretical best curve and the actual VSWR measured.

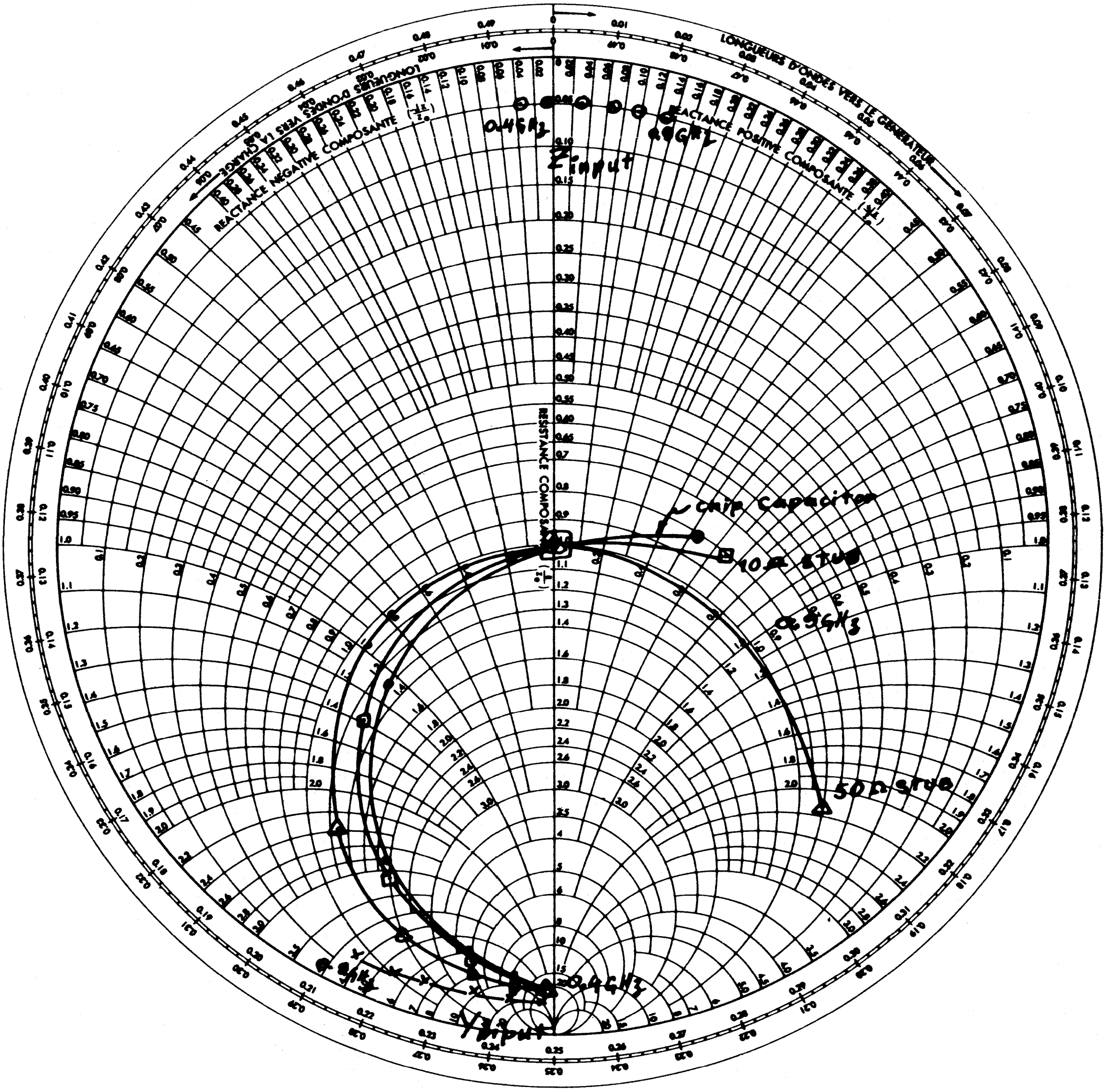
Graph (IV) shows the collector load VSWR for the calculated, optimized, and actual result.

Graph (V) is a plot of the single ended amplifier results taken with a network analyzer. No component losses were considered for the theoritical and optimized analysis. The final circuit was also optimized empirically from 470-860 MHz using a network analyzer.

The following results are a summary of performance, bias conditions circuit configuration and recommended hybrid adaptation.

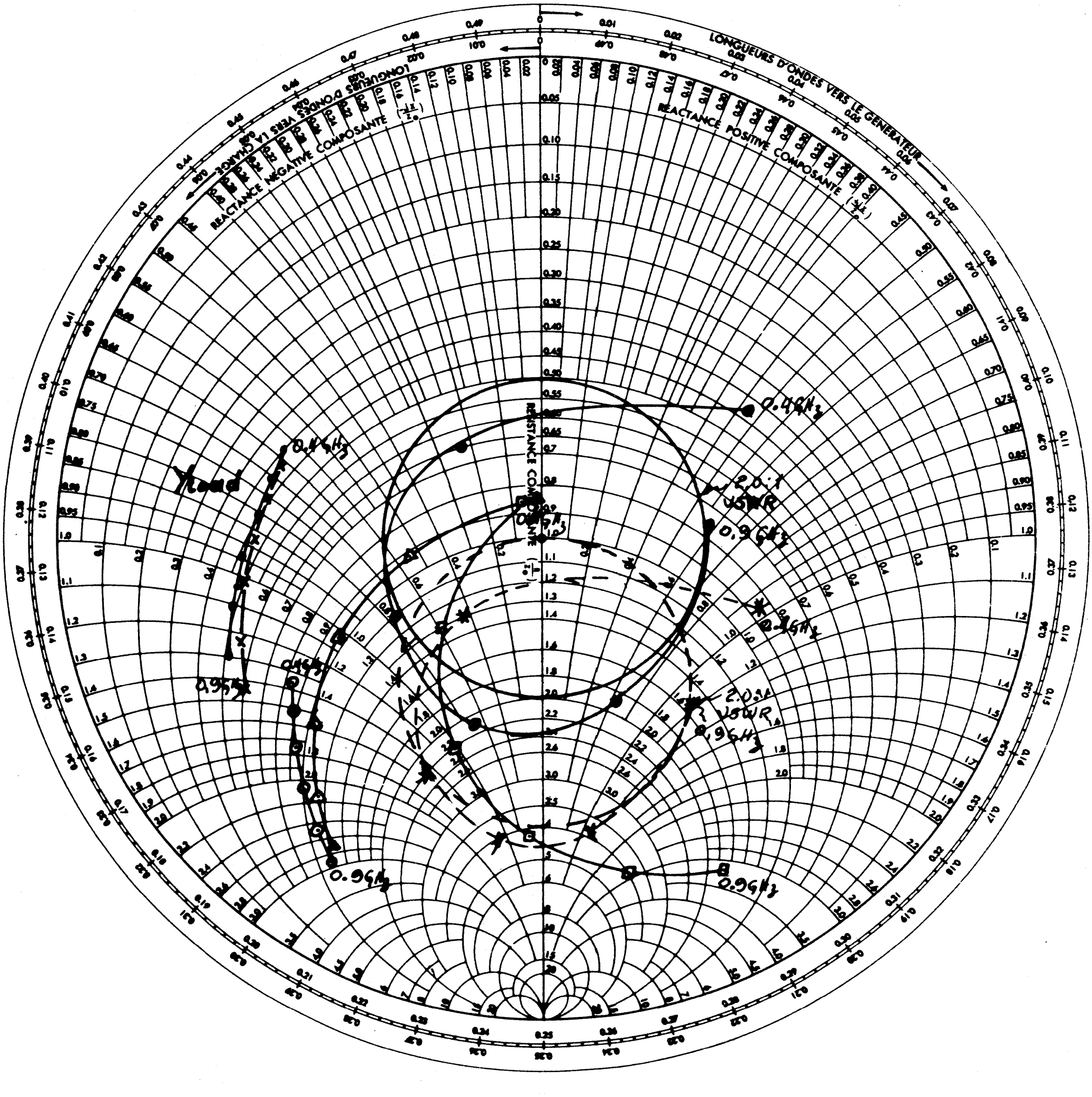
SMITH CHART (I)

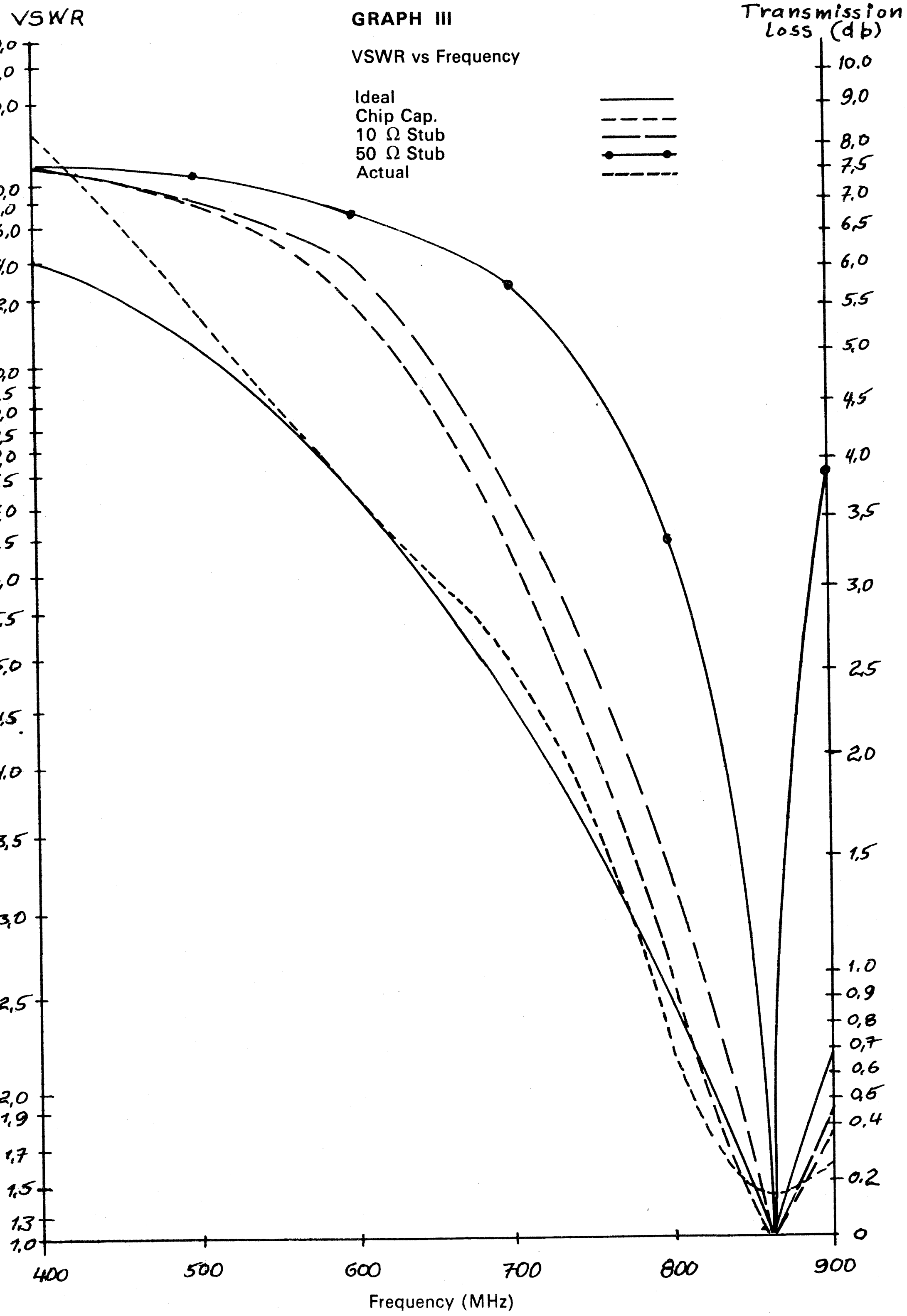
starting Imp. ⊙——⊙
rotated Adm. ×——×
final Adm. ω/Chip Cap. ●——●
final Adm. ω/10 Ω Stub ⊡——⊡
final Adm. ω/50 Ω Stub △——△



SMITH CHART (II)

starting Adm.	●——●
50 Ω rotation	×——×
100 Ω translation	⊙——⊙
equiv. shunt Ind.	△——△
100 Ω rotation	⊡——⊡
parallel L-C	×——×
final Adm. 50 Ω translation	●——●



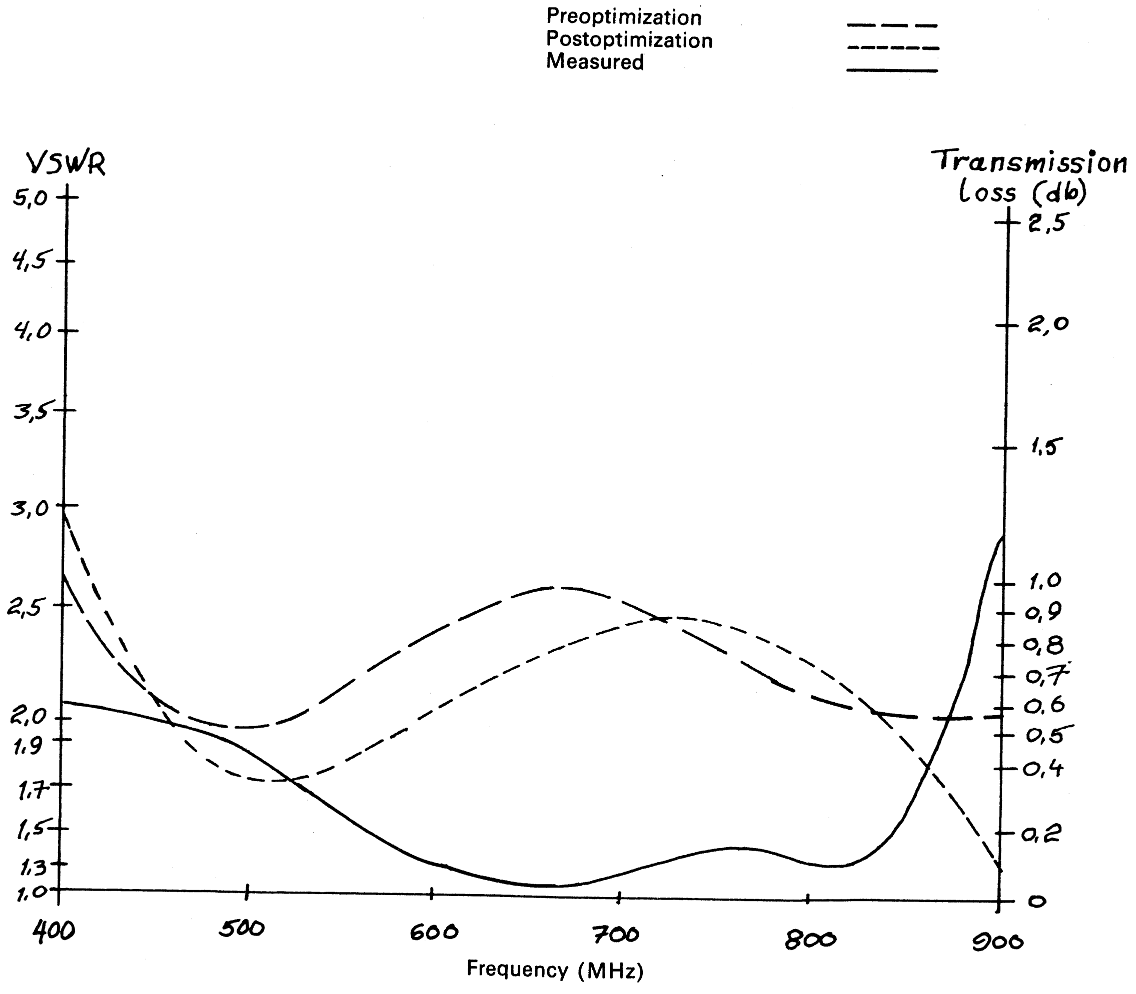


GRAPH III

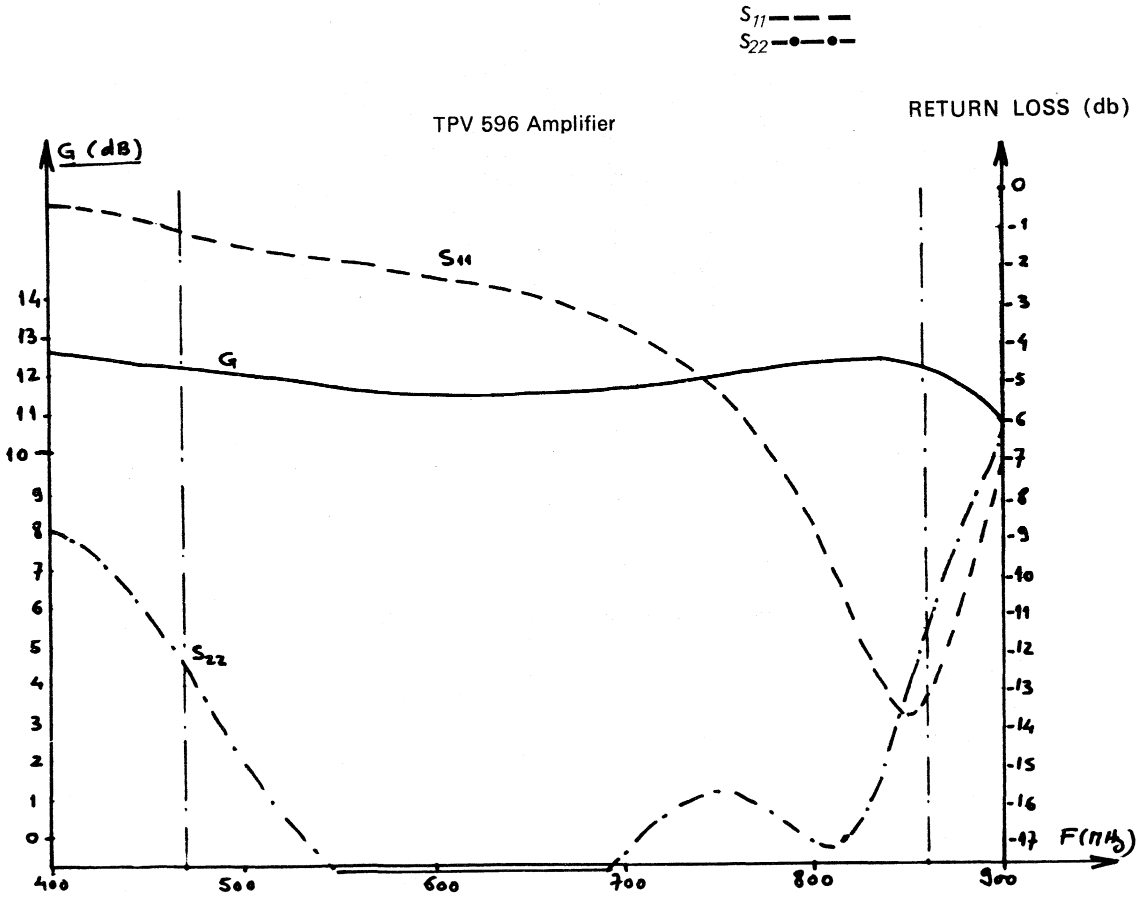
VSWR vs Frequency

GRAPH IV

VSWR vs : Frequency

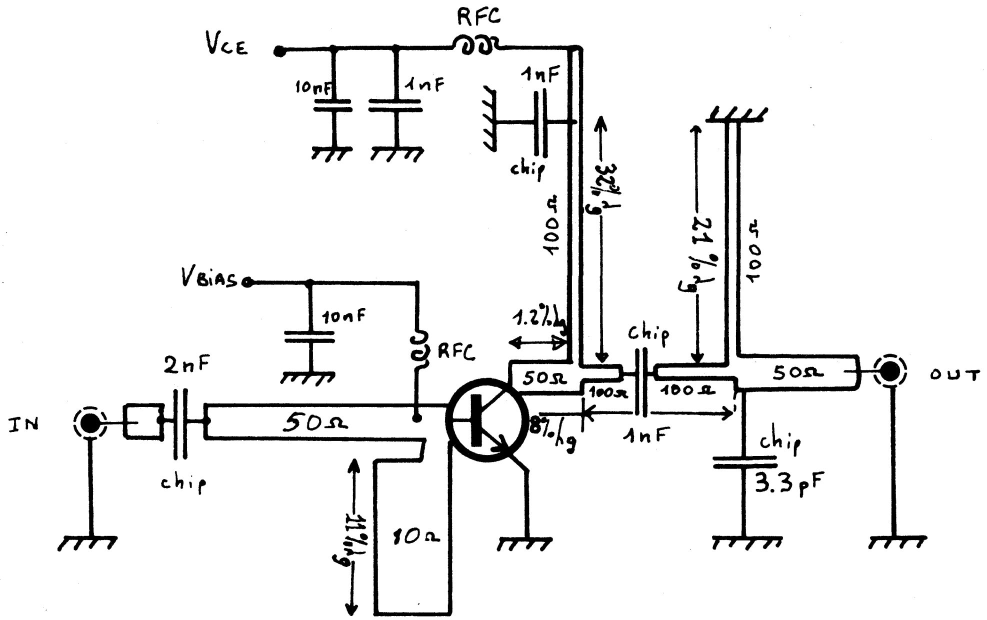


GRAPH V



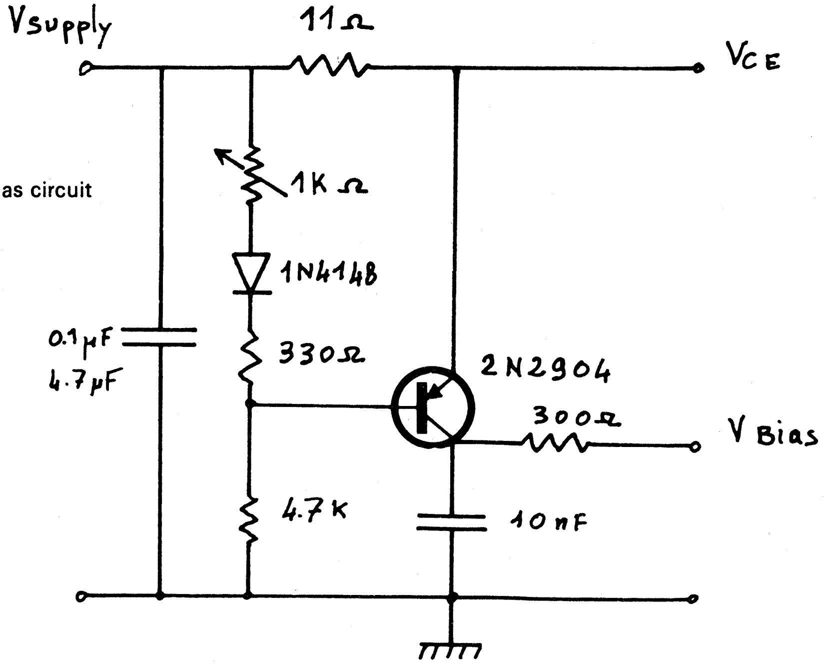
S11 — — —
S22 —•—•—
TPV 596 Amplifier
RETURN LOSS (db)
G (dB)
S11
G
S22
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
-12
-13
-14
-15
-16
-17
F(MHz)
400
500
600
700
800
900

470-860 MHz class A with TPV 596



V_{CE} = 20 V - I_C = 220 mA
F_0 = 860 MHz - WAVELENGTH (λg) at 860 MHz
(material : Glass teflon εr = 2.55 - 1/16″ used by TRW)

Class A bias circuit



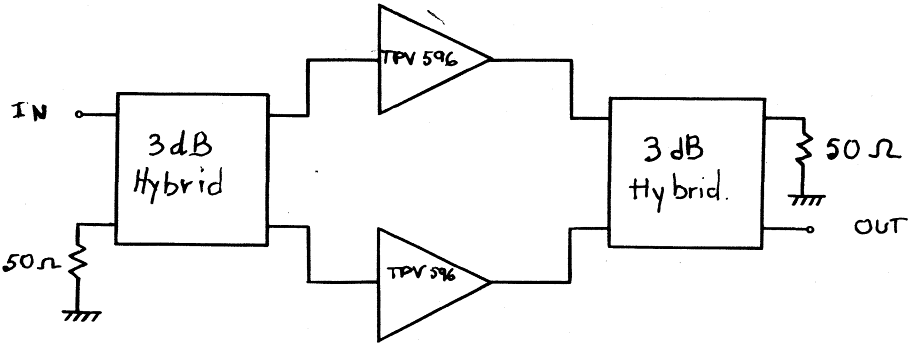
TPV 596 BROADBAND AMPLIFIER

FREQUENCY RANGE	: 470 MHz-860 MHz
POWER OUTPUT AT	: — 60 dB IMD* $\geqslant$ 0.5 W
POWER GAIN	: $11.5 \leqslant G \leqslant 12.7$ dB
INPUT RETURN LOSS*	: < — 1 dB
OUTPUT RETURN LOSS	: < — 11 dB
VOLTAGE SUPPLY	: ~ 23 V (V_{CE} = 20 V)
TOTAL CURRENT	: 220 mA

*IMD : Vision : — 8 dB ; Sound carried : — 7 dB ; Side band : — 16 dB

RECOMMENDED CONFIGURATION

*INPUT RETURN LOSS : This amplifier must be used by two connected together with two 3 dB quadrature hybrids to have a balance amplifier with a good input VSWR.



*3 dB - 90° Hybrid coupler from
- AMAREN 10 264-3
- SAGE wireline 3 dB Hybrid 4450 900

IMD VS OUTPUT FOR A SINGLE STAGE
VCE = 20 V-220 mA

F = 860 MHz ; Vision = — 8 dB ; Sound Carrier = — 7 dB ; Sideband = — 16 dB

Pout (W)	0.25 W	0.5 W	1 W
IMD (dB)	— 67 dB	— 61 dB	— 55 dB

F = 860 MHz ; IMD DIN 45004/B
RL = 75 ohms

1.5 V/75 ohms	IMD = — 66 dB
2 V/75 ohms	IMD = — 60 dB

APPLICATION NOTE No 7

A study of the advantages of GOLD METALLIZATION in the manufacture of

microwave transistors

M. FLAHIE - M. WEISS

ABSTRACT

The development of a high reliability metallization system for R.F. power transistors has been TRW Semiconductor's continuing primary R&D and Manufacturing priority.

This priority, of course, is a necessary part of TRWS' goal to sustain its leadership in R.F. power transistors by continually advancing the state-of-the-art in power and frequency.

This report summarizes the reasons for TRWS' commitment to a GOLD metallization system for the manufacture of high power microwave transistors.

