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MOTOROLA

MRF1047T1

NPN Silicon Low Noise Transistor

The MRF1047T1 is fabricated utilizing Motorola's latest 12 GHz f_τ discrete bipolar silicon process. The minimum noise figure is 1.0 dB at V_{CE} = 3.0 V and I_C = 3.0 mA. The noise performance of the MRF1047T1 at low bias makes this device the ideal choice in high gain, low noise applications. This device is well suited for low–voltage, low–current, front–end applications, for use in pagers, cellular and cordless phones, and other portable wireless systems.

The MRF1047T1 has 16 emitter fingers, with self–aligned and enhanced processing, resulting in a high f_τ, low operating current transistor with reduced parasitics. The MRF1047T1 is fully–ion implanted with gold metallization and nitride passivation for maximum device r
eliability, performance and uniformity.

- Low Noise Figure, NF_{min} = 1.0 dB (Typ) @1.0 GHz, 3.0 V and 3.0 mA
- High Current Gain–Bandwidth Product, f_τ = 12 GHz, 3.0 V @ 15 mA
- Maximum Stable Gain, 17 dB @ 1.0 GHz, 3.0 V and 10 mA
- Output Third Order Intercept, OIP_3 = 26 dBm @ 1.0 GHz 3.0 V and 15 mA
- Fully Ion–Implanted with Gold Metallization and Nitride Passivation

RF NPN SILICON TRANSISTOR

f_τ = 12 GHz

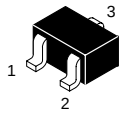
NF_{min} = 1.0 dB

I_{CMAX} = 45 mA

V_{CEO} = 5.0 V

SEMICONDUCTOR TECHNICAL DATA

Pin 1. Base
2. Emitter
3. Collector



PLASTIC PACKAGE
CASE 419
(SC–70, Tape & Reel Only)

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector–Emitter Voltage	V_{CEO}	5.0	Vdc
Collector–Base Voltage	V_{CBO}	12	Vdc
Emitter–Base Voltage	V_{EBO}	2.5	Vdc
Collector Current – Continuous [Note 3]	I_C	45	mAdc
Power Dissipation @ T_C = 75°C Derate Linearly above T_C = 75°C at	$P_{D(max)}$	0.172 2.3	W mW/°C
Storage Temperature Range	T_{stg}	–55 to 150	°C
Maximum Junction Temperature	$T_{J(max)}$	150	°C

NOTES: 1. Meets Human Body Model (HBM) ≤300 V and Machine Model (MM) ≤75 V.
2. ESD data available upon request.
3. For MTBF >10 years.

THERMAL CHARACTERISTIC

Characteristics	Symbol	Max	Unit
Thermal Resistance, Junction–to–Case	$R_{\theta JC}$	435	°C/W

NOTE: To calculate the junction temperature use $T_J = (P_D \times R_{\theta JC}) + T_C$. The case temperature measured on collector lead adjacent to the package body.

ORDERING INFORMATION

Device	Marking	Package
MRF1047T1	WB	SC–70 Tape & Reel*

*3,000 Units per 8 mm, 7 inch reel.

ELECTRICAL CHARACTERISTICS (T_C = 25°C, unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS [Note 1]					
Collector–Emitter Breakdown Voltage (I_C = 0.1 mA, I_B = 0)	$V_{(BR)CEO}$	5.0	–	–	Vdc
Collector–Base Breakdown Voltage (I_C = 0.1 mA, I_E = 0)	$V_{(BR)CBO}$	12	–	–	Vdc
Emitter–Base Breakdown Voltage (I_E = 0.1 mA, I_C = 0)	$V_{(BR)CBO}$	2.5	–	–	Vdc
Collector Cutoff Current (V_{CB} =1.0 V, I_E = 0)	I_{CBO}	–	–	0.2	μA
Emitter Cutoff Current (V_{EB} = 1.0 V, I_C = 0)	I_{EBO}	–	–	0.1	μA
ON CHARACTERISTICS [Note 1]					
DC Current Gain (V_{CE} = 3.0 V, I_C = 3.0 mA)	h_{FE}	100	–	300	–
DYNAMIC CHARACTERISTICS					
Collector–Base Capacitance (V_{CB} = 1.0 Vdc, I_E = 0, f = 1.0 MHz)	C_{cb}	–	0.4	–	pF
Current–Gain Bandwidth Product (V_{CE} = 3.0 Vdc, I_C = 15 mA, f = 1.0 GHz)	f_τ	–	12	–	GHz
PERFORMANCE CHARACTERISTICS					
Insertion Gain	$\|S_{21}\|^2$				dB
V_{CE} = 1.0 V, I_C = 1.0 mA, f = 1.0 GHz		–	8.0	–	
V_{CE} = 3.0 V, I_C = 3.0 mA, f = 1.0 GHz		–	13	–	
Maximum Stable Gain and/or Maximum Available Gain [Note 2]	MSG, MAG				dB
V_{CE} = 1.0 V, I_C = 1.0 mA, f = 1.0 GHz		–	11	–	
V_{CE} = 3.0 V, I_C = 3.0 mA, f = 1.0 GHz		–	16	–	
Minimum Noise Figure	NF_{min}				dB
V_{CE} = 1.0 V, I_C = 1.0 mA, f = 1.0 GHz		–	1.2	–	
V_{CE} = 3.0 V, I_C = 3.0 mA, f = 1.0 GHz		–	1.0	–	
Associated Gain at Minimum NF	G_{NF}				dB
V_{CE} = 1.0 V, I_C = 1.0 mA, f = 1.0 GHz		–	10	–	
V_{CE} = 3.0 V, I_C = 3.0 mA, f = 1.0 GHz		–	13	–	
Output Power at 1.0 dB Gain Compression [Note 3] (V_{CE} = 3.0 V, I_C = 3.0 mA, f = 1.0 GHz)	P_{1dB}	–	0.5	–	dBm
Output Third Order Intercept [Note 3] (V_{CE} = 3.0 V, I_C = 3.0 mA, f = 1.0 GHz)	OIP_3	–	22	–	dBm

NOTES: 1. Pulse width ≤300 μs, duty cycle ≤2% pulsed.

