PRELIMINARY DATA SHEET

ECG001

HIGH LINEARITY BROADBAND AMPLIFIER

DC - 6000 MHz

EiC Corp.

Excellence in Communications

Features

- DC to 6000 MHz
- 20.0 dB Gain at 1000 MHz
- 12.5 dBm Output P1dB at 1000 MHz
- 25 dBm Output IP3 at 1000 MHz
- 3.7 dB Noise Figure at 2000 MHz

Applications

- Broadband Gain Blocks
- High Linearity Amplifiers

Packages Available

(-B) SOT-89
(-C) 85 Mil Micro-X

Description

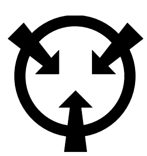
The ECG001 is a high reliability, high linearity, low cost broadband amplifier, optimized for commercial communications. The device is manufactured using in-house developed, advanced Indium Gallium Phosphide Heterojunction Bipolar Transistor (InGaP HBT) technology and is designed for use as a 50 Ohm gain block. The amplifier features excellent VSWR, low noise figure and highly linear performance. Typical OIP3 is +25dBm at 1000 MHz. The ECG001 operates from a single voltage supply and requires only two DC-blocking capacitors, a bias resistor and an inductor for operation. The device is ideal for wireless applications and is available in a low cost, surface-mountable plastic 85 mil Micro-X and SOT-89 packages. The ECG00x is designed in the Darlington configuration with direct feedback. Its operation frequency at low end is limited only by the DC blocking capacitor and the RF choke inductor (large values are required in both cases).

Electrical Specifications

Test Conditions: Ic= 30mA Ta = 25^{o}C,

SYMBOL	PARAMETER		LIMITS			UNIT	TEST CONDITION
			MIN.	TYP.	MAX.		
F	Frequency		DC		6000	MHz	
G	Gain (Small Signal)	f = 1000MHz f = 2000MHz f = 3000MHz f = 6000MHz	 17.0 17.0 	20.0 19.0 18.0 13.0		dB	
G	Gain(Large signal) Pin=-4.5dBm	f = 3000MHz	14.5	17.0		dB	
P_{1dB}	Output Power @ 1dB Compression	f = 1000MHz f = 2000MHz f = 3000MHz		12.5 12.5 12.6		dBm	
OIP3	Output Third Order Intercept	f = 1000MHz f = 2000MHz f = 3000MHz		25.0 26.0 26.0		dBm	Note 1
RL_{in}	Input Return Loss, 50 Ohm	f = 2000MHz		14.0		dB	
RL_{out}	Output Return Loss, 50 Ohm	f = 2000MHz		18.0		dB	
NF	Noise Figure	f = 2000MHz		3.7		dB	
Vde	Device Voltage		3.0	3.4	3.8	V	

Note 1: OIP3 = Pout (by power meter, total 2-tone power) + (IM3(dB))/2) - 3dB



CAUTION!
SENSITIVE ELECTRONIC DEVICE

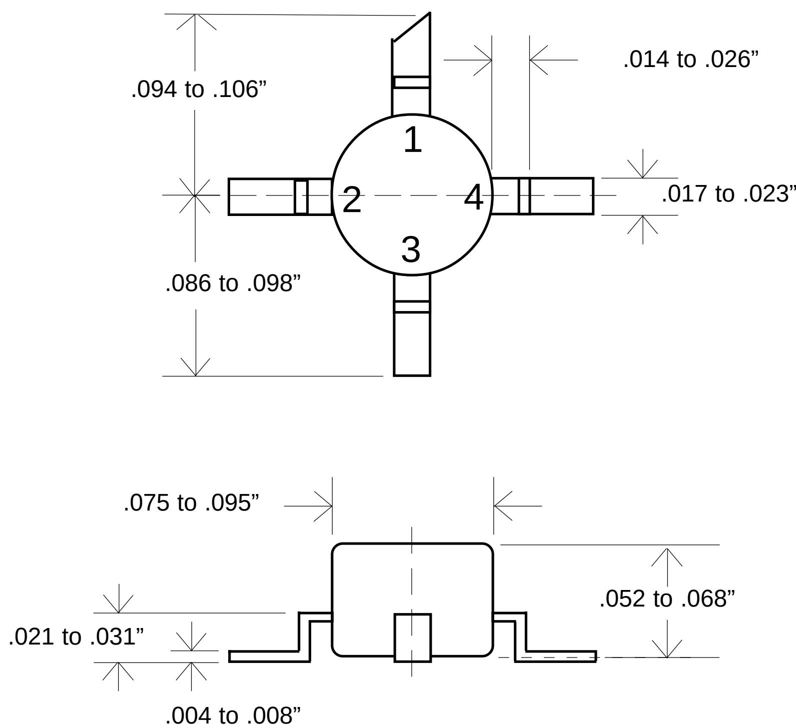
Absolute Maximum Ratings

Device Current	60	mA
RF Power Input	-2.5	dBm
Operating Temperature	-40 to +85	°C
Storage Temperature	-65 to +150	°C
Junction Temperature	+200	°C

Note: Exceeding any of the absolute maximum ratings may cause permanent damage to the device.

