UNIVERSITI SAINS MALAYSIA

First Semester Examination
Academic Session 2008/2009

November 2008

EEE 532 – MICROWAVE CIRCUIT DESIGN

Duration: 2 hours

Please check that this examination paper consists of EIGHT pages of printed material and TWENTY EIGHT pages Appendix before you begin the examination.

This paper contains SIX questions and three sections, Section A, Section B and Section C.

Instructions: Answer **FOUR (4)** questions. Answer ONE question in Section A, Section B and Section C. ONE question from any Section.

Use three answer booklets which is provided where the answer for questions in Section A, Section B and Section C are in difference answer booklets.

Answer to any question must start on a new page.

Distribution of marks for each question is given accordingly

All questions must be answered in English.

Section A: Answer ONE (1) question.

1. Design a matching section to match a 50 ohm transmission line to a load $Z_L = 5 - j\,10$ ohm at frequency 1GHz using:

   (i) A quarter wave transformer (35%)

   (ii) Graphical method (35%)

   (iii) What are the advantages and disadvantages of the graphical method (30%)

   Use FR4 ($\varepsilon_r = 4.5$, h=1.5mm.,$\sigma = 4.1$ e7 S)

2. (a) Design a single-section 10 dB line coupler using duroid of ε_r=2.25 , h=1mm at frequency 2GHz. Given that w_{50} =2.8mm and

   $C = 10^{-x/20}$; where x is the coupling in dB

$$Z_{oe} = Z_o\sqrt{\frac{1+C}{1-C}}$$

$$Z_{oo} = Z_o\sqrt{\frac{1-C}{1+C}}$$

$$\frac{1}{2}\left(Z_{oe} - Z_{oo}\right) = JZ_o$$

(50%)

   (b) A branch coupler is shown Figure 1. Design a 9 dB branch coupler taking Ysh=0.7 using FR4 of ε_r=4.5 , h=1.5mm at frequency 2GHz. Given that w_{50} =3mm and using

$$Y_{se}^2 = 1 + Y_{sh}^2$$

$$\frac{E_3}{E_2} = \frac{2Y_{sh}}{1 - Y_{sh}^2 + Y_{se}^2}$$

$$\frac{E_3}{E_1} = 10^{(-x/20)}$$

$$E_1^2 = E_2^2 + E_3^2$$

$$Z_o = \frac{377}{\sqrt{\varepsilon_r}\left[\frac{w}{h} + 1.6\right]}$$

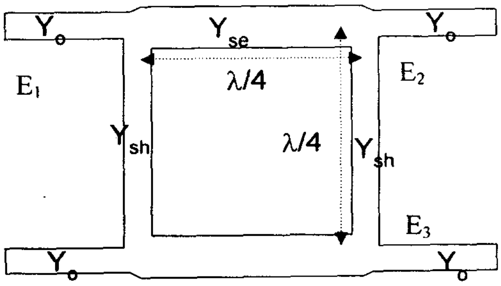

Figure 1

(50%)

Section B: Answer ONE (1) question.

3. (a) Draw the equivalent circuit of an incremental length of Δz using lumped-element equivalent circuit i.e. R,L and C.

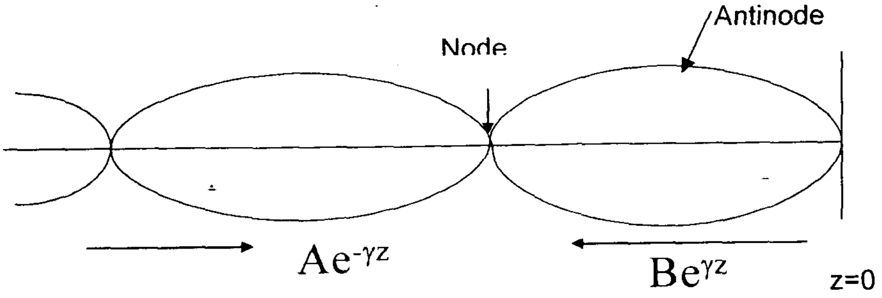

Figure 1

(20%)

(b) Using Figure 1, assume that an incident wave of the form $Ae^{-\gamma z}$ is generated from a source at z<0 and the line is terminated at z = 0 with $Z_L \neq Z_0$. The reflected wave is given as $Be^{\gamma z}$.

(i) Write the total voltage of the line V(z) and I(z) for the sum of incident and reflected wave.

(ii) State the Reflection Coefficient, ρ

(iii) Show that $VSWR = \dfrac{1+|\rho|}{1-|\rho|}$

(iv) Write the value for VSWR that implies a matched load.

(55%)

(c) Given that a lossless line of electrical length $l = 0.3\lambda$ is terminated with a complex load impedance shown below. Find the reflection coefficient of the load and the SWR of the line.

(25%)

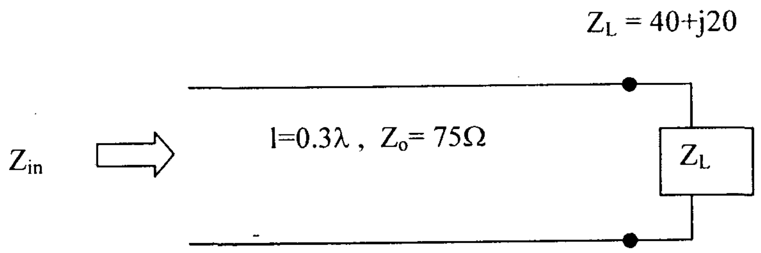

Figure 2

4. (a) The basic idea of impedance matching can be illustrated by putting an impedance matching network positioned between a load impedance and a transmission line. The matching network is ideally lossless, to avoid unnecessary loss of power, and is usually designed so that the impedance seen looking into the matching network is Z_0.

(i) Sketch the diagram to illustrate the above statement

(ii) State THREE (3) reasons why matching and tuning are important.

(25%)

(b) Answer the following questions:

(i) Matching with lumped elements (L Network) can be represented using 2 reactive elements to match an arbitrary load impedance. Draw and label correctly the configurations for $R_L > Z_o$ and $R_L < Z_o$. Show this on the smith chart.

(15%)

(ii) Design a possible solution for lossless L section matching network for the following the normalized load impedance. (Use Smith Chart)

$Z_L = 1.5 - j2.0$

$Z_o = 50\Omega$

$f = 500\text{MHz}$

(30%)

(c) Using Smith Chart, a load impedance $Z_L = 200 + j160\Omega$ is to be matched to a 100Ω line using a single shunt-stub tuner.

(i) Find TWO (2) solutions using open-circuited stubs.

(ii) Draw the solutions of the single shunt-stub tuner.

(30%)

Section C: Answer ONE (1) question.

5. Design a Low Noise Amplifier operating at 3 GHz, a biasing of the LNA should be V_{DS} = 3 V and I_{DS} = 40 mA. Required noise figure must be 0.8 dB. Select Γ_{in} for input matching at a point of C_{in}. Use single stub matching technique for the input and the output using quarterwave transformer matching. The length of the microstrip should be in millimeter. The parameters of the transistor can be found in Appendix VII. EPHEMT should be biased positively on the gate. The microstrip should be designed on Duroid having dielectric constants of 2.5 and thickness of 0.8mm.

(100%)

6. (a) Referring to Figure 2, show that the reflection coefficients Γ_L and Γ_{in} are related as $\Gamma_L\Gamma_{in} = 1$ for steady-state oscillation of the negative resistance oscillator.

(40%)

(b) Phase noise is a figure of merit of the oscillator, explain what the phase noise in the oscillator is.

(20%)

(c) Resonators are important components in the design of the oscillator, explain what resonator is and name three type of resonators that is typically been used in oscillator design.

(20%)

(d) Briefly describe the operation of the feedback type oscillator topology and explain the important criterion in the design of that oscillator.

(20%)

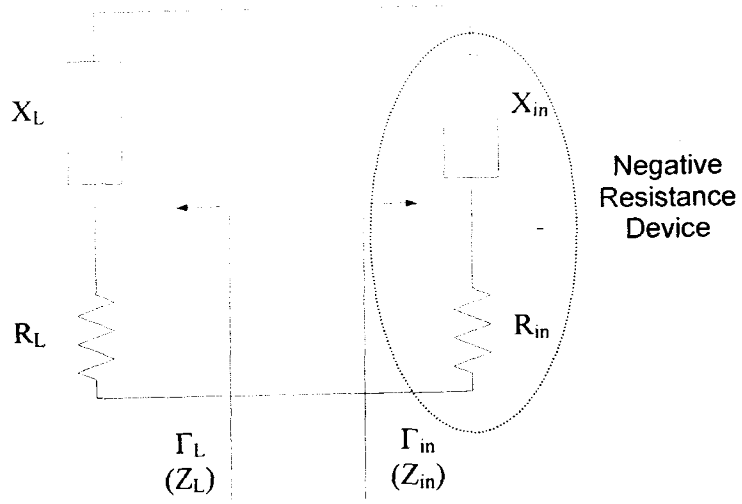

Figure 2

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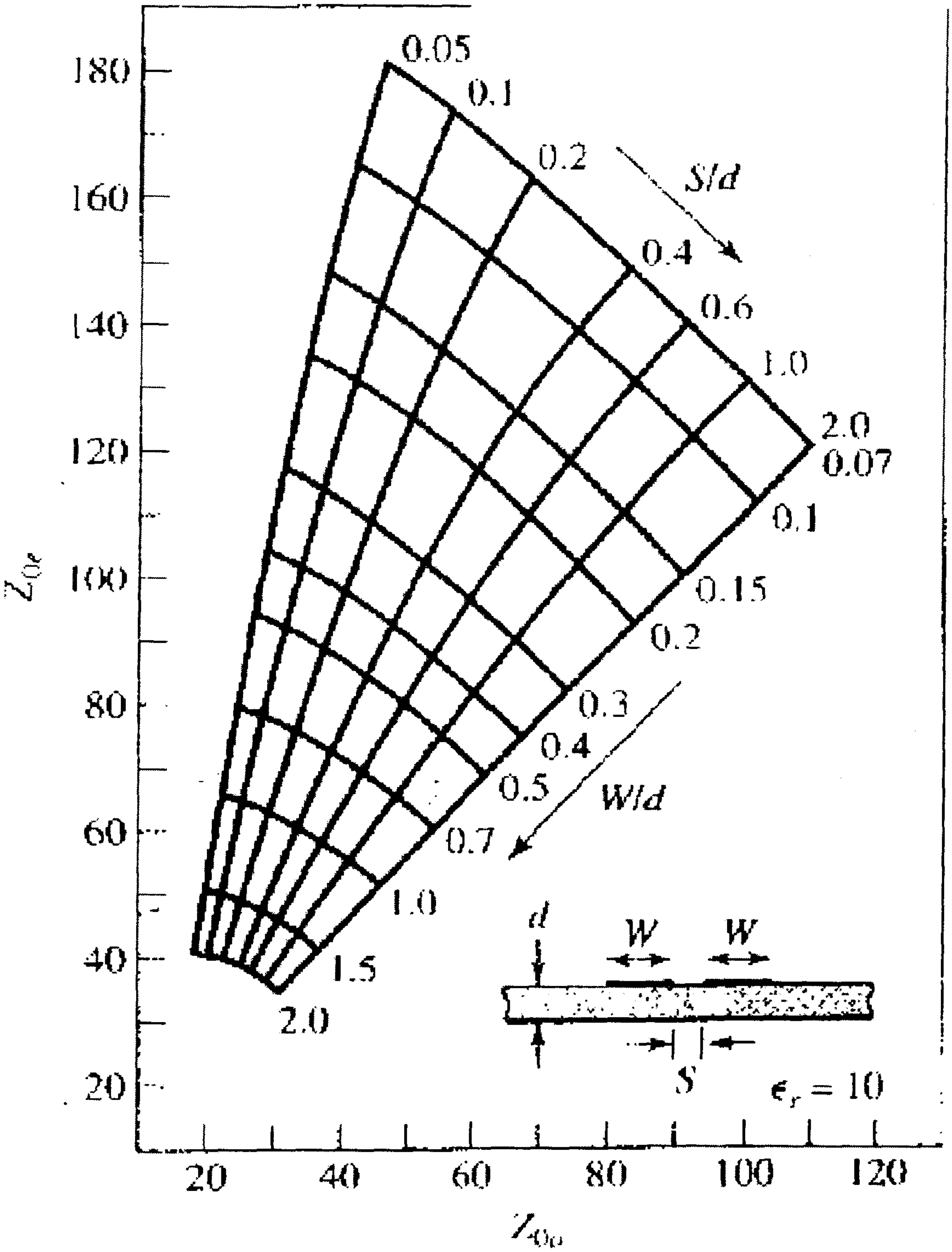

0.05
0.1
0.2
0.4
0.6
1.0
2.0
S/d
0.07
0.1
0.15
0.2
0.3
0.4
0.5
0.7
1.0
1.5
2.0
W/d
d
W
W
S
$\epsilon_r = 10$
Z_{0e}
180
160
140
120
100
80
60
40
20
20
40
60
80
100
120
Z_{0o}

APPENDIX II

Important Formulas:

Network parameters

S=parameter

$$S_{11} = \left.\frac{V_{r1}}{V_{i1}}\right|_{V_{r2}=0} \qquad S_{12} = \left.\frac{V_{t2}}{V_{i2}}\right|_{V_{r2}=0} \qquad S_{21} = \left.\frac{V_{t1}}{V_{i1}}\right|_{V_{r1}=0} \qquad S_{22} = \left.\frac{V_{rt2}}{V_{i2}}\right|_{V_{r1}=0}$$