2. Maximum Available Gain and Maximum Stable Gain are defined by the K factor as follows:

$$MAG = \left|\frac{S_{21}}{S_{12}}\left(K \pm \sqrt{K^2 - 1}\right)\right|, \text{ if } K > 1, \; MSG = \left|\frac{S_{21}}{S_{12}}\right|, \text{ if } K < 1$$

3. Z_{in} = 50 Ω and Z_{out} matched for optimum IP3.

Figure 1. Capacitance versus Voltage

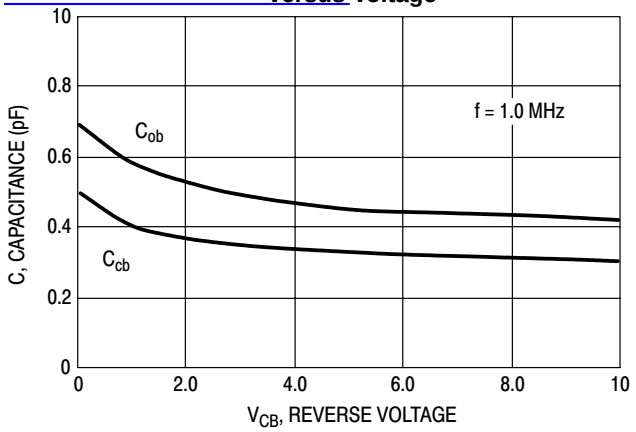


Figure 2. Input Capacitance versus Voltage

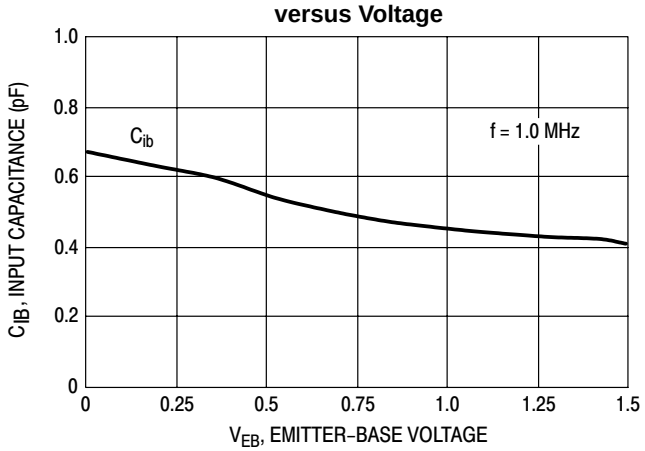


Figure 3. DC Current Gain versus Collector Current

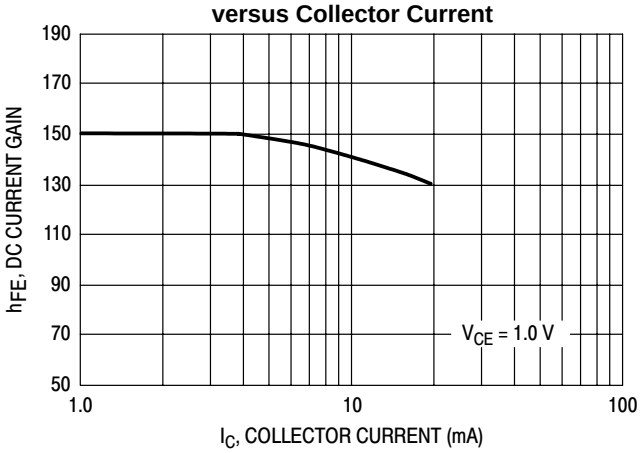


Figure 4. Gain–Bandwidth Product versus Collector Current

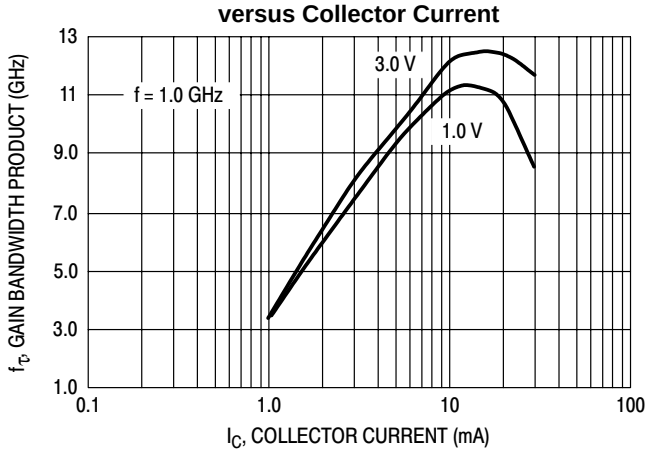


Figure 5. Functional Circuit Schematic

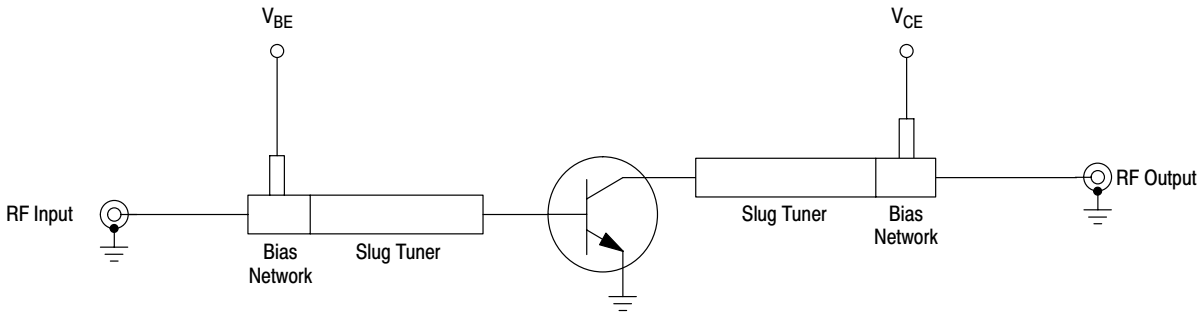


Figure 6. Maximum Stable/Available Gain and Forward Insertion Gain versus Frequency