Micro-X Package Outline

(all units are in inches)

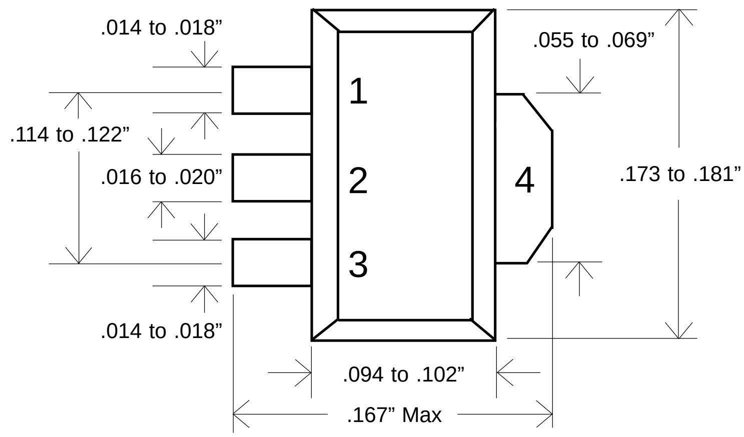


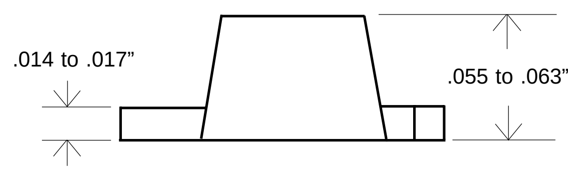
Pin Definitions

Pin #	Pin	Definition
1	RFin	This pin has a nominal 50 ohm input impedance. It requires a DC blocking capacitor large enough to handle the lowest frequency used.
2, 4	Gnd	The two ground connections should be directly connected together to the ground plane on the PCB.
3	RFout	This pin has a nominal 50 ohm output impedance. It requires a DC bias of 30mA typically through a series inductor/ resistor pair. Using a bypass capacitor (1.0 micro Farad) on the DC side of the the series inductor/ resistor is also recommended. Use a DC blocking capacitor on the output with similar requirements as the input side.

SOT-89 Package Outline

(all units are in inches)





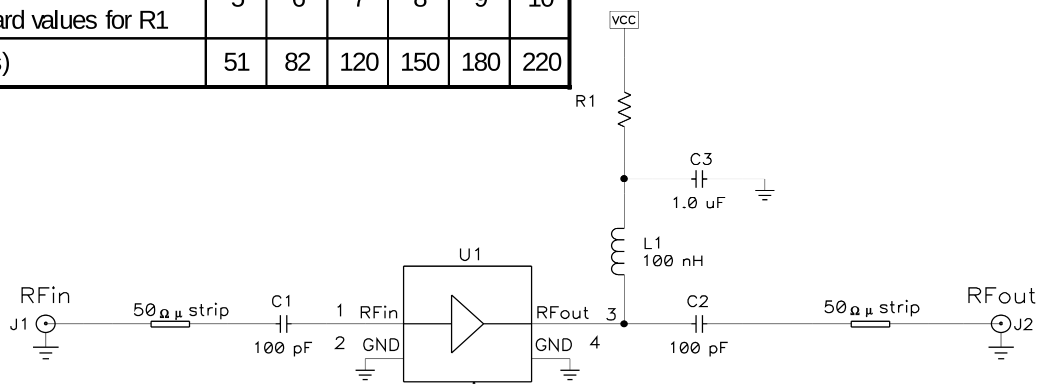
Pin Definitions

Pin #	Pin	Definition
1	RFin	This pin has a nominal 50 ohm input impedance. It requires a DC blocking capacitor large enough to handle the lowest frequency used.
2, 4	Gnd	The two ground connections should be directly connected together to the ground plane on the PCB. The ground connection also serves as a heatsink.
3	RFout	This pin has a nominal 50 ohm output impedance. It requires a DC bias of 30mA through a series inductor and a resistor. A bypass capacitor (1.0 micro Farad) on the DC side of the inductor is recommended for providing instantaneous current during a modulated RF signal. Use a DC blocking capacitor on the output with similar requirements as the input side.

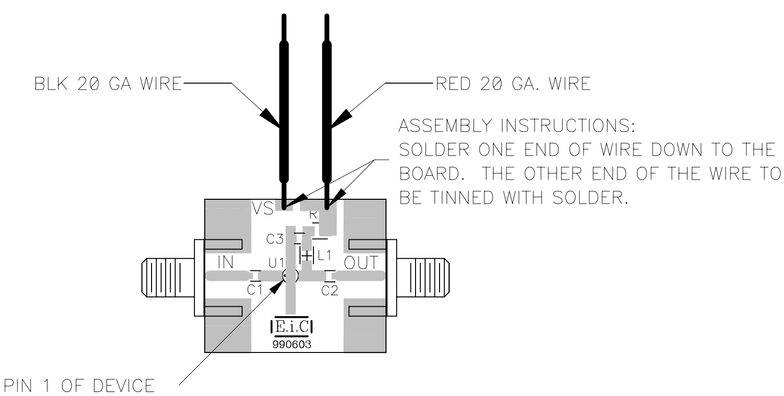
Evaluation Board Schematic
SOT-89 and Micro-X

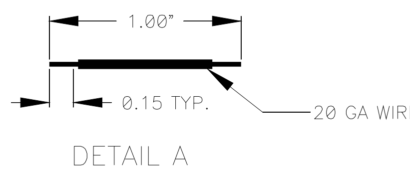
Recommended Bias Resistor Values
R = (Vcc-Vde)/Icc = (Vcc-3.4)/0.030