ABCD parameter

$$A = \left.\frac{V_1}{V_2}\right|_{I_2=0} \qquad B = \left.\frac{V_1}{-I_2}\right|_{V_2=0} \qquad C = \left.\frac{I_1}{V_2}\right|_{I_2=0} \qquad D = \left.\frac{I_1}{-I_2}\right|_{V_2=0}$$

Conversion

$$\begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} = \frac{1}{Z_oA + B + Z_o^2C + Z_oD}\begin{bmatrix} Z_oA + B - Z_o^2C - Z_oD & 2Z_o(AD - BC) \\ 2Z_o & -Z_oA + B - Z_o^2C + Z_oD \end{bmatrix}$$

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \frac{1}{2S_{21}}\begin{bmatrix} (1+S_{11})(1-S_{22}) + S_{12}S_{21} & Z_o((1+S_{11})(1+S_{22}) - S_{12}S_{21}) \\ \frac{1}{Z_o}((1-S_{11})(1-S_{22}) - S_{12}S_{21}) & (1-S_{11})(1+S_{22}) + S_{12}S_{21} \end{bmatrix}$$

Butterworth lowpass filter

$g_k = 2\sin(2k-1)\frac{\pi}{2n}$ where k=1,.........., n

$$g_0 = g_{n+1} = 1$$

$$n = \frac{\log_{10}(10^{A/10} - 1)}{2\log_{10}(\omega/\omega_c)}$$

$$C_k = \frac{g_k}{Z_o\omega_c}$$

$$L_k = \frac{Z_og_k}{\omega_c}$$

Bandpass filter

$$J_{01} = \left(\frac{\pi\,\Omega}{2g_0g_1}\right)^{\frac{1}{2}}$$

$J_{k,k+1} = \left(\dfrac{\pi\,\Omega}{2}\right)\dfrac{1}{\sqrt{g_k \cdot g_{k-1}}}$ where k=1,.........., n

$$J_{n,n+1} = \left(\frac{\pi\,\Omega}{2.g_n \cdot g_{n+1}}\right)$$

Amplifier design

Unilateral

$$\Gamma_S = \left(\frac{Z_S - Z_O}{Z_S + Z_O} \right) \qquad \Gamma_L = \left(\frac{Z_L - Z_O}{Z_L + Z_O} \right)$$

$$\Gamma_{in} = \left(S_{11} + \frac{S_{12}S_{21}\Gamma_L}{1 - S_{22}\Gamma_L} \right) \qquad \Gamma_{out} = \left(S_{22} + \frac{S_{12}S_{21}\Gamma_S}{1 - S_{11}\Gamma_S} \right)$$

Stability:

$$K = \frac{1 - |S_{11}|^2 - |S_{22}|^2 + |D|^2}{2|S_{12}S_{21}|}$$

$$D = S_{11}S_{22} - S_{12}S_{21}$$

Power gain:

$$G = \left(\frac{|S_{21}|^2 (1 - |\Gamma_L|^2)}{(1 - |\Gamma_{in}|^2)|1 - S_{22}\Gamma_L|^2} \right)$$

Available Power gain:

$$G_A = \left(\frac{|S_{21}|^2 (1 - |\Gamma_S|^2)}{|1 - S_{11}\Gamma_S|^2 (1 - |\Gamma_{out}|^2)} \right)$$

Transducer Power Gain:

$$G_T = \frac{|S_{21}|^2 (1 - |\Gamma_S|^2)(1 - |\Gamma_L|^2}{|1 - \Gamma_S\Gamma_{in}|^2 |1 - S_{22}\Gamma_L|^2}$$

Bilateral

$$\Delta = S_{11}S_{22} - S_{12}S_{21}$$

$$K = \frac{1 - |S_{11}|^2 - |S_{22}|^2 + |\Delta|}{2|S_{12}S_{21}|}$$

$$\Gamma_s = \frac{B_1 \pm \sqrt{B_1^2 - 4|C_1|^2}}{2C_1} \qquad B_1 = 1 + |S_{11}|^2 - |S_{22}|^2 - |\Delta|^2 \qquad C_1 = S_{11} - \Delta S_{22}^*$$

$$\Gamma_L = \frac{B_2 \pm \sqrt{B_2^2 - 4|C_2|^2}}{2C_2} \qquad B_2 = 1 + |S_{22}|^2 - |S_{11}|^2 - |\Delta|^2 \qquad C_2 = S_{22} - \Delta S_{11}^*$$

$$\Gamma_{in} = \Gamma_S^* = S_{11} + \frac{S_{12}S_{21}\Gamma_L}{1 - S_{22}\Gamma_L} \qquad \Gamma_{out} = \Gamma_L^* = S_{22} + \frac{S_{12}S_{21}\Gamma_S}{1 - S_{11}\Gamma_S}$$

$$C_L = \frac{\left(S_{22} - \Delta S_{11}^{*}\right)^{*}}{|S_{22}|^2 - |\Delta|^2} \qquad R_L = \left|\frac{S_{12}S_{21}}{|S_{22}|^2 - |\Delta|^2}\right|$$

$$C_S = \frac{\left(S_{11} - \Delta S_{22}^{*}\right)^{*}}{|S_{11}|^2 - |\Delta|^2} \qquad R_S = \left|\frac{S_{12}S_{21}}{|S_{11}|^2 - |\Delta|^2}\right|$$

$$G_{T\,\max} = \frac{1}{1 - |\Gamma_s|^2}|S_{21}|^2 \frac{1 - |\Gamma_L|^2}{|1 - S_{22}\Gamma_L|^2}$$

Low Noise Amplifier

Center: $$C_i = \frac{\Gamma_{opt}}{(1 + N_i)}$$

Radius: $$R_i = \frac{1}{1 + N_i}\sqrt{N_i^{\,2} + N_i(1 - |\Gamma_{opt}|^2)}$$

$$Ni = \frac{\left[(Fr - F\min)|1 + \Gamma_{opt}|^2\right]}{4\dfrac{R_n}{Z_o}}$$

$$\Gamma_L = \left(S_{22} + \frac{S_{12}S_{21}\Gamma_{in}}{1 - S_{11}\Gamma_{in}}\right)^{*}$$

Microstrip:

$$Z_O = \frac{377}{\sqrt{\varepsilon_r}\left(\dfrac{w}{h} + 2\right)}$$

Binomial transformer

$$\ln \frac{Z_{n+1}}{Z_n} \approx 2AC_n^N \approx 2^{-N} C_n^N \ln \frac{Z_L}{Z_o}$$

$$C_n^N = \frac{N!}{(N-n)!n!}$$

$$\Gamma_n = \frac{Z_{n+1} - Z_n}{Z_{n+1} + Z_n} \approx \frac{1}{2} \ln\left(\frac{Z_{n+1}}{Z_n}\right)$$

Trigonometry

$$\sin A \sin B = \tfrac{1}{2}\left[\cos(A-B) - \cos(A+B)\right]$$
$$\cos A \cos B = \tfrac{1}{2}\left[\cos(A-B) + \cos(A+B)\right]$$
$$\sin A \cos B = \tfrac{1}{2}\left[\sin(A+B) + \sin(A-B)\right]$$
$$\cos A \sin B = \tfrac{1}{2}\left[\sin(A+B) - \sin(A-B)\right]$$

APPENDIX III

NAME	TITLE	DWG. NO.
		DATE
SMITH CHART FORM ZY-01-N	Microwave Circuit Design - EE[illegible] - Fall 2006	

NORMALIZED IMPEDANCE AND ADMITTANCE COORDINATES

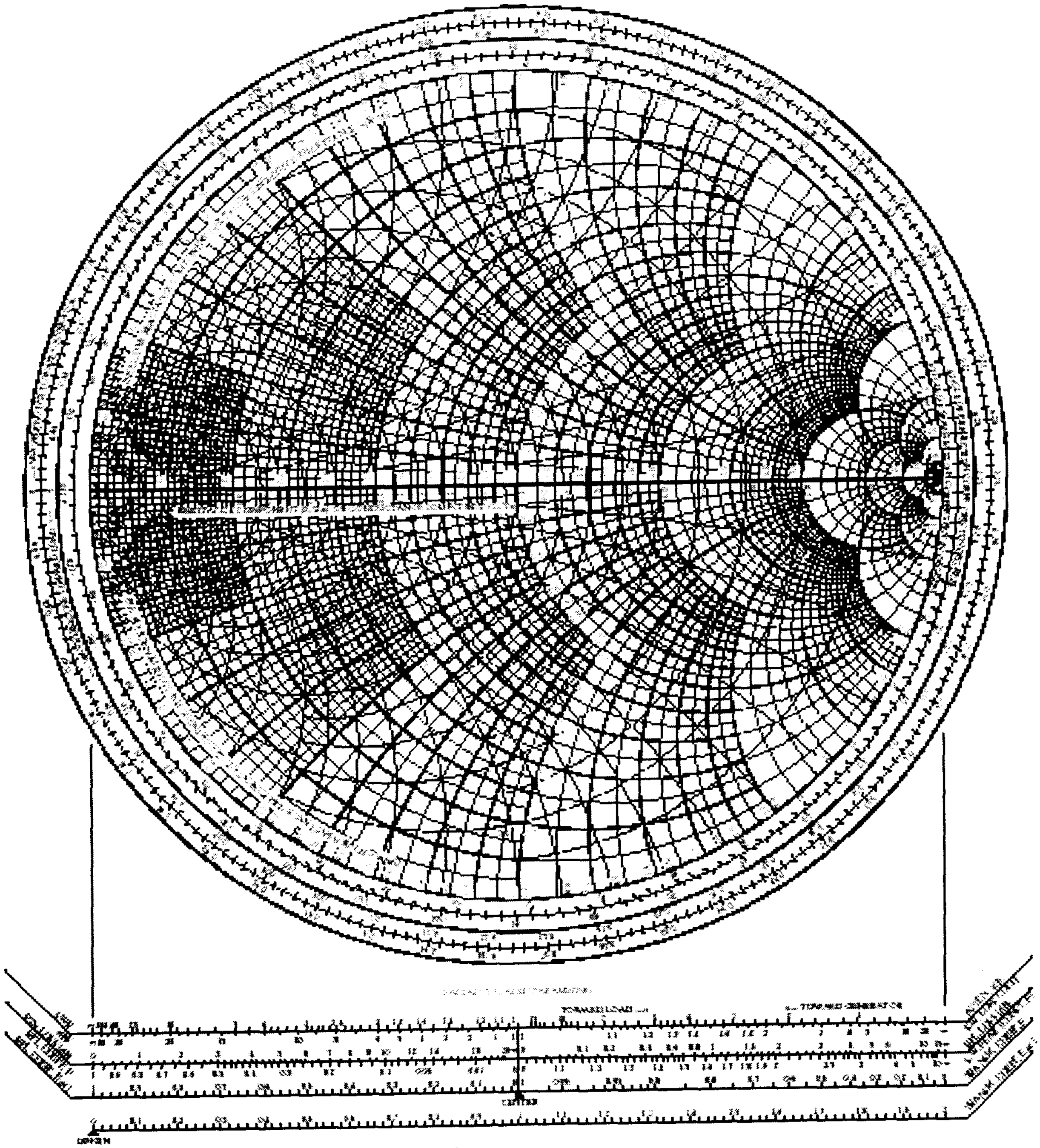
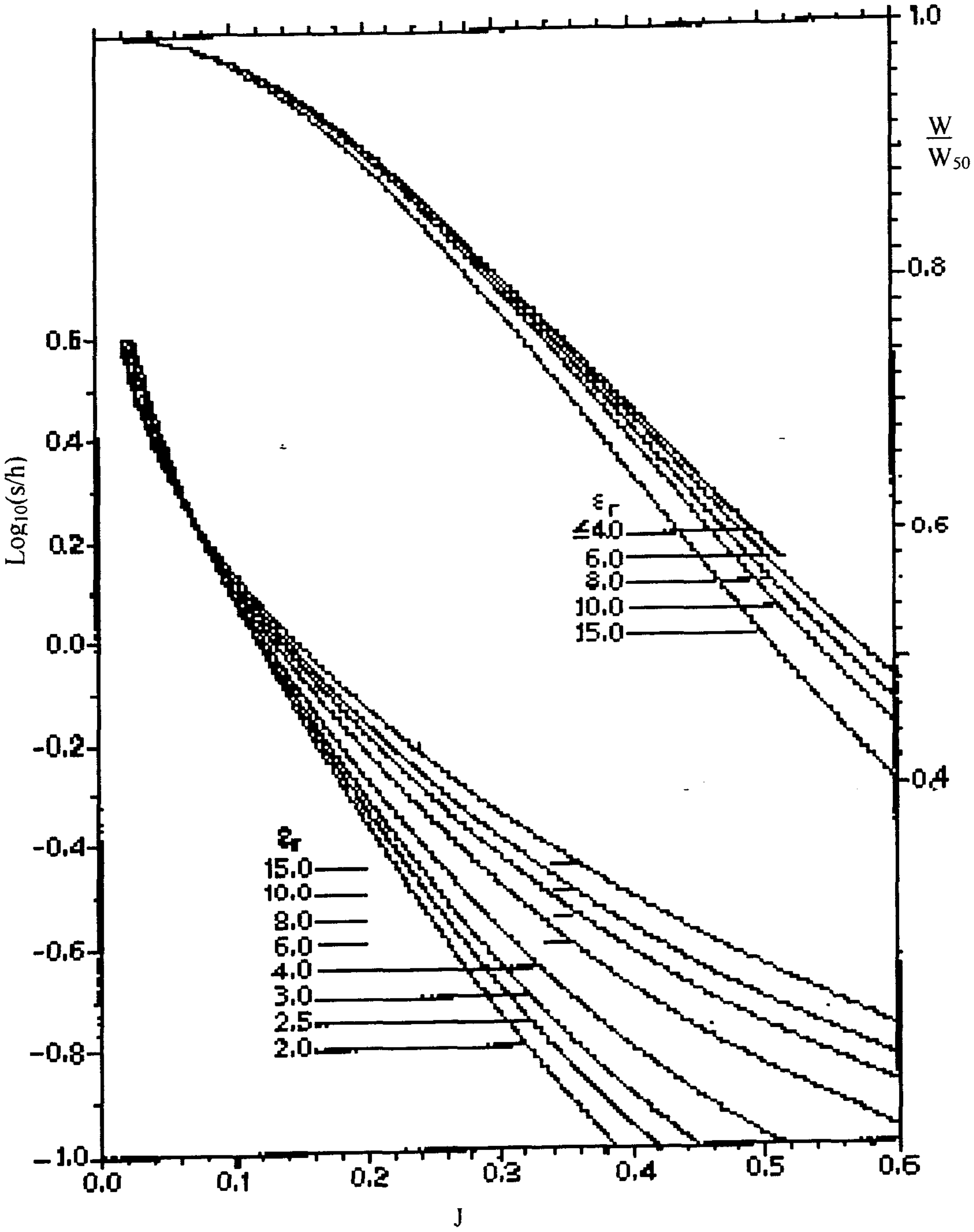