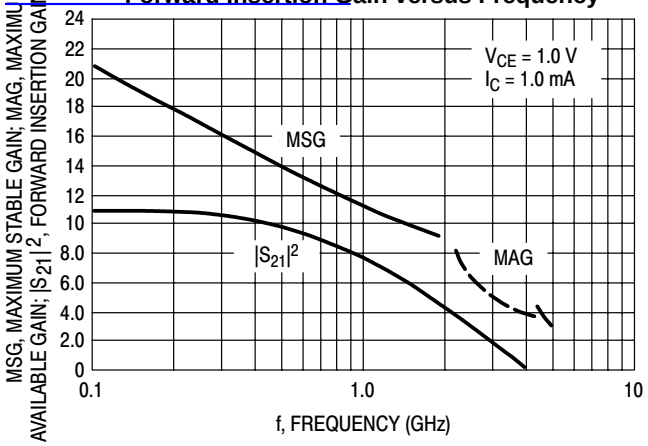


Figure 7. Maximum Stable/Available Gain and Forward Insertion Gain versus Frequency

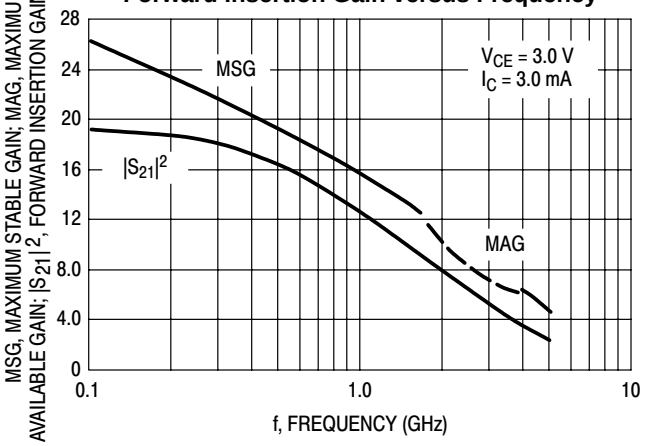


Figure 8. Maximum Stable/Available Gain and Forward Insertion Gain versus Collector Current

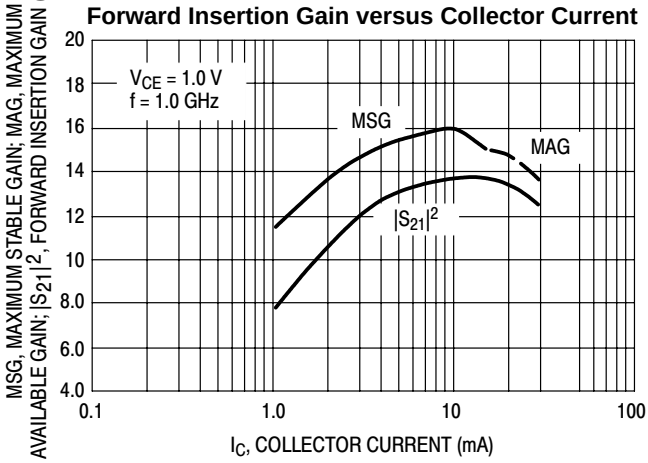


Figure 9. Maximum Stable/Available Gain and Forward Insertion Gain versus Collector Current