Approximate Supply Voltage (V_{cc}) based on standard values for R1	5	6	7	8	9	10
R1 (Ohms)	51	82	120	150	180	220



Evaluation Board Layout





Evaluation Board Materials

MANUFACTURER	PART NUMBER	QTY	VALUE	DESIGNATOR	
MARUWA	CE101J1NO	2	100 pF	C1,C2	NOTE 1 & 2
MARUWA	CE105K1NR	1	1.0 uF	C3	NOTE 1
ROHM	MCR10J700	1	68 ohm	R1	NOTE 1
TOKO	LL2012-FR10K	1	100 nH	L1	NOTE 1
EF JOHNSTON	142-0701-881	2		IN,OUT	NOTE 1
EIC CORP	ECG001	1		U1	
EIC CORP	60-000009-003	1	-		
20 GA. WIRE X 1.0"	ANY	1	RED		SEE DETAIL A
20 GA WIRE X 1.0"	ANY	1	BLK		SEE DETAIL A

1. EiC RECOMMENDED COMPONENTS ARE SHOW. EQUIVALENT COMPONENTS MAY BE USED.
2. LARGER VALUES GIVE BETTER LOW FREQUENCY RESPONSE(<500MHz)
NOTES: UNLESS OTHERWISE SPECIFIED