Table 1 : Conversions between two-port network parameters

	S	Z	Y	$ABCD$
S_{11}	S_{11}	$\frac{(Z_{11}-Z_0)(Z_{22}+Z_0)-Z_{12}Z_{21}}{\Delta Z}$	$\frac{(Y_0-Y_{11})(Y_0+Y_{22})+Y_{12}Y_{21}}{\Delta Y}$	$\frac{A+B/Z_0-CZ_0-D}{A+B/Z_0+CZ_0+D}$
S_{12}	S_{12}	$\frac{2Z_{12}Z_0}{\Delta Z}$	$\frac{-2Y_{12}Y_0}{\Delta Y}$	$\frac{2(AD-BC)}{A+B/Z_0+CZ_0+D}$
S_{21}	S_{21}	$\frac{2Z_{21}Z_0}{\Delta Z}$	$\frac{-2Y_{21}Y_0}{\Delta Y}$	$\frac{2}{A+B/Z_0+CZ_0+D}$
S_{22}	S_{22}	$\frac{(Z_{11}+Z_0)(Z_{22}-Z_0)-Z_{12}Z_{21}}{\Delta Z}$	$\frac{(Y_0+Y_{11})(Y_0-Y_{22})+Y_{12}Y_{21}}{\Delta Y}$	$\frac{-A+B/Z_0-CZ_0+D}{A+B/Z_0+CZ_0+D}$
Z_{11}	$Z_0\frac{(1+S_{11})(1-S_{22})+S_{12}S_{21}}{(1-S_{11})(1-S_{22})-S_{12}S_{21}}$	Z_{11}	$\frac{Y_{22}}{\lvert Y\rvert}$	$\frac{A}{C}$
Z_{12}	$Z_0\frac{2S_{12}}{(1-S_{11})(1-S_{22})-S_{12}S_{21}}$	Z_{12}	$\frac{-Y_{12}}{\lvert Y\rvert}$	$\frac{AD-BC}{C}$
Z_{21}	$Z_0\frac{2S_{21}}{(1-S_{11})(1-S_{22})-S_{12}S_{21}}$	Z_{21}	$\frac{-Y_{21}}{\lvert Y\rvert}$	$\frac{1}{C}$
Z_{22}	$Z_0\frac{(1-S_{11})(1+S_{22})+S_{12}S_{21}}{(1-S_{11})(1-S_{22})-S_{12}S_{21}}$	Z_{22}	$\frac{Y_{11}}{\lvert Y\rvert}$	$\frac{D}{C}$
Y_{11}	$Y_0\frac{(1-S_{11})(1+S_{22})+S_{12}S_{21}}{(1+S_{11})(1+S_{22})-S_{12}S_{21}}$	$\frac{Z_{22}}{\lvert Z\rvert}$	Y_{11}	$\frac{D}{B}$
Y_{12}	$Y_0\frac{-2S_{12}}{(1+S_{11})(1+S_{22})-S_{12}S_{21}}$	$\frac{-Z_{12}}{\lvert Z\rvert}$	Y_{12}	$\frac{BC-AD}{B}$
Y_{21}	$Y_0\frac{-2S_{21}}{(1+S_{11})(1+S_{22})-S_{12}S_{21}}$	$\frac{-Z_{21}}{\lvert Z\rvert}$	Y_{21}	$\frac{-1}{B}$
Y_{22}	$Y_0\frac{(1+S_{11})(1-S_{22})+S_{12}S_{21}}{(1+S_{11})(1+S_{22})-S_{12}S_{21}}$	$\frac{Z_{11}}{\lvert Z\rvert}$	Y_{22}	$\frac{A}{B}$
A	$\frac{(1+S_{11})(1-S_{22})+S_{12}S_{21}}{2S_{21}}$	$\frac{Z_{11}}{Z_{21}}$	$\frac{-Y_{22}}{Y_{21}}$	A
B	$Z_0\frac{(1+S_{11})(1+S_{22})-S_{12}S_{21}}{2S_{21}}$	$\frac{\lvert Z\rvert}{Z_{21}}$	$\frac{-1}{Y_{21}}$	B
C	$\frac{1}{Z_0}\frac{(1-S_{11})(1-S_{22})-S_{12}S_{21}}{2S_{21}}$	$\frac{1}{Z_{21}}$	$\frac{-\lvert Y\rvert}{Y_{21}}$	C
D	$\frac{(1-S_{11})(1+S_{22})+S_{12}S_{21}}{2S_{21}}$	$\frac{Z_{22}}{Z_{21}}$	$\frac{-Y_{11}}{Y_{21}}$	D

$|Z| = Z_{11}Z_{22} - Z_{12}Z_{21}$; $|Y| = Y_{11}Y_{22} - Y_{12}Y_{21}$; $\Delta Y = (Y_{11} + Y_0)(Y_{22} + Y_0) - Y_{12}Y_{21}$; $\Delta Z = (Z_{11} + Z_0)(Z_{22} + Z_0) - Z_{12}Z_{21}$; $Y_0 = 1/Z_0$


1.0
W / W50
0.8
0.6
0.4
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
Log10(s/h)
εr
≤4.0
6.0
8.0
10.0
15.0
εr
15.0
10.0
8.0
6.0
4.0
3.0
2.5
2.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
J

* Nota:
Nilai komponen laluan rendah Butterworth ternormal ialah

$$g_k = 2\sin(2k-1)\frac{\pi}{2n} \qquad \text{di sini k=1,.........., n}$$

$$g_0 = g_{n+1} = 1$$

$$n = \frac{\log_{10}\left(10^{A/10}-1\right)}{2\log_{10}(\omega/\omega_c)}$$

$$C_k = \frac{g_k}{Z_o\omega_c}$$

$$L_k = \frac{Z_o g_k}{\omega_c}$$

Nilai-nilai regangan penuras lulusjalur

$$J_{01} = \left(\frac{\pi\,\Omega}{2g_0g_1}\right)^{\frac{1}{2}}$$

$$J_{k,k+1} = \left(\frac{\pi\,\Omega}{2}\right)\frac{1}{\sqrt{g_k \cdot g_{k+1}}} \qquad \text{di sini k=1,.........., n}$$

$$J_{n,n+1} = \left(\frac{\pi\,\Omega}{2.g_n.g_{n+1}}\right)^{\frac{1}{2}}$$

Rekabentuk penguat

$$\Delta = S_{11}S_{22} - S_{12}S_{21}$$

$$K = \frac{1-|S_{11}|^2-|S_{22}|^2+|\Delta|}{2|S_{12}S_{21}|}$$

$$\Gamma_s = \frac{B_1 \pm \sqrt{B_1^2 - 4|C_1|^2}}{2C_1} \qquad B_1 = 1+|S_{11}|^2-|S_{22}|^2-|\Delta|^2 \qquad C_1 = S_{11} - \Delta S_{22}^*$$

$$\Gamma_L = \frac{B_2 \pm \sqrt{B_2^2 - 4|C_2|^2}}{2C_2} \qquad B_2 = 1+|S_{22}|^2-|S_{11}|^2-|\Delta|^2 \qquad C_2 = S_{22} - \Delta S_{11}^*$$

$$\Gamma_{in} = \Gamma_S^* = S_{11} + \frac{S_{12}S_{21}\Gamma_L}{1-S_{22}\Gamma_L} \qquad \Gamma_{out} = \Gamma_L^* = S_{22} + \frac{S_{12}S_{21}\Gamma_S}{1-S_{11}\Gamma_S}$$

$$C_L = \frac{\left(S_{22} - \Delta S_{11}^*\right)^*}{|S_{22}|^2 - |\Delta|^2} \qquad R_L = \left| \frac{S_{12}S_{21}}{|S_{22}|^2 - |\Delta|^2} \right|$$

$$C_S = \frac{\left(S_{11} - \Delta S_{22}^*\right)^*}{|S_{11}|^2 - |\Delta|^2} \qquad R_S = \left| \frac{S_{12}S_{21}}{|S_{11}|^2 - |\Delta|^2} \right|$$

$$G_{T\max} = \frac{1}{1 - |\Gamma_s|^2} |S_{21}|^2 \frac{1 - |\Gamma_L|^2}{|1 - S_{22}\Gamma_L|^2}$$

Series inductor and shunt capacitor in microstripline

$$C = \frac{2}{Z_c \omega} \sin\left(\frac{\omega \ell}{2c_1}\right)$$

trigometry values in radian

$$L = \frac{Z_L}{\omega} \sin\left(\frac{\omega \ell}{c_1}\right)$$

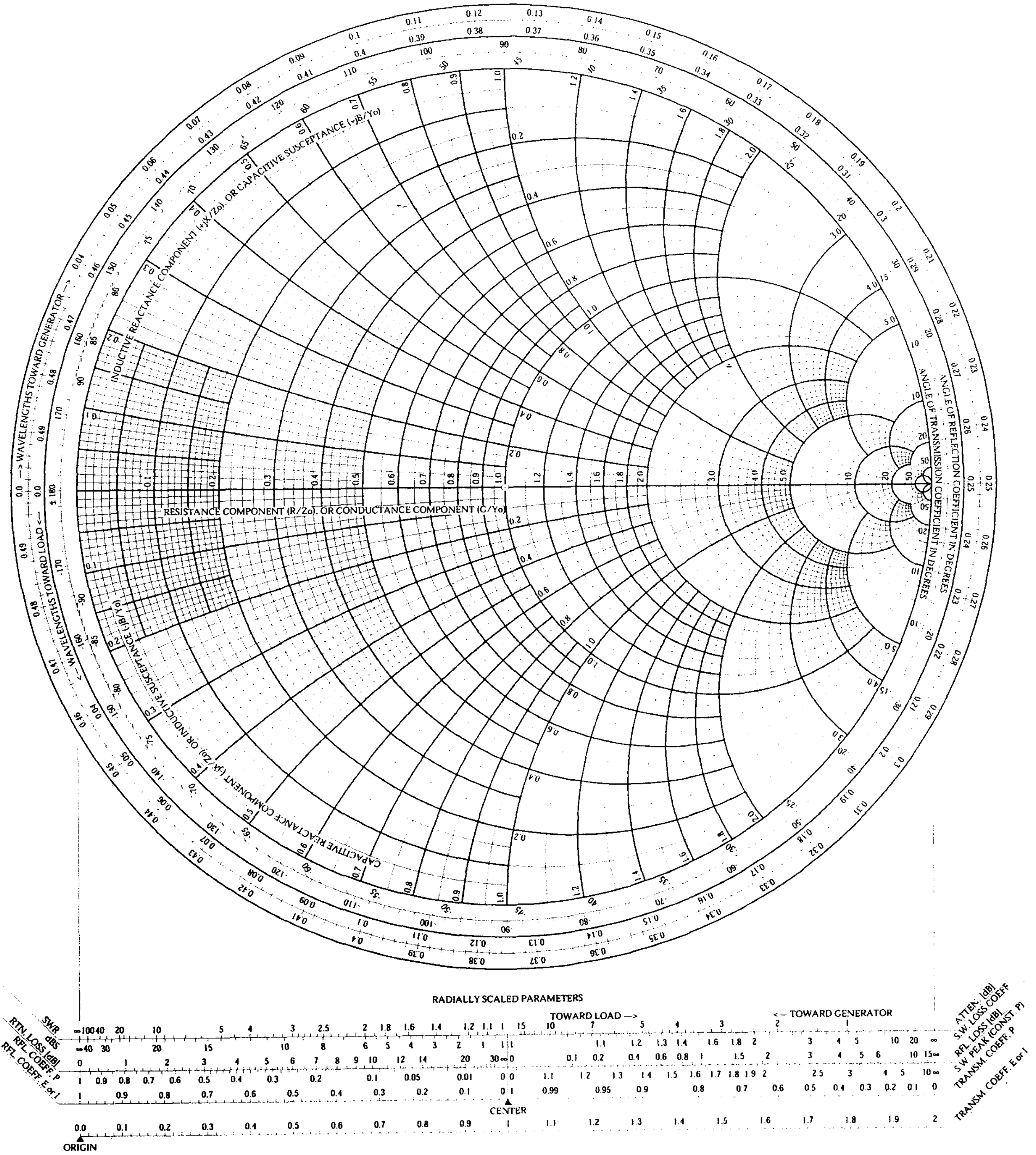
$$c_1 = \frac{3 \times 10^8}{\sqrt{\varepsilon_r}} \quad m/s$$