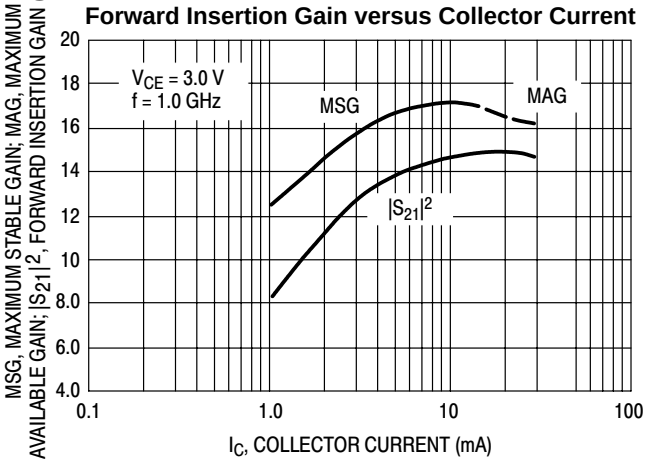


Figure 10. Minimum Noise Figure and Associated Gain versus Frequency

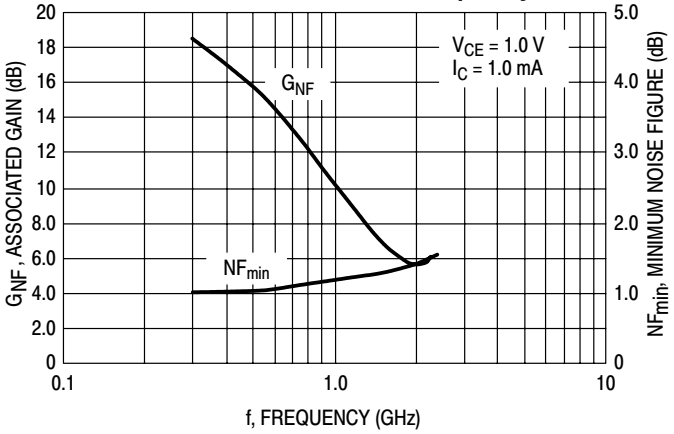


Figure 11. Minimum Noise Figure and Associated Gain versus Frequency

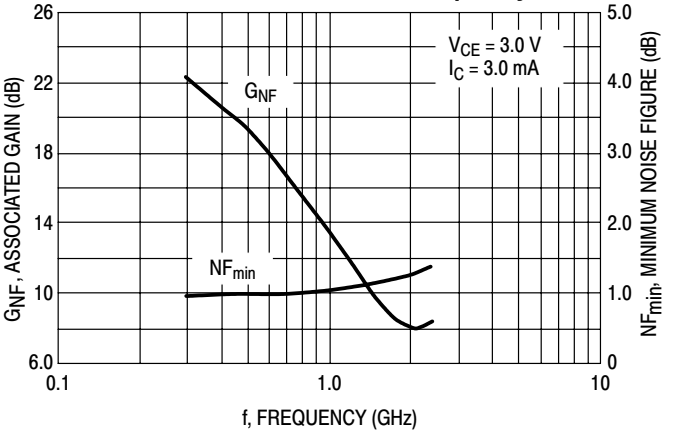


Figure 12. Minimum Noise Figure and Associated Gain versus Collector Current

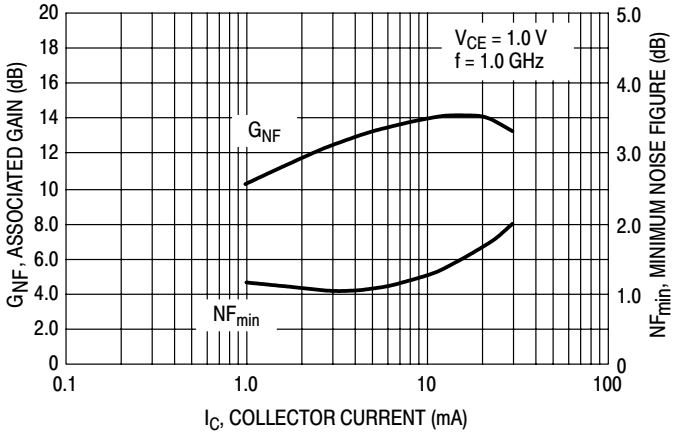


Figure 13. Minimum Noise Figure and Associated Gain versus Collector Current

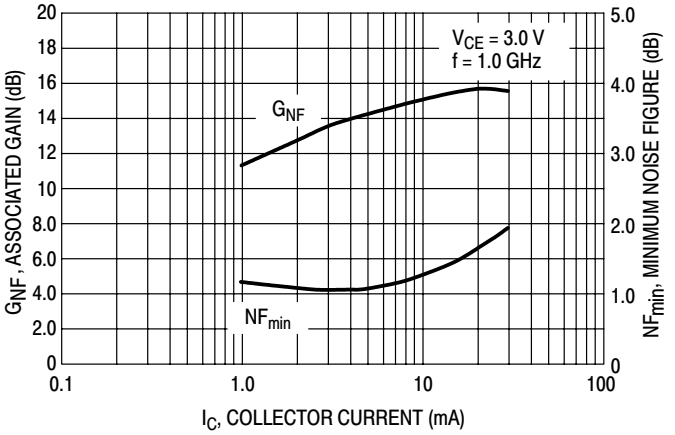


Figure 14. Output Third Order Intercept and Output Power at 1.0 dB Gain Compression versus Collector Current