Figure 1

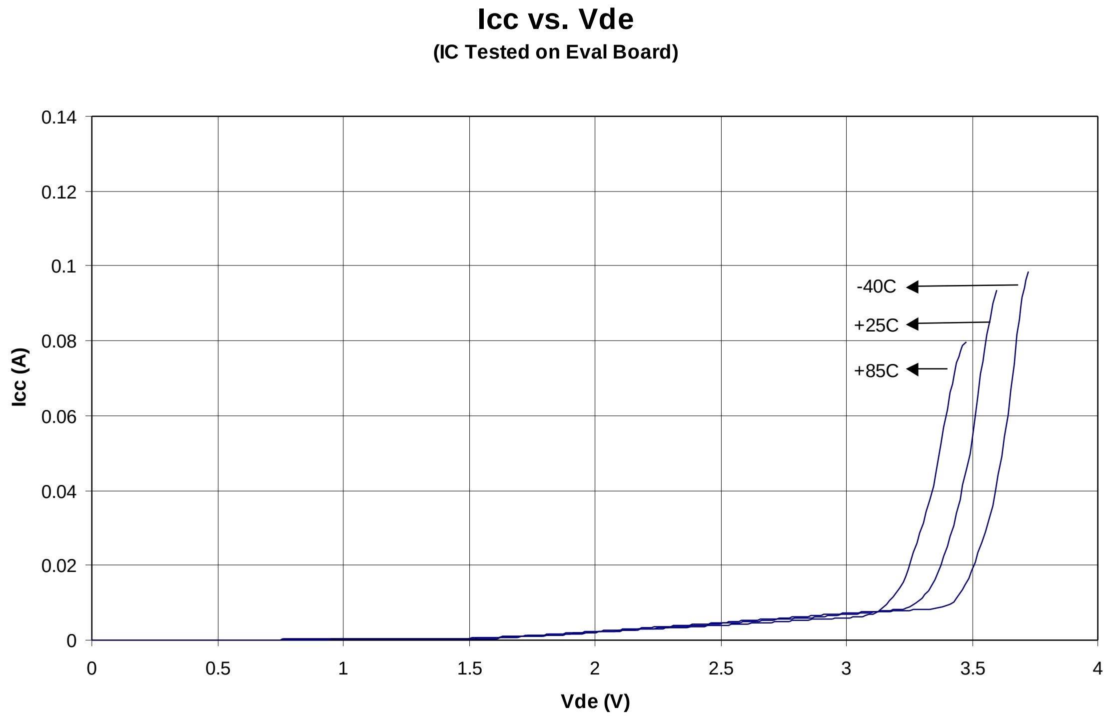


Figure 2

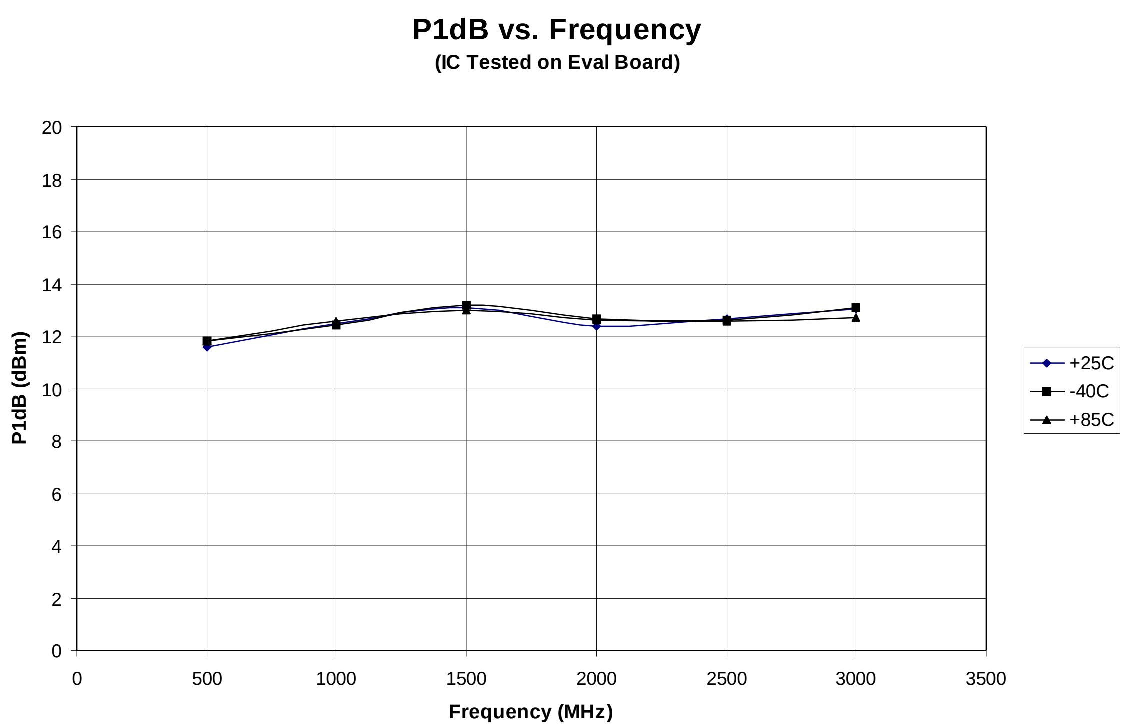


Figure 3

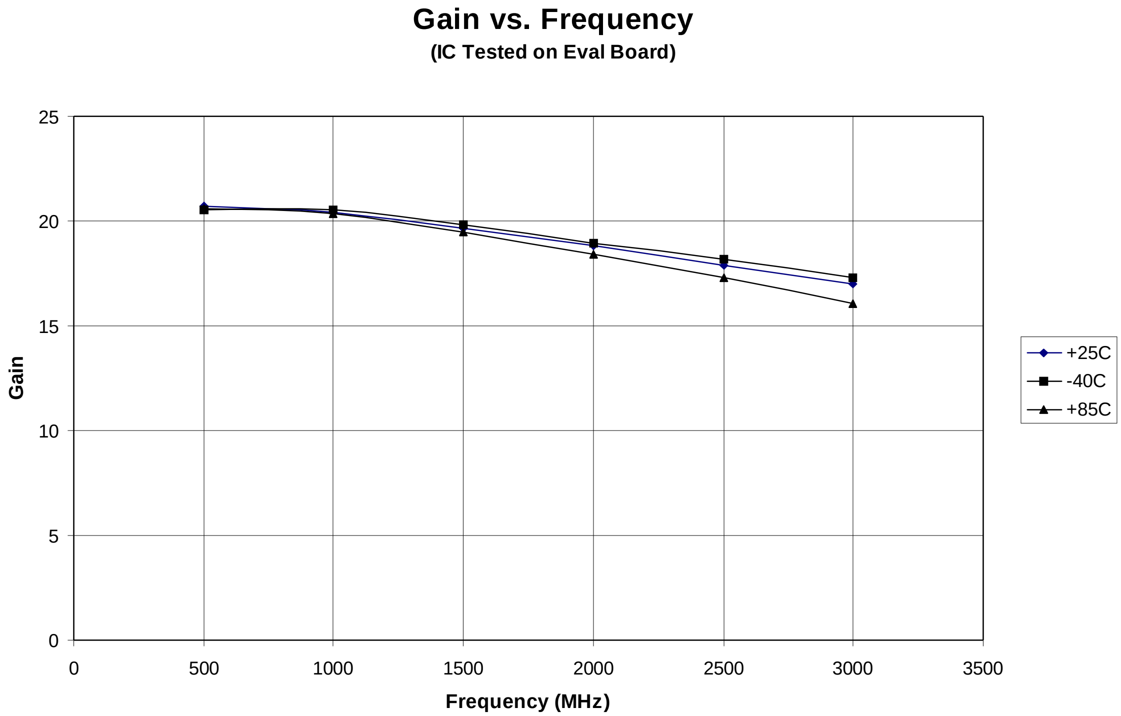


Figure 4

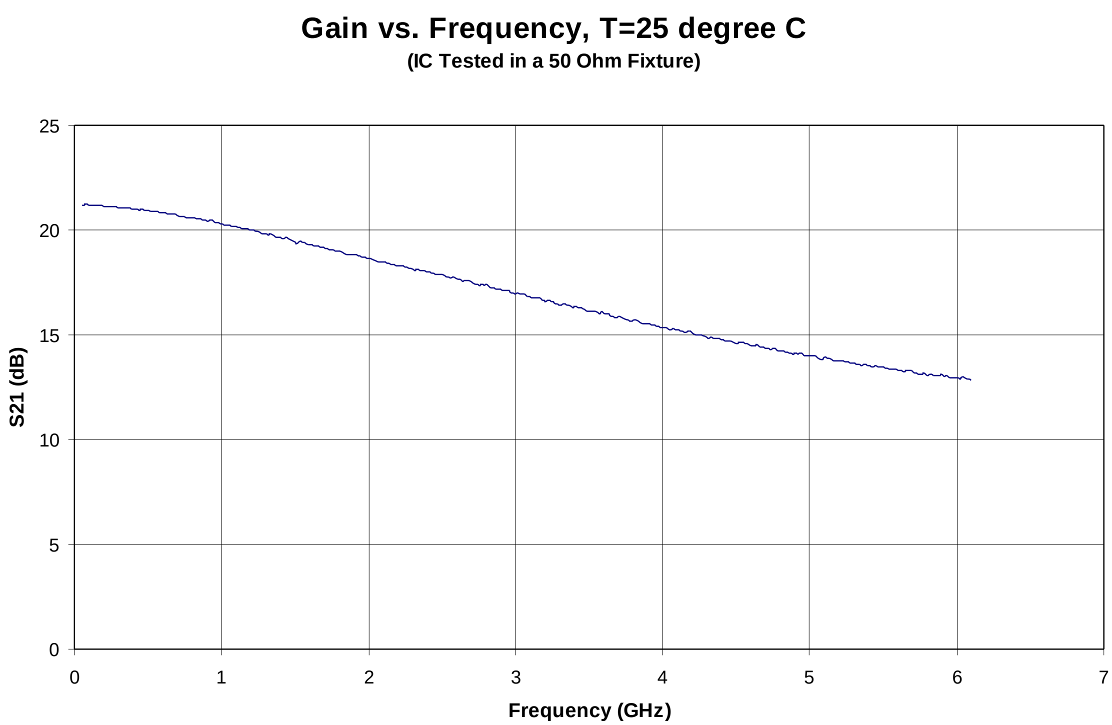