Z_{oc}= characteristic impedance of capacitor $<0.5\ Z_o$

Z_{oL}=characteristic impedance of inductor $> 2\ Z_o$

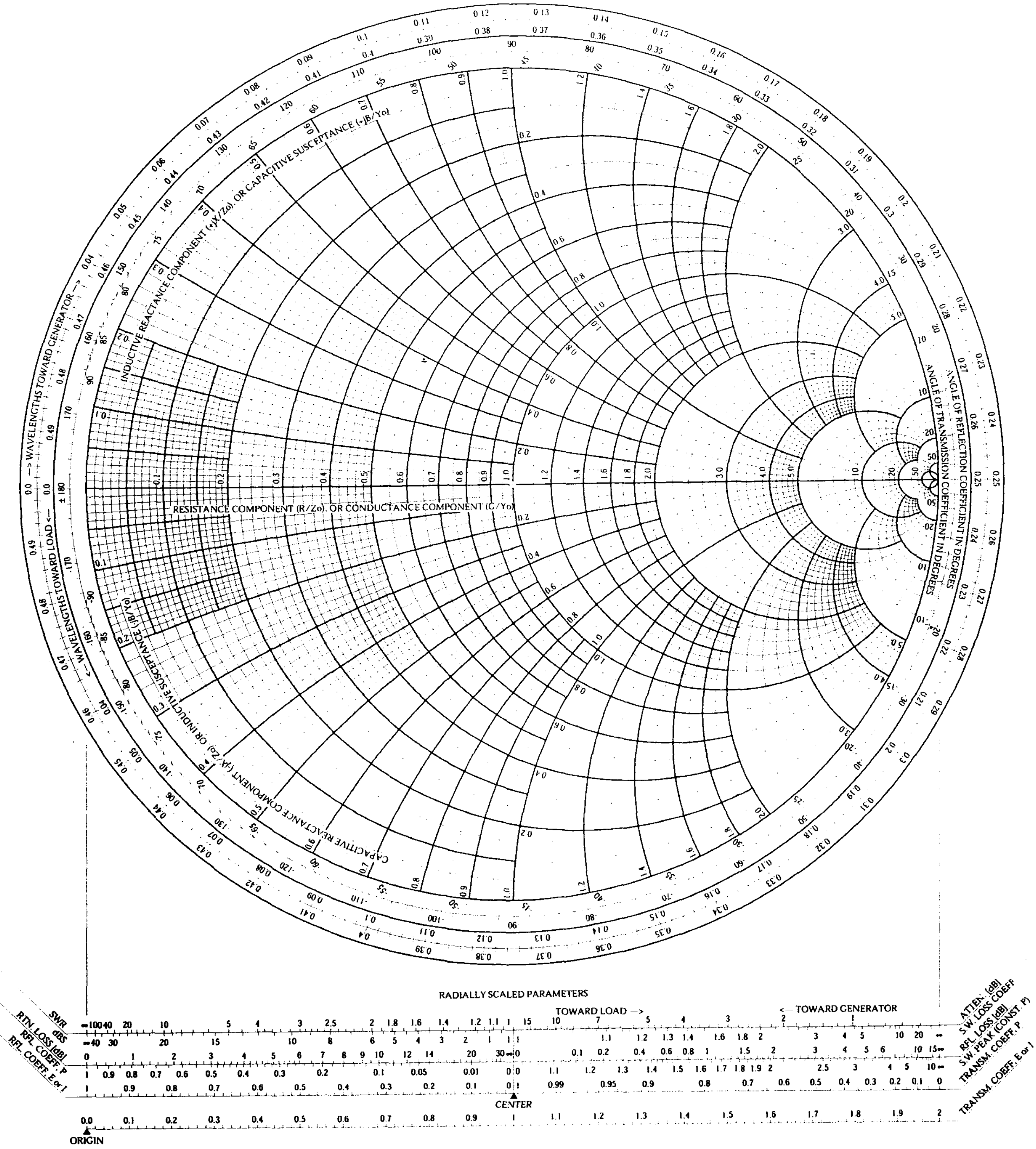
The Complete Smith Chart

Black Magic Design



The Complete Smith Chart

Black Magic Design



Agilent ATF-54143 Low Noise Enhancement Mode Pseudomorphic HEMT in a Surface Mount Plastic Package

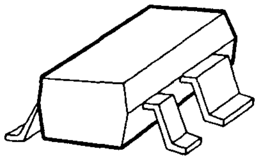
Data Sheet

Description

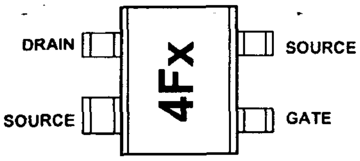
Agilent Technologies's ATF-54143 is a high dynamic range, low noise, E-PHEMT housed in a 4-lead SC-70 (SOT-343) surface mount plastic package.

The combination of high gain, high linearity and low noise makes the ATF-54143 ideal for cellular/PCS base stations, MMDS, and other systems in the 450 MHz to 6 GHz frequency range.

Surface Mount Package SOT-343



Pin Connections and Package Marking



Note:
Top View. Package marking provides orientation and identification

"4F" = Device Code
"x" = Date code character identifies month of manufacture.

Features

- High linearity performance
- Enhancement Mode Technology[1]
- Low noise figure
- Excellent uniformity in product specifications
- 800 micron gate width
- Low cost surface mount small plastic package SOT-343 (4 lead SC-70)
- Tape-and-Reel packaging option available

Specifications
2 GHz; 3 V, 60 mA (Typ.)

- 36.2 dBm output 3^{rd} order intercept
- 20.4 dBm output power at 1 dB gain compression
- 0.5 dB noise figure
- 16.6 dB associated gain

Applications

- Low noise amplifier for cellular/ PCS base stations
- LNA for WLAN, WLL/RLL and MMDS applications
- General purpose discrete E-PHEMT for other ultra low noise applications

Note:
1. Enhancement mode technology requires positive Vgs, thereby eliminating the need for the negative gate voltage associated with conventional depletion mode devices.

Agilent Technologies

[EEE 532]

ATF-54143 Absolute Maximum Ratings[1]

Symbol	Parameter	Units	Absolute Maximum
V_{DS}	Drain - Source Voltage[2]	V	5
V_{GS}	Gate - Source Voltage[2]	V	-5 to 1
V_{GD}	Gate Drain Voltage[2]	V	5
I_{DS}	Drain Current[2]	mA	120
P_{diss}	Total Power Dissipation[3]	mW	360
$P_{in\ max.}$	RF Input Power	dBm	10[5]
I_{GS}	Gate Source Current	mA	2[5]
T_{CH}	Channel Temperature	°C	150
T_{STG}	Storage Temperature	°C	-65 to 150
θ_{jc}	Thermal Resistance[4]	°C/W	162

Notes:

1. Operation of this device in excess of any one of these parameters may cause permanent damage.
2. Assumes DC quiescent conditions.
3. Source lead temperature is 25°C. Derate 6 mW/°C for $T_L > 92$°C.
4. Thermal resistance measured using 150°C Liquid Crystal Measurement method.
5. The device can handle +10 dBm RF Input Power provided I_{GS} is limited to 2 mA. I_{GS} at P_{1dB} drive level is bias circuit dependent. See application section for additional information.

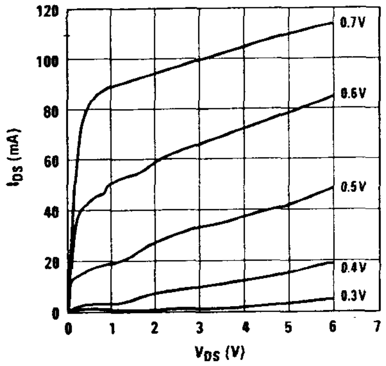


Figure 1. Typical I-V Curves.
(V_{GS} = 0.1 V per step)

Product Consistency Distribution Charts[6, 7]

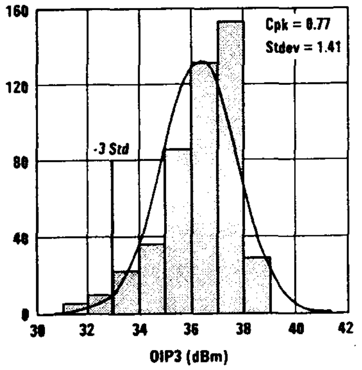


Figure 2. OIP3 @ 2 GHz, 3 V, 60 mA.
LSL = 33.0, Nominal = 36.575

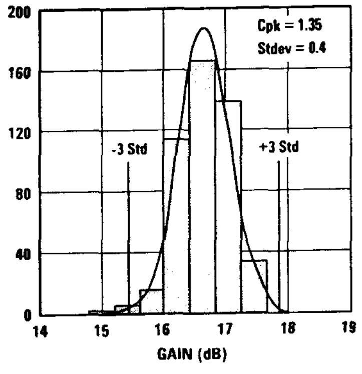


Figure 3. Gain @ 2 GHz, 3 V, 60 mA.
USL = 18.5, LSL = 15, Nominal = 16.6

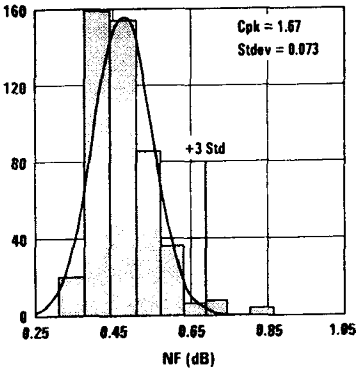


Figure 4. NF @ 2 GHz, 3 V, 60 mA.
USL = 0.9, Nominal = 0.49

Notes:

6. Distribution data sample size is 450 samples taken from 9 different wafers. Future wafers allocated to this product may have nominal values anywhere between the upper and lower limits.
7. Measurements made on production test board. This circuit represents a trade-off between an optimal noise match and a realizeable match based on production test equipment. Circut losses have been de-embeaded from actual measurements.

ATF-54143 Electrical Specifications

T_A = 25°C, RF parameters measured in a test circuit for a typical device

Symbol	Parameter and Test Condition			Units	Min.	Typ.[2]	Max.
Vgs	Operational Gate Voltage		Vds = 3V, Ids = 60 mA	V	0.4	0.59	0.75
Vth	Threshold Voltage		Vds = 3V, Ids = 4 mA	V	0.18	0.38	0.52
Idss	Saturated Drain Current		Vds = 3V, Vgs = 0V	μA	—	1	5
Gm	Transconductance		Vds = 3V, gm = ΔIdss/ΔVgs; ΔVgs = 0.75 - 0.7 = 0.05V	mmho	230	410	560
Igss	Gate Leakage Current		Vgd = Vgs = -3V	μA	—	—	200
NF	Noise Figure[1]	f = 2 GHz f = 900 MHz	Vds = 3V, Ids = 60 mA Vds = 3V, Ids = 60 mA	dB dB	— —	0.5 0.3	0.9 —
Ga	Associated Gain[1]	f = 2 GHz f = 900 MHz	Vds = 3V, Ids = 60 mA Vds = 3V, Ids = 60 mA	dB dB	15 —	16.6 23.4	18.5 —
OIP3	Output 3rd Order Intercept Point[1]	f = 2 GHz f = 900 MHz	Vds = 3V, Ids = 60 mA Vds = 3V, Ids = 60 mA	dBm dBm	33 —	36.2 35.5	— —
P1dB	1dB Compressed Output Power[1]	f = 2 GHz f = 900 MHz	Vds = 3V, Ids = 60 mA Vds = 3V, Ids = 60 mA	dBm dBm	— —	20.4 18.4	— —

Notes:

1. Measurements obtained using production test board described in Figure 5.
2. Typical values measured from a sample size of 450 parts from 9 wafers.

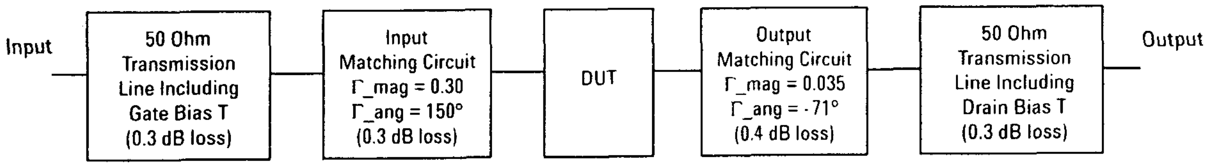


Figure 5. Block diagram of 2 GHz production test board used for Noise Figure, Associated Gain, P1dB, and OIP3 measurements. This circuit represents a trade-off between an optimal noise match and associated impedance matching circuit losses. Circuit losses have been de-embedded from actual measurements.

ATF-54143 Typical Performance Curves

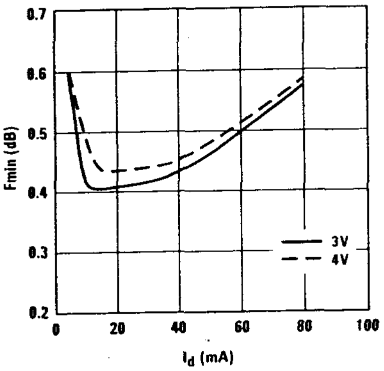


Figure 6. Fmin vs. I_{ds} and V_{ds} Tuned for Max OIP3 and Fmin at 2 GHz.