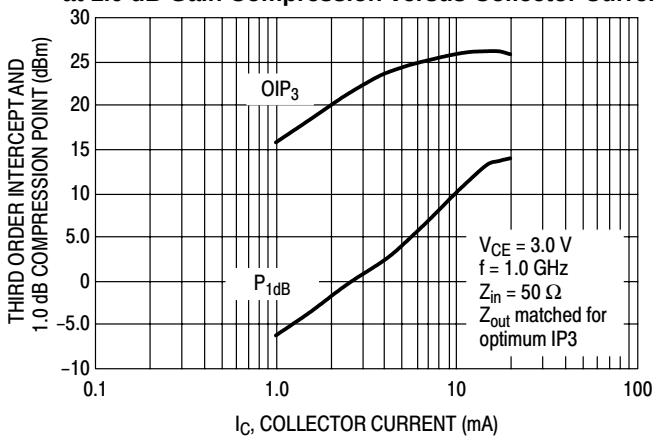


Table 1. Common Emitter S–Parameters

V_{CE}	I_C	f	S_{11}		S_{21}		S_{12}		S_{22}		K
(Vdc)	(mA)	(GHz)	$\|S_{11}\|$	∠ ϕ	$\|S_{21}\|$	∠ ϕ	$\|S_{12}\|$	∠ ϕ	$\|S_{22}\|$	∠ ϕ	
1.0	1.0	0.1	0.973	–10	3.49	171	0.029	84	0.987	–6	0.04
		0.3	0.938	–30	3.35	154	0.082	72	0.952	–17	0.12
		0.5	0.875	–48	3.03	137	0.124	60	0.877	–25	0.27
		0.7	0.770	–64	2.75	124	0.153	51	0.812	–33	0.36
		0.9	0.685	–79	2.51	112	0.174	45	0.745	–39	0.45
		1.0	0.649	–85	2.40	107	0.181	42	0.717	–42	0.49
		1.3	0.555	–105	2.09	92	0.195	36	0.639	–48	0.64
		1.5	0.509	–117	1.92	84	0.202	33	0.601	–53	0.72
		1.8	0.454	–136	1.72	72	0.204	30	0.553	–58	0.85
		2.0	0.434	–148	1.59	66	0.205	30	0.531	–62	0.92
		2.5	0.417	–175	1.38	50	0.208	32	0.477	–73	1.09
		3.0	0.403	164	1.23	39	0.227	37	0.457	–83	1.14
		3.5	0.416	142	1.10	28	0.259	41	0.454	–93	1.12
		4.0	0.442	125	1.00	20	0.310	43	0.448	–105	1.05
		4.5	0.454	109	0.95	12	0.378	41	0.433	–118	0.99
		5.0	0.478	96	0.89	6	0.445	37	0.437	–133	0.95
	3.0	0.1	0.917	–17	9.30	165	0.028	80	0.955	–11	0.10
		0.3	0.792	–48	7.94	140	0.072	65	0.831	–29	0.26
		0.5	0.630	–69	6.31	121	0.098	56	0.674	–39	0.47
		0.7	0.505	–87	5.11	107	0.116	51	0.571	–45	0.62
		0.9	0.418	–103	4.26	97	0.131	50	0.498	–49	0.74
		1.0	0.388	–110	3.93	93	0.138	49	0.471	–50	0.78
		1.3	0.317	–129	3.20	82	0.158	49	0.406	–54	0.91
		1.5	0.289	–142	2.84	76	0.172	48	0.380	–58	0.96
		1.8	0.265	–161	2.45	67	0.192	48	0.346	–62	1.02
		2.0	0.260	–173	2.24	61	0.206	48	0.329	–65	1.05
		2.5	0.282	164	1.88	49	0.244	47	0.284	–76	1.07
		3.0	0.283	147	1.65	39	0.287	45	0.271	–85	1.07
		3.5	0.306	128	1.47	30	0.330	42	0.269	–95	1.04
		4.0	0.334	115	1.34	21	0.374	38	0.262	–107	1.02
		4.5	0.354	103	1.25	13	0.423	34	0.256	–119	0.99
		5.0	0.382	93	1.176	6	0.470	29	0.260	–133	0.97
	5.0	0.1	0.861	–23	13.74	160	0.027	78	0.923	–15	0.15
		0.3	0.671	–59	10.50	130	0.064	63	0.727	–36	0.38
		0.5	0.489	–81	7.68	112	0.085	57	0.552	–44	0.62
		0.7	0.379	–100	5.95	100	0.103	56	0.455	–48	0.77
		0.9	0.311	–115	4.82	92	0.119	55	0.393	–50	0.87
		1.0	0.289	–122	4.41	88	0.128	55	0.372	–51	0.90
		1.3	0.241	–143	3.53	78	0.153	55	0.323	–54	0.98
		1.5	0.223	–155	3.11	72	0.171	55	0.303	–57	1.01
		1.8	0.214	–175	2.66	65	0.197	54	0.277	–62	1.04
		2.0	0.217	174	2.43	60	0.215	53	0.263	–65	1.05
		2.5	0.251	154	2.03	49	0.260	50	0.222	–77	1.06
		3.0	0.256	138	1.77	39	0.306	46	0.213	–86	1.05
		3.5	0.282	122	1.58	30	0.351	42	0.212	–97	1.03
		4.0	0.310	110	1.44	22	0.395	37	0.205	–111	1.01
		4.5	0.330	100	1.34	14	0.440	32	0.202	–123	1.00
		5.0	0.360	91	1.26	7	0.483	27	0.206	–138	0.98
3.0	3.0	0.1	0.926	–13	9.03	167	0.021	82	0.967	–8	0.10
		0.3	0.820	–37	7.99	145	0.056	70	0.877	–22	0.26
		0.5	0.673	–55	6.60	126	0.079	61	0.750	–30	0.48
		0.7	0.541	–69	5.47	113	0.096	57	0.663	–34	0.62
		0.9	0.441	–80	4.63	103	0.110	56	0.595	–38	0.73
		1.0	0.402	–85	4.30	99	0.117	55	0.571	–39	0.78
		1.3	0.308	–100	3.53	87	0.136	55	0.512	–42	0.90
		1.5	0.262	–109	3.16	81	0.149	54	0.485	–45	0.95
		1.8	0.208	–126	2.73	72	0.169	54	0.453	–48	1.01
		2.0	0.185	–139	2.50	67	0.183	54	0.436	–51	1.03
		2.5	0.176	–172	2.11	55	0.219	52	0.389	–59	1.06
		3.0	0.160	165	1.85	45	0.259	51	0.379	–66	1.05

Table 1. Common Emitter S–Parameters (continued)

V_{CE} (Vdc)	I_C (mA)	f (GHz)	S_{11}		S_{21}		S_{12}		S_{22}		K
			$\|S_{11}\|$	∠ ϕ	$\|S_{21}\|$	∠ ϕ	$\|S_{12}\|$	∠ ϕ	$\|S_{22}\|$	∠ ϕ	
		3.5	0.177	137	1.65	35	0.301	48	0.374	–74	1.03
		4.0	0.208	120	1.50	27	0.346	45	0.363	–84	1.00
		4.5	0.228	106	1.40	19	0.395	41	0.354	–93	0.97
		5.0	0.261	96	1.32	11	0.444	37	0.353	–105	0.94
	5.0	0.1	0.884	–19	13.66	162	0.020	80	0.941	–12	0.14
		0.3	0.713	–49	10.92	135	0.052	67	0.786	–28	0.37
		0.5	0.529	–68	8.25	116	0.071	61	0.632	–34	0.61
		0.7	0.406	–83	6.48	104	0.086	59	0.546	–37	0.75
		0.9	0.324	–95	5.31	95	0.101	59	0.489	–38	0.85
		1.0	0.293	–101	4.87	92	0.108	59	0.470	–39	0.89
		1.3	0.223	–118	3.90	82	0.131	59	0.426	–41	0.97
		1.5	0.192	–129	3.45	76	0.146	59	0.406	–44	1.00
		1.8	0.163	–149	2.96	68	0.169	58	0.383	–47	1.03
		2.0	0.155	–163	2.70	64	0.185	57	0.369	–49	1.04
		2.5	0.176	168	2.25	53	0.226	55	0.327	–58	1.05
		3.0	0.174	149	1.96	43	0.269	52	0.321	–65	1.03
		3.5	0.198	128	1.74	34	0.311	48	0.317	–74	1.01
		4.0	0.229	115	1.59	26	0.355	44	0.306	–84	0.99
		4.5	0.249	104	1.47	18	0.400	40	0.299	–93	0.97
		5.0	0.279	95	1.38	11	0.446	35	0.297	–105	0.94
	10.0	0.1	0.781	–27	21.48	155	0.019	77	0.886	–17	0.25
		0.3	0.530	–62	14.32	123	0.045	66	0.648	–33	0.56
		0.5	0.350	–79	9.81	106	0.062	65	0.504	–35	0.80
		0.7	0.257	–92	7.38	96	0.078	66	0.439	–35	0.91
		0.9	0.198	–105	5.90	89	0.096	66	0.401	–35	0.96
		1.0	0.179	–110	5.37	86	0.105	66	0.389	–36	0.98
		1.3	0.133	–128	4.24	78	0.131	65	0.362	–37	1.02
		1.5	0.114	–142	3.73	73	0.149	64	0.348	–40	1.03
		1.8	0.104	–166	3.18	66	0.176	62	0.331	–43	1.03
		2.0	0.106	178	2.90	62	0.194	61	0.320	–46	1.04
		2.5	0.144	154	2.41	52	0.239	57	0.280	–55	1.03
		3.0	0.149	137	2.09	43	0.284	53	0.276	–62	1.02
		3.5	0.176	118	1.85	35	0.327	48	0.273	–72	1.00
		4.0	0.208	108	1.69	27	0.370	43	0.260	–82	0.99
		4.5	0.228	99	1.56	19	0.414	39	0.253	–92	0.97
		5.0	0.257	91	1.47	12	0.457	34	0.250	–104	0.95