Figure 5

S11, S22 vs. Frequency, T=25 degree C
(IC Tested in a 50 Ohm Fixture)

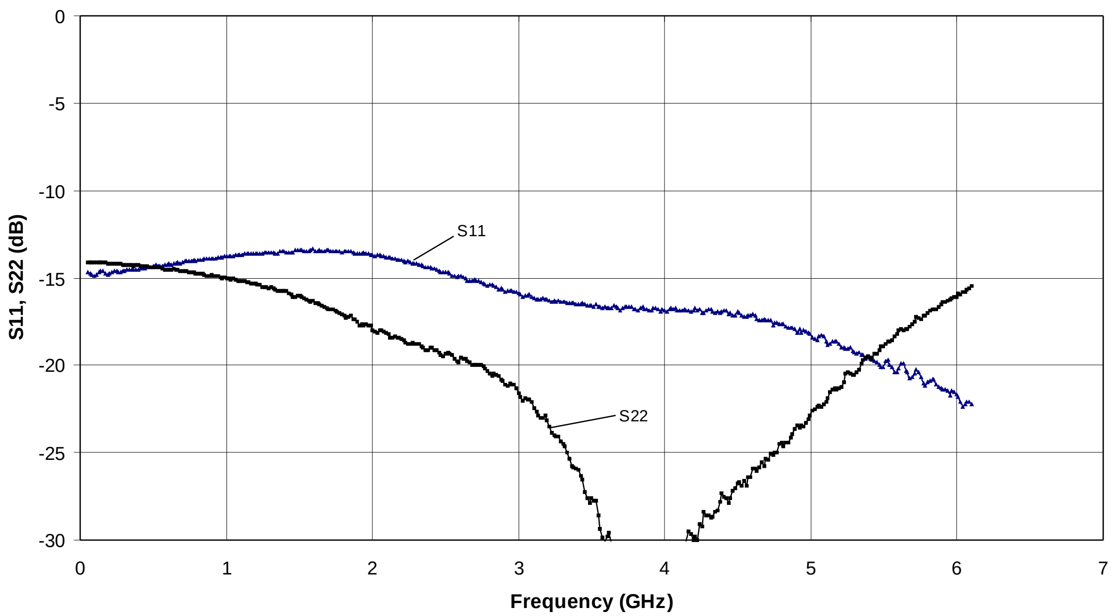


Figure 6

Reverse Isolation vs. Frequency, T=25 degree C
(IC Tested in a 50 Ohm Fixture)