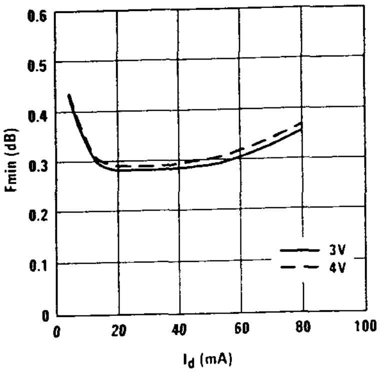


Figure 7. Fmin vs. I_{ds} and V_{ds} Tuned for Max OIP3 and Min NF at 900 MHz.

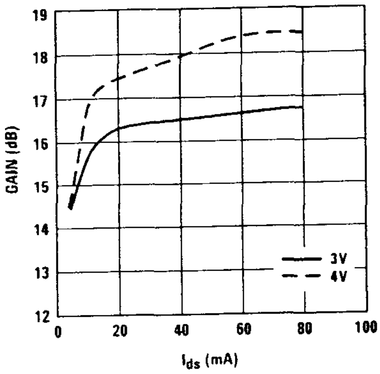


Figure 8. Gain vs. I_{ds} and V_{ds} Tuned for Max OIP3 and Fmin at 2 GHz.

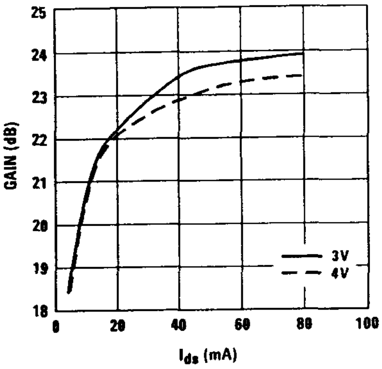


Figure 9. Gain vs. I_{ds} and V_{ds} Tuned for Max OIP3 and Fmin at 900 MHz.

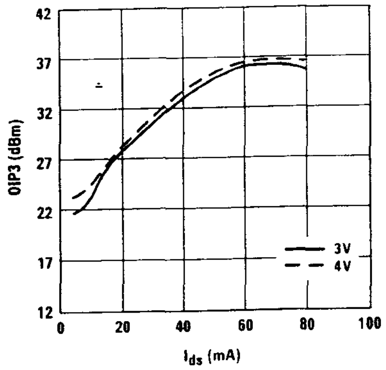


Figure 10. OIP3 vs. I_{ds} and V_{ds} Tuned for Max OIP3 and Fmin at 2 GHz.

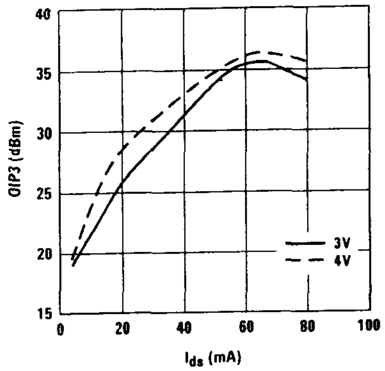


Figure 11. OIP3 vs. I_{ds} and V_{ds} Tuned for Max OIP3 and Fmin at 900 MHz.

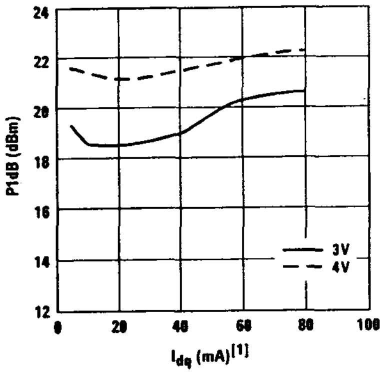


Figure 12. P1dB vs. I_{dq} and V_{ds} Tuned for Max OIP3 and Fmin at 2 GHz.

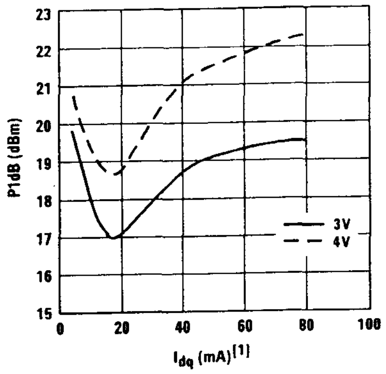


Figure 13. P1dB vs. I_{dq} and V_{ds} Tuned for Max OIP3 and Fmin at 900 MHz.

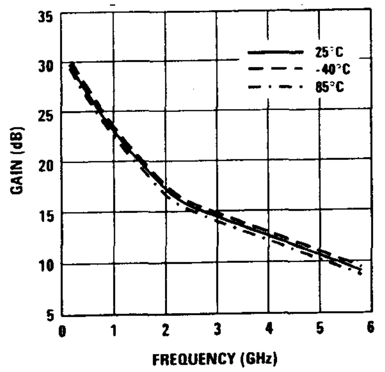


Figure 14. Gain vs. Frequency and Temp Tuned for Max OIP3 and Fmin at 3V, 60 mA.

Notes:

1. I_{dq} represents the quiescent drain current without RF drive applied. Under low values of I_{ds}, the application of RF drive will cause I_d to increase substantially as P1dB is approached.
2. Fmin values at 2 GHz and higher are based on measurements while the Fmins below 2 GHz have been extrapolated. The Fmin values are based on a set of 16 noise figure measurements made at 16 different impedances using an ATN NP5 test system. From these measurements a true Fmin is calculated. Refer to the noise parameter application section for more information.

[EEE 532]

ATF-54143 Typical Performance Curves, continued

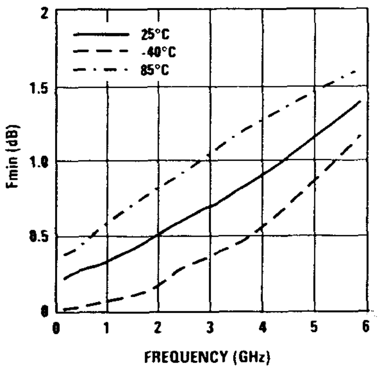


Figure 15. Fmin[2] vs. Frequency and Temp Tuned for Max OIP3 and Fmin at 3V, 60 mA.

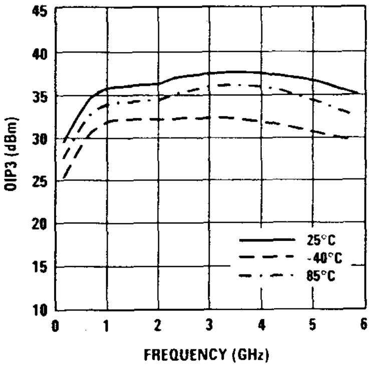


Figure 16. OIP3 vs. Frequency and Temp Tuned for Max OIP3 and Fmin at 3V, 60 mA.

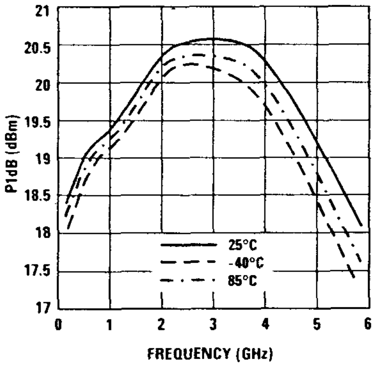


Figure 17. P1dB vs. Frequency and Temp Tuned for Max OIP3 and Fmin at 3V, 60 mA.

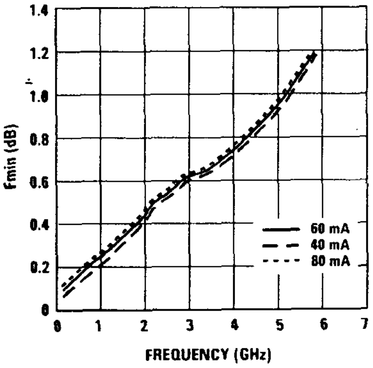


Figure 18. Fmin[1] vs. Frequency and I_{ds} at 3V.

ATF-54143 Reflection Coefficient Parameters tuned for Maximum Output IP3, V_{DS} = 3V, I_{DS} = 60 mA

Freq (GHz)	ΓOut_Mag.[1] (Mag)	ΓOut_Ang.[1] (Degrees)	OIP3 (dBm)	P1dB (dBm)
0.9	0.017	115	35.54	18.4
2.0	0.026	-85	36.23	20.38
3.9	0.013	173	37.54	20.28
5.8	0.025	102	35.75	18.09

Note:

1. Gamma out is the reflection coefficient of the matching circuit presented to the output of the device.

Note:

1. Fmin values at 2 GHz and higher are based on measurements while the Fmins below 2 GHz have been extrapolated. The Fmin values are based on a set of 16 noise figure measurements made at 16 different impedances using an ATN NP5 test system. From these measurements a true Fmin is calculated. Refer to the noise parameter application section for more information.

ATF-54143 Typical Scattering Parameters, V_{DS} = 3V, I_{DS} = 40 mA

Freq.	S_{11}		S_{21}			S_{12}		S_{22}		MSG/MAG
GHz	Mag.	Ang.	dB	Mag.	Ang.	Mag.	Ang.	Mag.	Ang.	dB
0.1	0.99	-17.6	27.99	25.09	168.5	0.009	80.2	0.59	-12.8	34.45
0.5	0.83	-76.9	25.47	18.77	130.1	0.036	52.4	0.44	-54.6	27.17
0.9	0.72	-114	22.52	13.37	108	0.047	40.4	0.33	-78.7	24.54
1.0	0.70	-120.6	21.86	12.39	103.9	0.049	38.7	0.31	-83.2	24.03
1.5	0.65	-146.5	19.09	9.01	87.4	0.057	33.3	0.24	-99.5	21.99
1.9	0.63	-162.1	17.38	7.40	76.6	0.063	30.4	0.20	-108.6	20.70
2.0	0.62	-165.6	17.00	7.08	74.2	0.065	29.8	0.19	-110.9	20.37
2.5	0.61	178.5	15.33	5.84	62.6	0.072	26.6	0.15	-122.6	19.09
3.0	0.61	164.2	13.91	4.96	51.5	0.080	22.9	0.12	-137.5	17.92
4.0	0.63	138.4	11.59	3.80	31	0.094	14	0.10	176.5	16.06
5.0	0.66	116.5	9.65	3.04	11.6	0.106	4.2	0.14	138.4	14.57
6.0	0.69	97.9	8.01	2.51	-6.7	0.118	-6.1	0.17	117.6	13.28
7.0	0.71	80.8	6.64	2.15	-24.5	0.128	-17.6	0.20	98.6	12.25
8.0	0.72	62.6	5.38	1.86	-42.5	0.134	-29.3	0.22	73.4	11.42
9.0	0.76	45.2	4.20	1.62	-60.8	0.145	-40.6	0.27	52.8	10.48
10.0	0.83	28.2	2.84	1.39	-79.8	0.150	-56.1	0.37	38.3	9.66
11.0	0.85	13.9	1.42	1.18	-96.9	0.149	-69.3	0.45	25.8	8.98
12.0	0.88	-0.5	0.23	1.03	-112.4	0.150	-81.6	0.51	12.7	8.35
13.0	0.89	-15.1	-0.86	0.91	-129.7	0.149	-95.7	0.54	-4.1	7.84
14.0	0.87	-31.6	-2.18	0.78	-148	0.143	-110.3	0.61	-20.1	7.36
15.0	0.88	-46.1	-3.85	0.64	-164.8	0.132	-124	0.65	-34.9	6.87
16.0	0.87	-54.8	-5.61	0.52	-178.4	0.121	-134.6	0.70	-45.6	6.37
17.0	0.87	-62.8	-7.09	0.44	170.1	0.116	-144.1	0.73	-55.9	5.81
18.0	0.92	-73.6	-8.34	0.38	156.1	0.109	-157.4	0.76	-68.7	5.46

Typical Noise Parameters, V_{DS} = 3V, I_{DS} = 40 mA

Freq GHz	F_{min} dB	Γ_{opt} Mag.	Γ_{opt} Ang.	$R_{n/50}$	G_a dB
0.5	0.17	0.34	34.80	0.04	27.83
0.9	0.22	0.32	53.00	0.04	23.57
1.0	0.24	0.32	60.50	0.04	22.93
1.9	0.42	0.29	108.10	0.04	18.35
2.0	0.45	0.29	111.10	0.04	17.91
2.4	0.51	0.30	136.00	0.04	16.39
3.0	0.59	0.32	169.90	0.05	15.40
3.9	0.69	0.34	-151.60	0.05	13.26
5.0	0.90	0.45	-119.50	0.09	11.89
5.8	1.14	0.50	-101.60	0.16	10.95
6.0	1.17	0.52	-99.60	0.18	10.64
7.0	1.24	0.58	-79.50	0.33	9.61
8.0	1.57	0.60	-57.90	0.56	8.36
9.0	1.64	0.69	-39.70	0.87	7.77
10.0	1.8	0.80	-22.20	1.34	7.68

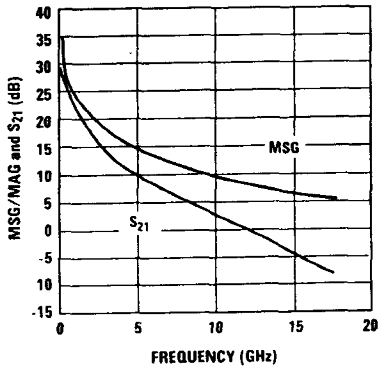


Figure 19. MSG/MAG and $|S_{21}|^2$ vs. Frequency at 3V, 40 mA.