Table 2. Common–Emitter Noise Parameters

V_{CE} (Vdc)	I_C (mA)	f (GHz)	NF_{min} (dB)	Γ_O Magnitude	Γ_O Angle	R_N Ω	r_n	G_{NF} (dB)	K
1.0	1.0	0.3	1.00	0.67	15	28	0.55	18.6	0.12
		0.5	1.04	0.64	25	26	0.52	15.8	0.27
		0.7	1.08	0.61	35	25	0.49	13.3	0.36
		0.9	1.13	0.59	46	23	0.46	11.2	0.45
		1.0	1.16	0.57	51	22	0.44	10.2	0.49
		1.5	1.28	0.52	81	16	0.33	6.8	0.72
		2.0	1.41	0.48	116	10	0.20	5.5	0.92
		2.4	1.52	0.47	146	6.0	0.12	6.0	1.07
	3.0	0.3	0.83	0.56	14	17	0.34	20.9	0.26
		0.5	0.88	0.52	23	16	0.32	18.0	0.47
		0.7	0.94	0.48	32	15	0.30	15.5	0.62
		0.9	0.99	0.45	42	14	0.29	13.3	0.74
		1.0	1.02	0.43	47	14	0.28	12.4	0.78
		1.5	1.16	0.38	79	11	0.22	8.7	0.96
		2.0	1.31	0.35	117	8.0	0.15	7.1	1.05
		2.4	1.44	0.35	152	5.0	0.10	7.3	1.07
	5.0	0.3	0.90	0.48	13	15	0.29	21.6	0.38
		0.5	0.94	0.44	21	14	0.28	18.8	0.62
		0.7	0.98	0.40	31	13	0.26	16.3	0.77
		0.9	1.03	0.36	42	12	0.25	14.1	0.87
		1.0	1.06	0.35	48	12	0.24	13.1	0.90
		1.5	1.20	0.30	82	10	0.19	9.4	1.01
		2.0	1.37	0.28	123	7.0	0.14	7.7	1.05
		2.4	1.53	0.30	161	5.0	0.11	7.7	1.06
3.0	1.0	0.3	1.11	0.67	14	31	0.62	19.7	0.11
		0.5	1.12	0.65	22	30	0.59	16.8	0.26
		0.7	1.13	0.64	31	28	0.56	14.3	0.35
		0.9	1.16	0.62	41	26	0.52	12.2	0.44
		1.0	1.17	0.60	46	25	0.50	11.2	0.48
		1.5	1.26	0.56	74	19	0.38	7.7	0.70
		2.0	1.39	0.51	106	12	0.24	6.5	0.91
		2.4	1.51	0.47	135	7.0	0.15	7.0	1.05
	3.0	0.3	0.94	0.60	13	21	0.41	22.3	0.26
		0.5	0.96	0.57	19	20	0.40	19.3	0.48
		0.7	0.98	0.54	25	19	0.39	16.7	0.62
		0.9	1.01	0.51	33	18	0.36	14.5	0.73
		1.0	1.03	0.50	37	18	0.35	13.5	0.78
		1.5	1.13	0.44	61	15	0.29	9.7	0.95
		2.0	1.26	0.37	92	11	0.21	8.1	1.03
		2.4	1.39	0.32	121	8.0	0.15	8.3	1.06
	5.0	0.3	0.92	0.53	13	17	0.34	22.8	0.37
		0.5	0.95	0.49	20	16	0.32	19.9	0.61
		0.7	0.99	0.46	28	16	0.31	17.4	0.75
		0.9	1.03	0.43	37	15	0.29	15.2	0.85
		1.0	1.06	0.42	42	14	0.28	14.2	0.89
		1.5	1.20	0.36	72	12	0.23	10.4	1.00
		2.0	1.36	0.32	109	8.0	0.17	8.7	1.04
		2.4	1.53	0.30	144	6.0	0.12	8.8	1.05
	10.0	0.3	1.17	0.39	13	15	0.29	23.8	0.56
		0.5	1.18	0.35	21	14	0.28	20.9	0.80
		0.7	1.21	0.32	31	13	0.26	18.3	0.91
		0.9	1.24	0.29	42	13	0.25	16.1	0.96
		1.0	1.26	0.28	48	12	0.25	15.1	0.98
		1.5	1.40	0.24	83	10	0.21	11.2	1.03
		2.0	1.59	0.23	128	8.0	0.16	9.3	1.04
		2.4	1.79	0.24	170	7.0	0.13	9.3	1.03

Table 3. Spice Parameters (MRF1047 Die Gummel–Poon Parameters)