The conclusions are that the GOLD metallization system is superior to ALUMINIUM systems in the following respects :

- Electromigration resistance
- Temperature stability
- Corrosion resistance
- Mechanical strength
- Oxide step coverage
- Manufacturability

SECTION 1 - ELECTROMIGRATION

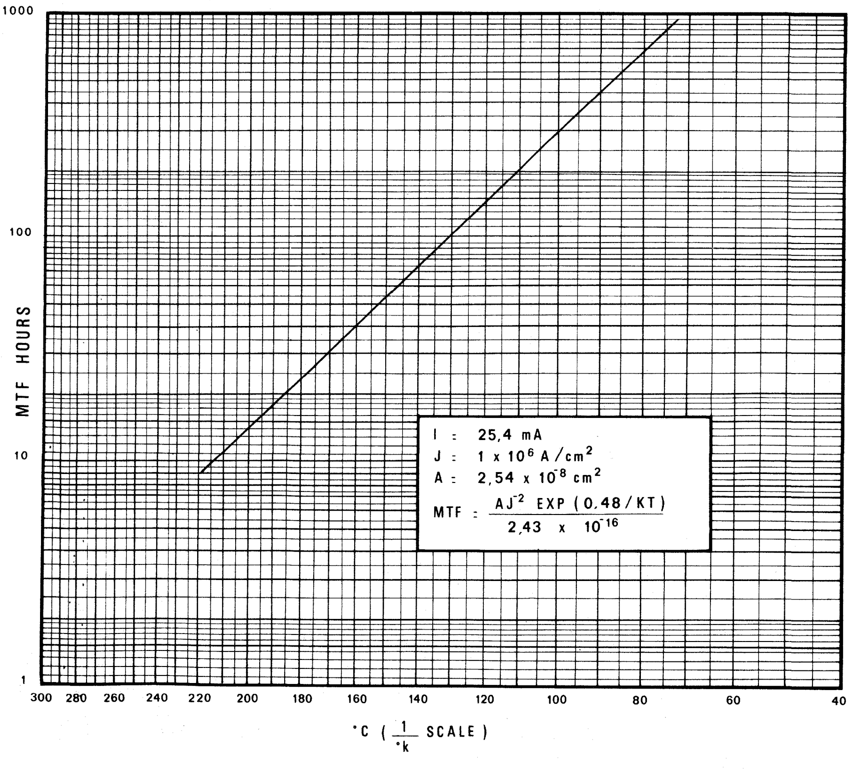
The phenomena of electromigration occurs as follows (1). For any given temperature, a certain equilibrium concentration of vacancies exists in all metal films. Self diffusion of metal ions throughout the film will arise due to the metal ions being thermally activated from their normal lattice sites into adjacent vacancies. In the absence of any external forces, the metal ion diffusion will be isotropic and will result in no net accumulation or depletion of mass in any given site. Upon the application of an electric field, however, the thermally activated metal ions will experience a force due to their charge and the electric field inducting an ion flux toward the cathodic end of the film. In addition, the conduction flow of electrons in the metal due to the electric field will cause electron scattering off the activated ions and impart momentum to them inducing an ion flux toward the anodic end of the film. In good conductors, the momentum exchange force dominates the electrostatic force. This results in a net mass transport toward the anodic end of the film.

In the case of device interconnections, the ne tflux of mass due to momentum transfer causes void formation at the negative terminals. This void formation causes eventual contact opens resulting in destruction of the device. Void formation, hence, device failure, is accelerated by high temperatures (i.e., more metal ions will be activated) and high current densities (i.e., more electrons will collide with the activated ions and impart more momentum to them).

A simplified theory, Black (1), describing this phenomena provides the following expression for Median Time before Failure of device interconnections :

$$\text{MTF} = \frac{\omega . t\, e\, \phi / KT}{CJ^2}$$

where ω = Stripe width
t = Stripe thickness
J = Current density
ϕ = Activation energy for self diffusion of the metal
K = Boltzmann's constant
T = Temperature in °K
C = Constant depending on degree of film crystallinity, resistivity, ion mass, density and stripe geometry.



TEMPERATURE IN °C
MTF for a 1 μ × 2.54 μ
ALUMINIUM STRIPE

Figure 1

ALUMINIUM SYSTEM

Figure 1 shows the expected best case MTF for an ALUMINUM stripe 1 μ thick by 2.54 μ wide, with a current density of 10^6 amps/cm^2 at various temperatures.

Figure 2 shows the effect of current density and temperature on life time of small crystallite ALUMINUM, Black (1).

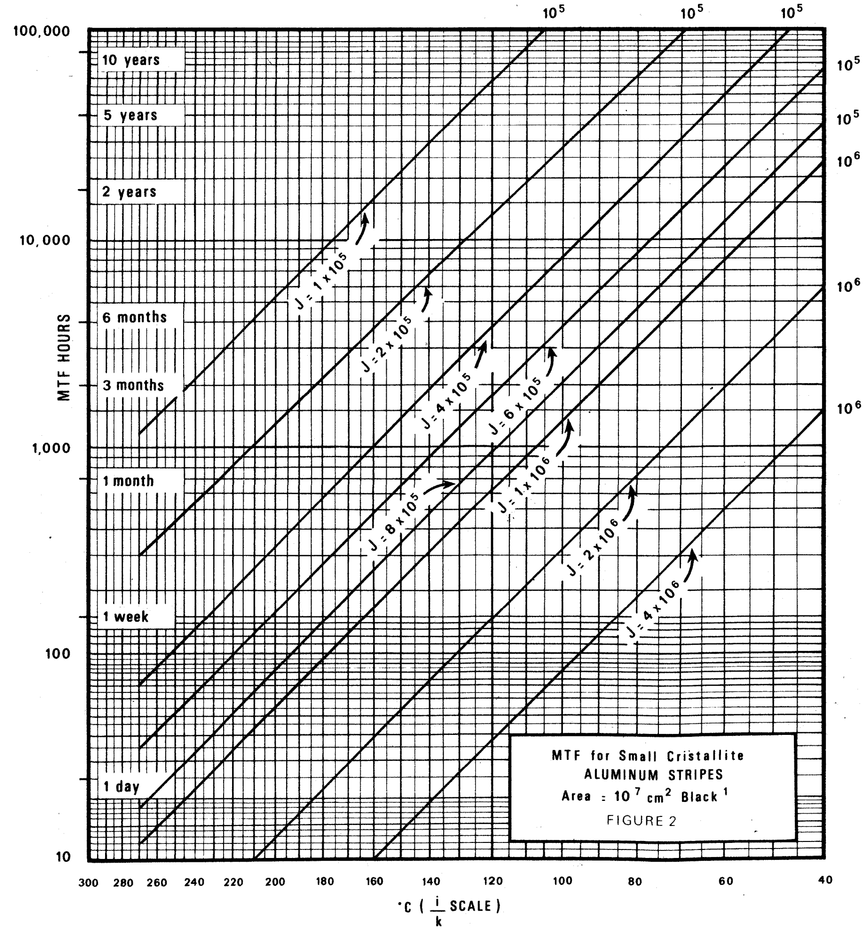
GOLD SYSTEM

In order to incresse the MTF of devices, two options exist :

1. Reduction of current density and/or device temperature.
2. Selection of a metal with a higher activation energy and higher mass (since electromigration is a momentum transfer process between the conduction electrons and metal ions thermally activated out of the crystal lattice).

Current density reduction cannot always be exercised due to device performance limitations (i.e., prerequisite geometry for frequency response considerations, etc.). Reducing the thermal stresses is possible; however, practical limits still make critical demands on the metallization. Utilization of a metal with a higher mass and activation energy is the remaining approach to incressing MTF.

GOLD is preferred as the main conductor due to its high activation energy for self-diffusion, high mass and density, resistance to oxidation and corrosion, facility of chemical pattern delineation, and ease of lead wire bonding. Unfortunately, GOLD cannot be used as single layer metallization system due to its poor adherence to both Si and SiO_2, and the low Au-Si eutectic temperature of 367 °C. To prevent the GOLD from alloying with the silicon, a barrier metal layer must be employed.



MTF for Small Cristallite ALUMINUM STRIPES

Area : 10^7 cm^2 Black^1

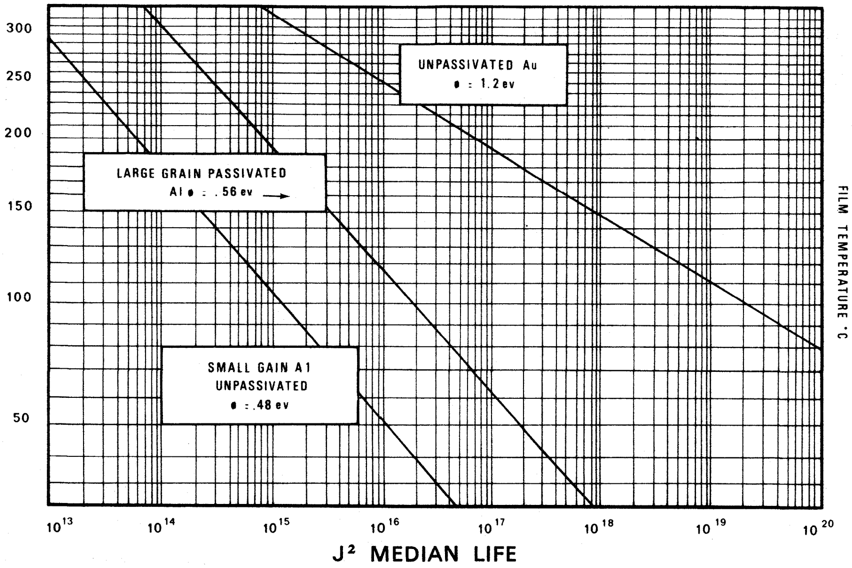
FIGURE 2

The composite system PtSi-Ti-TUNGSTEN-GOLD* meets all the aforementioned requirements for a superior metallization system. PtSi is used to provide a stable, ohmic contact to silicon. The TUNGSTEN layer is also used as a barrier against GOLD diffusion into, and eutectic alloying with Si, as well as to provide adhesion of the GOLD to silicon and SiO_2. Extensive investigation and life testing of the GOLD composite system has been done by TRW Semiconductors and others.

The following discussion, figures, and tables (sections 1-5) are a summary of these investigations.

Figure 3 compares unpassivated small grain ALUMINUM and passivated large grain ALUMINUM to unpassivated TUNGSTEN-GOLD composite metallization.

The lifetime improvement for GOLD vs. ALUMINUM is dramatic, as shown in Table I. For example, the improvement is nearly two orders of magnitude in lifetime for GOLD vs. large grain ALUMINUM (passivated), even at an extreme of 200 °C, and over three orders of improvement at 100 °C. The data used to compile Figure 3 and Table I was obtained by accelerating the failure with high currents being passed through 0.5 mil by 13.5 mil dog bones (2) and using actual transistor structures (7).



Temperature	Median lifetime improvement	
	Gold vs. Small grain Aluminum Un-passivated	Gold vs. Large grain Aluminum Passivated
200	1,250 times	88 times
150	4,750 times	264 times
100	17,000 times	1150 times

Table I

A life test under severe conditions is under way at TRW. Identically processed, actual transistors made by both ALUMINUM and GOLD processes are base-emitter forward biased such that Tj = 200 °C and $J = 1.4 \times 10^6$ A/cm^2. After 197 hours, 50 % of the ALUMINUM transistors had failed. At 272 hours, all had failed due to open metallization.

At this writing the GOLD units have survived over 9000 hours of testing without degradation (as evidenced by regular power, gain, and leakage tests). This establishes 30 times life improvement for GOLD over ALUMINUM (a mathmatical model indicates 100 times) as a minimum.

Keep in mind that test is a severe, accelerated life

* First developed by Texas Instruments and described in U.S. Patents 3,575,570 and 3,601,666 and U.K. Patent 1,265,896.

test and does not indicate that acceptable lifetimes cannot be realized from ALUMINUM in lower frequency, larger geometry devices. GOLD appears necessary in microwave, sub-micron geometry devices.

SECTION 2 - TEMPERATURE STABILITY

Temperature stability involves two areas of interest. The first and most important is the silicon-metal ohmic (non-rectifying) contact; secondly, is the formation of intermetallics or solid-solubility.

SILICON-METAL CONTACT

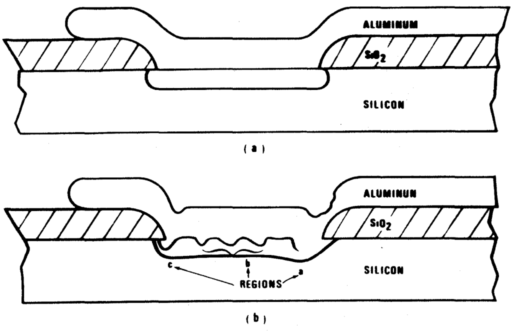
Previously (section 1) it was shown that transistors fail as « open » due to electromigration. In this section, it will be shown how transistors fails as base-emitter « shorts » due to alloying of silicon with the contacting metallization.

ALUMINUM SYSTEM

Again, the problem is most severe with ALUMINUM. Figure 4 illustrates the etch-pit that forms when ALUMINUM is alloyed with silicon (caused by dissolution (1) of silicon into ALUMINUM). The alloying rate at 400 °C is .021 angstrom/minute. Three gigahertz transistors have emitter diffusion depths of 3000-4000 angstroms.

Therefore, in 100 hours of operation under a hot-spot condition of 400 °C, the transistor will fail as an emitter-base short. Output power will have degraded over time due to the even increasing base-emitter leakage.

E-B SHORTS DUE TO SINTERING
OF Al INTO CONTACTS



	Temp. (°C)	Å/Min.
Silicon etch pit formation	400	.021
by : (a) As deposited		
(b) After alloying	500	6.36
	600	520.86

Figure 4
TYPICAL ALLOYING RATES OF Al INTO Si

At practical microwave device operating temperatures (150 °C) and practical current density (1×10^5 A/cm^2), the calculated lifetime of ALUMINUM is limited to slightly over two years.

However, it is not uncommon with microwave geometries to have current densities of 2×10^5 A/cm^2, again at 150 °C, the ALUMINUM lifetime in this case is limited to 5,500 hours or approximately 7.5 months.

Therefore, ALUMINUM metallization is deemed unsatisfactory for fine geometry device applications which approach the above conditions, expecially those requiring practical lifetimes of over six months, and all high reliability applications.

GOLD SYSTEM

The GOLD composite metallization has lower alloying rates as shown in Table II (2).

PtSi is used at TRW as the ohmic contact. Pt is sputtered on to the silicon, then PtSi, is formed at greater than 500 °C for times much in excess required to complete the reaction. Excess Pt, which was not exposed to silicon, is then etched away chemically. PtSi contacts are much less resistive than alloyed ALUMINUM contacts, thus reducing power loss.

With the use of TUNGSTEN to contact the Si-PtSi surface, a very stable connection is achieved which eliminates any etch-pit formation due to hot-spots.

ALUMINUM SYSTEM

« Although the alloying times given for Al in Table II were obtained without the use of a PtSi contact layer (450 °C), it was found that a reaction occurred between the two materials which caused alloying in slightly more than thirty minutes » (2).

INTERMETALLIC FORMATION

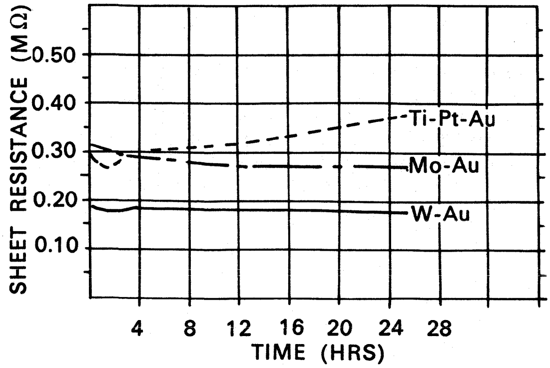
Osborne, et al (2) investigated the change in contact resistance for various GOLD systems. This is shown in Figure 5. PtSi formed the preohmic contact. Again, the TUNGSTEN-GOLD composite is the most stable.

TIME TO ALLOY JUNCTIONS
AT 450 °C AND 550 °C (2)

Test Metal	450 °C	550 °C
Al	20 min.	—
Mo-Au	3.5 hr.	40 min.
Ti-Pt-Au	5.0 hr.	50 min.
W-Au	4.5 hr.	50 min.

Table II

SHEET RESISTANCE CHANGE AT 450°C IN N_2(2)



SECTION 3 - ELECTROLYTIC CORROSION

Osborne, et al (2) investigated electrolytic corrosion for Al, Mo-Au, Ti-Pt-Au, and W-Au as shown in Table III.

Two test condition were used; (1) 85 °C - 85 % Relative Humidity, and (2) 98 °C - 98 % Relative Humidity. In each case, the test samples were two parallel 0.3 mil width stripes separated by 0.9 mils. A bias voltage of 3 Vdc was applied across the two stripes under the above test conditions.

ALUMINUM SYSTEM

The ALUMINUM samples under test exhibited electro-chemical dissolution of ALUMINUM on the nagative stripe while the positive biased side was nearly unchanged. Passivated ALUMINUM (6000 Å SiO_2) was also tested with observance of the same reaction at the exposed bonding pad areas.

Biasing was shown to accelerate the ALUMINUM corrosion. In ten hours at 98 °C - 98 % R.H. no signs of corrosion was observed. However, with 3 Vdc bias applied (98 °C - 98 % R.H.), severe corrosion was observed in one and a half hours.

GOLD SYSTEM

GOLD deplating from the positively to the negatively biased stripe was the limiting parameter for the TUNGSTEN-GOLD system (also for Ti-Pt-Au).

The time required for this failure is much longer than for ALUMINUM.

« The apparent differences in lifetime between Au on PtSi vs. Au on W as shown in Table III was attributed to a difference in surface topology of the GOLD resulting from different deposition conditions rather than any inherent effect of the underlying metallization » (2).

CORROSION LIFETIME FOR Al, Mo-Au, Ti-Pt-Au, AND W-Au* (2)

Test / Metal	85-85	98-98	Comments
Al**	4.5 hrs.	1.5 hrs.	Electro-chemical dissolution negative terminal
Mo-Au	—	25 hrs.	Mo-corrosion
Ti-Pt-Au	18 hrs.	4 hrs.	Au-deplating from positive terminal
W-Au	16 hrs.	3 hrs.	

* All tests were conducted with 3 V dc bias.

** Unpassivated. Osborne, et al (2).

Table III

SECTION 4 - ADHESION

Adhesion of the metal system to SiO_2 and Si is of a major importance to the mechanical and electrical reliability of any transistor.

Pull strengths of thermo-compression wire bonds were used to obtain a quantitative determination of adhesion (2).

Figures 6 and 7 show the gaussian distribution of bond failures. The GOLD metallization systems all tend to show higher average wire pull strengths with GOLD wire than ALUMINUM with GOLD wire (2).

Similar tests conducted at TRW Semiconductors on the PtSi-Ti-TUNGSTEN GOLD compared to ALUMINUM, also show higher average strength for GOLD vs. ALUMINUM (GOLD wire thermal-compression bonds).

WIRE BOND PULL STRENGTH
AL METAL
(Osborne, et al (2))

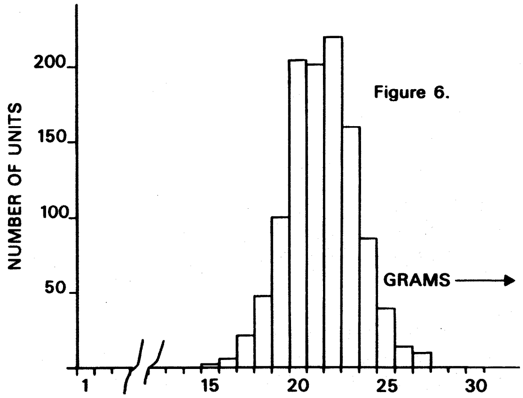


Figure 6.

WIRE-BOND PULL STRENGTH
W-Au METAL
(Osborne, et al (2))

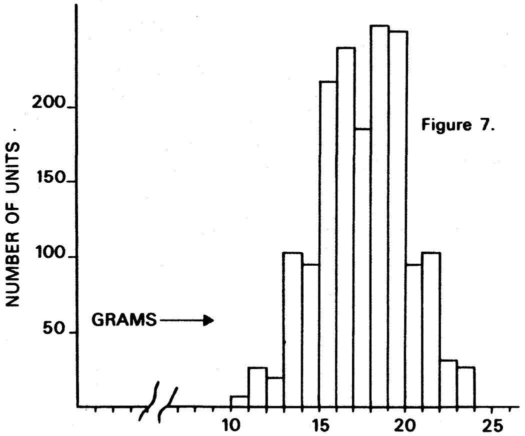


Figure 7.

SECTION 5 - PROCESSING ADVANTAGES OF GOLD SYSTEMS COMPARED TO ALUMINUM

The reliability of all metal systems depends not only on those factors discussed in the previous sections, but the following three processing factors :

1. **Deposition reproductibility,**
2. **Etchability** to define metal geometries, and
3. **Oxide step coverage,** the ability to cover oxide steps without decrease of metal thickness or cracking.

The method of deposition makes the greatest difference between the quality factors of GOLD and ALUMINUM metallizations.

SPUTTERING is used at TRW Semiconductors for the PtSi-Ti-TUNGSTEN GOLD system, where vacuum evaporation is the industry-wide method to deposit ALUMINUM.

VACUUM EVAPORATION of ALUMINUM is accomplished via electron beam or resistive heating of the ALUMINUM to its vaporization temperature.

ALUMINUM SYSTEM

A point source for the ALUMINUM is used and since the mean free path of the ALUMINUM particle is long before collision, the wafer substrate must be rotated through all possible angles to achieve perfect coverage of all oxide steps. In practice, only an approximation to this ideal requirement is possible (see Figure 8).

OXIDE STEP COVERAGE
ALUMINUM VACUUM EVAPORATION

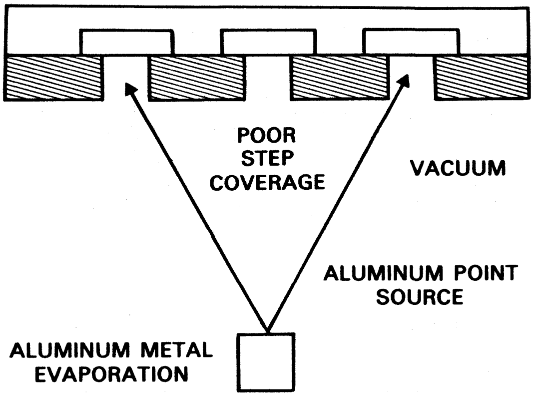


Figure 8.

This process problem alone is sufficient to justify an improved technique, but the task is only made impossible when the many difficult to control process variables are considered. A complete discussion of these process variables is beyond the scope of this paper ; however, the impact on reliability of these process variables and problems is the subject of the Goddard Space Flight Center Specification S-311-P-12A entitled, « Scanning Electron Microscope inspection of Semiconductor Device Metallization, Specification for ».

Figure 9 shows a SEM photograph of an oxide step coverage problem with ALUMINUM.

Etchability of ALUMINUM is a problem which has been solved for large geometries, but is still (even though it has wide usage) a major process reliability problem with small geometry microwave transistors.

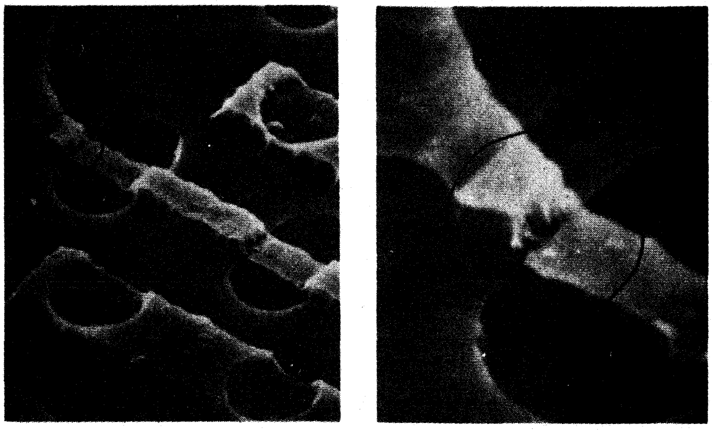


Figure 9

Photomicrographs of a transistor with ALUMINUM metallization showing poor step coverage. The blowup (6000 X) shows a typical step with poor continuity in metallization. This gives rise to regions of extremely high current densities and the resultant failures.

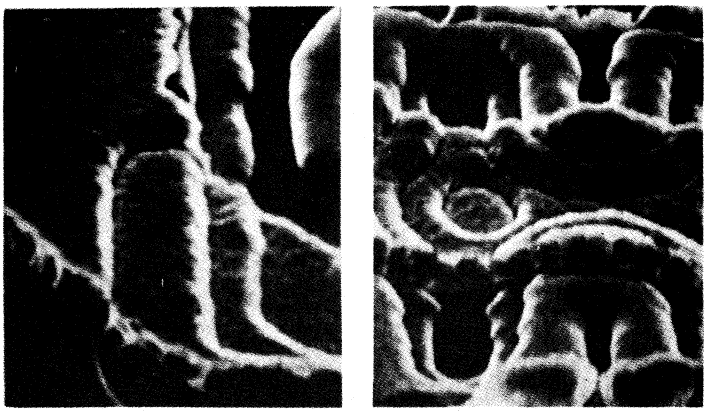


Figure 10 A

6000 X photomicrograph of a GOLD metallized transistor section. Note the uniform metallization without discontinuities.

Figure 10 B

Cross section photomicrograph of a GOLD metallized stripe showing uniform stripe thickness.

GOLD SYSTEM

The sputtering and etching processes used for PtSiTi-TUNGSTEN-GOLD (at TRW Semiconductors) solves these process-reliability problems.

Sputtering to deposit the metals is done in a high purity-inert gas atmosphere under pressure where the mean free path to collision of the metal particle is short.

The infinite number of metal particle to gas molecule collisions cause the metal to impinge on the wafer substrate surface at every possible angle. All oxide steps are easily and reproducibly covered (both sides of the substrate could be coated at one time!). Figure 10 shows a portion of the TRW 5 watt - 3 GHz transistor.

This picture demonstrates that etchability is no longer a problem with the proprietary processes developed by TRW Semiconductors.

Sputtered PtSiTi-TUNGSTEN-GOLD forms the metallization. Step coverage and etchability is seen to be ideal, even though the device structure would be nearly impossible to process with ALUMINUM.

CONCLUSION

- TRW has Adapted the PtSiTi-TUNGSTEN-GOLD metallization system to solve the reliability problems which exist with ALUMINUM metallizations.
- The reliability problems with ALUMINUM are generally confined to R.F. power transistors designed for operation **above** 750 MHz.
- PtSiTi-TUNGSTEN-GOLD metallization system removes the question of metal-reliability with microwave R.F. transistors.
- SUMMARY OF TEST RESULTS :

Section 1 - ELECTROMIGRATION

Median lifetimes of transistor metallization can be improved over 17,000 times over ALUMINUM by using GOLD systems.

Section 2 - TEMPERATURE STABILITY

PtSi-W contacts to silicon have more than 100 times the stability of ALUMINUM contacts.

Section 3 - ELECTROLYTIC CORROSION

PtSiTi-TUNGSTEN-GOLD is over 3 1/2 times more corrosion resistant than ALUMINUM.

Section 4 - ADHESION

PtSiTi-TUNGSTEN-GOLD has better adhesion to Si and SiO_2 than ALUMINUM.

Section 5 - PROCESSING ADVANTAGES OF GOLD METAL SYSTEMS

1. GOLD metal systems are more reproducible.
2. GOLD metal systems have improved etchability.
3. GOLD metal systems, sputter-deposited, solve all oxide step coverage problems.

The conclusion to be found within this report is :

- **PtSiTi-TUNGSTEN-GOLD** is a reliable, reproducible, and highly manufacturable metallization system which can increase the reliability (lifetime) of any R.F. power transistor, especially microwave transistors which are designed for operation above 750 MHz.

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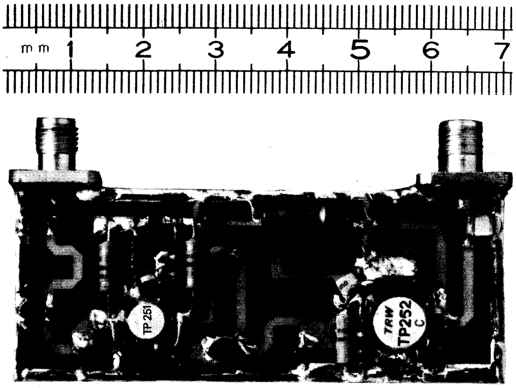
6. E. M. Ruggiero, *Ohmic Contacts Consisting of a First Level of Molybdenum-Gold Mixture of Gold and Vanadlum and a second Level of Molybdenum-Gold,* Patent 3,434,020, March 18, 1969.
7. TRW Semi conductors Test Data.