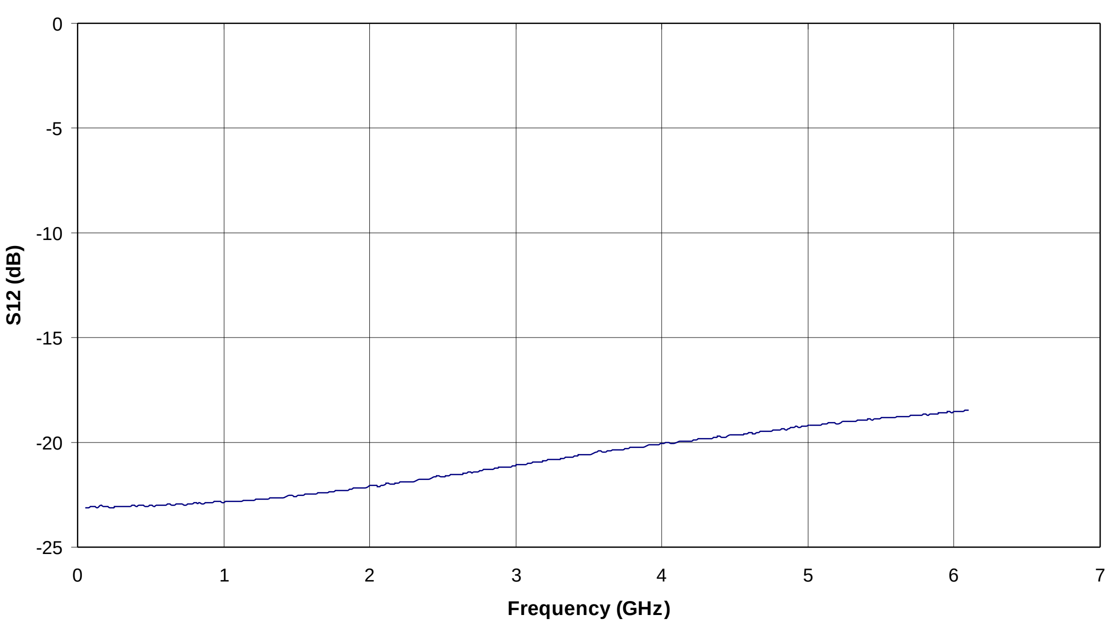


Figure 7

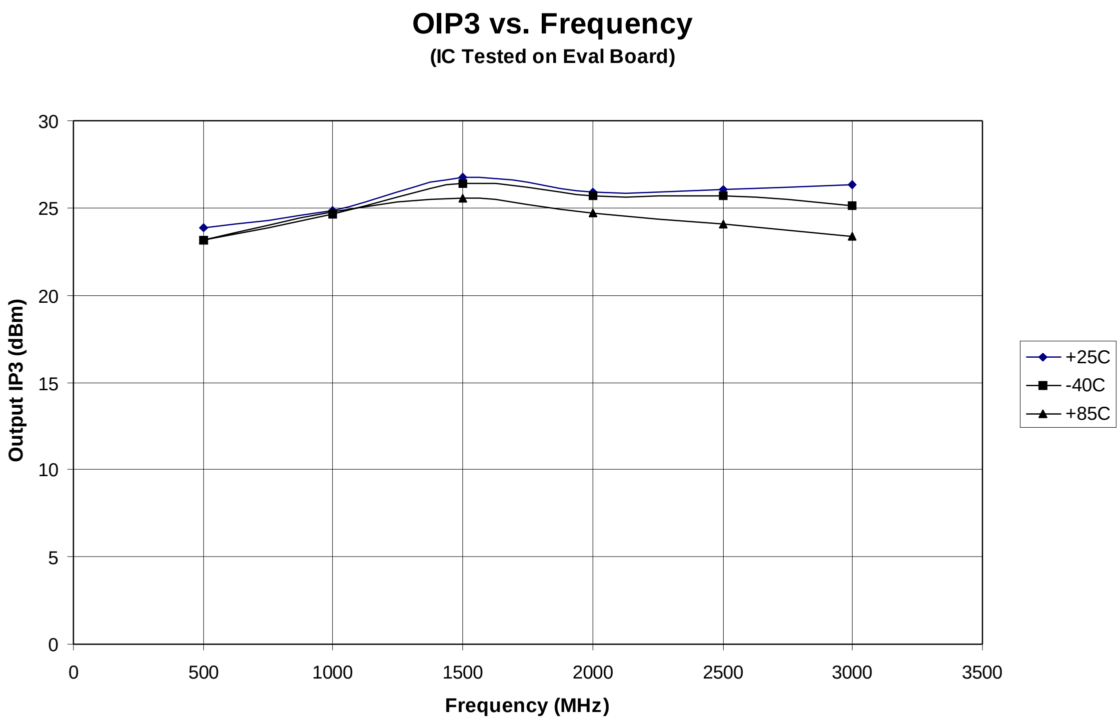
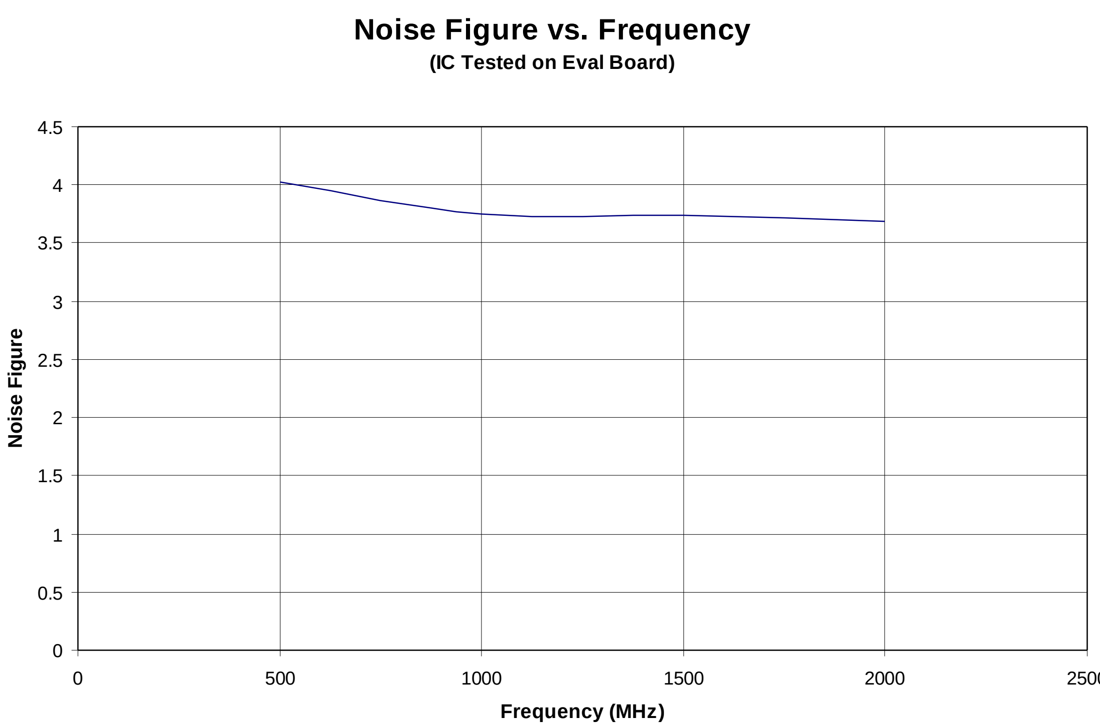