Notes:

1. F_{min} values at 2 GHz and higher are based on measurements while the F_{mins} below 2 GHz have been extrapolated. The F_{min} values are based on a set of 16 noise figure measurements made at 16 different impedances using an ATN NP5 test system. From these measurements a true F_{min} is calculated. Refer to the noise parameter application section for more information.
2. S and noise parameters are measured on a microstrip line made on 0.025 inch thick alumina carrier. The input reference plane is at the end of the gate lead. The output reference plane is at the end of the drain lead. The parameters include the effect of four plated through via holes connecting source landing pads on top of the test carrier to the microstrip ground plane on the bottom side of the carrier. Two 0.020 inch diameter via holes are placed within 0.010 inch from each source lead contact point, one via on each side of that point.

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ATF-54143 Typical Scattering Parameters, V_{DS} = 3V, I_{DS} = 60 mA

Freq.	S_{11}			S_{21}		S_{12}		S_{22}		MSG/MAG
GHz	Mag.	Ang.	dB	Mag.	Ang.	Mag.	Ang.	Mag.	Ang.	dB
0.1	0.99	-18.9	28.84	27.66	167.6	0.01	80.0	0.54	-14.0	34.88
0.5	0.81	-80.8	26.04	20.05	128.0	0.03	52.4	0.40	-58.8	27.84
0.9	0.71	-117.9	22.93	14.01	106.2	0.04	41.8	0.29	-83.8	25.13
1.0	0.69	-124.4	22.24	12.94	102.2	0.05	40.4	0.27	-88.5	24.59
1.5	0.64	-149.8	19.40	9.34	86.1	0.05	36.1	0.21	-105.2	22.46
1.9	0.62	-164.9	17.66	7.64	75.6	0.06	33.8	0.17	-114.7	21.05
2.0	0.62	-168.3	17.28	7.31	73.3	0.06	33.3	0.17	-117.0	20.71
2.5	0.60	176.2	15.58	6.01	61.8	0.07	30.1	0.13	-129.7	19.34
3.0	0.60	162.3	14.15	5.10	51.0	0.08	26.5	0.11	-146.5	18.15
4.0	0.62	137.1	11.81	3.90	30.8	0.09	17.1	0.10	165.2	16.17
5.0	0.66	115.5	9.87	3.11	11.7	0.11	6.8	0.14	131.5	14.64
6.0	0.69	97.2	8.22	2.58	-6.4	0.12	-3.9	0.18	112.4	13.36
7.0	0.70	80.2	6.85	2.20	-24.0	0.13	-15.8	0.20	94.3	12.29
8.0	0.72	62.2	5.58	1.90	-41.8	0.14	-28.0	0.23	70.1	11.45
9.0	0.76	45.0	4.40	1.66	-59.9	0.15	-39.6	0.29	50.6	10.53
10.0	0.83	28.4	3.06	1.42	-78.7	0.15	-55.1	0.38	36.8	9.71
11.0	0.85	13.9	1.60	1.20	-95.8	0.15	-68.6	0.46	24.4	9.04
12.0	0.88	-0.2	0.43	1.05	-111.1	0.15	-80.9	0.51	11.3	8.43
13.0	0.89	-14.6	-0.65	0.93	-128.0	0.15	-94.9	0.55	-5.2	7.94
14.0	0.88	-30.6	-1.98	0.80	-146.1	0.14	-109.3	0.61	-20.8	7.43
15.0	0.88	-45.0	-3.62	0.66	-162.7	0.13	-122.9	0.66	-35.0	6.98
16.0	0.88	-54.5	-5.37	0.54	-176.6	0.12	-133.7	0.70	-45.8	6.49
17.0	0.88	-62.5	-6.83	0.46	171.9	0.12	-143.2	0.73	-56.1	5.95
18.0	0.92	-73.4	-8.01	0.40	157.9	0.11	-156.3	0.76	-68.4	5.66

Typical Noise Parameters, V_{DS} = 3V, I_{DS} = 60 mA

Freq GHz	F_{min} dB	Γ_{opt} Mag.	Γ_{opt} Ang.	$R_n/50$	G_a dB
0.5	0.15	0.34	42.3	0.04	28.50
0.9	0.20	0.32	62.8	0.04	24.18
1.0	0.22	0.32	67.6	0.04	23.47
1.9	0.42	0.27	116.3	0.04	18.67
2.0	0.45	0.27	120.1	0.04	18.29
2.4	0.52	0.26	145.8	0.04	16.65
3.0	0.59	0.29	178.0	0.05	15.56
3.9	0.70	0.36	-145.4	0.05	13.53
5.0	0.93	0.47	-116.0	0.10	12.13
5.8	1.16	0.52	-98.9	0.18	11.10
6.0	1.19	0.55	-96.5	0.20	10.95
7.0	1.26	0.60	-77.1	0.37	9.73
8.0	1.63	0.62	-56.1	0.62	8.56
9.0	1.69	0.70	-38.5	0.95	7.97
10.0	1.73	0.79	-21.5	1.45	7.76

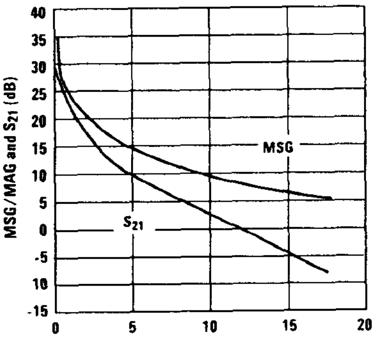


Figure 20. MSG/MAG and $|S_{21}|^2$ vs. Frequency at 3V, 60 mA.

Notes:

1. F_{min} values at 2 GHz and higher are based on measurements while the F_{mins} below 2 GHz have been extrapolated. The F_{min} values are based on a set of 16 noise figure measurements made at 16 different impedances using an ATN NP5 test system. From these measurements a true F_{min} is calculated. Refer to the noise parameter application section for more information.
2. S and noise parameters are measured on a microstrip line made on 0.025 inch thick alumina carrier. The input reference plane is at the end of the gate lead. The output reference plane is at the end of the drain lead. The parameters include the effect of four plated through via holes connecting source landing pads on top of the test carrier to the microstrip ground plane on the bottom side of the carrier. Two 0.020 inch diameter via holes are placed within 0.010 inch from each source lead contact point, one via on each side of that point.

[EEE 532]

ATF-54143 Typical Scattering Parameters, V_{DS} = 3V, I_{DS} = 80 mA

Freq. GHz	S_{11} Mag.	S_{11} Ang.	S_{21} dB	S_{21} Mag.	S_{21} Ang.	S_{12} Mag.	S_{12} Ang.	S_{22} Mag.	S_{22} Ang.	MSG/MAG dB
0.1	0.98	-20.4	28.32	26.05	167.1	0.01	79.4	0.26	-27.6	34.16
0.5	0.80	-85.9	25.32	18.45	126.8	0.04	53.3	0.29	-104.9	27.10
0.9	0.72	-123.4	22.10	12.73	105.2	0.05	43.9	0.30	-138.8	24.15
1.0	0.70	-129.9	21.40	11.75	101.3	0.05	42.7	0.30	-144.3	23.63
1.5	0.66	-154.6	18.55	8.46	85.4	0.06	38.6	0.30	-165.0	21.35
1.9	0.65	-169.5	16.81	6.92	74.9	0.07	35.7	0.29	-177.6	19.89
2.0	0.64	-172.8	16.42	6.62	72.6	0.07	35.0	0.29	179.4	19.52
2.5	0.64	172.1	14.69	5.42	61.1	0.09	30.6	0.29	164.4	18.05
3.0	0.63	158.5	13.24	4.59	50.1	0.10	25.5	0.29	150.2	16.80
4.0	0.66	133.8	10.81	3.47	29.9	0.12	13.4	0.33	126.1	14.76
5.0	0.69	112.5	8.74	2.74	11.1	0.13	1.2	0.39	107.8	13.20
6.0	0.72	94.3	7.03	2.25	-6.5	0.14	-11.3	0.42	91.8	11.96
7.0	0.73	77.4	5.63	1.91	-23.5	0.15	-24.5	0.44	75.5	10.97
8.0	0.74	59.4	4.26	1.63	-41.1	0.16	-38.1	0.47	55.5	10.14
9.0	0.78	42.1	2.98	1.41	-58.7	0.17	-51.1	0.52	37.8	9.32
10.0	0.84	25.6	1.51	1.19	-76.4	0.16	-66.8	0.59	24.0	8.60
11.0	0.86	11.4	0.00	1.00	-92.0	0.16	-79.8	0.64	11.8	8.04
12.0	0.88	-2.6	-1.15	0.88	-105.9	0.16	-91.7	0.68	-0.8	7.52
13.0	0.89	-17.0	-2.18	0.78	-121.7	0.15	-105.6	0.70	-16.7	7.12
14.0	0.87	-33.3	-3.48	0.67	-138.7	0.14	-119.5	0.73	-31.7	6.77
15.0	0.87	-47.3	-5.02	0.56	-153.9	0.13	-132.3	0.76	-44.9	6.42
16.0	0.86	-55.6	-6.65	0.47	-165.9	0.12	-141.7	0.78	-54.9	5.99
17.0	0.86	-63.4	-7.92	0.40	-175.9	0.11	-150.4	0.79	-64.2	5.55
18.0	0.91	-74.2	-8.92	0.36	171.2	0.10	-163.0	0.81	-76.2	5.37

Typical Noise Parameters, V_{DS} = 3V, I_{DS} = 80 mA

Freq GHz	F_{min} dB	Γ_{opt} Mag.	Γ_{opt} Ang.	$R_n/50$	G_a dB
0.5	0.19	0.23	66.9	0.04	27.93
0.9	0.24	0.24	84.3	0.04	24.13
1.0	0.25	0.25	87.3	0.04	23.30
1.9	0.43	0.28	134.8	0.04	18.55
2.0	0.42	0.29	138.8	0.04	18.15
2.4	0.51	0.30	159.5	0.03	16.44
3.0	0.61	0.35	-173	0.03	15.13
3.9	0.70	0.41	-141.6	0.06	12.97
5.0	0.94	0.52	-113.5	0.13	11.42
5.8	1.20	0.56	-97.1	0.23	10.48
6.0	1.26	0.58	-94.8	0.26	10.11
7.0	1.34	0.62	-75.8	0.46	8.86
8.0	1.74	0.63	-55.5	0.76	7.59
9.0	1.82	0.71	-37.7	1.17	6.97
10.0	1.94	0.79	-20.8	1.74	6.65

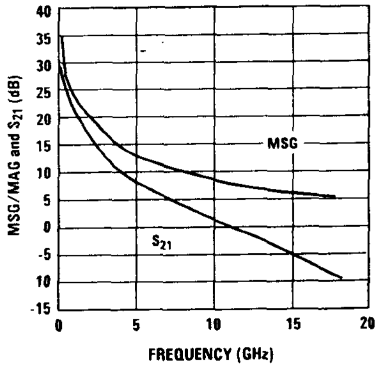


Figure 21. MSG/MAG and $|S_{21}|^2$ vs. Frequency at 3V, 80 mA.

Notes:

1. F_{min} values at 2 GHz and higher are based on measurements while the F_{mins} below 2 GHz have been extrapolated. The F_{min} values are based on a set of 16 noise figure measurements made at 16 different impedances using an ATN NP5 test system. From these measurements a true F_{min} is calculated. Refer to the noise parameter application section for more information.
2. S and noise parameters are measured on a microstrip line made on 0.025 inch thick alumina carrier. The input reference plane is at the end of the gate lead. The output reference plane is at the end of the drain lead. The parameters include the effect of four plated through via holes connecting source landing pads on top of the test carrier to the microstrip ground plane on the bottom side of the carrier. Two 0.020 inch diameter via holes are placed within 0.010 inch from each source lead contact point, one via on each side of that point.

ATF-54143 Typical Scattering Parameters, V_{DS} = 4V, I_{DS} = 60 mA

Freq.	S_{11}			S_{21}		S_{12}		S_{22}		MSG/MAG
GHz	Mag.	Ang.	dB	Mag.	Ang.	Mag.	Ang.	Mag.	Ang.	dB
0.1	0.99	-18.6	28.88	27.80	167.8	0.01	80.1	0.58	-12.6	35.41
0.5	0.81	-80.2	26.11	20.22	128.3	0.03	52.4	0.42	-52.3	28.14
0.9	0.71	-117.3	23.01	14.15	106.4	0.04	41.7	0.31	-73.3	25.38
1.0	0.69	-123.8	22.33	13.07	102.4	0.04	40.2	0.29	-76.9	24.83
1.5	0.64	-149.2	19.49	9.43	86.2	0.05	36.1	0.22	-89.4	22.75
1.9	0.62	-164.5	17.75	7.72	75.7	0.06	34.0	0.18	-95.5	21.32
2.0	0.61	-167.8	17.36	7.38	73.3	0.06	33.5	0.18	-97.0	21.04
2.5	0.60	176.6	15.66	6.07	61.9	0.07	30.7	0.14	-104.0	19.64
3.0	0.60	162.6	14.23	5.15	51.1	0.07	27.3	0.11	-113.4	18.48
4.0	0.62	137.4	11.91	3.94	30.9	0.09	18.7	0.07	-154.7	16.46
5.0	0.65	115.9	10.00	3.16	11.7	0.10	9.0	0.09	152.5	14.96
6.0	0.68	97.6	8.36	2.62	-6.6	0.11	-1.4	0.12	127.9	13.61
7.0	0.70	80.6	7.01	2.24	-24.3	0.12	-12.9	0.15	106.9	12.57
8.0	0.72	62.6	5.76	1.94	-42.3	0.13	-24.7	0.17	78.9	11.67
9.0	0.76	45.4	4.60	1.70	-60.5	0.14	-36.1	0.23	56.8	10.72
10.0	0.83	28.5	3.28	1.46	-79.6	0.15	-51.8	0.32	42.1	9.88
11.0	0.86	14.1	1.87	1.24	-97.0	0.15	-65.4	0.41	29.4	9.17
12.0	0.88	-0.4	0.69	1.08	-112.8	0.15	-78.0	0.47	16.0	8.53
13.0	0.90	-14.9	-0.39	0.96	-130.2	0.15	-92.2	0.51	-1.1	7.99
14.0	0.87	-31.4	-1.72	0.82	-148.8	0.15	-107.3	0.58	-17.6	7.46
15.0	0.88	-46.0	-3.38	0.68	-166.0	0.14	-121.2	0.63	-32.6	6.97
16.0	0.88	-54.8	-5.17	0.55	179.8	0.13	-132.2	0.69	-43.7	6.41
17.0	0.87	-62.8	-6.73	0.46	168.4	0.12	-142.3	0.72	-54.2	5.85
18.0	0.92	-73.7	-7.93	0.40	154.3	0.11	-155.6	0.75	-67.2	5.54