Name	Value	Name	Value	Name	Value
IS	5.8 E–16	IRB	7.50E–03	TF	1.50E–11
BF	180	RBM	4.0	XTF	8.0
NF	0.99	RE	1.0	VTF	4.2355
VAF	40	RC	7.0	ITF	0.2
IKF	0.18	XTB	0	PTF	60
ISE	3.140E–14	EG	1.11	TR	1.00E–09
NE	1.78	XTI	3.0	FC	0.95
BR	26.8	CJE	5.70E–13		
NR	0.9974	VJE	0.98		
VAR	2.0	MJE	0.5		
IKR	7.50E–03	CJC	4.00E–13		
ISC	2.200E–14	VJC	0.59		
NC	1.48	MJC	0.314		
RB	6.924	XCJC	0.6		

Figure 15. MRF1047 SC–70 Package Equivalent Circuit

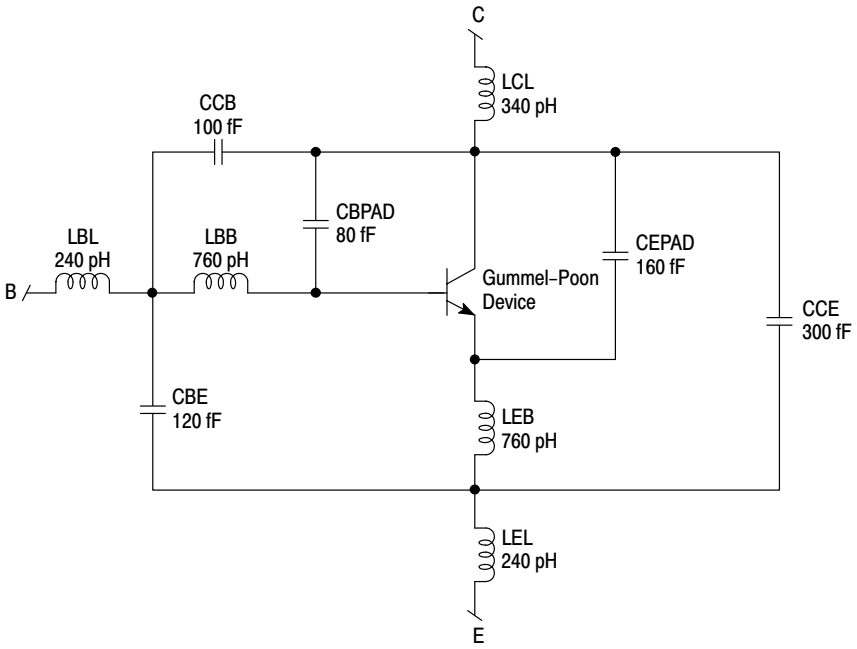
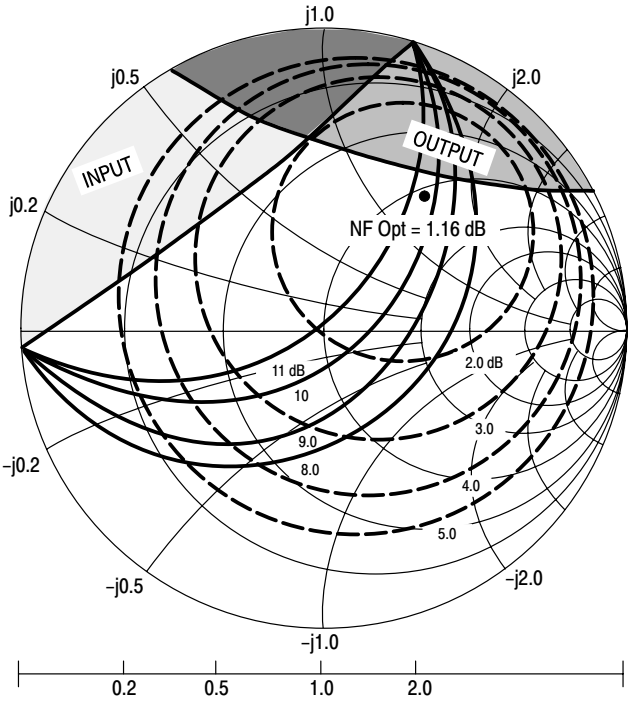


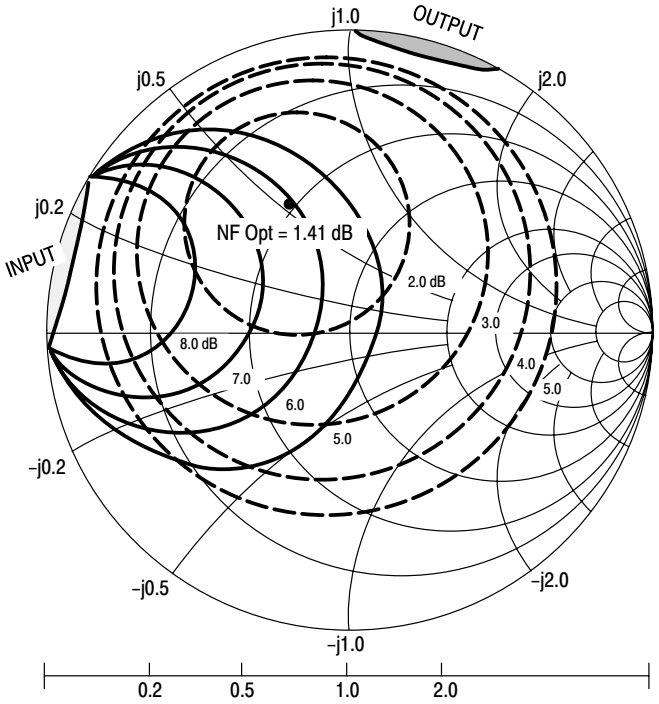
Figure 16. Constant Gain and Noise Figure Contours (f = 1.0 GHz)