TRW® SEMICONDUCTORS **MOB-001-77**

APPLICATION NOTE N° 8



7.5V - BROADBAND AMPLIFIER

- 1,5 Watts - 20 dB -
- 400 - 512 MHz -

Introduction

For portable FM equipment, it is necessary to design RF power amplifiers supplied by low voltage batteries. The typical voltages used are 7.5 V to 9.6 V. Output power required is about 1.5 watts out of the amplifier. The most important problem is to provide very good efficiency in order to have a longer battery operating time. Small size is also required.

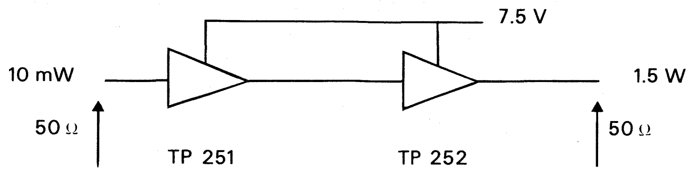
General design considerations

The design of a broadband power amplifier that will operate from a 7.5 V source and provide 1.5 W output with 50 % typical efficiency requires that careful attention be paid to impedance matching.

Performance constraints :

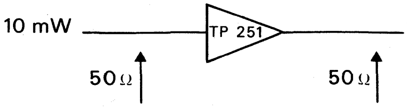
V_{CC} = 7.5 V.
P_{out} = 1.5 watts min. with 20 dB gain.
Frequency range = 400-512 MHz broadband.
Efficiency = 40 % min. 45 % to 50 % typical.
Input return loss = — 10 dB max.
Input and output load impedance = 50 ohms.

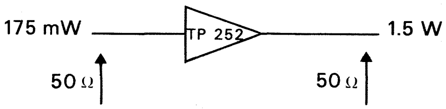
TRW's new 7.5 V transistor family offers the capability of meeting this specification with only 2 stages.



Looking at the TP 251 data sheet we can see that the real part of the output impedance is ≃ 50 ohms for 175 mW output.

For this reason we have taken the approach of designing the matching networks around each device such that each transistor is matched 50 Ω in/50 Ω out. This gives us the added advantage that, during early design, each stage may be looked at on an individual basis.





Analysis and optimization of circuits was made by computer (compact program).

Example of calculation

Since it is necessary to have a very good efficiency, as one example, we will describe the design of the output matching for the final stage TP 252.

The TP 252 data sheet gives us :

Frequency	Z_{out} (Ω)	
400 MHz	13 — j 7.5	V_{CC} = 7.5 V
470 MHz	11 — j 6	
520 MHz	10 — j 4.5	P_{out} = 1.5 W

In order to facilitate easy connection of the transistor collector lead to the circuit, it is necessary to start with a short length of line with sufficient width. For this reason a stripline L_{11} (Z_0 = 25 Ω, l = 4 mm for εr = 1) is connected at the output of the TP 252 (fig. 1). The resulting transformation of the output impedance is the following :

$$\begin{array}{ll} f^- \ 400 \text{ MHz} & \quad 12.75 - j\,6.82\ (\Omega) \\ f_0 \ 470 \text{ MHz} & Z = 10.81 - j\,5.15\ (\Omega) \\ f^+ \ 520 \text{ MHz} & \quad 9.86 - j\,3.55\ (\Omega) \end{array}$$

After normalization to Z_0 = 70 Ω (We have chosen 70 ohms transmission line in order to realize a small mechanical size). Fig. 2.

$$\begin{array}{llcll} f^- \ 400 \text{ MHz} & 0.18 - j\,0.1 & & 4.24 + j\,2.35 & \\ f_0 \ 470 \text{ MHz} & z_1 = 0.15 - j\,0.07 & \text{or} & y_1 = 5.30 + j\,2.51 & \text{with} \quad Y_0 = \frac{1}{70}\ \mho \\ f^+ \ 520 \text{ MHz} & 0.14 - j\,0.05 & & 6.31 + j\,2.30 & \end{array}$$

If we connect in parallel an admittance value — j 2.51 this improves the real impedance at f_0.
The Smith chart shows this is possible using a line L_{12} (Z_0 = 70 Ω - l = 0.06 λ) connected in parallel and with short circuit termination - fig. 2.

$$y_1 \rightarrow y_2 = \begin{array}{ll} 4.24 - j\,0.68 & f^- \\ 5.30 + j\,0 & f_0 \\ 6.31 + j\,0.03 & f^+ \end{array}$$

For f_0, the intersection with the circle y = 1.4 — jX is possible if we connect a line L_{13} (Z_0 = 70 Ω, l = 0.052 λ).

$$y_2 \rightarrow y_3 = \begin{array}{ll} 1.60 - j\,1.94 & f^- \\ 1.41 - j\,2.18 & f_0 \\ 1.09 - j\,2.21 & f^+ \end{array}$$

Admittance C_{11} y = j 2.18, Y = 31 mV (10.5 pF for f_0 = 470 MHz) completes the matching to y = 1.4 or Z = 50 Ω.

$$y_3 \rightarrow y_4 = \begin{array}{ll} 1.60 - j\,0.12 & f^- \\ 1.41 + j\,0 & f_0 \\ 1.09 + j\,0.17 & f^+ \end{array} \qquad Y_0 = \frac{1}{70}\ \mho$$

After normalization to Z_0 = 50 ohms, we can write :

$$\begin{array}{llcl} f^- = 400 \text{ MHz} & 0.87 + j\,0.066 & & 43.5 - j\,3.3\ (\Omega) \\ f_0 = 470 \text{ MHz} & z_4 = 1 + j\,0 & \text{or} & Z_4 = 50 + j\,0\ (\Omega) \\ f^+ = 520 \text{ MHz} & 1.25 - j\,0.19 & & 63.5 - j\,9.5\ (\Omega) \end{array}$$

The final circuit is the following :

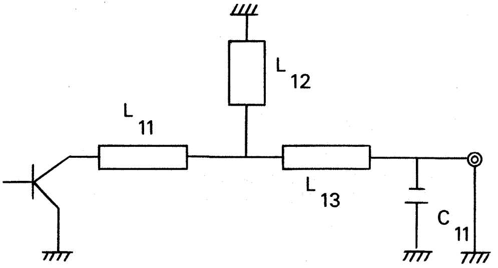


Fig. 1

L_{11} Z_0 = 25 Ω	l = 0.006 λ	εr = 1
L_{12} Z_0 = 70 Ω	l = 0.06 λ	εr = 1
L_{13} Z_0 = 70 Ω	l = 0.052 λ	εr = 1
F_{REF} = 470 MHz		
C_{11} = 10.5 pF		

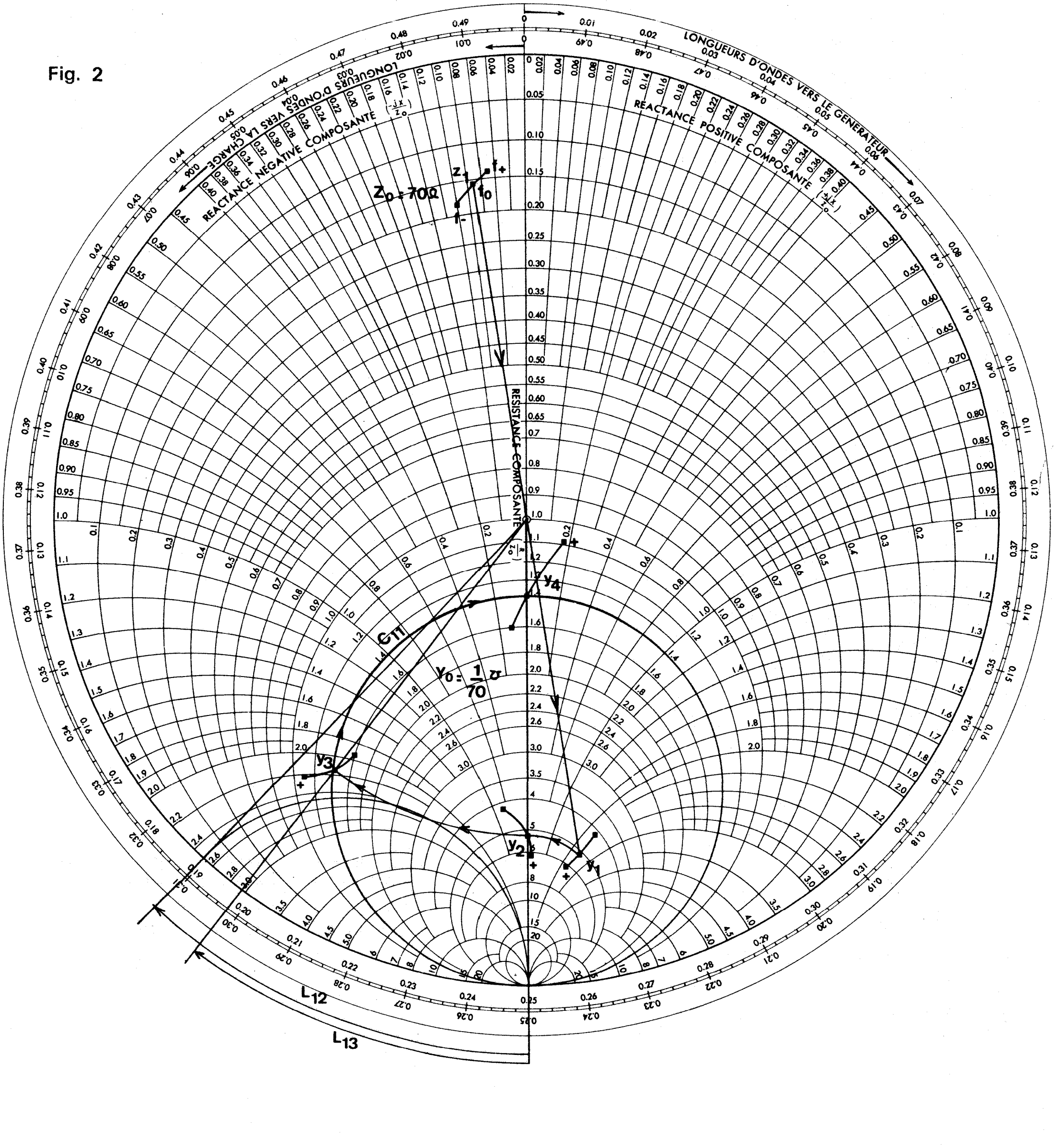
Analysis of this circuit by computer gives the following results :

Output refl. coef. and VSWR in 50. ohm system

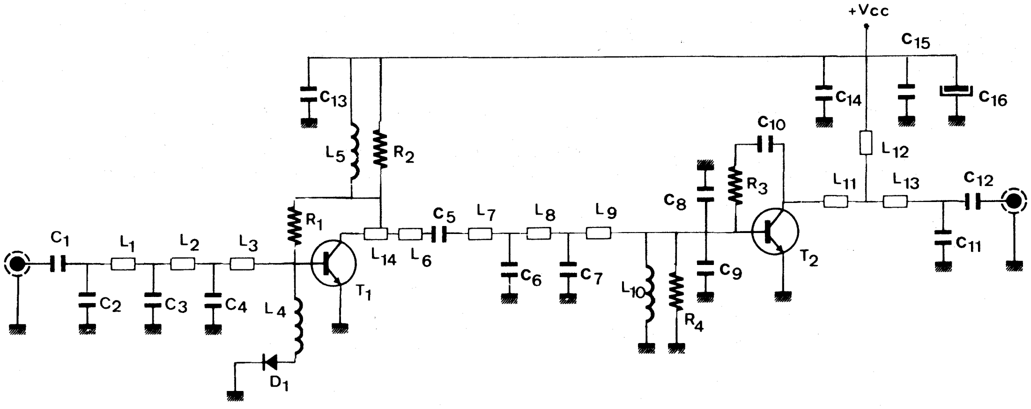
F (MHz)	Rho (magn. < angle)		VSWR	Ret L/G (dB)	Z (R + jX) ohm	
400.000	0.067	150.2	1.14 : 1	— 23.47	44.4	3.0
470.000	0.002	— 172.2	1.00 : 1	— 53.25	49.8	— 0.0
520.000	0.149	— 37.9	1.35 : 1	— 16.56	62.1	— 11.6

N.B. —
- Line L_{12} is a convenient point to supply the transistor but it is necessary to realize a good RF short circuit at this end.
- L_{12} provides a low load impedance for the transistor at low **frequencies (stability).**
- The good matching over the frequency range ensures that we acheive optimum efficiency.

Fig. 2



SCHEMATIC



List of components

C_1 = 27 pF Ceramic 632 RTC
C_2 = 8.2 pF Ceramic 632 RTC
C_3 = 18 pF Ceramic 632 RTC
C_4 = 22 pF Ceramic 632 RTC
C_5 = C_{10} = C_{12} = C_{13} = C_{14} = 1 nF Ceramic 629 RTC
C_6 = 12 pF Ceramic 632 RTC
C_7 = 15 pF Ceramic 632 RTC
C_8 = C_9 = 39 pF Ceramic Chip ATC
C_{11} = 10 pF Ceramic Chip ATC
C_{15} = 10 nF Ceramic 629 RTC
C_{16} = 10 μF/25 V Electrolytic

L_1 = Stripline Z_0 = 70 ohms 0.061 λ
L_2 = Stripline Z_0 = 70 ohms 0.026 λ
L_3 = Stripline Z_0 = 50 ohms 0.031 λ
L_4 = L_5 = L_{10} = 0.15 μH Molded Coil
L_6 = Stripline Z_0 = 100 ohms 0.045 λ
L_7 = Stripline Z_0 = 70 ohms 0.043 λ
L_8 = Stripline Z_0 = 70 ohms 0.041 λ
L_9 = Stripline Z_0 = 25 ohms 0.031 λ
L_{11} = Stripline Z_0 = 25 ohms 0.006 λ
L_{12} = Stripline Z_0 = 70 ohms 0.064 λ
L_{13} = Stripline Z_0 = 70 ohms 0.052 λ
L_{14} = Stripline Z_0 = 50 ohms 0.009 λ

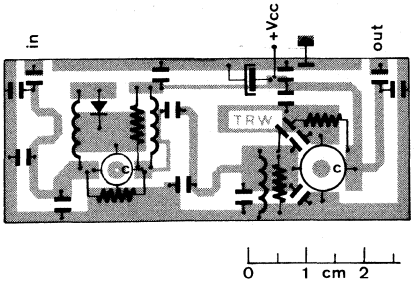
R_1 = 510 ohms 1/4 W carbon composition
R_2 = 270 ohms 1/4 W carbon composition
R_3 = 150 ohms 1/4 W carbon composition
R_4 = 10 ohms 1/4 W carbon composition

D_1 = 1 N 4001

T_1 = TP 251 TRW
T_2 = TP 252 TRW

F_{REF} = 480 MHz

Example of realisation with epoxy glass substrate



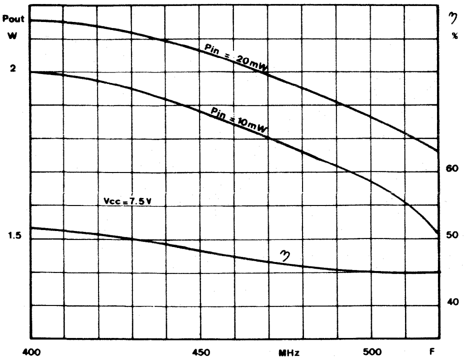
(h = 1/16″ and εr = 4.1)

Edge of the PC board must bemetallized and it is necessary to locate plated through holes underneath the emitter leads of transistors.

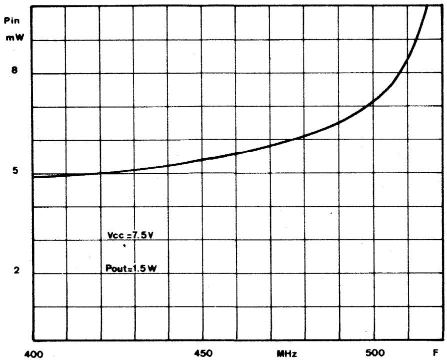
Components are mounted on the circuit side.

TYPICAL RESULTS

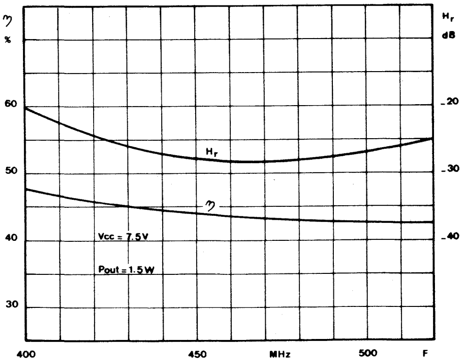
Output Power vs Frequency and Input Power



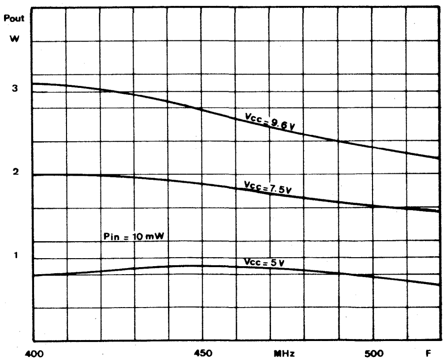
Input Power vs Frequency for 1.5 watts Output



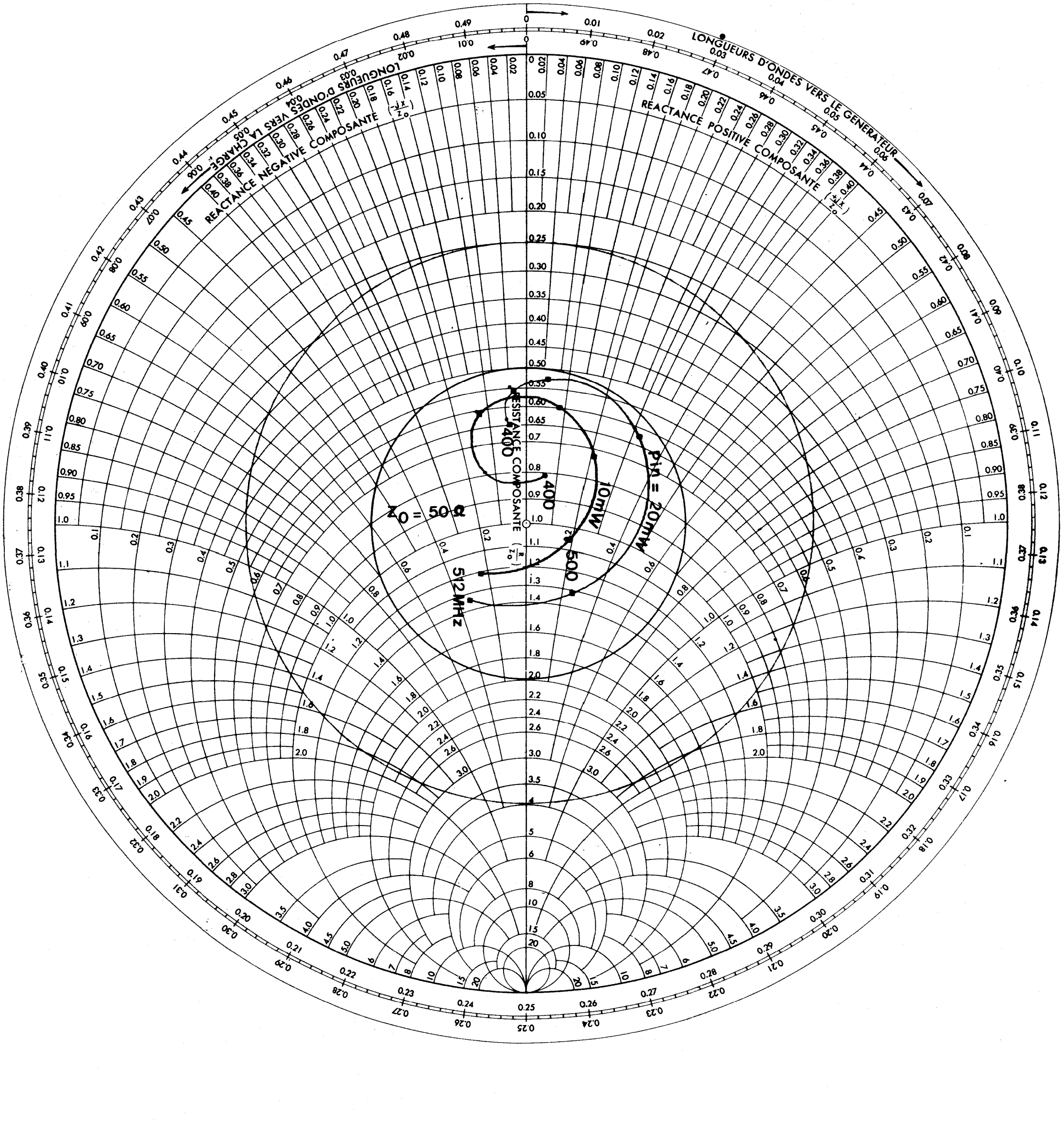
Efficiency and Harmonic Rejection vs Frequency



Output Power vs Frequency and Voltage Supply



Input Impedance vs Frequency and Input Power



Stability

To improve stability with VSWR at the output, it is necessary to put resistor (R_1 and R_3) between collector and base of transistors. In this condition, it is possible to guarantee stability with 3 : 1 VSWR all phases.

$5\ V \leqslant V_{CC} \leqslant 10\ V$ $\qquad$ P_{in} 0 to 20 mW

TRW *SEMICONDUCTORS* - **APPLICATION NOTE N° 9 - MATV-001-77**

A BROADBAND AMPLIFIER FOR MATV APPLICATIONS

200 mV; 40-860 MHz

This note describes the performance of a broadband 200 mV three stage linear amplifier designed for service in the band 40-860 MHz as MATV amplifier.

DEVICES USED

Three TP 491 (T-pack)

BASIC SPECIFICATION

Frequency range : 40-860 MHz
Gain : 29.5 ± 1.8 dB
Noise figure : 6 dB at 500 MHz
Input and output impedances : 75 Ω
VSWR input $\leqslant$ 3 : 1
VSWR output $\leqslant$ 1.7 : 1
IMD* $\leqslant$ — 60 dB at 200 mV and 500 MHz
Supply voltage : 12 V
Supply current : 70 mA
* DIN 45004/B

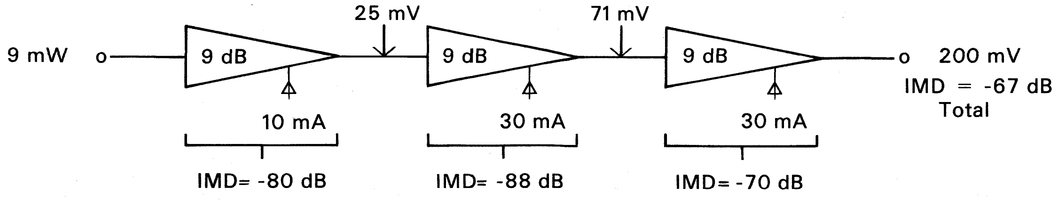
GENERAL CONSIDERATIONS

The aim was to design a low cost broadband amplifier for MATV using the TP 491 (T-pack) transistor. With a typical gain of 11.5 dB for the TP 491 at 860 MHz, we can expect for a broadband amplifier using negative feedback to stabilize the gain over the bandwidth, about 9 dB per stage. This gives about 27 d B for the total amplifier. The collector currents of the two last stages were chosen to obtain good distortion performance (I_E = 30 mA) and the first stage current was chosen as a compromise between noise figure and distortion (I_E = 10 mA) :

at 10 mA : — NF = 2 dB (with optimum noise source impedance).
— IMD = — 80 dB for 25 mV output voltage.

From the IMD versus Ic curve on the data sheet and using the approximate rule that the IMD/output power slope is 2 dB/1 dB, we can estimate the IMD at 500 MHz of each stage and then by adding the IMD vectors (they have the same phase for the 3rd order distortion) we can estimate the total IMD at 500 MHz.

$$IMD_{Total} = 20 \log (10^{-80/20} + 10^{-88/20} + 10^{-70/20}) = -67 \text{ dB}$$



In order to obtain a good IMD performance we have tried to optimize the output VSWR for each stage.

The noise figure is not easy to estimate since :

— the amplifier is not optimized for noise but to have a relatively good input match, which means the noise source impedance is not optimized,

— the negative feedback is achieved using resistors which increases the noise figure.

If a low noise figure is required without IMD consideration, we must modify the first stage by reducing the current which should be optimized for noise performance.

AMPLIFIER DESIGN

The amplifier consists of three identical basic stages called CC on figure 1, using shunt feedback and serie feedback to stabilize the gain-frequency characteristic, and single matching networks for the input, interstage and output matching.

The calculation using the S-parameters of TP 491, was done with the aid of a computer and the COMPACT program, which is an analysis and optimization program for passive and active circuits. The program, the final values and the final analysis are shown in figures 1, 2 and 3.

The difficulty with this kind of amplifier is that we use lumped elements up to 860 MHz. Unfortunately their behaviour above 500 MHz tends to deviate from the theoretical, which means we have to optimize the more critical elements empirically.

Figure 8 shows the empirical schematic.

Figure 3 shows the difference between calculated and empirical values.

Calculated gain : see figure 4

Calculated Zin : see figure 5

Calculated Zout : see figure 6

AMPLIFIER PERFORMANCE

- — Gain versus frequency : Figure 4
- — Input impedance : Figure 5
- — Output impedance : Figure 6
- — NF at 500 MHz : 6 dB
- — IMD versus output voltage : Figure 7
- — Bias conditions : Vcc = 12 V I_{Total} = 70 mA

TECHNOLOGY AND LAYOUT CONSIDERATIONS

Epoxy-glass 1/16 inch (Er = 4.1) is used as board material but no transmission line is used and the substrate can therefore be changed without changing the PC board layout.