Figure 8



Application Note:

1. Bias Resistor
Bias resistor is needed for the Darlington type gain blocks. As shown in the Icc vs. Vde chart, the curve shifts with temperature as a result of the HBT Vbe versus temperature. To minimize the impact, dc resistor is required to maintain the gain block operating at the same current range over temperature.

The larger voltage drop across the bias resistor, the more stable operation current will be maintained. 2V or more voltage drop would be sufficient. A table of bias resistor value is given for convenience; user can find their own solution.

The bias resistor size needs to be sufficient to sustain the power dissipation across it.

2. operation frequency
The Darlington type amplifier has direct feedback through resistors. Therefore the low end operation frequency is only limited by the dc blocking capacitors (C1 and C2) and the RF choke (L1).

When the IC is tested in the 50 ohm fixture, the S parameters are measured down to the low end limit by the network analyzer.

3. Gain flatness versus frequency
The plastic package plays an important role in the gain versus frequency, as well as the PCB layout. The package introduces parasitic inductance. The PCB has the ground plane in the backside, and the package is connected to the backside board through PCB via holes. The PCB via holes also introduces inductance. Therefore the IC operates with parasitic grounding inductance which limits the frequency response and reduces the gain into higher frequency. A thick PCB will have large parasitic grounding inductance and will reduce the gain even more at several GHz range.

EiC Gain Blocks Series

Introduction

EiC Gain Block family is made up of a series of high reliability Darlington Amplifier. They are broad band feedback amplifiers matched for 50 ohms operation.

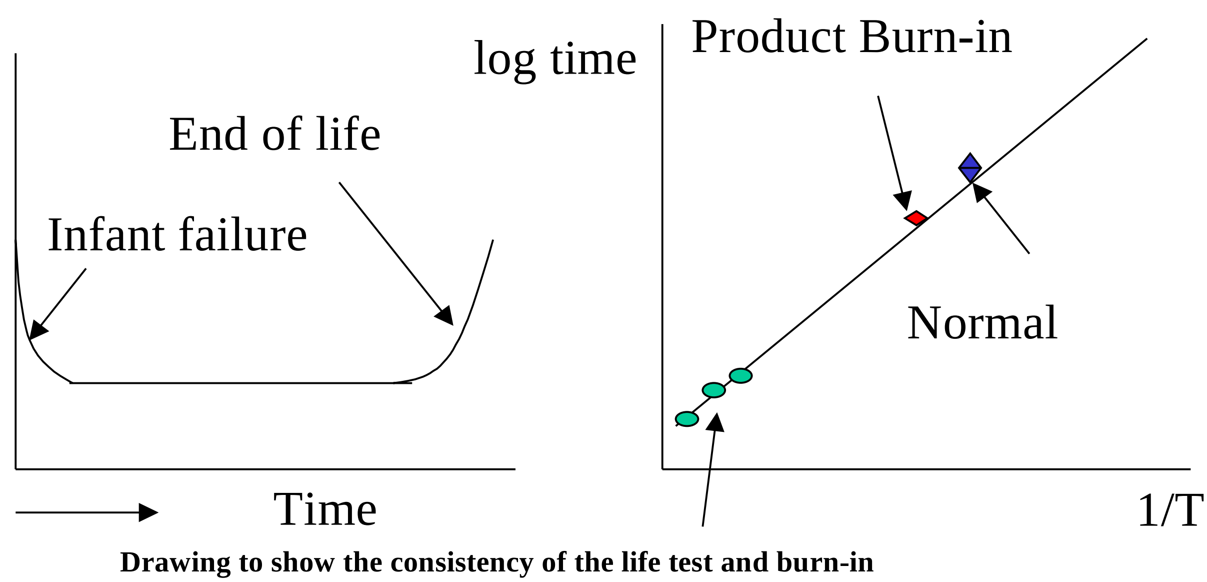
The amplifier series covers from a low 10dBm P1dB to the 23dBm range, with OIP3 up to 40dBm.

They are packaged typically in the plastic micro-X package. The high power amplifiers are in the SOT89 package for better thermal dissipation. All the parts were designed with low thermal resistance to provide low junction temperatures and long lifetime.

I. InGaP HBT offers Reliability and Quality

EiC proprietary InGaP HBT provides excellent reliability and is used in infrastructure industry. The InGaP HBT is inherently superior to AlGaAs HBT. The surface defect density in InGaP is much lower than AlGaAs.