Typical Noise Parameters, V_{DS} = 4V, I_{DS} = 60 mA

Freq GHz	F_{min} dB	Γ_{opt} Mag.	Γ_{opt} Ang.	$R_{n/50}$	G_a dB
0.5	0.17	0.33	34.30	0.03	28.02
0.9	0.25	0.31	60.30	0.04	24.12
1.0	0.27	0.31	68.10	0.04	23.43
1.9	0.45	0.27	115.00	0.04	18.72
2.0	0.49	0.27	119.80	0.04	18.35
2.4	0.56	0.26	143.50	0.04	16.71
3.0	0.63	0.28	176.80	0.04	15.58
3.9	0.73	0.35	-145.90	0.05	13.62
5.0	0.96	0.47	-116.20	0.11	12.25
5.8	1.20	0.52	-98.80	0.19	11.23
6.0	1.23	0.54	-96.90	0.21	11.02
7.0	1.33	0.60	-77.40	0.38	9.94
8.0	1.66	0.63	-56.20	0.64	8.81
9.0	1.71	0.71	-38.60	0.99	8.22
10.0	1.85	0.82	-21.30	1.51	8.12

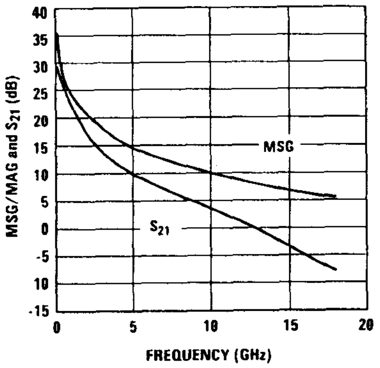


Figure 22. MSG/MAG and $|S_{21}|^2$ vs. Frequency at 4V, 60 mA.

Notes:

1. F_{min} values at 2 GHz and higher are based on measurements while the F_{mins} below 2 GHz have been extrapolated. The F_{min} values are based on a set of 16 noise figure measurements made at 16 different impedances using an ATN NP5 test system. From these measurements a true F_{min} is calculated. Refer to the noise parameter application section for more information.
2. S and noise parameters are measured on a microstrip line made on 0.025 inch thick alumina carrier. The input reference plane is at the end of the gate lead. The output reference plane is at the end of the drain lead. The parameters include the effect of four plated through via holes connecting source landing pads on top of the test carrier to the microstrip ground plane on the bottom side of the carrier. Two 0.020 inch diameter via holes are placed within 0.010 inch from each source lead contact point, one via on each side of that point.

ATF-54143 Applications Information

Introduction

Agilent Technologies's ATF-54143 is a low noise enhancement mode PHEMT designed for use in low cost commercial applications in the VHF through 6 GHz frequency range. As opposed to a typical depletion mode PHEMT where the gate must be made negative with respect to the source for proper operation, an enhancement mode PHEMT requires that the gate be made more positive than the source for normal operation. Therefore a negative power supply voltage is not required for an enhancement mode device. Biasing an enhancement mode PHEMT is much like biasing the typical bipolar junction transistor. Instead of a 0.7V base to emitter voltage, the ATF-54143 enhancement mode PHEMT requires about a 0.6V potential between the gate and source for a nominal drain current of 60 mA.

Matching Networks

The techniques for impedance matching an enhancement mode device are very similar to those for matching a depletion mode device. The only difference is in the method of supplying gate bias. S and Noise Parameters for various bias conditions are listed in this data sheet. The circuit shown in Figure 1 shows a typical LNA circuit normally used for 900 and 1900 MHz applications (Consult the Agilent Technologies website for application notes covering specific applications). High pass impedance matching networks consisting of L1/C1 and L4/C4 provide the appropriate match for noise figure, gain, S11 and S22. The high pass structure also provides low frequency gain reduction which can be beneficial from the standpoint of improving out-of-band rejection at lower frequencies.

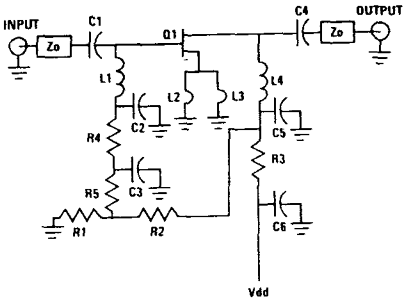


Figure 1. Typical ATF-54143 LNA with Passive Biasing.

Capacitors C2 and C5 provide a low impedance in-band RF bypass for the matching networks. Resistors R3 and R4 provide a very important low frequency termination for the device. The resistive termination improves low frequency stability. Capacitors C3 and C6 provide the low frequency RF bypass for resistors R3 and R4. Their value should be chosen carefully as C3 and C6 also provide a termination for low frequency mixing products. These mixing products are as a result of two or more in-band signals mixing and producing third order in-band distortion products. The low frequency or difference mixing products are bypassed by C3 and C6. For best suppression of third order distortion products based on the CDMA 1.25 MHz signal spacing, C3 and C6 should be 0.1 µF in value. Smaller values of capacitance will not suppress the generation of the 1.25 MHz difference signal and as a result will show up as poorer two tone IP3 results.

Bias Networks

One of the major advantages of the enhancement mode technology is that it allows the designer to be able to dc ground the source leads and then merely apply a positive voltage on the gate to set the desired amount of quiescent drain current I_d.

Whereas a depletion mode PHEMT pulls maximum drain current when $V_{gs} = 0V$, an enhancement mode PHEMT pulls only a small amount of leakage current when $V_{gs} = 0V$. Only when V_{gs} is increased above V_{to}, the device threshold voltage, will drain current start to flow. At a V_{ds} of 3V and a nominal V_{gs} of 0.6V, the drain current I_d will be approximately 60 mA. The data sheet suggests a minimum and maximum V_{gs} over which the desired amount of drain current will be achieved. It is also important to note that if the gate terminal is left open circuited, the device will pull some amount of drain current due to leakage current creating a voltage differential between the gate and source terminals.

Passive Biasing

Passive biasing of the ATF-54143 is accomplished by the use of a voltage divider consisting of R1 and R2. The voltage for the divider is derived from the drain voltage which provides a form of voltage feedback through the use of R3 to help keep drain current constant. Resistor R5 (approximately 10kΩ) provides current limiting for the gate of enhancement mode devices such as the ATF-54143. This is especially important when the device is driven to P_{1dB} or P_{SAT}.

Resistor R3 is calculated based on desired V_{ds}, I_{ds} and available power supply voltage.

$$R3 = \frac{V_{DD} - V_{ds}}{I_{ds} + I_{BB}} \quad (1)$$

V_{DD} is the power supply voltage.
V_{ds} is the device drain to source voltage.
I_{ds} is the desired drain current.
I_{BB} is the current flowing through the R1/R2 resistor voltage divider network.

The values of resistors R1 and R2 are calculated with the following formulas

$$R1 = \frac{V_{gs}}{I_{BB}} \quad (2)$$

$$R2 = \frac{(V_{ds} - V_{gs})\,R1}{V_{gs}} \quad (3)$$

Example Circuit

$V_{DD} = 5V$
$V_{ds} = 3V$
$I_{ds} = 60$ mA
$V_{gs} = 0.59V$

Choose I_{BB} to be at least 10X the normal expected gate leakage current. I_{BB} was chosen to be 2 mA for this example. Using equations (1), (2), and (3) the resistors are calculated as follows

R1 = 295Ω
R2 = 1205Ω
R3 = 32.3Ω

Active Biasing

Active biasing provides a means of keeping the quiescent bias point constant over temperature and constant over lot to lot variations in device dc performance. The advantage of the active biasing of an enhancement mode PHEMT versus a depletion mode PHEMT is that a negative power source is not required. The techniques of active biasing an enhancement mode device are very similar to those used to bias a bipolar junction transistor.

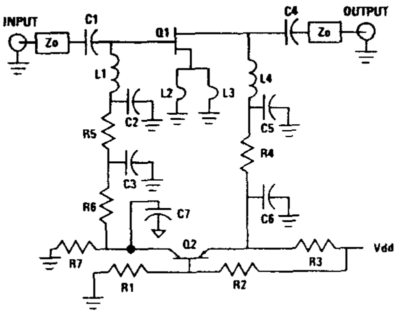


Figure 2. Typical ATF-54143 LNA with Active Biasing.

An active bias scheme is shown in Figure 2. R1 and R2 provide a constant voltage source at the base of a PNP transistor at Q2. The constant voltage at the base of Q2 is raised by 0.7 volts at the emitter. The constant emitter voltage plus the regulated V_{DD} supply are present across resistor R3. Constant voltage across R3 provides a constant current supply for the drain current. Resistors R1 and R2 are used to set the desired Vds. The combined series value of these resistors also sets the amount of extra current consumed by the bias network. The equations that describe the circuit's operation are as follows.

$$V_E = V_{ds} + (I_{ds} \cdot R4) \quad (1)$$

$$R3 = \frac{V_{DD} - V_E}{I_{ds}} \quad (2)$$

$$V_B = V_E - V_{BE} \quad (3)$$

$$V_B = \frac{R1}{R1 + R2} V_{DD} \quad (4)$$

$$V_{DD} = I_{BB}\,(R1 + R2) \quad (5)$$

Rearranging equation (4) provides the following formula

$$R2 = \frac{R_1\,(V_{DD} - V_B)}{V_B} \quad (4A)$$

and rearranging equation (5) provides the following formula

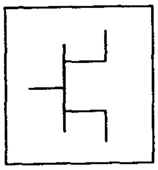
$$R1 = \frac{V_{DD}}{I_{BB}\left(1 + \frac{V_{DD} - V_B}{V_B}\right)} \quad (5A)$$

Example Circuit

$V_{DD} = 5V$
$V_{ds} = 3V$
$I_{ds} = 60$ mA
R4 = 10Ω
$V_{BE} = 0.7V$

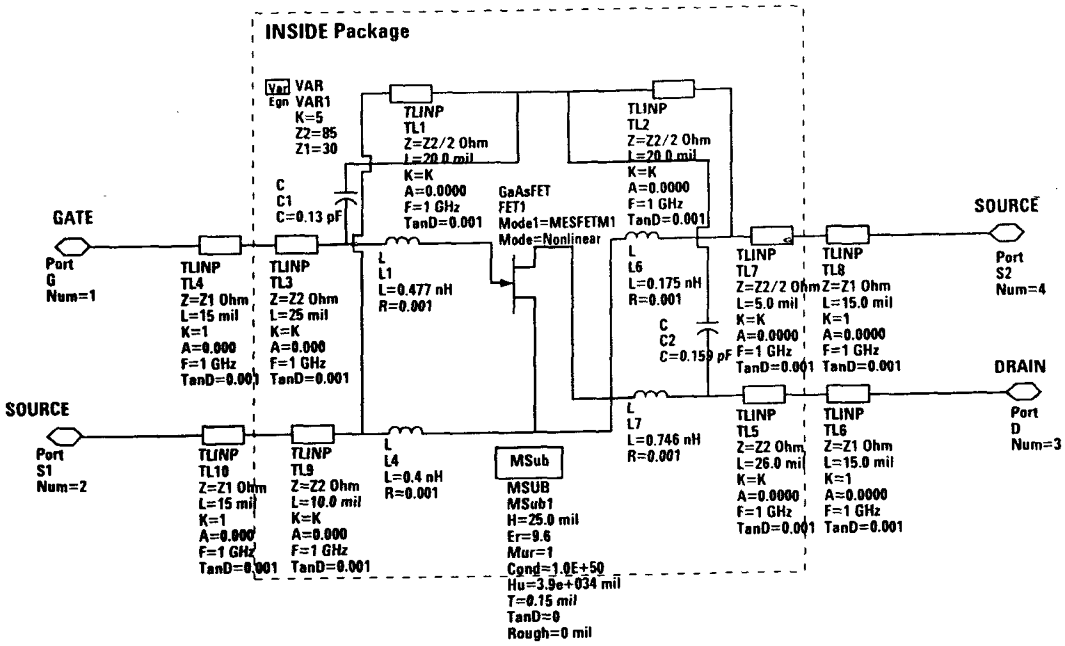
Equation (1) calculates the required voltage at the emitter of the PNP transistor based on desired V_{ds} and I_{ds} through resistor R4 to be 3.6V. Equation (2) calculates the value of resistor R3 which determines the drain current I_{ds}. In the example R3 = 23.3Ω. Equation (3) calculates the voltage required at the junction of resistors R1 and R2. This voltage plus the step-up of the base emitter junction determines the regulated V_{ds}. Equations (4) and (5) are solved simultaneously to determine the value of resistors R1 and R2. In the example R1 = 1450Ω and R2 = 1050Ω. R7 is chosen to be 1kΩ. This resistor keeps a small amount of current flowing through Q2 to help maintain bias stability. R6 is chosen to be 10kΩ. This value of resistance is necessary to limit Q1 gate current in the presence of high RF drive level (especially when Q1 is driven to P_{1dB} gain compression point).