- — Schematic : Figure 8
- — PC board layout : Figure 9

RF EQUIVALENT CIRCUIT FOR COMPACT PROGRAM

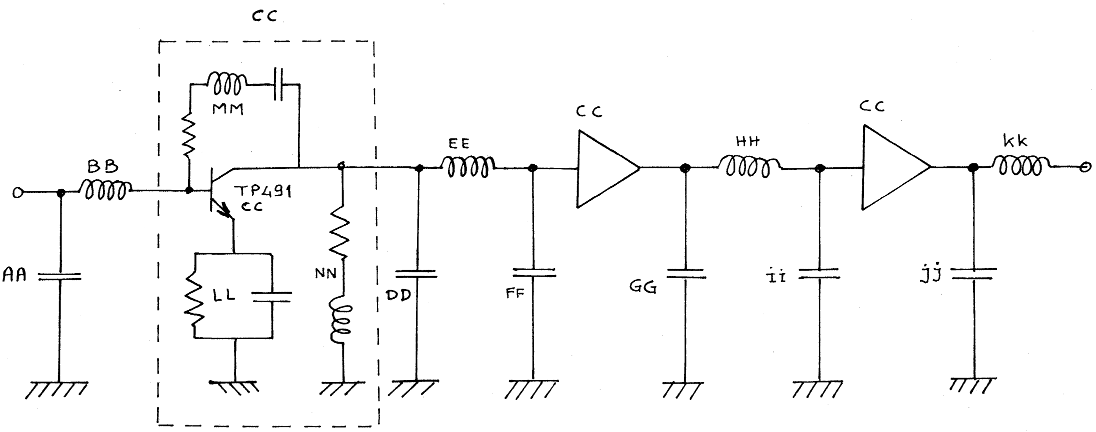


Figure 1

COMPACT PROGRAM

```
CAP  AA  PA  — 4.038
IND  BB  SE  — 6.694
TWØ  CC  S1    50.00
PRC  LL  PA  — 9.448       — 12.24
SER  CC  LL
SRX  MM  SE  — 265.9         4.300       56.00
PAR  CC  MM
SRL  NN  PA    91.00         120.0
CAS  CC  NN
CAP  DD  PA    1.400
IND  EE  SE    4.400
CAP  FF  PA    3.200
CAS  FF  CC
CAP  GG  PA    1.800
IND  HH  SE    28.10
CAP  II  PA    1.700
CAS  II  CC
CAP  JJ  PA  — 2.594
IND  KK  SE  — 6.709
CAX  AA  KK
PRI AA   S1    75.00
END
```

CIRCUIT DEFINITION
(— : variables)

```
40  100  200  500  750  900
END
```

FREQUENCY (MHz)

```
.599 320 28.5  105  .0113 61 .75    330
.450 278 17.78 122  .0159 63 .66    342
.333 225 11.09 105  .0224 65 .517   341
.267 196 5.37  76   .0562 68 .5119  335
.271 176 4.08  71   .0768 66 .515   329
.279 164 3.31  68.5 .0891 65 .517   325
END
```

POLAR S-PARAMETERS
FOR TWO CC (TP 491)

```
1
10  10  1  29
END
```

OPTIMIZATION DATA

```
 VARIABLES                 GRADIENTS

(1) : 4.03804            ( 1) :    .213757
( 2) : 6.69433           ( 2) :    .126163E-01
( 3) : 9.44751           ( 3) : — 1.20523
( 4) : 12.2431           ( 4) :    .472764
( 5) : 265.861           ( 5) :    1.02654
( 6) : 2.59366           ( 6) :    .605981E-02
( 7) : 6.70918           ( 7) :    .131875
ERR. F. =     2.651
```

```
SEARCH  INTERRUPTED, FINAL ANALYSIS FOLLOW

                         POLAR S-PARAMETERS IN 75.0 OHM SYSTEM

FREQ.         S11              S21                S12                S22           S21      K
         (MAGN<ANGL)     (MAGN<ANGL)        (MAGN<ANGL)        (MAGN<ANGL)       DB     FACT.

  40.00   0.13 < — 122   30.38 <    124.4   0.002 <     28.1   0.31 <    179    29.65    6.48
 100.00   0.19 < — 135   25.34 <    125.9   0.003 < —    0.4   0.28 <    170    28.08    6.20
 200.00   0.19 < — 133   30.51 <     65.7   0.003 < —   42.2   0.30 < — 167    29.69    4.47
 500.00   0.64 < — 148   27.23 < — 111.5   0.002 < — 117.7   0.39 <     89    28.70    4.77
 750.00   0.56 <   159   30.05 <    150.6   0.003 < — 153.2   0.13 <     15    29.56    4.45
 900.00   0.23 <    15   26.15 <     41.3   0.004 <    144.5   0.18 < — 156    28.35    4.77
```

Figure 2

ELEMENT VALUES

		Calc. Value	Empirical Value
AA	pF	4.0	1.8
BB	nH	6.7	5 + parasitic
CC	Transistor	TP 491	TP 491
LL	Ω	9.4	10
	pF	12.2	13.8
MM	Ω	266	300
	nH	4.3	10 + parasitic
	pF	56	56
NN	Ω	91	91
	nH	120	120
DD	pF	1.4	1.8
EE	nH	4.4	10 + parasitic
FF	pF	3.2	1.2
GG	pF	1.8	0
HH	nH	28.1	2 + parasitic
II	pF	1.7	2.7
JJ	pF	2.6	1.2
KK	nH	6.7	10 + parasitic

Figure 3

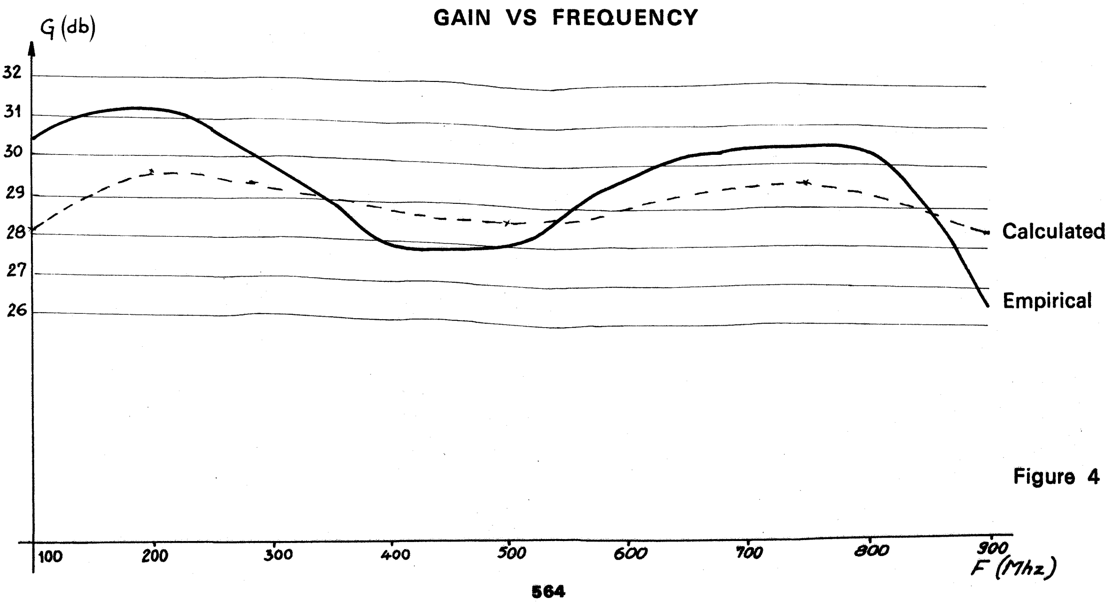

GAIN VS FREQUENCY

Figure 4

INPUT IMPEDANCE

o——o——o Empirical value

△- -△- -△ Calculated value

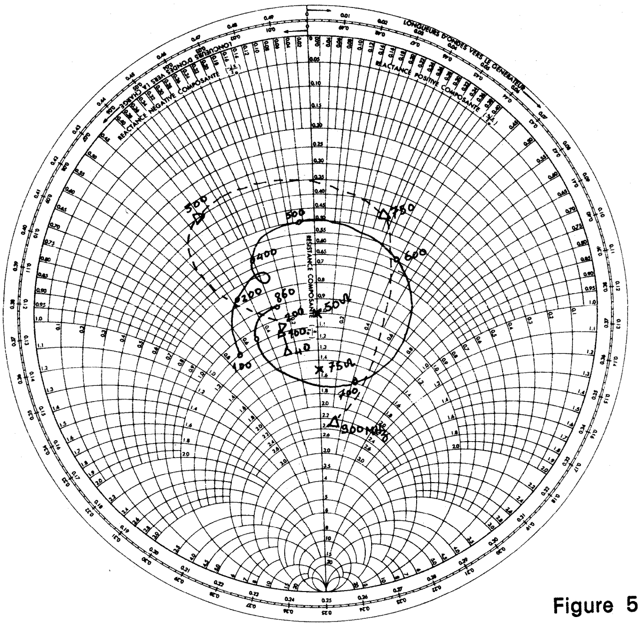


Figure 5

OUTPUT IMPEDANCE

o——o——o Empirical value

△- - △- -△ Calculated value

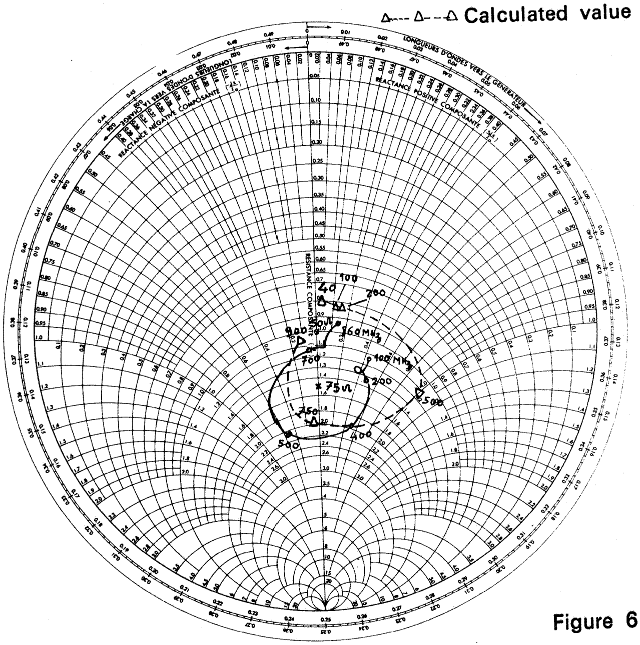
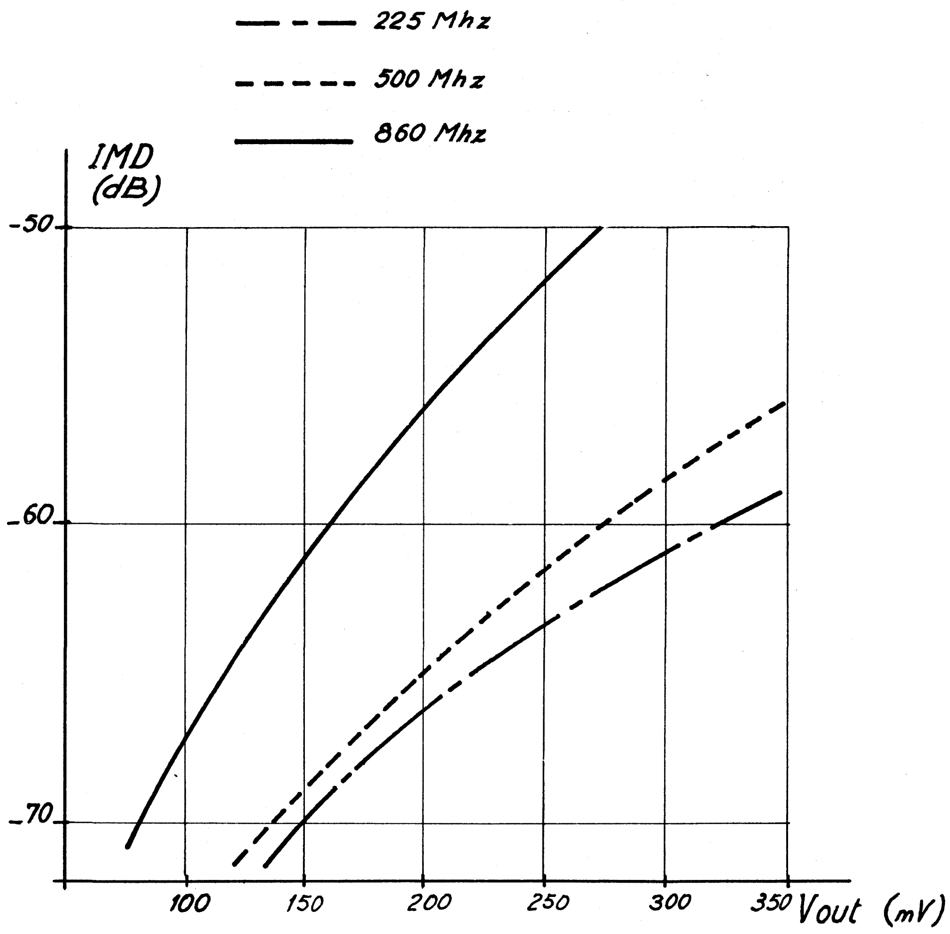
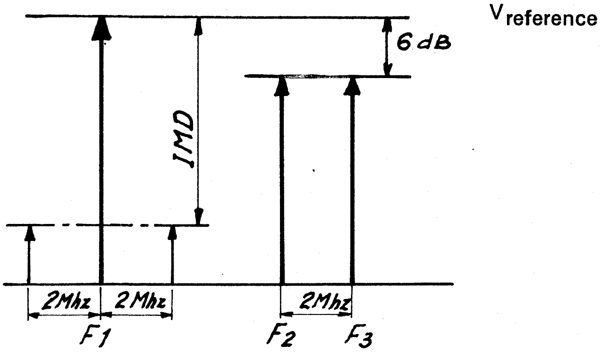


Figure 6

IMD* VS FREQUENCY AND OUTPUT VOLTAGE



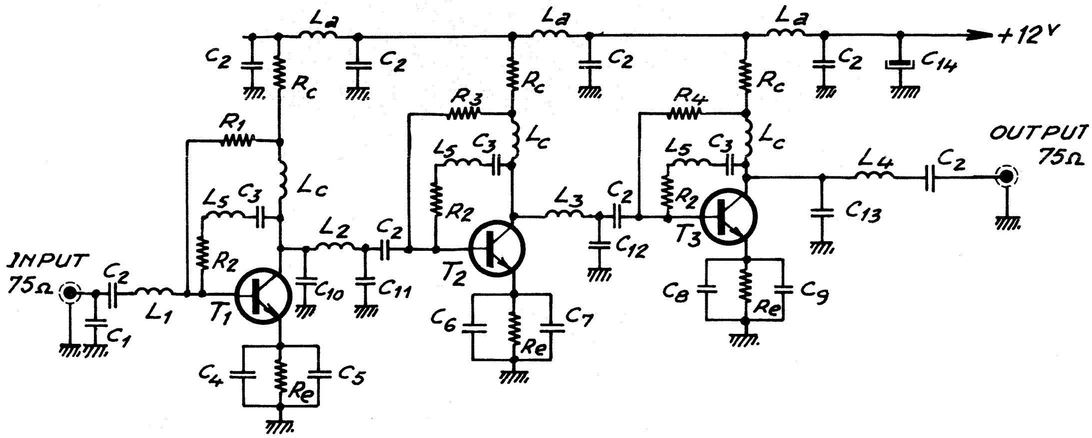
* DIN 45004 B



TRW-CE

Figure 7

DIAGRAM CIRCUIT



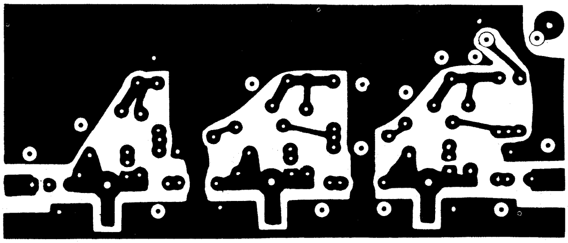
R_e	10 Ω 1/4 W metal-film resistor
R_c	91 Ω 1/4 carbon-composition
R_1	100 kΩ 1/4 W carbon-composition
R_2	300 Ω 1/4 W carbon-composition
R_3	33 kΩ 1/4 W carbon-composition

Capacitor-ceramic

C_1	1.8 pf C632 RTC
C_2	10 nf C629 RTC
C_3	56 pf C632 RTC
$C_4C_6C_8$	8.2 pf C632 RTC
C_5C_7	5.6 pf C632 RTC
C_9	6.8 pf C632 RTC
C_{10}	1.8 pf C632 RTC
$C_{11}C_{13}$	1.2 pf C632 RTC
C_{12}	2.7 pf C632 RTC
C_{14}	50 µf 25 volts
L_1	1 turn 5/10 mm Cu ID 4 mm 5 nh
$L_2L_4L_5$	2 turns 5/10 mm Cu ID 3 mm 10 nH
L_5	1/2 turn 5/10 mm Cu ID 3 mm 2 nH
L_a	0.33 µH molded coil
L_c	120 nH 14 turns 7/10 enameled wire ID 3 mm
$T_1.T_2.T_3$	TP 491 TRW-CE

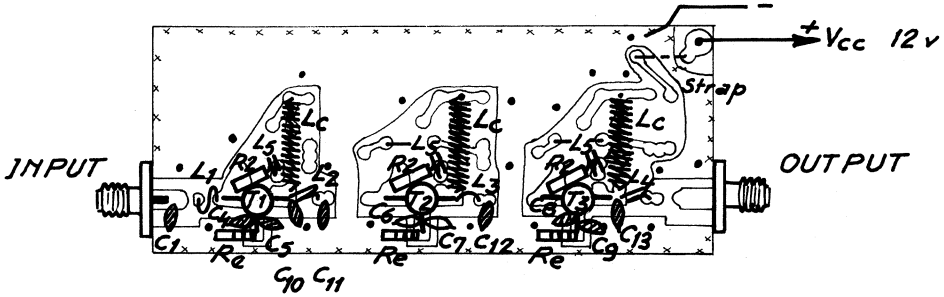
Figure 8

PC BOARD LAYOUT



COMPONENT LAYOUT

Topside



BOARD MATERIAL : EPOXY GLASS (G 10) 1/16 inch $\varepsilon_r \simeq 4.2$

● Strap between the planes. **** Foil wrap or plate around to ground plane.

Back side

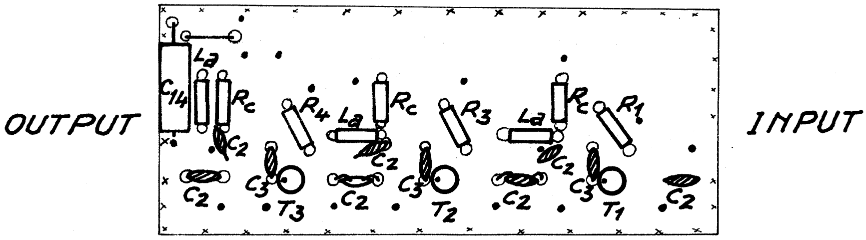


Figure 9

TRW® *SEMICONDUCTORS* — **APPLICATION NOTE N° 10 — TV-002-77**

1 W/2 W BROADBAND TV AMPLIFIER BAND IV & V

This note describes the performance of a broadband (470-860 MHz) ultra linear amplifier designed for service in band IV and V T.V. transposers.

Device used : TPV 597

Basic specifications

IMD (1) = — 60 dB at $P_0 = 1$ W
V_{ce} = 20 V; I_e = 440 mA
P_{gain} = 11.5 dB.

(1) Vision carrier — 8 dB, sound carrier — 7 dB, sideband signal — 16 dB.

General design considerations

In general to obtain a flat gain for broadband amplifiers which use transistors with about — 6 dB power gain variation per octave we can use two techniques :

- feedback technique (eg emitter resistor and a negative feedback with a selective circuit between the collector and the base),
- or reflect the input or the output power selectivly to have an insertion loss of 6 dB per octave with 0 dB for the highest frequency.
  (There is also another technique which uses a selective attenuator).

With the feedback technique we can have a good input and output match. With the second technique we need to reflect the input power and have a good output match in order to obtain a good IMD. It means the input VSWR is very high for the low frequencies.

The second solution is simpler than the first and if we use two amplifiers connected together with 3 dB quadrature hybrids to have a balanced amplifier this inconvenience disappears. We have chosen for this amplifier this second solution. For the larger broadband amplifier (eg 170-860 MHz) this solution must be rejected and the only acceptable solution is to use the feedback technique.

Amplifier design

The first approach fcr the circuit calculation was made by using the Smith Chart from the input and output impedances given in the TPV 597 data sheet to have, at the input, a reflected power so that the gain will be flat and at the output to obtain the best match possible.

INPUT VSWR VERSUS FREQUENCY TO OBTAIN A FLAT GAIN :

The power gain can be approximated by :

$$G \simeq \left(\frac{F_{max}}{F}\right)^2$$

F_{max} is the frequency for which power gain drops to unity.

The transmission loss due to the input reflection is :

$$\alpha = 1 - |\rho|^2$$

ρ is the reflection coefficient.

To have $G\alpha$ constant we must have :

$$G\alpha \simeq \left(\frac{F_{max}}{F}\right)^2 [1 - |\rho|^2] = G_H = \left(\frac{F_{max}}{F_H}\right)^2$$

G_H is the gain at the highest frequency used (F_H)

or

$$|\rho| \simeq \left[1 - \left(\frac{F}{F_H}\right)^2\right]^{1/2}$$

$$\text{VSWR} = \frac{1 + |\rho|}{1 - |\rho|} \simeq \frac{1 + \left[1 - \left(\frac{F}{F_H}\right)^2\right]^{1/2}}{1 - \left[1 - \left(\frac{F}{F_H}\right)^2\right]^{1/2}}$$

Figure 1 shows the theoritical VSWR versus frequency with an insertion loss of 0 dB (implies $\rho = 0$) for 860 MHz.

We have defined the input circuit from the TPV 597 input impedance to have an input VSWR as close as possible to this curve, and have assumed that output circuit losses versus frequency is negligeable.

After we have calculated separatly the input and the output circuits, we optimized some of the parameters by means of the global amplifier and the TPV 597 S-parameters, with the COMPACT Program.

- RF equivalent circuit : Figure 2
- Program : Figure 3
- Calculated gain and empirical gain : Figure 4
- Calculated and empirical input VSWR : Figure 5
- Calculated and empirical output VSWR : Figure 6

Amplifier Performance

- IMD versus output power : Figure 7
- IMD versus frequency : Figure 7'
- Input return loss and VSWR : Figure 5
- Output return loss and VSWR : Figure 6
- Gain versus frequency : Figure 4
- Bias conditions : $V_{ce} = 20$ V ; $I_e = 440$ mA

Technology and layout considerations

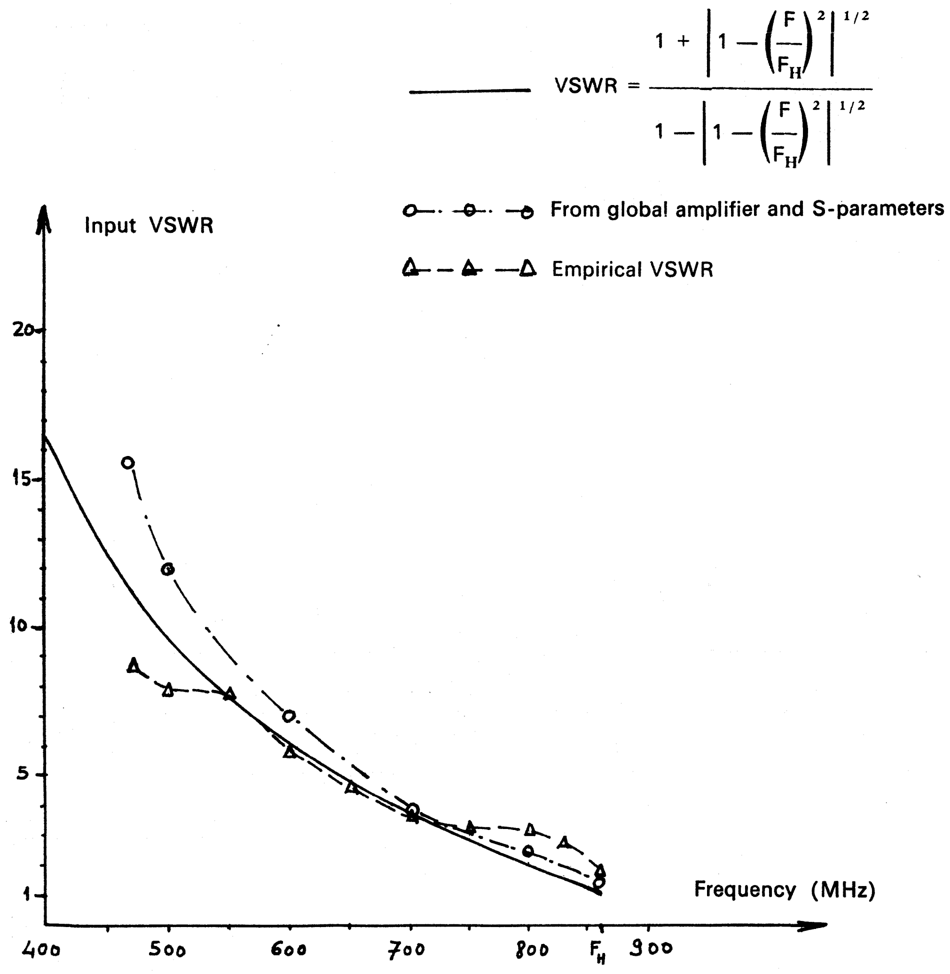
- The glass Teflon 1/16 inch ($\varepsilon_r = 2.55$) is used as board material. This substrat is soldered to the heat sink to have a good contact and repeatable results.

Figure 8 shows the circuit diagram and the bias circuit ; figure 9 shows the PC board layout.

Combined - Transistor Stage

In many instance the power output requirements of transposers exceed the capability of a single transistor, which forces the designer to use combinations of transistors. They can be combined by pair with quadrature combiners (See figure 10). Since quadrature combiners have the ability to channel the reflected power from the amplifier into the fourth port of the combiner it means the input and output VSWR become very low (VSWR < 1.2). The power gain is reduced due to the couplers insertion loss by 0.6 dB. Coupler imbalance should also be taken into account as causing some IMD degration.

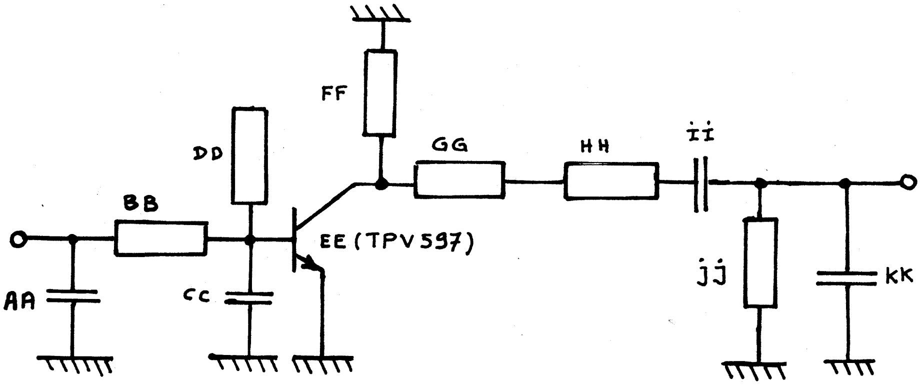
INPUT VSWR



$$\mathrm{VSWR} = \frac{1 + \left|1 - \left(\frac{F}{F_H}\right)^2\right|^{1/2}}{1 - \left|1 - \left(\frac{F}{F_H}\right)^2\right|^{1/2}}$$

Figure 1

RF EQUIVALENT CIRCUIT
FOR COMPACT PROGRAM



	AA	BB		CC	DD		FF	
	pF	Z_0 (Ω)	L (mm)	pF	Z_0 (Ω)	L (mm)	Z_0 (Ω)	L (mm)
Calc. value	4.5	50	32.0	29.3	25	14	50	72.2
Empirical value	4.7	50	45.4	10.0	25	14	50	34.9

	GG		HH		II	JJ		KK
	Z_0 (Ω)	L (mm)	Z_0 (Ω)	L (mm)	pF	Z_0 (Ω)	L (mm)	pF
Calc. value	110	28.4	45	14	5.1	75	50	3.5
Empirical value	110	27.9	45	14	3.9	75	38.4	3.3

L are given for $\varepsilon_r = 1$.