V_{CE} = 1.0 V
I_C = 1.0 mA
— Potentially Unstable

f (GHz)	NF Opt (dB)	Γ_o	Rn	K
1.0	1.16	0.57 ∠ 51.3°	21.8	0.49

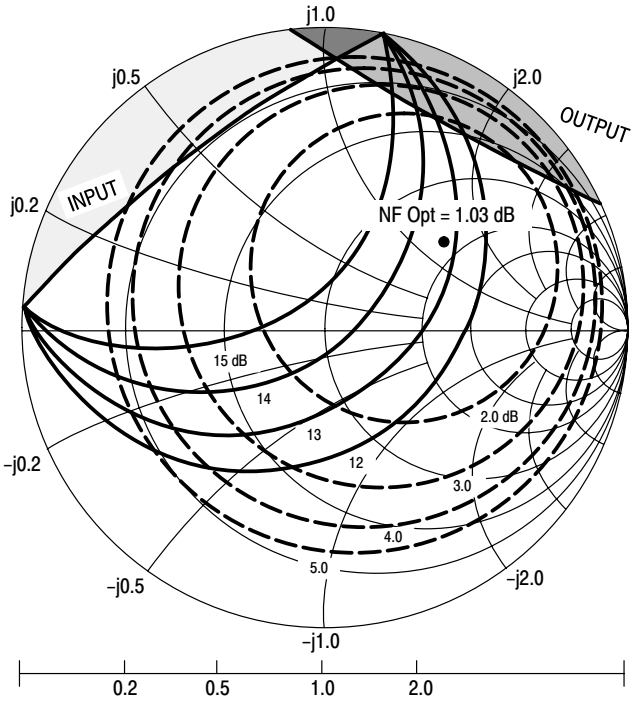
Figure 17. Constant Gain and Noise Figure Contours (f = 2.0 GHz)



V_{CE} = 1.0 V
I_C = 1.0 mA
— Potentially Unstable

f (GHz)	NF Opt (dB)	Γ_o	Rn	K
2.0	1.41	0.48 ∠ 115.6°	9.8	0.92

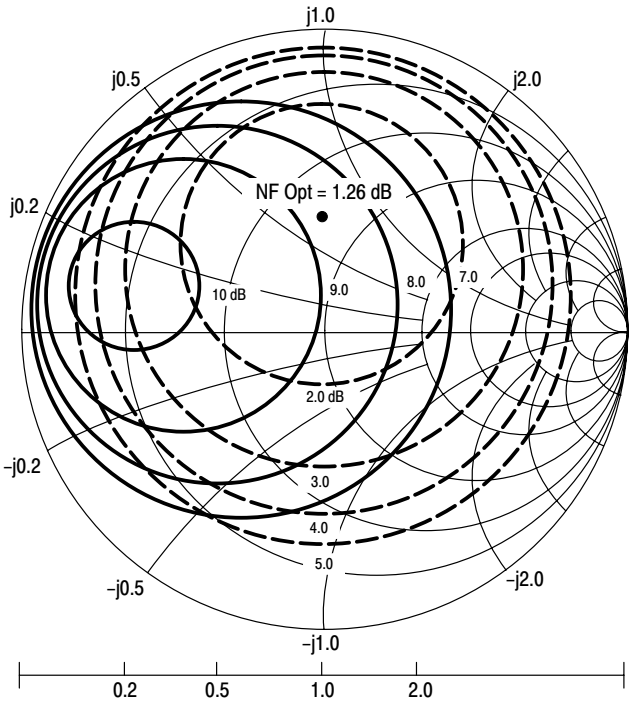
Figure 18. Constant Gain and Noise Figure Contours (f = 1.0 GHz)



V_{CE} = 3.0 V
I_C = 3.0 mA
— Potentially Unstable

f (GHz)	NF Opt (dB)	Γ_o	Rn	K
1.0	1.03	0.50 ∠ 37.1°	17.6	0.78

Figure 19. Constant Gain and Noise Figure Contours (f = 2.0 GHz)

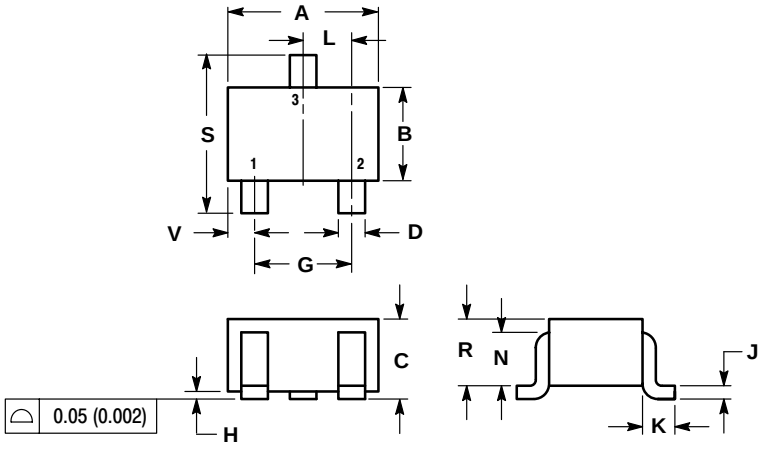


V_{CE} = 3.0 V
I_C = 3.0 mA
— Potentially Unstable

f (GHz)	NF Opt (dB)	Γ_o	Rn	K
2.0	1.26	0.37 ∠ 91.7°	10.7	1.03

OUTLINE DIMENSIONS

PLASTIC PACKAGE
CASE 419–02
(SC–70)
ISSUE J



NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.

	INCHES		MILLIMETERS	
DIM	MIN	MAX	MIN	MAX
A	0.071	0.087	1.80	2.20
B	0.045	0.053	1.15	1.35
C	0.035	0.049	0.90	1.25
D	0.012	0.016	0.30	0.40
G	0.047	0.055	1.20	1.40
H	0.000	0.004	0.00	0.10
J	0.004	0.010	0.10	0.25
K	0.017 REF		0.425 REF	
L	0.026 BSC		0.650 BSC	
N	0.028 REF		0.700 REF	
R	0.031	0.039	0.80	1.00
S	0.079	0.087	2.00	2.20
V	0.012	0.016	0.30	0.40

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