ATF-54143 Die Model



Advanced_Curtice2_Model
MESFETM1
NFET=yes
PFET=no
Vto=0.3
Beta=0.9
Lambda=82e-3
Alpha=13
Tau=
Tnom=16.85
Idstc=
Ucrit=-0.72
Vgexp=1.91
Gamds=1e-4
Vtotc=
Betatce=
Rgs=0.25 Ohm
Rf=
Gscap=2
Cgs=1.73 pF
Cgd=0.255 pF
Gdcap=2
Fc=0.65
Rgd=0.25 Ohm
Rd=1.0125 Ohm
Rg=1.0 Ohm
Rs=0.3375 Ohm
Ld=
Lg=0.18 nH
Ls=
Cds=0.27 pF
Rc=250 Ohm
Crf=0.1 F
Gsfwd=
Gsrev=
Gdfwd=
Gdrev=
R1=
R2=
Vbi=0.8
Vbr=
Vjr=
Is=
Ir=
Imax=
Xti=
Eg=
N=
Fnc=1 MHz
R=0.08
P=0.2
C=0.1
Taumdl=no
wVgfwd=
wBvgs=
wBvgd=
wBvds=
wIdsmax=
wPmax=
AllParams=

ATF-54143 curtice ADS Model



Designing with S and Noise Parameters and the Non-Linear Model

The non-linear model describing the ATF-54143 includes both the die and associated package model. The package model includes the effect of the pins but does not include the effect of the additional source inductance associated with grounding the source leads through the printed circuit board. The device S and Noise Parameters do include the effect of 0.020 inch thickness printed circuit board vias. When comparing simulation results between the measured S parameters and the simulated non-linear model, be sure to include the effect of the printed circuit board to get an accurate comparison. This is shown schematically in Figure 3.

For Further Information

The information presented here is an introduction to the use of the ATF-54143 enhancement mode PHEMT. More detailed application circuit information is available from Agilent Technologies. Consult the web page or your local Agilent Technologies sales representative.

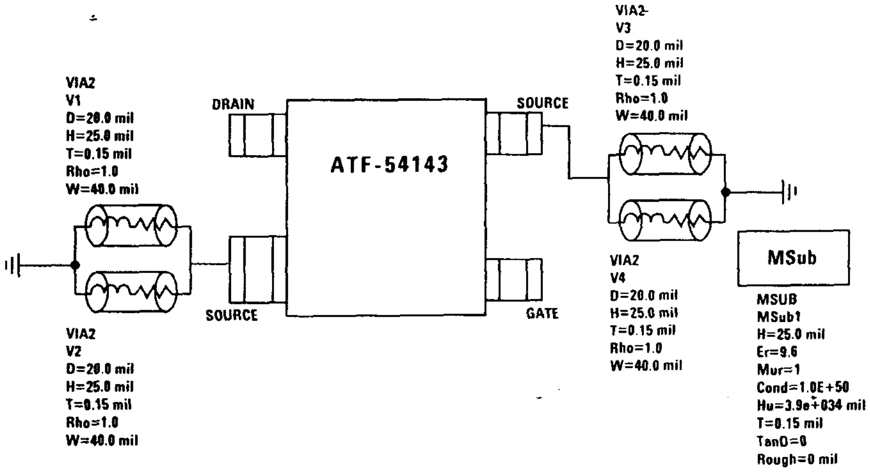


Figure 3. Adding Vias to the ATF-54143 Non-Linear Model for Comparison to Measured S and Noise Parameters.

Noise Parameter Applications Information

F_{min} values at 2 GHz and higher are based on measurements while the F_{mins} below 2 GHz have been extrapolated. The F_{min} values are based on a set of 16 noise figure measurements made at 16 different impedances using an ATN NP5 test system. From these measurements, a true F_{min} is calculated. F_{min} represents the true minimum noise figure of the device when the device is presented with an impedance matching network that transforms the source impedance, typically 50Ω, to an impedance represented by the reflection coefficient G_o. The designer must design a matching network that will present G_o to the device with minimal associated circuit losses. The noise figure of the completed amplifier is equal to the noise figure of the device plus the losses of the matching network preceding the device. The noise figure of the device is equal to F_{min} only when the device is presented with G_o. If the reflection coefficient of the matching network is other than G_o, then the noise figure of the device will be greater than F_{min} based on the following equation.

$$NF = F_{min} + \frac{4\,R_n}{Zo}\;\frac{|\Gamma_s - \Gamma_o|^2}{(|1 + \Gamma_o|^2)(1 - |\Gamma_s|^2)}$$

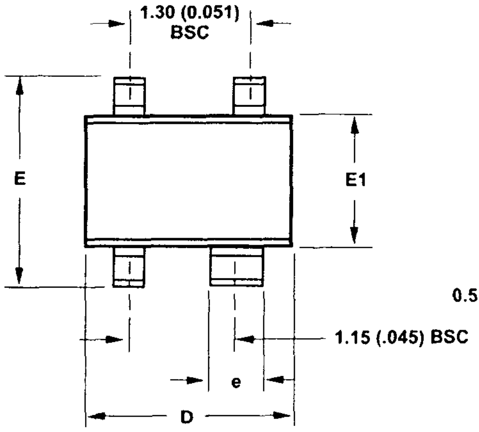
Where R_n/Z_o is the normalized noise resistance, Γ_o is the optimum reflection coefficient required to produce F_{min} and Γ_s is the reflection coefficient of the source impedance actually presented to the device. The losses of the matching networks are non-zero and they will also add to the noise figure of the device creating a higher amplifier noise figure. The losses of the matching networks are related to the Q of the components and associated printed circuit board loss. Γ_o is typically fairly low at higher frequencies and increases as frequency is lowered. Larger gate width devices will typically have a lower Γ_o as compared to narrower gate width devices. Typically for FETs, the higher Γ_o usually infers that an impedance much higher than 50Ω is required for the device to produce F_{min}. At VHF frequencies and even lower L Band frequencies, the required impedance can be in the vicinity of several thousand ohms. Matching to such a high impedance requires very hi-Q components in order to minimize circuit losses. As an example at 900 MHz, when airwwound coils ($Q > 100$) are used for matching networks, the loss can still be up to 0.25 dB which will add directly to the noise figure of the device. Using muiltilayer molded inductors with Qs in the 30 to 50 range results in additional loss over the airwound coil. Losses as high as 0.5 dB or greater add to the typical 0.15 dB F_{min} of the device creating an amplifier noise figure of nearly 0.65 dB. A discussion concerning calculated and measured circuit losses and their effect on amplifier noise figure is covered in Agilent Application 1085.

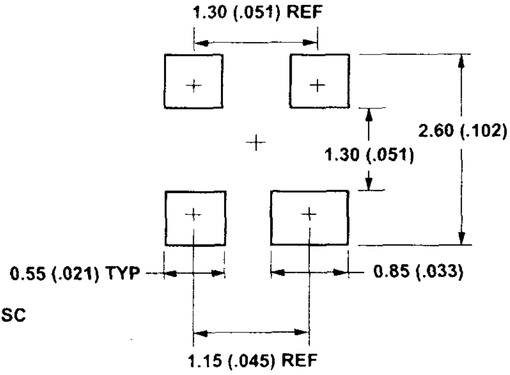
[EEE 532]

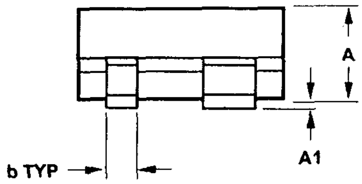
Ordering Information

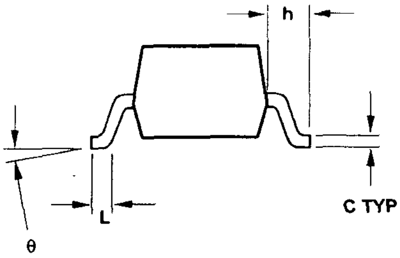
Part Number	No. of Devices	Container
ATF-54143-TR1	3000	7" Reel
ATF-54143-TR2	10000	13"Reel
ATF-54143-BLK	100	antistatic bag

Package Dimensions
Outline 43
SOT-343 (SC70 4-lead)





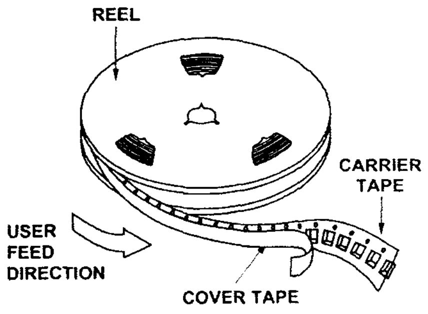


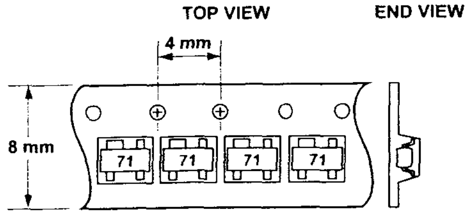


SYMBOL	DIMENSIONS	
	MIN.	MAX.
A	0.80 (0.031)	1.00 (0.039)
A1	0 (0)	0.10 (0.004)
b	0.25 (0.010)	0.35 (0.014)
C	0.10 (0.004)	0.20 (0.008)
D	1.90 (0.075)	2.10 (0.083)
E	2.00 (0.079)	2.20 (0.087)
e	0.55 (0.022)	0.65 (0.025)
h	0.450 TYP (0.018)	
E1	1.15 (0.045)	1.35 (0.053)
L	0.10 (0.004)	0.35 (0.014)
θ	0	10

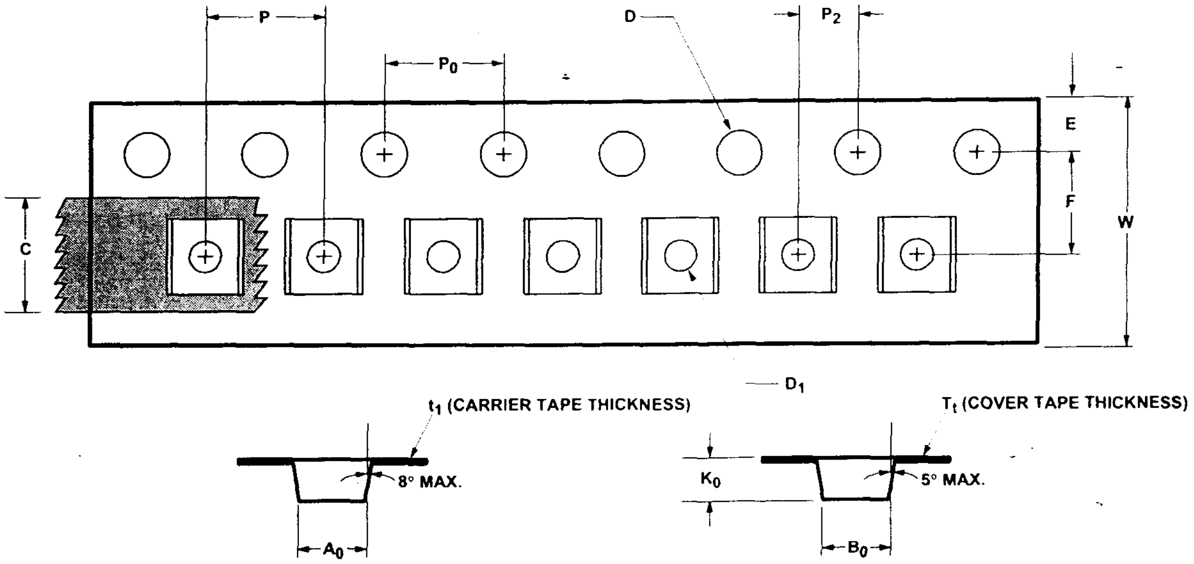
DIMENSIONS ARE IN MILLIMETERS (INCHES)

Device Orientation





Tape Dimensions For Outline 4T



DESCRIPTION		SYMBOL	SIZE (mm)	SIZE (INCHES)
CAVITY	LENGTH	A_0	2.24 ± 0.10	0.088 ± 0.004
	WIDTH	B_0	2.34 ± 0.10	0.092 ± 0.004
	DEPTH	K_0	1.22 ± 0.10	0.048 ± 0.004
	PITCH	P	4.00 ± 0.10	0.157 ± 0.004
	BOTTOM HOLE DIAMETER	D_1	1.00 + 0.25	0.039 + 0.010
PERFORATION	DIAMETER	D	1.55 ± 0.05	0.061 ± 0.002
	PITCH	P_0	4.00 ± 0.10	0.157 ± 0.004
	POSITION	E	1.75 ± 0.10	0.069 ± 0.004
CARRIER TAPE	WIDTH	W	8.00 ± 0.30	0.315 ± 0.012
	THICKNESS	t_1	0.255 ± 0.013	0.010 ± 0.0005
COVER TAPE	WIDTH	C	5.4 ± 0.10	0.205 ± 0.004
	TAPE THICKNESS	T_t	0.062 ± 0.001	0.0025 ± 0.00004
DISTANCE	CAVITY TO PERFORATION (WIDTH DIRECTION)	F	3.50 ± 0.05	0.138 ± 0.002
	CAVITY TO PERFORATION (LENGTH DIRECTION)	P_2	2.00 ± 0.05	0.079 ± 0.002

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Data subject to change.

Obsoletes 5988-0450EN
May 31, 2001
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Agilent Technologies