Figure 2

COMPACT PROGRAM

```
MET  AA  ZZ
CAP  AA  PA   — 4.61
TRL  BB  SE   50  — 41.64  1
CAP  CC  PA   — 25.39
ØST  DD  PA   25   14  1
TWØ  EE  S1   50
SST  FF  PA   50  — 63.43  1                    CIRCUIT
TRL  GG  SE   110  28.44  1                     DEFINITION
TRL  HH  SE   45  14  1
CAP  II  SE   — 5.134
SST  JJ  PA   75  49.98  1
CAP  KK  PA   — 4.129
CAX  AA  KK
PRI  AA  SI   50
END

470  500  600  700
800  860                                        FREQUENCY (MHz)
END

.92  176  2.38  72  .033  31  .55  — 166
.91  175  2.21  71  .034  33  .54  — 167
.93  171  1.80  63  .037  34  .56  — 170        POLAR S PARAMETERS
.93  170  1.57  59  .039  36  .59  — 168        FOR TWØ EE (TPV 597)
.92  169  1.40  54  .043  38  .58  — 165
.91  167  1.30  52  .045  40  .58  — 166
END

.5
0  100  1  12                                   OPTIMIZATION DATA
100  100  2  12
END

VARIABLES (—)                 GRADIENTS

  (1) : 4.51899               (1) : — .894864
  (2) : 32.0136               (2) :    .704452E-01
  (3) : 29.2938               (3) :   2.69282
  (4) : 72.2399               (4) :    .287748
  (5) : 5.16145               (5) :   1.68585
  (6) : 3.53445               (6) : — .267730
  ERR. F. =   7.809

HOW MANY ITERATIONS BEFORE NEXT STOP? , O ' RESULTS IN FINAL ANALYSIS.
WANT INTERMEDIATE PRINTS (YES = 1' NO = 0)? TYPE TWO NUMBERS : (I, J) : 0
SEARCH INTERRUPTED, FINAL ANALYSIS FOLLOWS :

                    POLAR S-PARAMETERS IN  50.0 OHM SYSTEM

FREQ.        S11               S21               S12                S22           S21     K
        (MAGN <ANGL)      (MAGN <ANGL)      (MAGN <ANGL)       (MAGN <ANGL)       DB    FACT.

470.00   0.88 <    134    3.53 <    86.3    0.049 <    45.3    0.11 <    105    10.97   0.75
500.00   0.85 <    128    3.46 <    68.4    0.053 <    30.4    0.12 <    109    10.79   0.90
600.00   0.75 <     92    4.19 <    12.2    0.086 < —  16.8    0.05 <      5    12.45   0.78
700.00   0.59 <     55    4.48 < —  39.2    0.111 < —  62.2    0.19 < — 127    13.02   0.78
800.00   0.43 <     11    4.34 < —  93.2    0.133 < — 109.2    0.26 <    180    12.75   0.86
860.00   0.20 < —   44    4.08 < — 135.2    0.141 < — 147.2    0.26 <    114    12.22   1.01
```

Figure 3

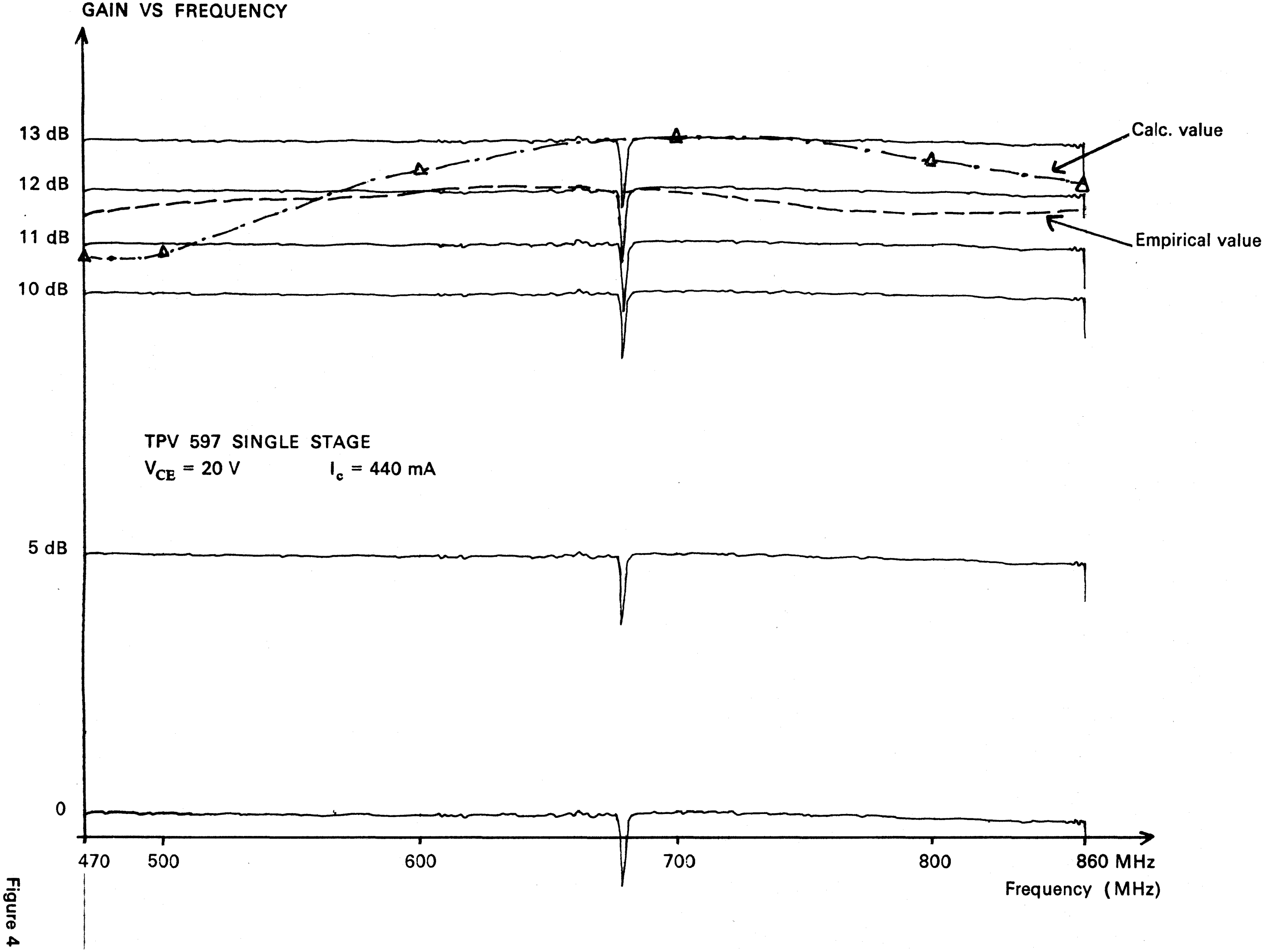

GAIN VS FREQUENCY
13 dB
12 dB
11 dB
10 dB
5 dB
0
Calc. value
Empirical value
TPV 597 SINGLE STAGE
V_{CE} = 20 V
I_c = 440 mA
470
500
600
700
800
860 MHz
Frequency (MHz)

Figure 4

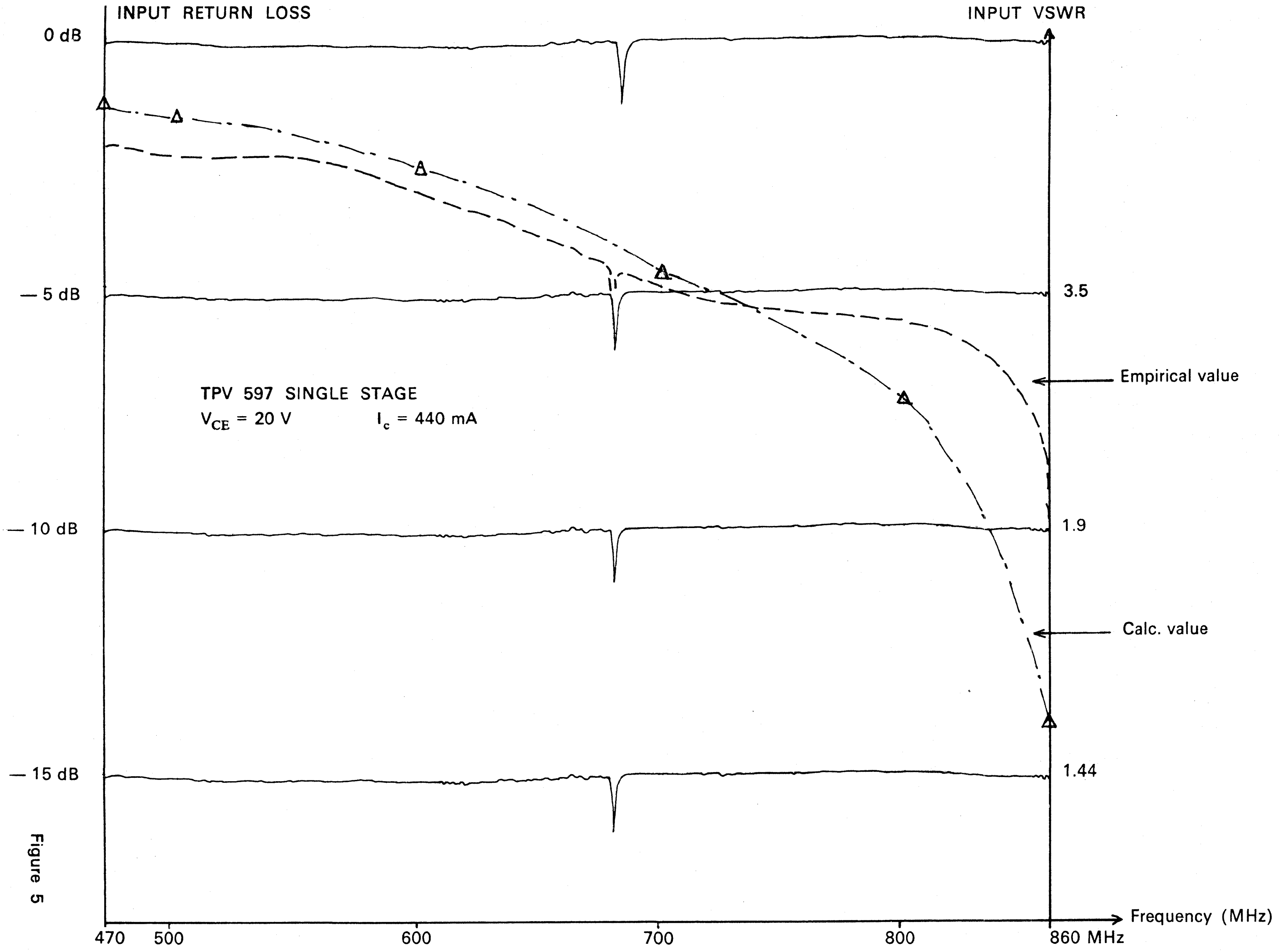

INPUT RETURN LOSS
INPUT VSWR
0 dB
— 5 dB
— 10 dB
— 15 dB
3.5
1.9
1.44
Empirical value
Calc. value
TPV 597 SINGLE STAGE
V_{CE} = 20 V
I_c = 440 mA
Frequency (MHz)
470
500
600
700
800
860 MHz

Figure 5

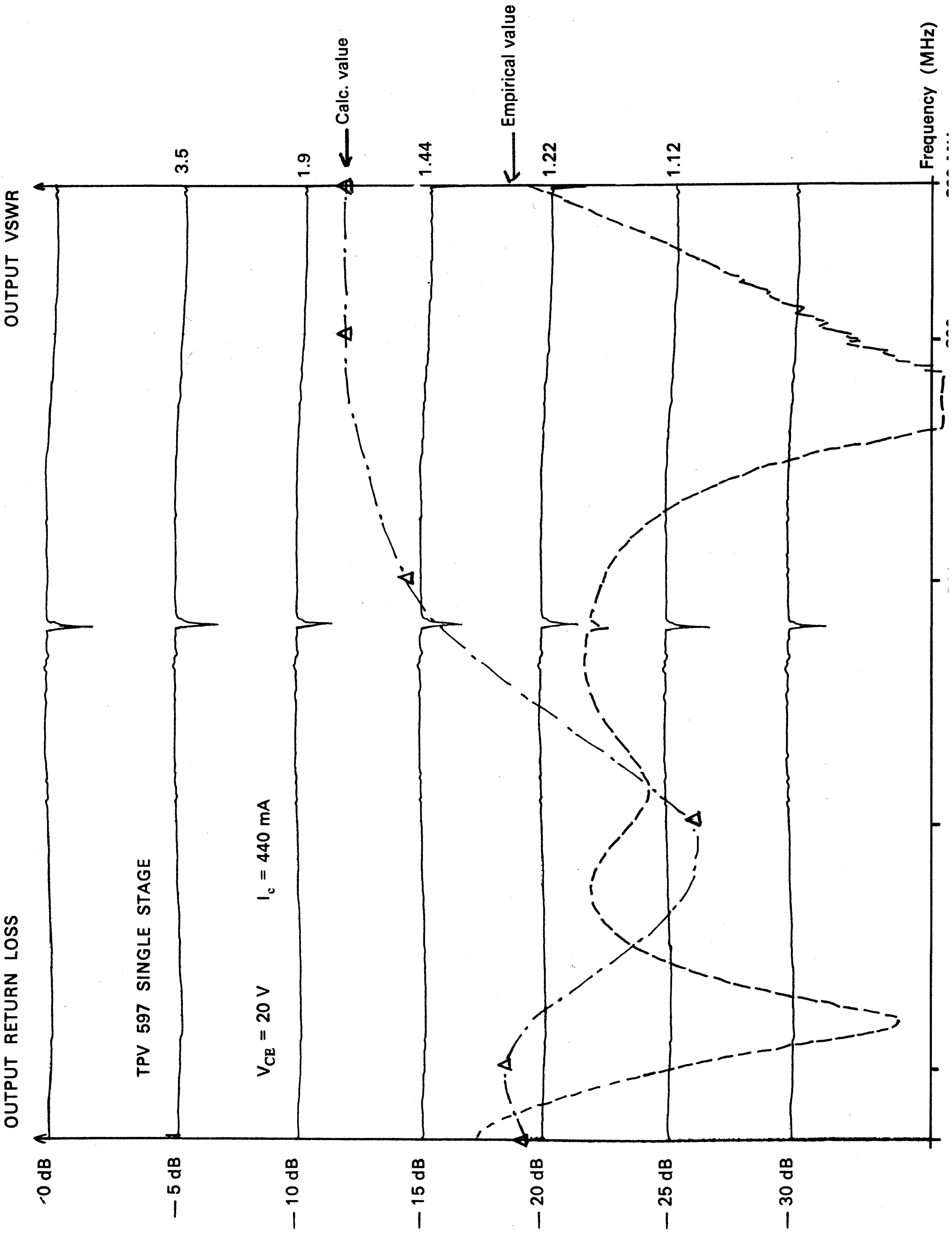

OUTPUT RETURN LOSS
OUTPUT VSWR
TPV 597 SINGLE STAGE
V_{CE} = 20 V
I_c = 440 mA
-0 dB
— 5 dB
— 10 dB
— 15 dB
— 20 dB
— 25 dB
— 30 dB
3.5
1.9
1.44
1.22
1.12
Calc. value
Empirical value
Frequency (MHz)

Figure 6

IMD VS PEAK SYNCH OUTPUT

TPV 597 Single Stage

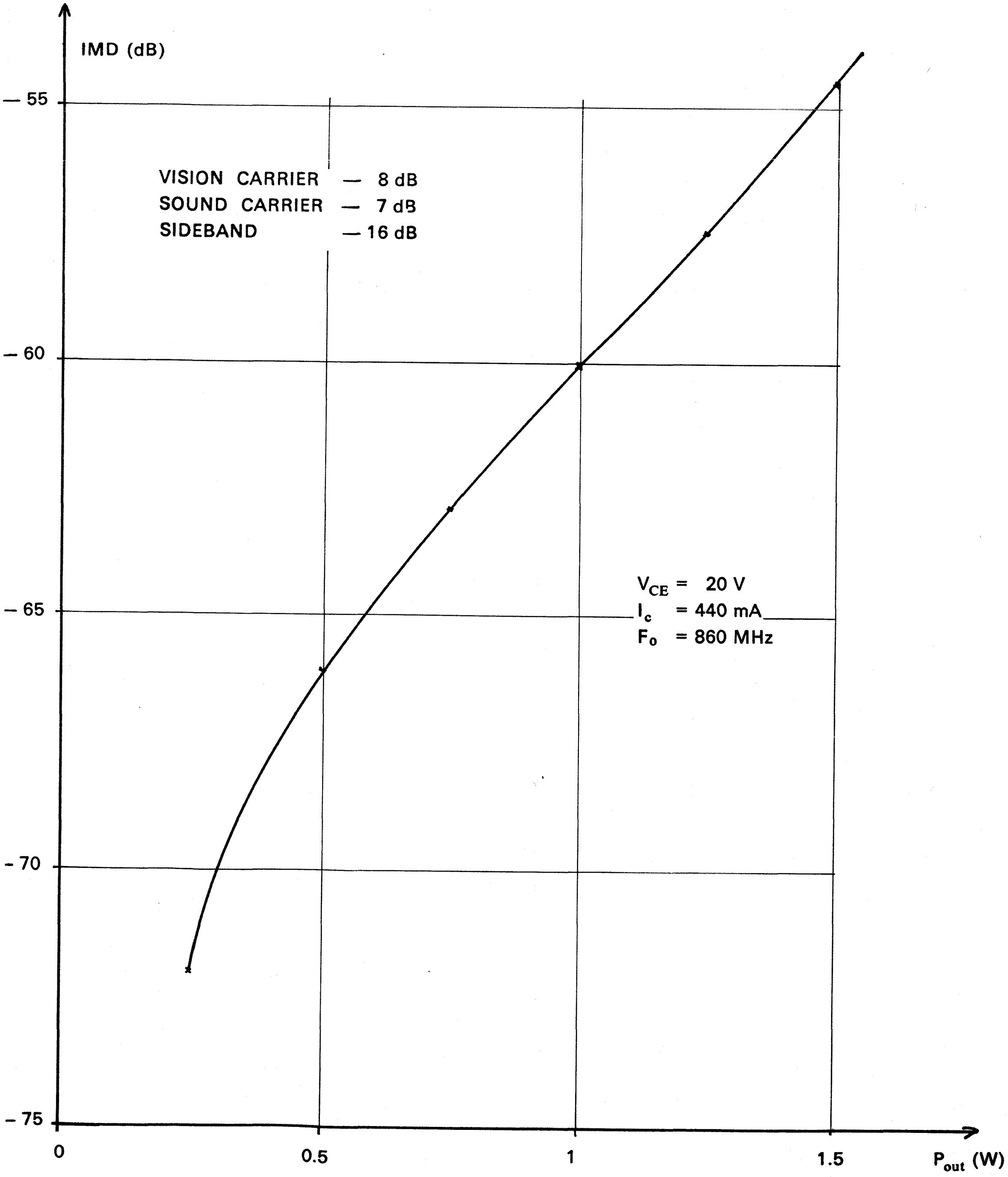


Figure 7

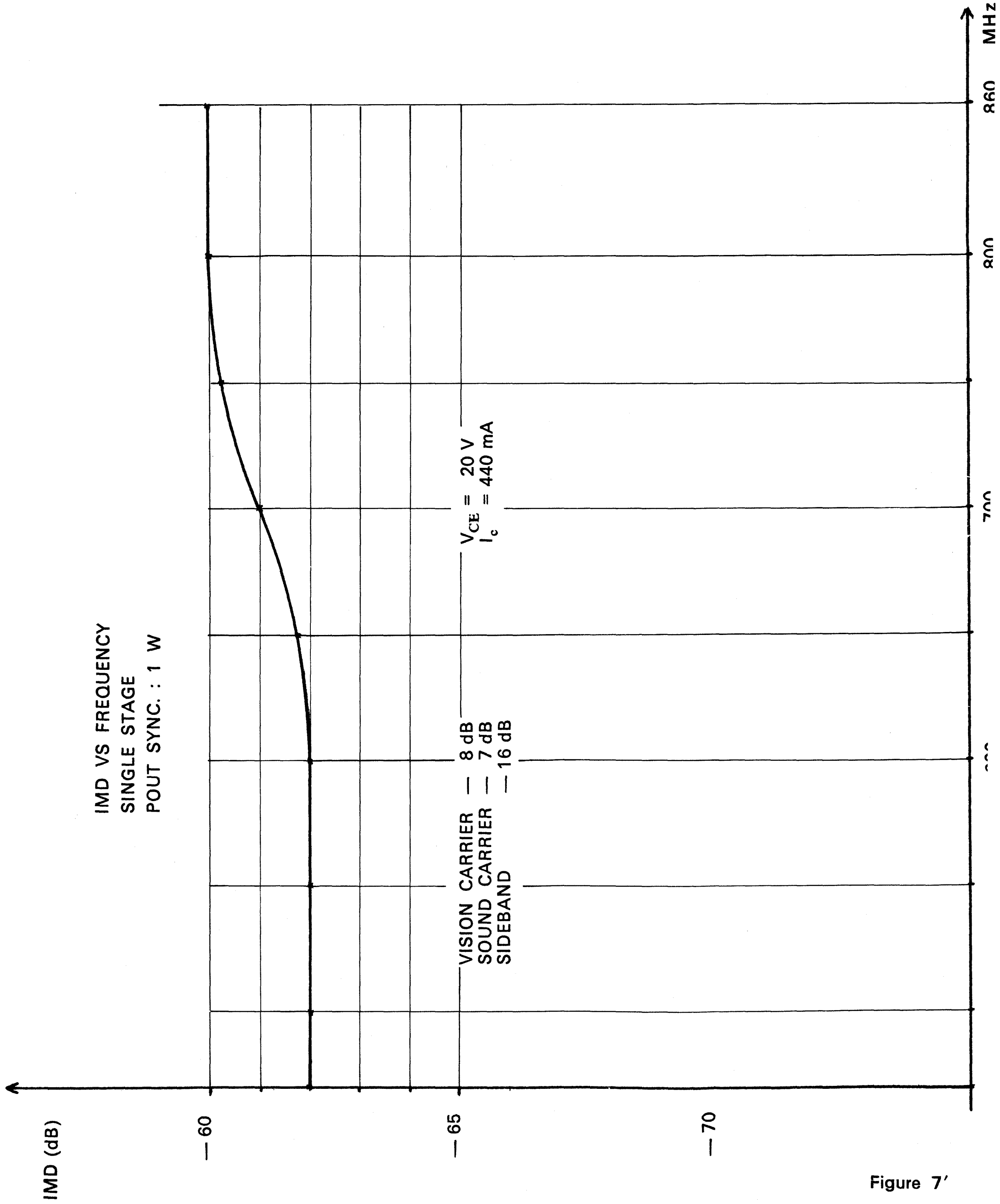
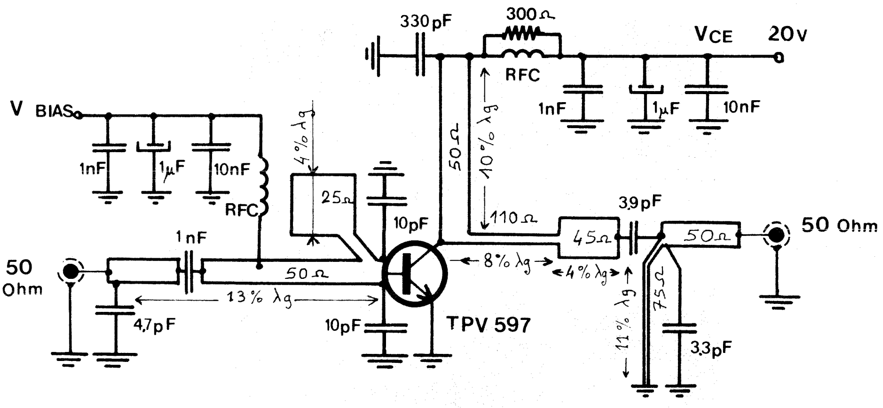

IMD VS FREQUENCY
SINGLE STAGE
POUT SYNC. : 1 W
VISION CARRIER — 8 dB
SOUND CARRIER — 7 dB
SIDEBAND — 16 dB
V_{CE} = 20 V
I_c = 440 mA
IMD (dB)
—60
—65
—70
860
800
700
MHz

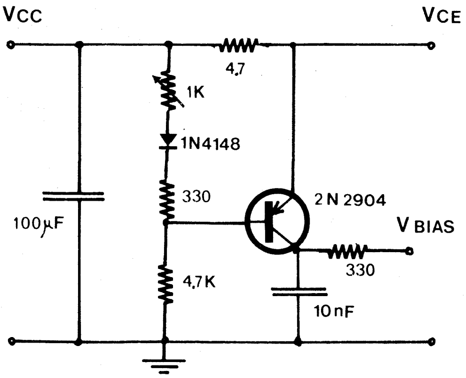
Figure 7′

DIAGRAM CIRCUIT



Lengths are given at F_0 = 860 MHz $\left(\lambda g = \frac{3.10^8}{F_0 \sqrt{\varepsilon_{eff}}}\right)$

Glass teflon E_r = 2.55   1/16″ used by TRW.

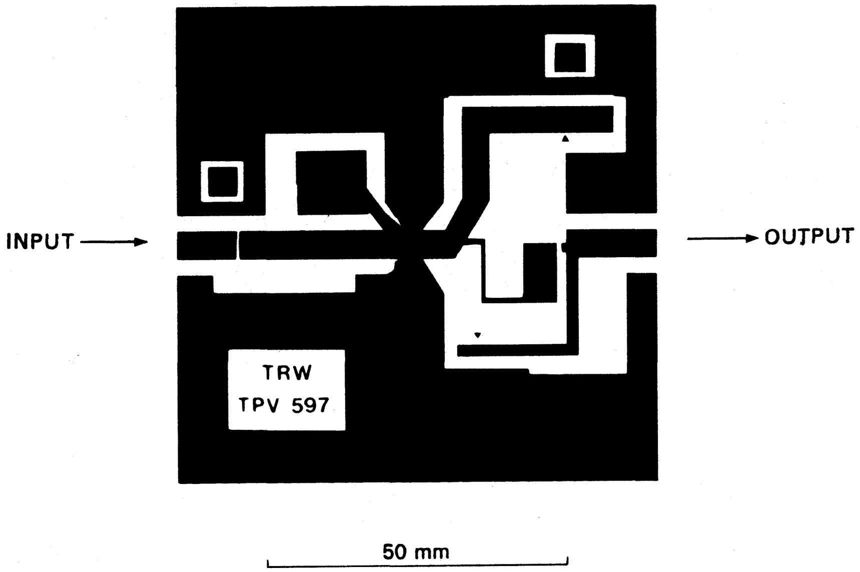


CLASS A BIAS CIRCUIT

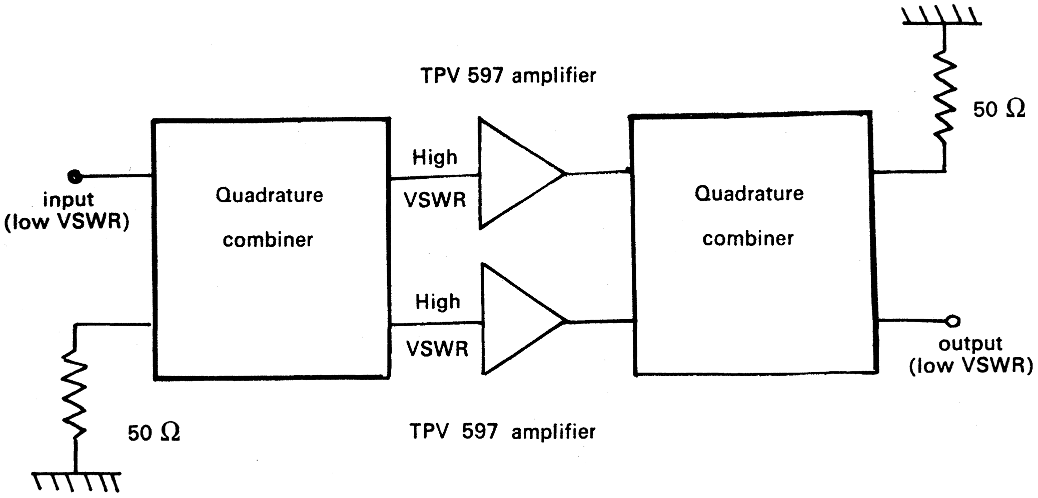
Figure 8

PC BOARD LAYOUT

Board material : Glass Teflon ; 1/16 inch ; $\varepsilon_r = 2.55$



TWO BROADBAND AMPLIFIERS COMBINED WITH QUADRATURE COMBINERS



The 3 dB quadrature combiners can be supplied by :

- ANAREN (10 264-3)
- SAGE wireline (4450900)

Figure 10

TRW® SEMICONDUCTORS — APPLICATION NOTE N° 11 — TV-003-77

35/50 WATT BROADBAND (160-240 MHz)

PUSH-PULL TV AMPLIFIER BAND III

This note describes the performance of a broadband ultra linear push pull amplifier designed for service in band III TV transposers and transmitters.

Devices used : two TPV 375.

Basic amplifier specifications :

IMD (1) = — 51 dB at P_0 = 35 W
IMD (1) = — 48 dB at P_0 = 50 W
V_{ce} = 28 volts ; Total = 4.4 A
P_{gain} = 10 dB
input VSWR : < 1.6
output VSWR : < 1.5

(1) vision carrier — 8 dB, sound carrier — 7 dB, sideband signal — 16 dB.

General design Consideration

The principal aims were :

— employ a relatively simple solution permitting us to obtain the optimal performances from TWO TPV 375.
— simplify the design and reduce the cost.

The main consideration was to obtain the maximum output power with the best IMD over the band. To obtain this requirement the output match and losses must be the best possible in all the band.

The second consideration was to obtain the maximum gain by reducing the input matching circuit losses to a minimum.

These factors led us to choose matching circuits using quarter-wavelength transformers at the input and output which permit us to :

— reduce the load and source impedances to low values with low losses
— couple two transistors in a push pull configuration.

Because the output and input transistor impedances are in series, due to the push-pull configuration, the required transformation ratio is one half of that required for a single ended stage.

The first approach for the circuit calculation was made from the input and output impedances given in the TPV 375 data sheet and matched to the proper impedance levels using a smith chart. The element values were then optimized with the aid of «COMPACT » program.

Amplifier Design

The basic block diagram for the amplifier is shown in Figure 1 and the circuit schematic is shown in Figure 2.

The input and output circuits are each composed of two networks : a quarter-wavelength transformer-balun and a matching network.

The quarter-wavelength transformer impedances have been chosen to be easily built using microstrip technology.

Input circuit

The input circuit is shown in Figure 3 and the input impedances are shown in Smith Chart 1.

The low transistor input impedances are transformed into higher impedances near the real axe by capacitors FF.

The (EE, DD) series elements and (CC, BB) parallel elements collapse the amplifier input impedances around 8,5 Ω.

Since the devices can be considered in series at this point the impedance is doubled to 17 Ω. The quarter-wavelength transformer balun (AA) completes the match to 50 Ω.

The transformation ratio is 2.8 : 1.

The maximum theoritical input VSWR is 1.80 : 1 and the maximum experimental VSWR is 1.60 : 1.

Output circuit

The output circuit is shown in Figure 4 and the output impedances on Smith Chart. II. Since the output impedances are higher than the input impedances, the output matching network is simpler and the quarter-wavelength transformer ratio is lower.

The inductors aid the matching but primarily provide for good stability at the low frequencies, and are used for collector bias. The output quarter-wave-length transformer ratio is 1.6 : 1.

The maximum theoritical VSWR is 1.16 : 1 and the maximum experimental VSWR is 1.44 : 1.

Amplifier Performances

— IMD versus output power : Figure 5

— Input and output return loss and VSWR = Figure 6

— Gain versus frequency : see Figure 7

— 1 dB gain point compression : 70 W

— Bias conditions : V_{ce} = 28 V ; Total = 4.4 A.

Technology and layout considerations

The epoxy-Glass 1/16 inch ($\varepsilon_r = 4.1$) is used as board material except for the input and ouput transformers.

The glass - Teflon 1/50 inch ($\varepsilon_r = 2.55$) is used for the transformers (see the details Figure 8).

We have considered for a microstrip line that after W (Width) from the conductor strip edge the fields are negligible and we can size the ground conductor to be 3 W without perturbing the propagation. This kind of transformer has the following characteristics :

— We can have any impedance values within realizable min-max limits.

— The vertical dimensions are small and the mechanical realibility is good.

— Good repeatibility.

The bias circuits are included with RF circuits in order to give a compact amplifier : Figures 10 and 11 show the layouts and the Figure 12 the physical layout of the push-pull amplifier.

Combined pairs of push-pull Amplifiers

— In general several push-pull amplifiers are used for the final stage of the TV transmitter amplifiers.

They can be combined by pair with quadrature combiners (see block diagram Figure 9).

The advantage of using this kind of coupler is that the input and output VSWR become good (> 20 dB rtn. loss) in comparison with the relatively high original VSWR of the push-pull amplifier.

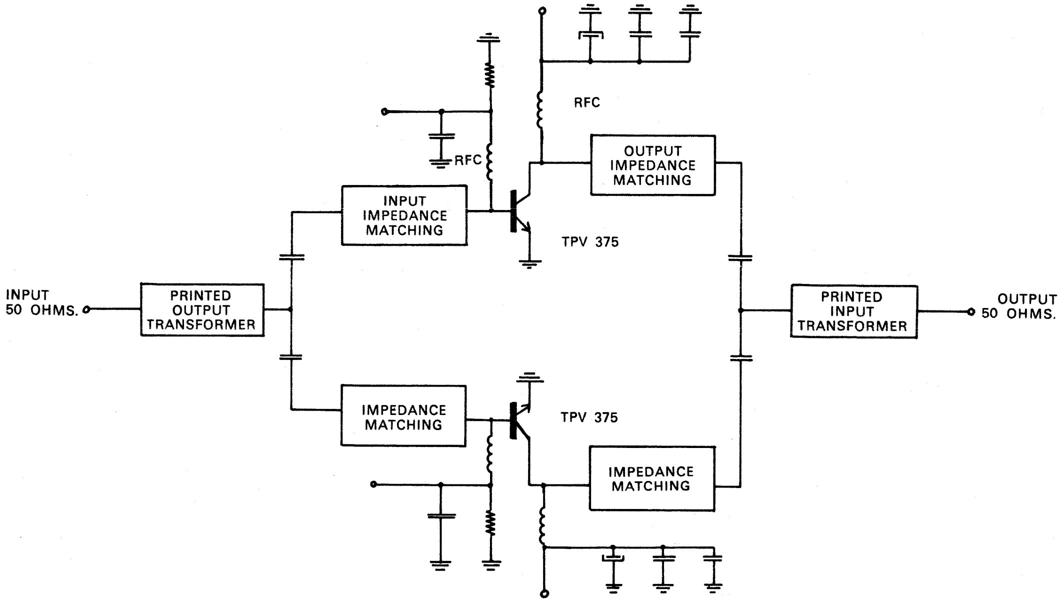
General Conclusions

— Pushpull techniques simplify the required circuitry and associated losses.

— The problems associated with 3 dB hybrids in cascade — insertion loss and imbalance — when four devices in parallel are required are minimized.

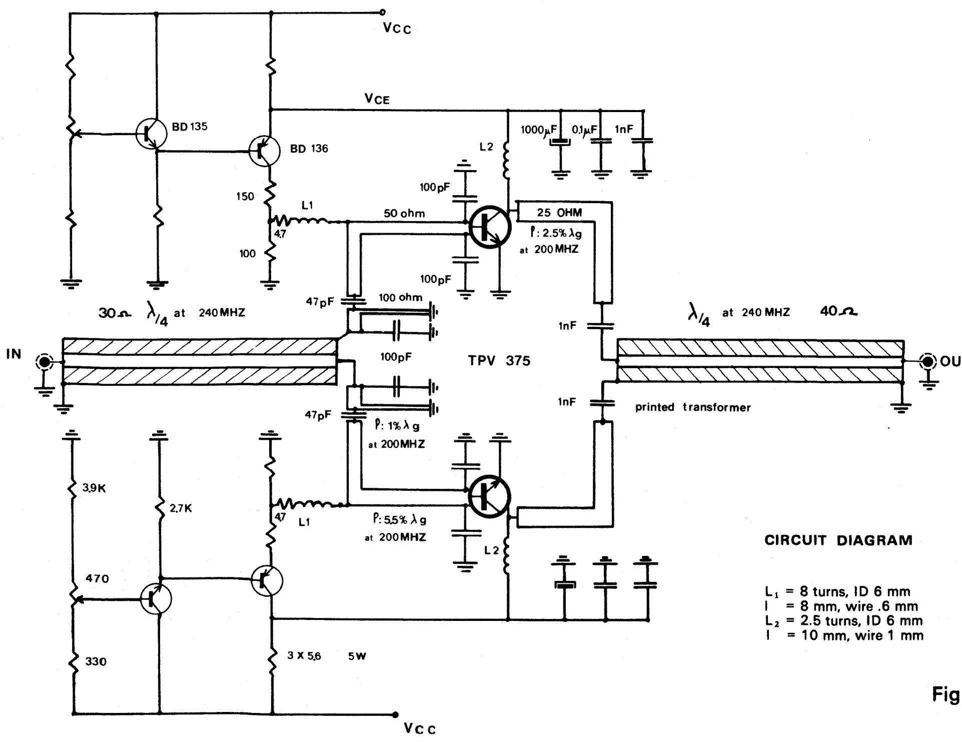
— With additional effort both the input and output VSWR could be improved to 1.2 : 1.

— Good repeatability in production without variable components being required.



PUSH-PULL CIRCUIT

Figure 1



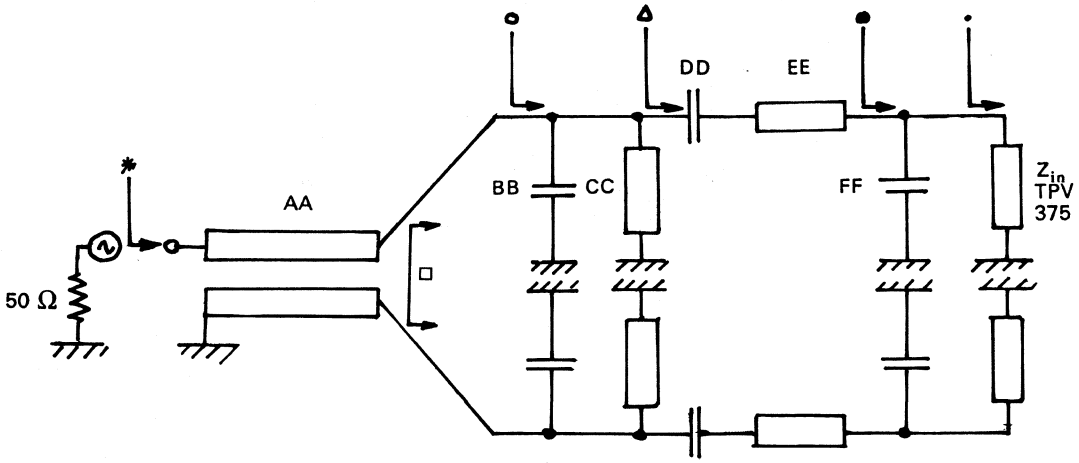
CIRCUIT DIAGRAM

L_1 = 8 turns, ID 6 mm
l = 8 mm, wire .6 mm
L_2 = 2.5 turns, ID 6 mm
l = 10 mm, wire 1 mm

Figure 2

INPUT CIRCUIT

On the smith chart the impedances are represented by :



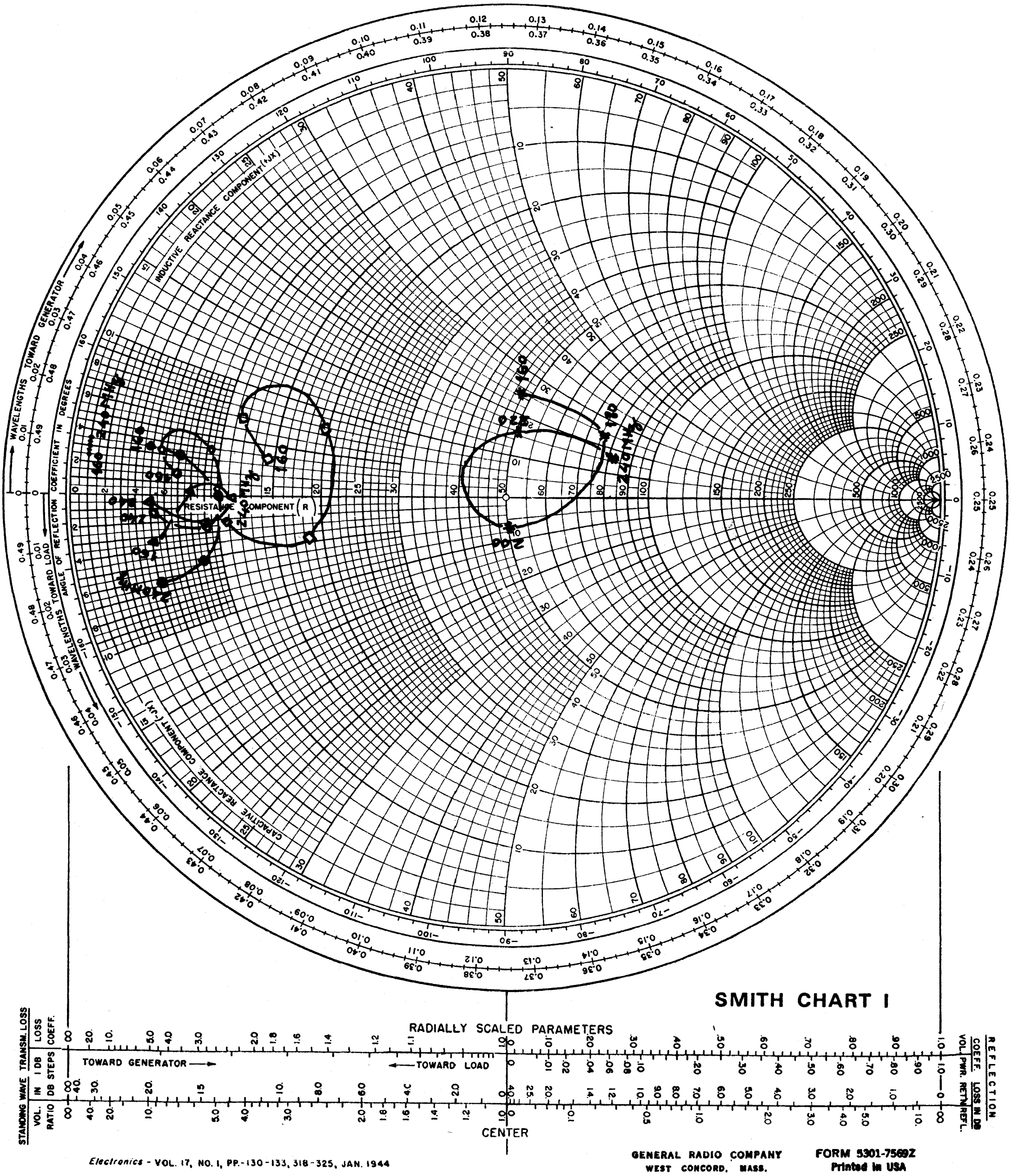
	AA		BB	CC		DD	EE		FF
	Z_0 (Ω)	L* (mm)	(pF)	Z_0 (Ω)	L* (mm)	(pF)	Z_0 (Ω)	L* (mm)	(pF)
Calc. value	30	313	139	100	11.3	47	50	80.8	238
Empirical value	30	313	100	100	15.0	47	50	82.5	200

* L is given for $\varepsilon_r = 1$

Figure 3

TITLE **INPUT CIRCUIT** DATE

IMPEDANCE COORDINATES—50-OHM CHARACTERISTIC IMPEDANCE



SMITH CHART I

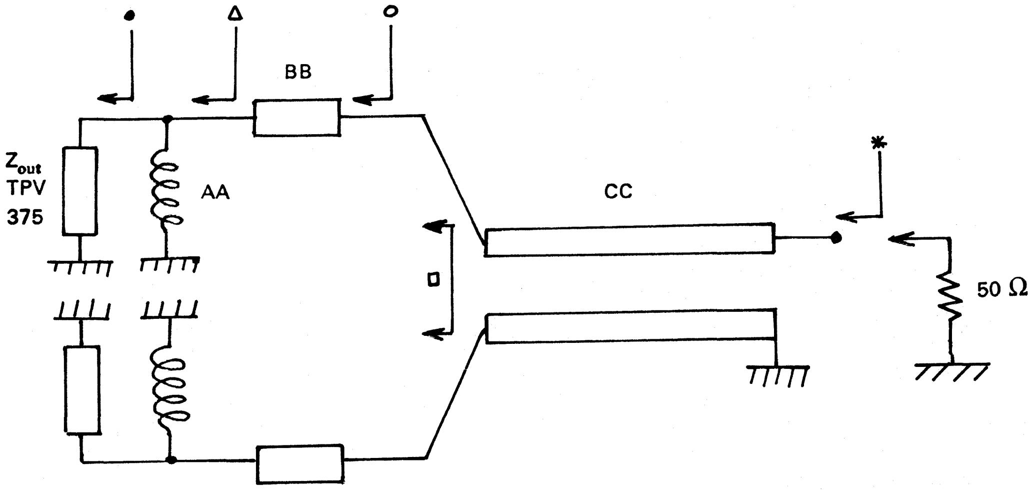
Electronics - VOL. 17, NO. 1, PP.-130-133, 318-325, JAN. 1944

GENERAL RADIO COMPANY
WEST CONCORD, MASS.

FORM 5301-7569Z
Printed in USA

OUPUT CIRCUIT

On the smith chart the impedances are represented by :



	AA	BB		CC	
	(nH)	Z_0 (Ω)	L* (mm)	Z_0 (Ω)	L* (mm)
Calc. value	11.7	21.6	37.5	33	312.5
Empirical value	53.1	25.0	37.5	40	312.5

* L is given for $\varepsilon_r = 1$

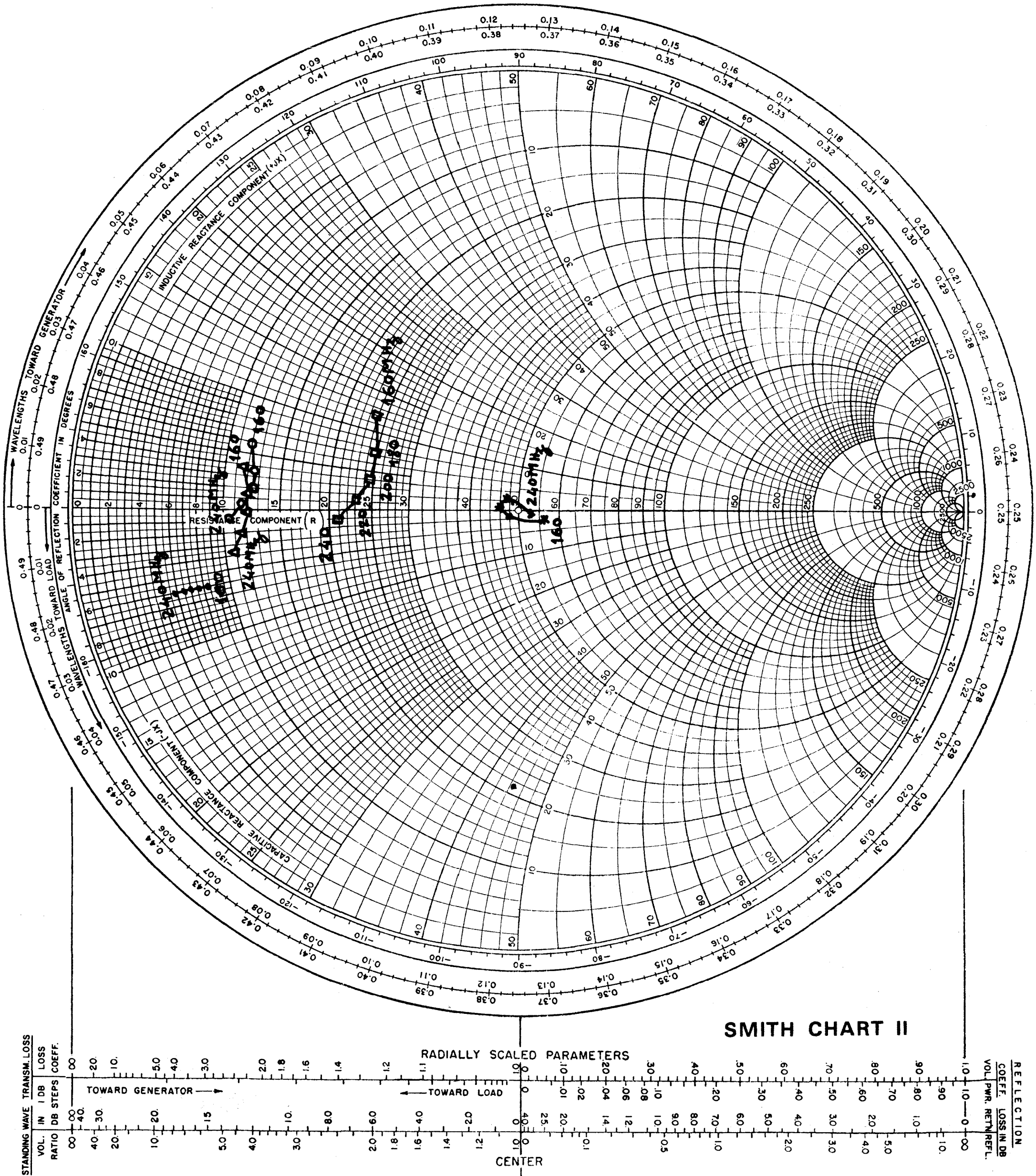
Figure 4

TITLE

OUTPUT CIRCUIT

DATE

IMPEDANCE COORDINATES—50-OHM CHARACTERISTIC IMPEDANCE



SMITH CHART II

Electronics - VOL. 17, NO. 1, PP.-130-133, 318-325, JAN. 1944

GENERAL RADIO COMPANY
WEST CONCORD, MASS.

FORM 5301-7569Z
Printed in USA

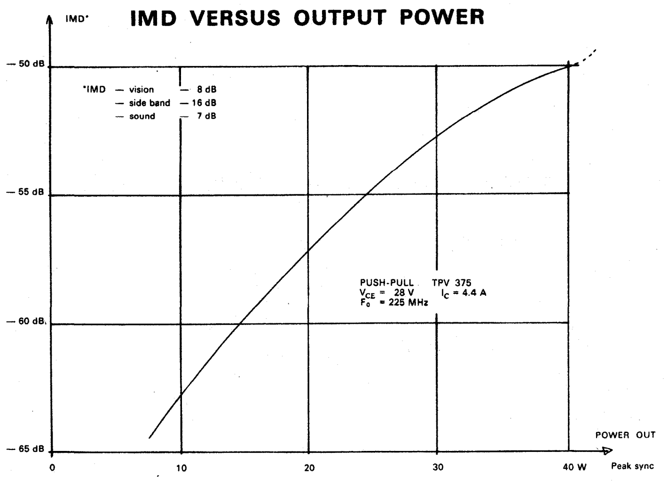

IMD VERSUS OUTPUT POWER

Figure 5

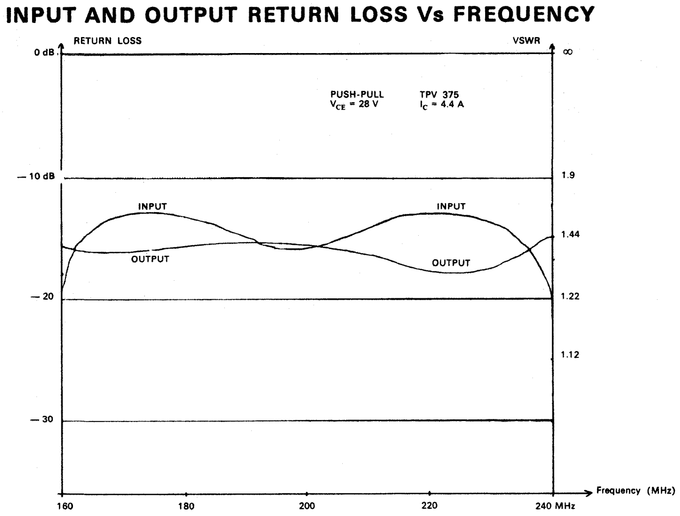

INPUT AND OUTPUT RETURN LOSS Vs FREQUENCY

Figure 6

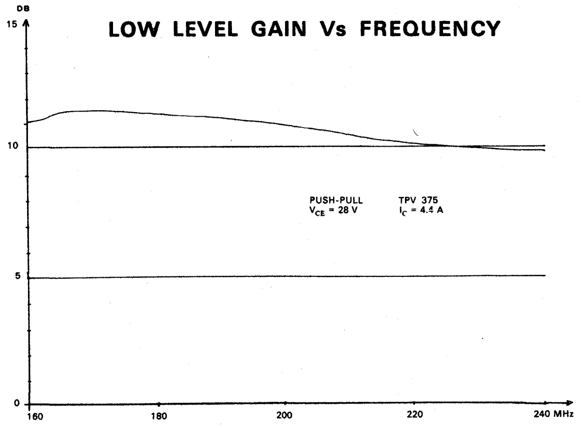
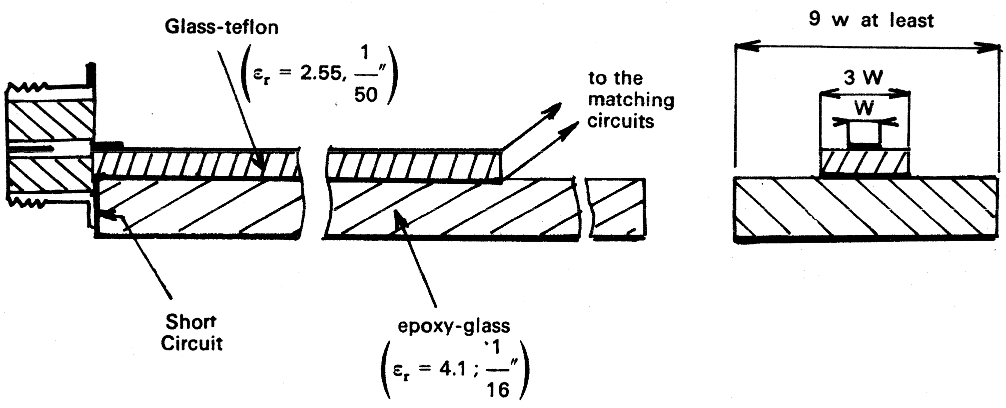

LOW LEVEL GAIN Vs FREQUENCY

Figure 7

QUATER WAVELENGTH BALUN



EQUIVALENT CIRCUIT

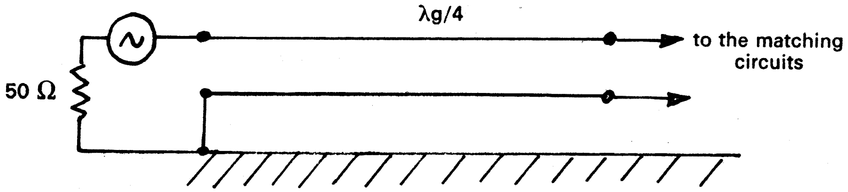


Figure 8

COMBINED PAIR OF PUSH-PULL AMPLIFIERS

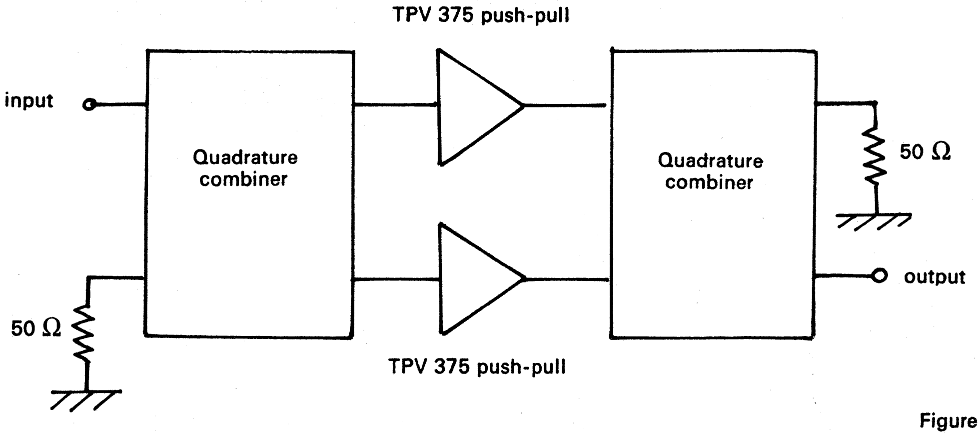


Figure 9

PC BOARD LAYOUT FOR INPUT AND OUTPUT QUATER-WAVELENGHT TRANSFORMER

Board material : glass teflon ; 1/50 inch ; $\varepsilon_r = 2.55$

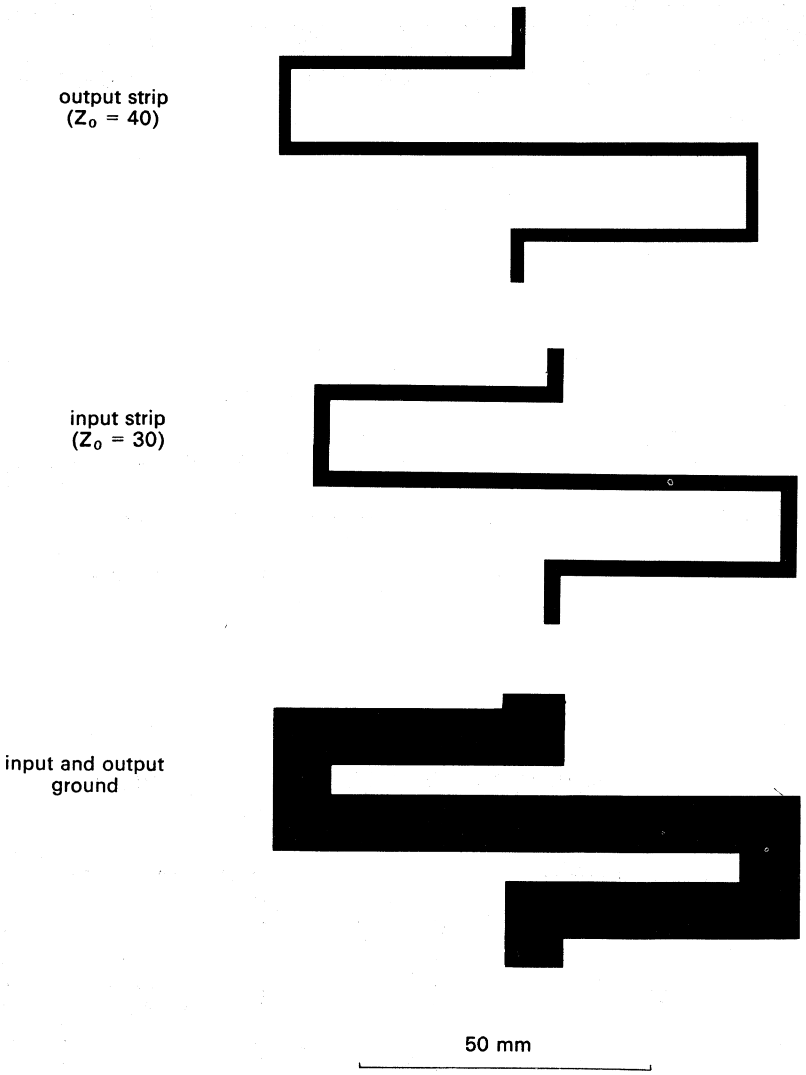


Figure 11

PC BOARD LAYOUT

Board material : epoxy-glass ; 1/16 inch ; $\varepsilon_r = 4.1$

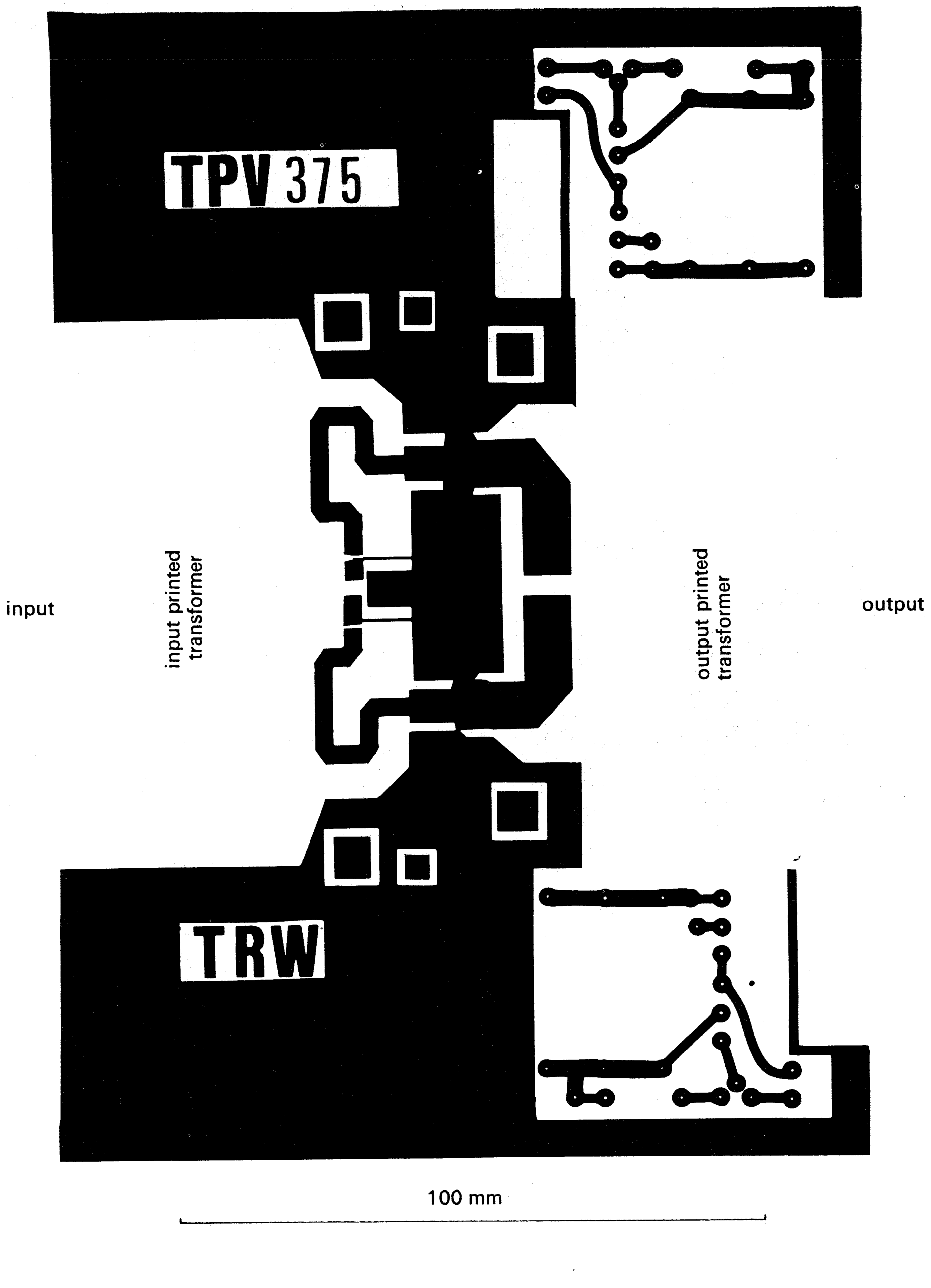


Figure 10

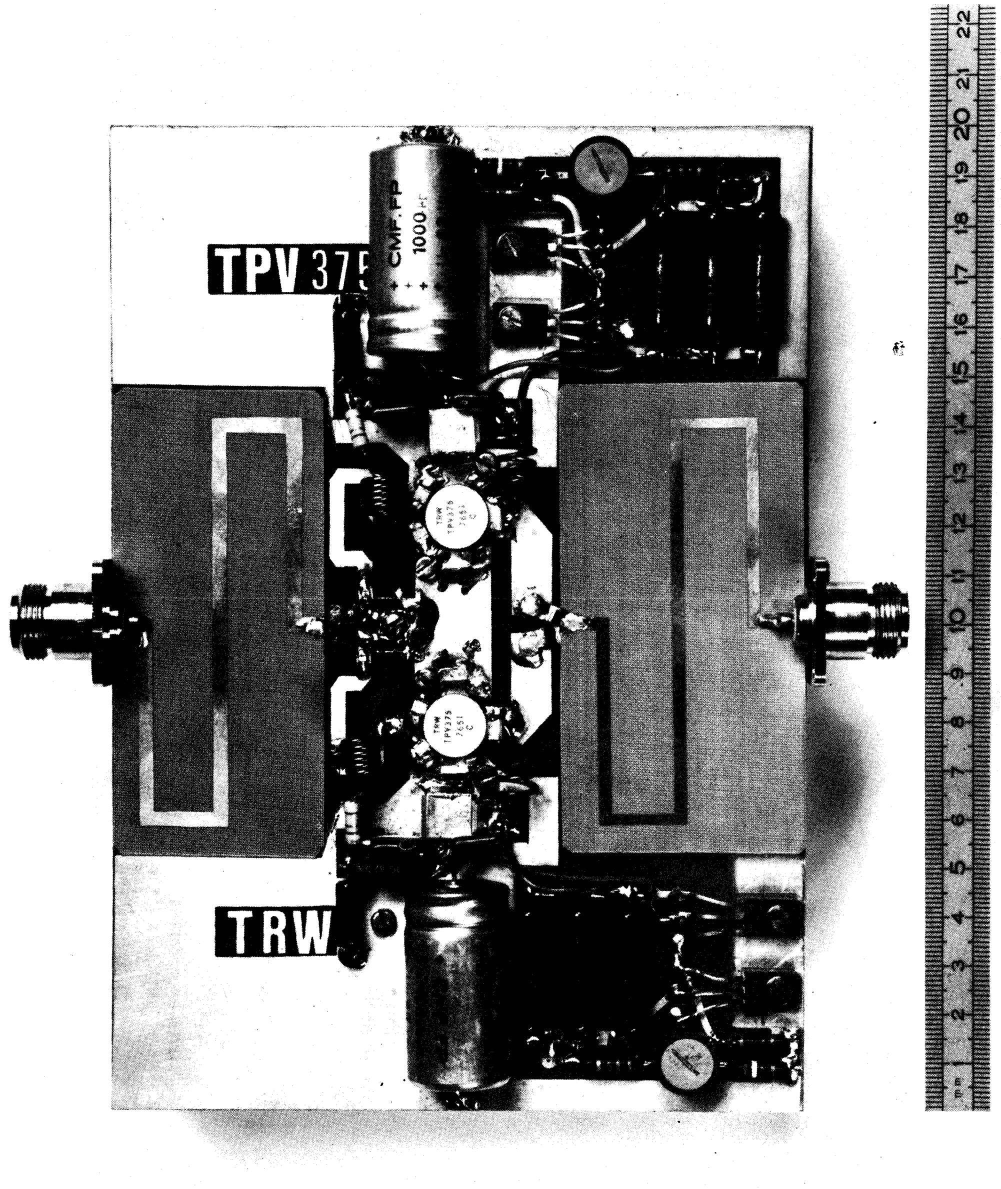


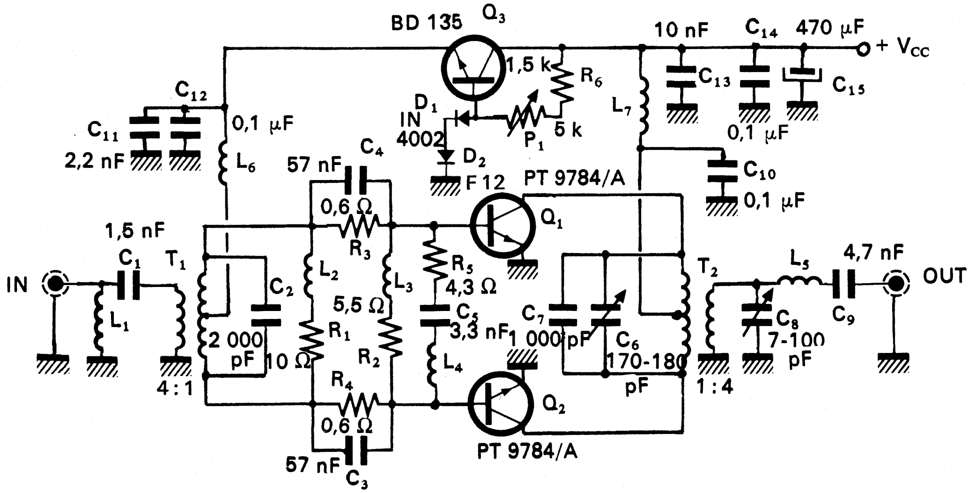
Figure 12

TRW *SEMICONDUCTORS* - **APPLICATION NOTE N° 12 - SSB-001-78**

150 WATT LINEAR AMPLIFIER
2 TO 28 MHz, 13.5 VOLT D.C.

This application note describes the design of a push-pull linear 150 W solid state power amplifier intended for SSB transmitter applications.
The broadband amplifier operates directly from a 13.5 V DC source and covers the 2 — 28 MHz band.

The circuit calculation, the major performance characteristics and the complete construction details are presented. Devices used : Two PT 9784/A.



1. — BASIC AMPLIFIER SPECIFICATION

V_{CE} = 13.5 V

Bandwidth : 2 to 28 MHz

Pgain at 150 W : 15 ± 1.3 dB

IMD at 28 MHz and 150 W PEP $\leqslant$ — 30 dB

INPUT VSWR $\leqslant$ 1.6 : 1

2. — GENERAL DESIGN CONSIDERATION

The principal aims were :

— employ a relatively simple solution permitting us to obtain optimal performance from two PT 9784/A,

— use components available on European market.

In order to comply with ourself imposed criteria, we chose a push-pull configuration to improve even harmonic suppression and to simplify the matching problems due to very low input and output transistor impedances.

In push-pull configuration, the transistor input or output impedances are in series, making the required transformation ratio one quarter of that required for parallel operation.
We also chose a ferrite manufacturer whose product is freely available on the European market.

The circuit calculation was made as follows :

- choice of the input and output transformer ratio,
- choice of the transformer type,
- estimation of the transformer volumes,
- calculation of the transformer compensation,
- calculation of an input network between the input transformer and the transistors to match 2 Zin to 3 Ω and to stabilize the gain-frequency characteristic.

The figure 1 shows the schematic of the amplifier.

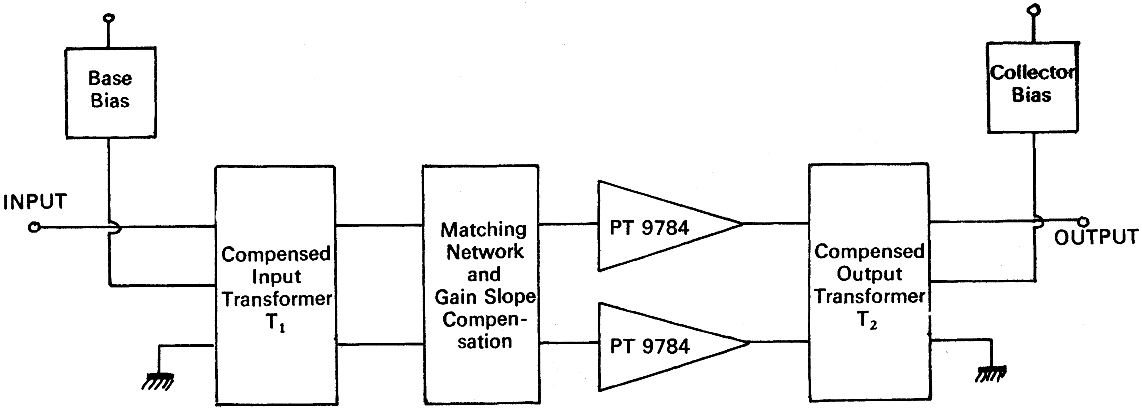


Fig. 1

3. — IMPEDANCE TRANSFORMATION CHOICE

3. — 1. Input voltage transformation ratio

$Zin = R + JX\ (\Omega)$ typical values :

F (MHz)	2	5	10	15	20	25	30
R (Ω)	15	8	5	3	2	1.5	1.2
X (Ω)	− 8	− 11	− 7.5	− 5	− 4	− 3.5	− 3

In order to obtain a good match at high frequency, we consider Zin at 25 MHz. The real part at this frequency is 1.5 Ω, which means for a push-pull configuration the real part is 3 Ω between the two bases.

The voltage transformation ratio is determined by :

$$n = \sqrt{\frac{50}{3}} \simeq 4 \qquad \boxed{n_{IN} = 4}$$

3. — 2. Output voltage transformation ratio

The transistor equivalent output circuit is :

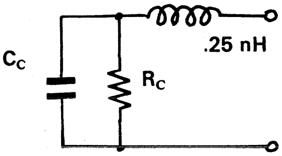


Fig 2.

With :

$C_C \simeq 270$ pF

$$R_C = \frac{(V_{CC} - V_{sat})^2}{2\ P_o}$$

Where :

V_{CC} : collector supply voltage = 13.5 V
V_{sat} : RF saturation voltage = 1.0 V
P_o : Output power for one transistor = 75 W
$R_C \simeq 1.1\ \Omega$

The output transformer matches 2 Z_{out} to 50 Ω for push-pull configuration. The voltage transformation ratio is defined by :

$$n = \sqrt{\frac{50}{2.2}} = 4.7 \simeq 5$$

In fact we found empirically that the best ratio is n = 4.

$$\boxed{n_{out} = 4}$$

4. — TRANSFORMER TYPES USED

Since the input and output voltage transformation ratios are 4, we can use the small pratical transformer show by figures 3 and 4.

The low impedance winding always consists of one turn, which limits the available impedance transformation ratio to 1, 4, 9...

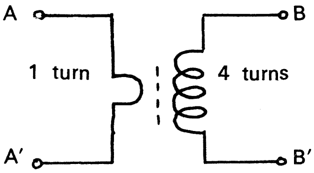


Fig. 3.

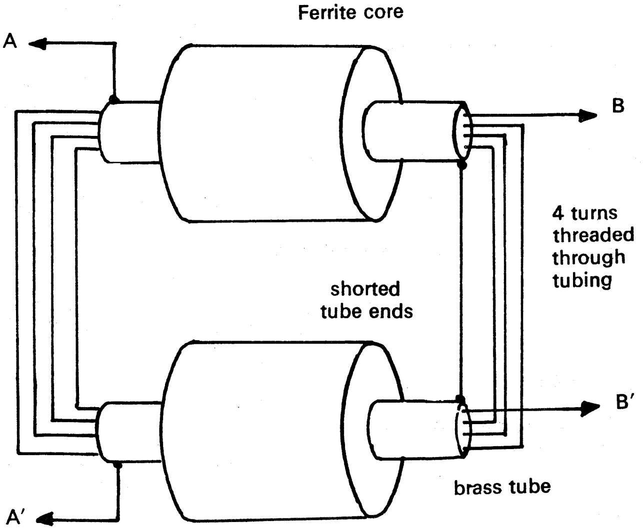


Fig. 4.

5. — TRANSFORMER VOLUME ESTIMATION

5. — 1. Output transformer

Toroid dimensions.

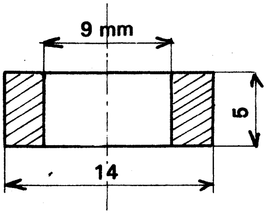


Fig. 5.

Ferrite used : 4 C 6 material made by RTC.
Reference : Tore 14/9/5 — 4 C 6
4322 020 97 180

$\mu_r = 120 \pm 20\,\%$

The primary inductance can be calculated with the following formula :

$$L_p = \mu_o\,\mu_r\,n^2\,\frac{S}{l} \qquad (5\text{-}1\text{-}1)$$

Where :

L_p : inductance (H)
$\mu_o = 4\,\pi\,10^{-7}$
μ_r : Relative permeability
s : ferrite cross section (m^2)
l : average lenght of the lines force (m)
n : number of turns.

The value of L_p must be chosen high, but not higher than really necessary, because otherwise the performance at the high end of the band will be degraded.

We take :

$$2\,\pi\,L_p\,F\ \text{min} \simeq 3\,R$$

in which :

R : load impedance = 50 Ω
F mini = 2 MHz

$$L_p = \frac{150}{2\,\pi\,2\,10^6} = 12\,\mu H$$

The ferrite cross section is :

$$S = Nh\,\frac{(D - d)}{2}$$

in which N is the number of toroids.

$$S = N\,5\,10^{-3}\,2.5\,10^{-3} = 1.25\,10^{-5}\,N\ (m^2)$$

From 5 — 1 — 1 we can calculate N :

$$N = \frac{L_p l}{\mu_o\,\mu_r\,n^2\,1.25\,10^{-5}} = \frac{12\,10^{-6}\,36.1\,10^{-3}}{4\,\pi\,10^{-7}\,120\,16\,12.5\,10^{-5}}$$

$N \simeq 14$ toroids.

In fact we use 16 cores, which gives :

$$\boxed{Lp = 13.7\,\mu\,H \qquad \text{and} \qquad S = 2\,10^{-4}\ (m^2)}$$

The highest toroid losses occur in this case at 2 MHz under large signal conditions. RTC give the power loss density, i.e. the power loss related to the unit of volume versus the maximum induction and the frequency. The maximum induction $\hat{B}$ can be calculated with the following formula :

$$\hat{B} = \frac{\hat{V}}{2\,\pi\,FSn} \qquad (5\text{-}1\text{-}2)$$

in which :

$\hat{B}$: maximum induction (T)
S : ferrite cross section (m^2)
n : number of turns
$\hat{V}$: maximum value of voltage accross n turns (V)
F : frequency

$\hat{V}$ is given by :

$$\hat{V} = \sqrt{2\,P_o\,R_L} \qquad (5\text{-}1\text{-}3)$$

where :

- P_o : output power
- $R_L = 50\ \Omega$

$$\hat{V} = \sqrt{2\ 150\ 50} = 122.5\text{ V}$$

$$\hat{B} = \frac{122.5}{2\,\pi\,2\,10^6\,2\,10^{-4}\,4} = 1.2\,10^{-2}\text{ T}$$

for $\hat{B} = 12$ mT and F = 2 MHz the power loss density is $2\,10^2\ mW \cdot cm^{-3}$.

The ferrite volume is :

$$v = \frac{\pi}{4}\,(D^2 - d^2)\,hN = \frac{\pi}{4}\,(14^2 - 9^2)\,5\,16\,10^{-3} = 7.2\text{ cm}^3$$

This gives a loss α :

$$\alpha = 2\,10^2\,7.2 = 1440\text{ mW or } \frac{1.4}{150} = 1\ \%$$

This 0.05 dB loss in the ferrite is acceptable.

5. — 2. Input transformer

Ferrite used : 4 C 6 material made by RTC
Reference : Tore 9/6/3 — 4 C 6
4322 020 97170

$\mu_r = 120 \pm 20\ \%$

Toroid dimensions.

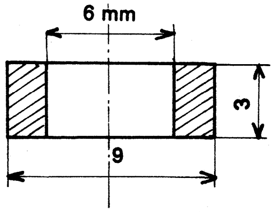


Fig. 6.

In order to reduce the transformer dimensions we use a transformer with a primary inductance at 2 MHz given by :

$$2\,\pi\,L_p\,F\text{ mini} \simeq R_s \qquad (5\text{-}2\text{-}1) \qquad \text{where } R_s = 50\ \Omega$$

this inductance is compensated at low frequencies by the following circuit (figure 7) :

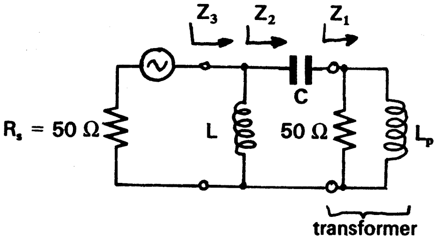


Fig. 7.

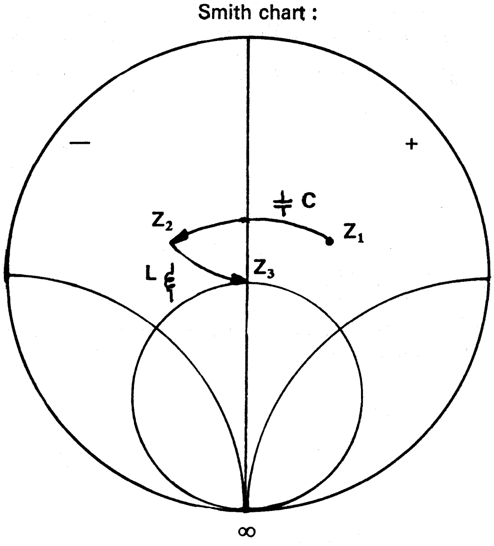


Fig. 8.

From 5-2-1 :

$$L_p \simeq \frac{50}{2\,\pi\,2\,10^6} = 4\,\mu\,H$$

The ferrite cross section S is :

$$S = N\,\frac{D - d}{2}\,h = N\,1.5\,10^{-3}\,3\,10^{-3} = 4.5\,N\,10^{-6}\ (m^2)$$

where N is the number of toroids.

The average length of the line force l is :

$$l = \pi\,\frac{D + d}{2} = \pi\,7.5\,10^{-3} = 23.6\,10^{-3}\ (m)$$

N can be calculated from 5-1-1 :

$$N = \frac{L_p l}{\mu_0\,\mu_r\,n^2\,4.5\,10^{-6}} = \frac{4\,10^{-6}\,23.6\,10^{-3}}{4\,\pi\,10^{-7}\,120\,16\,4.5\,10^{-6}}$$

$N = 8.7 \simeq 9$.

In fact we use $\boxed{N = 10}$ toroids, which means :

$$\boxed{L_p = 4.6\,\mu H}$$

By using the same reasoning and formula as the output transformer :

$P_{in} \simeq 3$ W at 2 MHz

$$\hat{V} = \sqrt{2\,P_{in}\,R} = \sqrt{2\cdot 3\cdot 50} = 17.3\ V$$

$$\hat{B} = \frac{\hat{V}}{2\,\pi\,FSn} = \frac{17.3}{2\,\pi\,2\,10^6\,4.5\,10^{-5}\,4} = 7.6\,10^{-3}\ T$$

for $\hat{B} = 8$ mT and F = 2 MHz the power loss density is 70 mW·cm^{-3}.

The ferrite volume is:

$$v = \frac{\pi}{4} (D^2 - d^2) hN = \frac{\pi}{4} (9^2 - 6^2) 3\ 10\ 10^{-3} = 1 \text{ cm}^3$$

This gives a loss α :

$$\alpha = 70 \times 1 = 70 \text{ mW or } \frac{70}{3000} = 2.3\ \%$$

This 0.1 dB loss in the ferrite is acceptable.

6. — OUTPUT CIRCUIT

Figure 9 shows the RF equivalent output circuit :

- Resistor AA, capacitor AA and inductor BB are the equivalent circuit to 2 Zout in series.
- Capacitor CC, capacitor EE and inductor FF are the transformer HF compensation.
- Capacitor FF is for low frequency compensation.
- The transformer is a black box described by its S-parameters.

The compensation elements are optimized with the aid of an analysis and optimization computer programme COMPACT.

Figure 10 shows the programme with final values and the final analysis :

The maximum output VSWR is lower than 1.6 : l.

ELEMENTS		CALC. VALUE	EMPIRICAL VALUE
CC	CAP (pF)	1474	1000 + 100/700*
EE	CAP (pF)	136	20/100*
FF	IND (nH)	256	90
	CAP (pF)	2993	4700

* variable capacitor.

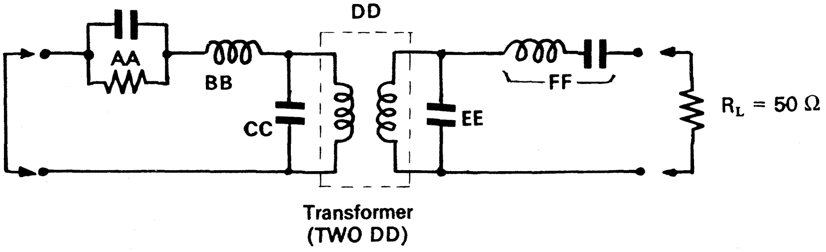


Fig. 9.

OUTPUT CIRCUIT

COMPACT PROGRAM

```
PRC  AA SE    3.000         135.0
IND  BB SE    .5000
CAP  CC PA — 1474.
TWØ  DD S1 — 50.00
CAP  EE PA — 136.0
SLC  FF SE — 251.4        — 2993.
CAX  AA FF
PRI  AA ØR   50.00
END
```

DEFINITIONS + INTERCONNECTIONS
THE ELEMENT VALUES ARE THE FINAL VALUES

```
2  5  10  15  20  25  30
END
```

FREQUENCY (MHz)

```
.909 176.5 .409    26   .390    20.5 .881    57.5
.884 177   .449     9.5 .435    10   .877    23
.884 176   .458     2   .439     2   .865     9
.877 174.5 .460 —  2.5  .437 —   1.5 .858     3
.884 173   .453 —  6    .439 —   4   .871 —   0.5
.885 172   .453 —  8    .437 —   6.5 .870 —   4.
.886 170   .456 — 10    .432 —   9   .867 —   8
END
```

POLAR S-PARAMETERS FOR
THE TRANSFORMER (TWØ DD)

```
1
0 1 0 0
END
```

OPTIMIZATION DATA

FINAL ANALYSIS

```
ØUTPUT      REFL.     CØEF.     AND VSWR IN     50.ØHM SYSTEM WITH      0.0ØHM SOURCE

                       RHØ                                 RET L/G
F (MHZ)          (MAGN.< ANGLE)            VSWR             (DB)             Z (R + JX) ØHM

 2.000         0.107        — 167.8       1.24 : 1         — 19.08          40.46         — 1.85
 5.000         0.051        —  24.1       1.11 : 1         — 25.79          54.86           2.31
10.000         0.053           59.3       1.11 : 1         — 25.57          52.54           4.77
15.000         0.076           52.0       1.16 : 1         — 22.44          54.46           6.52
20.000         0.107           27.5       1.24 : 1         — 19.41          60.15           6.02
25.000         0.047        —   9.8       1.10 : 1         — 26.62          54.81         — 0.88
30.000         0.232        — 148.8       1.60 : 1         — 12.68          32.60         — 8.30
```

Fig. 10.

7. — INPUT CIRCUIT

Figure 11 shows the RF equivalent input circuit:

- IMP JJ is the two transistor input impedances in series,
- inductor AA and capacitor BB are for transformer compensation at low frequency,
- capacitor DD is for high frequency transformer compensation,
- circuits EE, FF, GG and HH have two functions :
  - form a selective attenuator with 3 Ω input impedance to stabilize the gain-frequency characteristic ;
  - match the two transistors input impedance which are in series to 3 Ω, with the minimum of loss at the highest frequency.

Figure 12 shows the programme with final values and the final analysis : the maximum input VSWR is lower than 1.6 : 1.

ELEMENTS		CAL. VALUE	EMPIRICAL VALUE
AA	IND (nH)	5732	4000
BB	CAP (pF)	1294	1680
DD	CAP (pF)	1146	2000
EE	RES (Ω)	13.4	10
	IND (nH)	189	200
FF	RES (Ω)	1.3	1.2
	CAP (pF)	33350	57000
GG	RES (Ω)	7.2	5.5
	IND (nH)	93.3	95
HH	RES (Ω)	6.8	4.3
	IND (nH)	31.5	45
	CAP (pF)	3040	3300

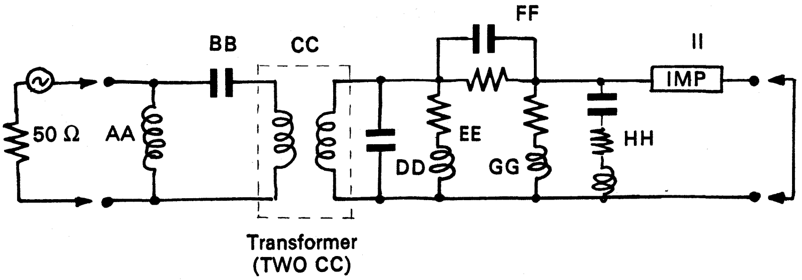


Fig. 11.

INPUT CIRCUIT

COMPACT PROGRAM

```
IND  AA PA — 5732.                                         DEFINITIONS + INTERCONNECTIONS
CAP  BB SE — 1294.
TWØ  CC S1    50.00                                        THE ELEMENT VALUES
CAP  DD PA — 1146.                                         ARE THE FINAL VALUES
SRL  FE PA — 13.43       — 189.0
PRC  FF SE — 1.325       — .3335 E + 05
SRL  GG PA — 7.161       — 93.26
SRX  HH PA — 6.817       — 01.50         — 3040.
IMP  II SE
CAX  AA II
PRI  AA IR    50.00
END

2 5 10 15 20 25 30                                         FREQUENCY (MHz)
END

.917 87.5  .321 — 139  .337 — 139  .949 176                POLAR S-PARAMETERS FOR
.891 41.5  .414 — 161  .428 — 161  .909 177                THE TRANSFORMER (TWØ CC)
.868 19    .430 — 172  .452 — 172  .891 176
.863 11    .437 — 176  .453 — 177  .883 172
.861  6.5  .439 — 179  .455   180  .883 175
.854  2.5  .441   178  .452   177  .884 174
.852  0    .445   175  .443   175  .885 174
END

30  — 16                                                   2 ZIN IN SERIES R + JX (Ω)
16  — 22
10  — 15
 6  — 10
 4  —  8
 3  —  7
 2.4 — 6
END

1                                                          OPTIMIZATION  DATA
0  1  0  0
END
```

FINAL ANALYSIS

```
INPUT     REFL.     CØEF.     AND VSWR IN     50. ØHM SYSTEM WITH     0.0 ØHM LØAD

                RHØ                               RET L/G
F (MHZ)     (MAGN<ANGLE)             VSWR          (DB)             Z (R + JX) ØHM

 2.000       0.129        — 93.6     1.30 : 1     — 17.79        47.60          — 12.46
 5.000       0.186          55.7     1.46 : 1     — 14.60        58.51            13.64
10.000       0.108          45.6     1.24 : 1     — 19.36        57.41             8.93
15.000       0.248          74.0     1.66 : 1     — 12.10        50.76            25.80
20.000       0.083          48.6     1.18 : 1     — 21.66        55.32             6.91
25.000       0.054          87.5     1.11 : 1     — 25.33        49.95             5.42
30.000       0.115         159.0     1.26 : 1     — 18.78        40.18             3.35
```

Fig 12.

8. — BIAS CIRCUIT

The transistors which heat up during operation, need a thermally compensated bias current.

The circuit used is an emitter follower giving a low output resistance, in which the base voltage is fixed through a thermally variable component : a diode.

The diode is thermally connected with the heatsink (D2).

D1 is needed to compensate the VBE of the transistor.

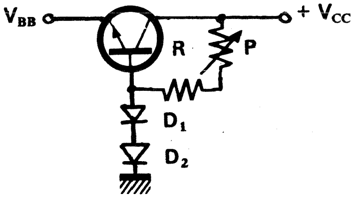


Fig. 13.

With the potentiometer, we adjust the current through the diodes, changing the voltage accross them.

We could have made a more sophisticated circuit, but this one is enough for our purpose.

9. — AMPLIFIER PERFORMANCES

The test set up used is the following (figure 14) :

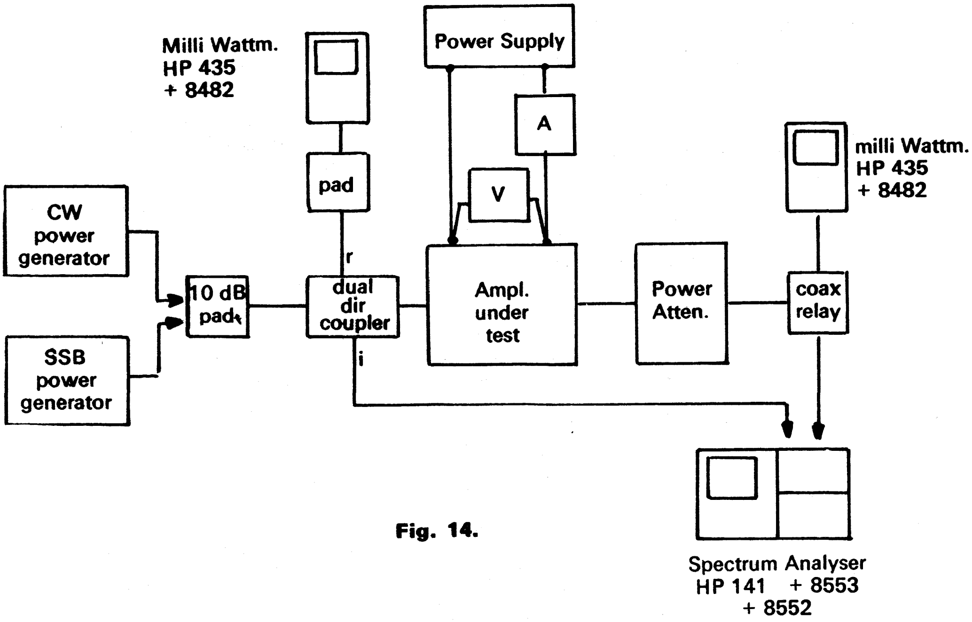


Fig. 14.

The performances are given in the following figures :

Power output versus frequency : Figure 15
Input VSWR versus frequency : Figure 16
IMD versus power output : Figure 17
Gain output versus power input and frequency : Figure 18

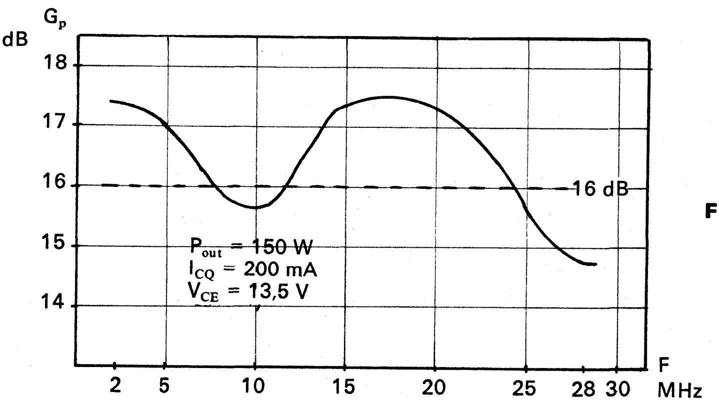


Fig. 15.

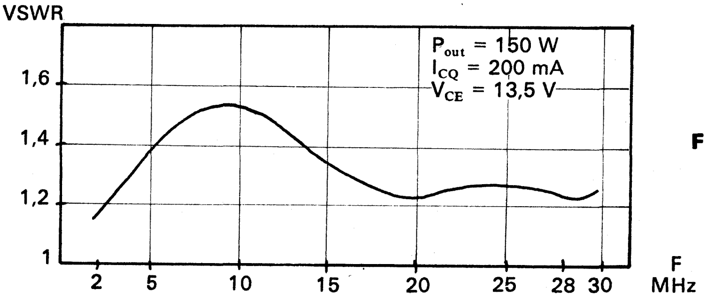


Fig. 16.

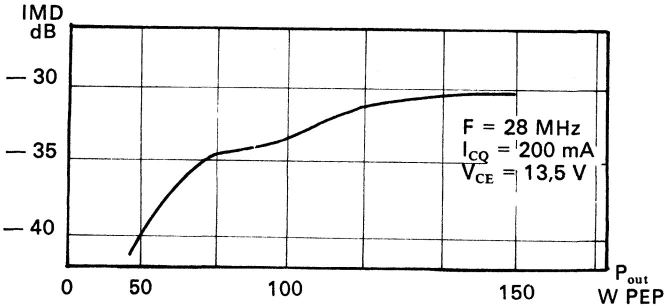


Fig. 17.

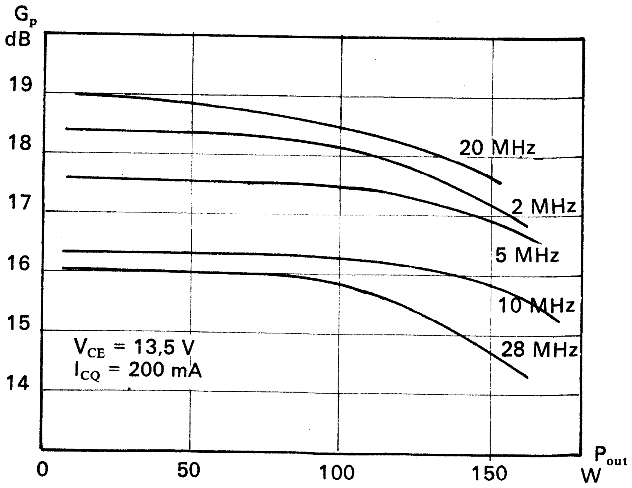


Fig. 18.

10. — TECHNOLOGY AND LAYOUT CONSIDERATIONS

AMPLIFIER SCHEMATIC

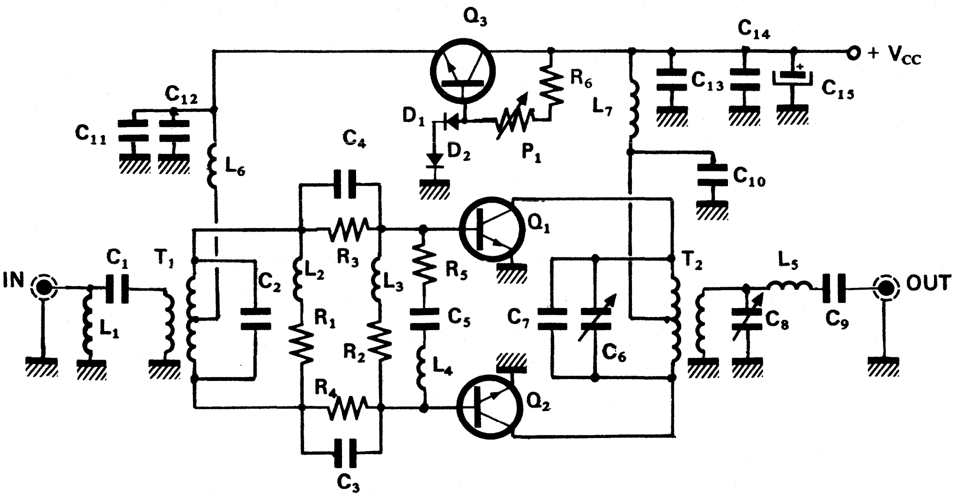


Fig. 19.

COMPONENTS PART LIST

CAPACITORS

C 1	1000 pF + 560 pF	
C 2	1000 pF + 1000 pF	
C 3	47 nF + 10 nF	
C 4	47 nF + 10 nF	
C 5	3300 pF	
C 6	ARCO 469	170 — 780 pF
C 7	1000 pF Mica	
C 8	ARCO 423	7 — 100 pF
C 9	4700 pF	
C 10	0.1 μ F	
C 11	2200 pF	
C 12	0.1 μ F	
C 13	10 nF	
C 14	0.1 μ F	
C 15	470 μ F/25 V	

RESISTORS

R 1	10 Ω made by 20 Ω + 20 Ω½ W in parallel
R 2	5.5 Ω made by 10 Ω + 12 Ω½ W in parallel
R 3	0.6 Ω made by 1.2 Ω + 1.2 Ω½ W in parallel
R 4	0.6 Ω made by 1.2 Ω + 1.2 Ω½ W in parallel
R 5	4.3 Ω 1/2 W
R 6	1.5 K Ω½ W
P 1	2 K Ω

SEMICONDUCTORS

D 1	1N 4002
D 2	F 12 metallic case (cathode to case)
Q 1	PT 9784/A
Q 2	PT 9784/A
Q 3	BD 135

INDUCTORS

L1	15 turns 0.5 mm wire wound on a ferrite core same as used for T1		
L 2	6 turns 0.7 mm	0.8 mm wire	
L 3	4 turns 0.7 mm	1 mm wire	
L 4	4 turns 0.6 mm	0.8 mm wire	6 mm length
L 5	4 turns 0.8 mm	1.4 mm wire	9 mm length
L 6	1 μ H molded choke		
L 7	10 turns 1.4 mm wire wound on a ferrite core same as used for T 2.		

TRANSFORMERS

Refer to figure 20 for complete view of the transformers.

T 1

PRIMARY : 2 times 5 ferrite cores 9 × 6 × 3 mm $\mu_r = 120$ material 4 C 6 reference RTC 4322 020 97170, on 2 brass tubes $\varnothing$ 5 mm, 22 mm length, with a 10 × 20 mm PCB piece on each side (figure 21).

SECONDARY : 4 turns of 0.5 mm^2 insulated wire wound through the 2 brass tubes.

T 2

PRIMARY : 2 times 8 ferrite cores 14 × 9 × 5 mm $\mu_r = 120$ material 4 C 6 reference RTC 4322 020 97180 on 2 brass tubes $\varnothing$ 8 mm, 49 mm lenght, with a 15 × 30 mm PCB piece on each side (figure 22).

SECONDARY : 4 turns of 1.8 mm^2 insulated wire wound through the 2 brass tubes.

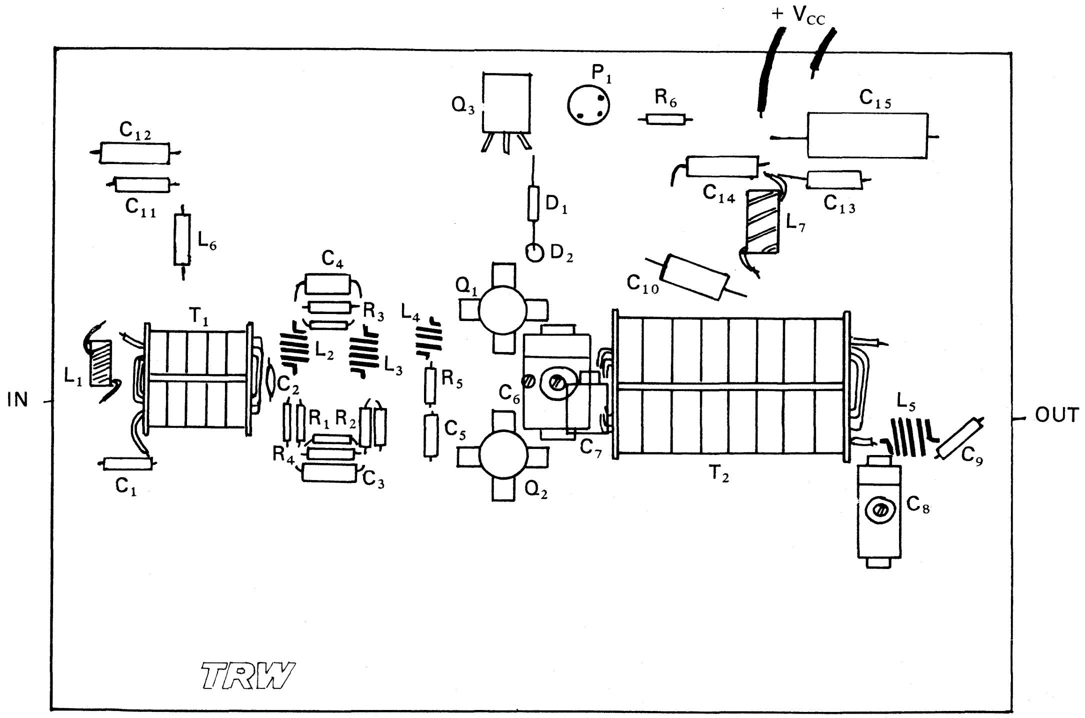


Fig. 24

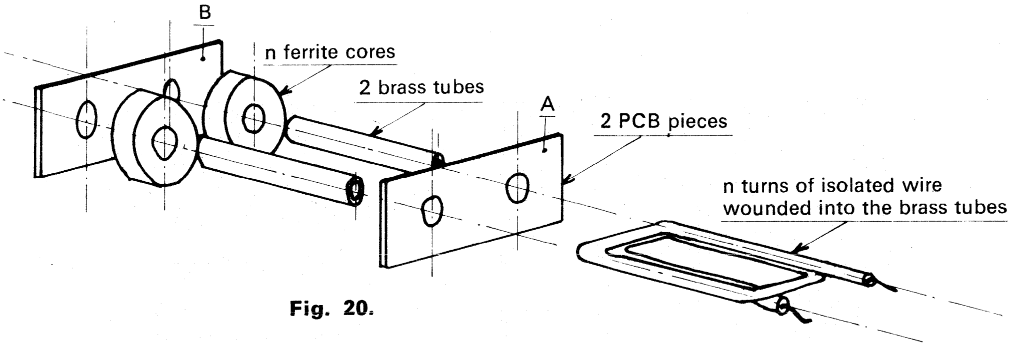
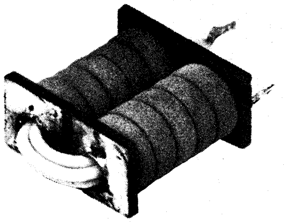


Fig. 20.



INPUT TRANSFORMER

PARTS A AND B FOR T1 (INPUT)

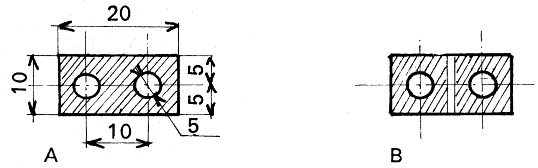
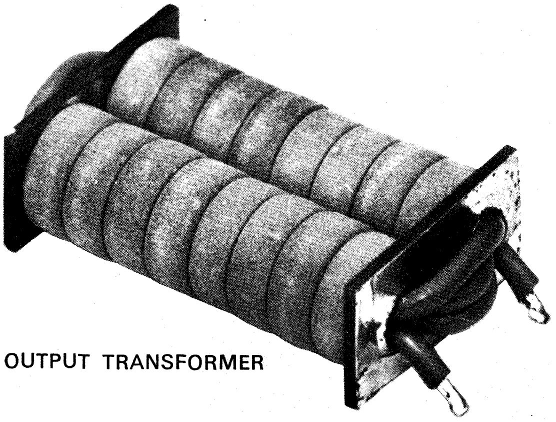


Fig. 21.



OUTPUT TRANSFORMER

PARTS A AND B FOR T2 (OUTPUT)

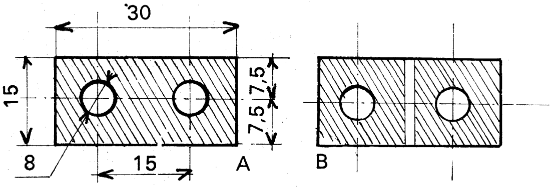
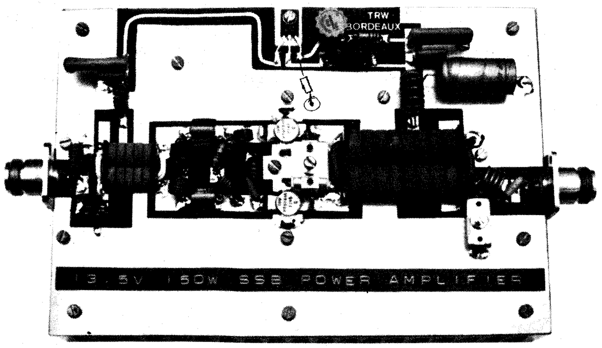


Fig. 22.



PRINTED CIRCUIT
FULL SCALE

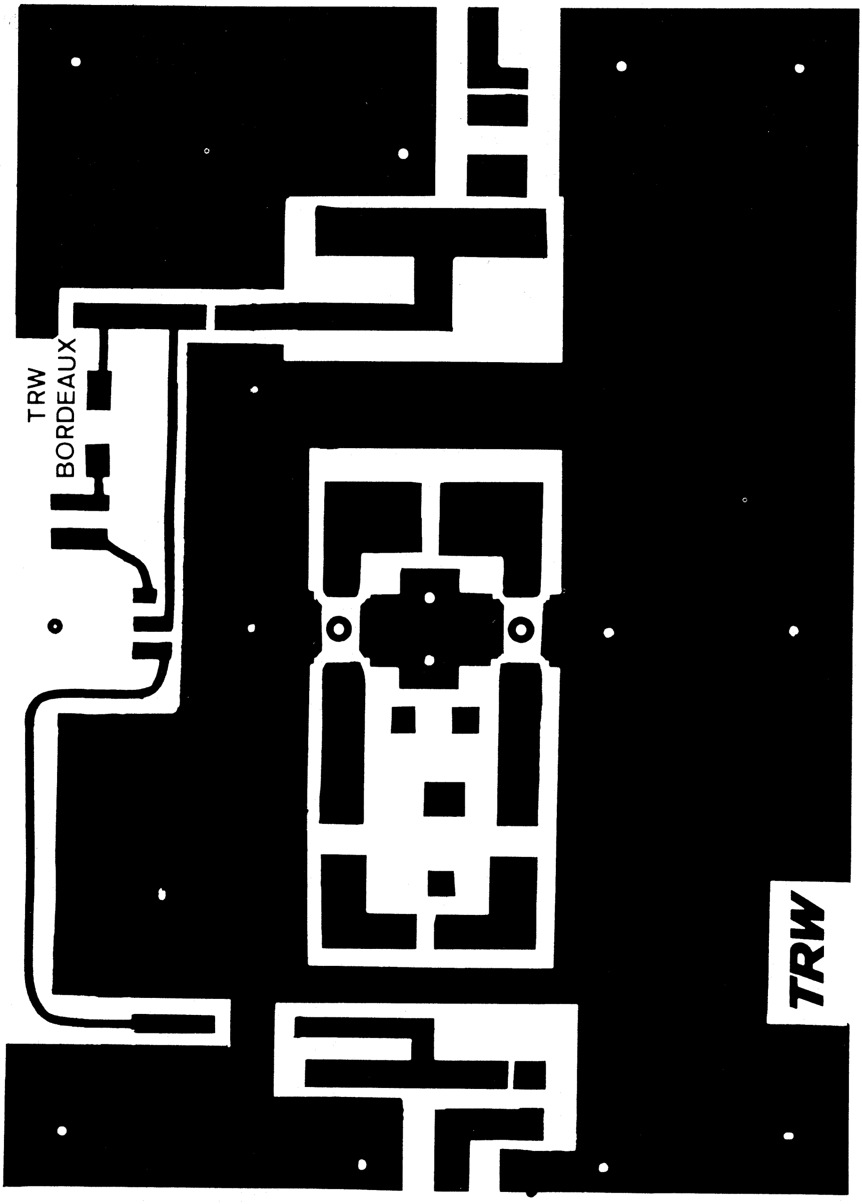


Fig. 23.

Union Française d'Impression, 18-20, avenue Gustave-Eiffel, 33600 Pessac - Imprimé en France - Dépôt légal effectué, 4e trimestre 1978