The HBT life test of EiC InGaP HBT has gone through 315^{o}C junction temperature and 50kA/cm^2 for over 6000 hours (8 ½ months), translating to millions of hours of lifetime at normal operating conditions [1]. **This life test result is far superior to the conventional AlGaAs HBT, as well as many other reported InGaP HBT**.



Drawing to show the consistency of the life test and burn-in

Product Burn-in time

HBT lifetime ACLT (Accelerated lifetime testing)

The InGaP HBT product would go through product burn-in test as well. A large sample group, usually 100 pieces, goes through burn-in test at ambient temperature of 125 to 145 ^{o}C for 1000 hours. The FIT can be calculated based on the number of failed devices, activation energy, etc. The MTTF is simply 1/FIT. This MTTF should agree with the HBT life test result when HBT is the dominant failure mechanism (not other IC components like resistor, inductor, capacitor, etc).

The agreement between the MTTF of HBT from life test and the FIT is essential: it validates both tests. If there is a large discrepancy [2], the quality claim can be flawed.

II. Careful Thermal Design of the Darlington Amplifier

Although the Darlington Amplifier series is not high power (<25dBm), the thermal design is still a key factor affecting the reliability. Even for a low power amplifier, if the HBT cells are closely spaced on the IC die, the transistor junction temperature can still be high, negatively affecting the reliability.

Utilizing EiCs experience on Power Amplifiers, each Darlington Amplifier is carefully designed and laid out to provide a low thermal resistance. The ballasting is also carefully crafted, which is a must for any bipolar transistor (Si BJT, SiGe BJT, AlGaAs/GaAs HBT, InGaP/GaAs HBT, HBT family on InP substrate).

III. High Linearity

HBT is known for its high linearity [3]. Applying this feature to the Darlington Amplifier, a high OIP3 amplifier is made.

Compared with other transistor technology, InGaP HBT has easy process control which allows the OIP3 to be maintained in volume production.

IV. Broad Frequency Band Operation

The Darlington Amplifiers are designed with direct feedback. There is no capacitor on the circuits to limit the operation frequency. The application of the circuit is very simple: dc blocking capacitors at input and output, a choke inductor at the output, followed by a temperature stabilizing resistor.

The low end of the frequency band is limited by the external components: the dc blocking capacitors and the choke. The dc blocking capacitors must have a large value to allow the RF signal to go through: 50 ohms>>$1/(\omega C)$. For example, at 100MHz, a 1000pF capacitor has an impedance of 1/j0.628~-j1.6 ohms, and will allow the RF signal to go through easily; but a 10pF capacitor has an impedance of 160 ohms, effectively blocked the RF signal.

The choke has a similar effect: ωL must be large enough at the low frequency compared with 50 ohms. At 100MHz, a 1000nH will provides a shunt impedance of j628ohms and is effective as a choke; but a 100nH will have only j62.8ohms, affecting the output matching impedance of the Darlington Amplifier.

The high end of frequency band is determined by the package parasitics and the transistor's own capacitance. The package parasitics is presented as inductance from the pin. The pin inductance at input and output will deviate the impedance from 50ohms. A 1nH pin inductance at 5GHz presents an impedance of j31.4ohms, sufficient to deviate the input and output return loss. The ground pin inductance will have even more profound effect on the amplifier performance.

The transistor has its own parasitic capacitance, which limits the frequency bandwidth as we learned from Electronics 101. A higher power amplifier will need a larger size HBT, and the associated large transistor capacitance will reduce the frequency bandwidth. Therefore the frequency bandwidth of the high power version will be more limited than the low power ones.

Since the amplifier drives 50 ohms load directly, a high power amplifier will need to deliver more RF current and sustain more RF voltage swings. Therefore the high power amplifier will need to be biased at higher voltage and draw more dc bias current.

If an amplifier needs to operate with very broad frequency band, the external components need to be carefully traded off. A large capacitor will have a low self-resonance frequency (SRF), and turns inductive above SRF. Multiple capacitors may need to be used in parallel. It is also true for the inductors.

V. Temperature Stabilization

All bipolar transistors have a negative temperature coefficient for V_{be}(temperature). For Si BJT, it is about –2mV/^{o}C, and for GaAs HBT -1mV/^{o}C. As a result, the I-V curve of the circuit will shift to lower voltage as temperature rises. This is more severe in Si BJT circuit with twice as large a temperature coefficient.

If the amplifier is directly connected to a power supply through a choke, the heating will cause more current to flow into the amplifier, and the higher current causes more heating, more current, more heating, and finally the circuit will reach thermal self-destruction. The solution is very simple: have a resistor inserted between the power supply and the RF choke.

As heating causes more current to flow, the resistor will force the amplifier Vde to drop. If the new Vde*Icc is lower than original value, the heating is reduced and the overall circuit stabilized. Therefore there is a minimal resistor value for stable temperature operation.

Conclusion

EiC's InGaP HBT Darlington Amplifier Series is a complete family of high reliability, high performance 50 ohm matched gain blocks. Careful thermal design assures a cool operating temperature. Cross-check between the product burn-in and the transistor life test result validates both tests. This series of products will best serve the infrastructure market.

Reference

[1]. "InGaP HBTs offer Enhanced Reliability", Barry Lin, Applied Microwave and Wireless. pp 115-116, Dec. 2000

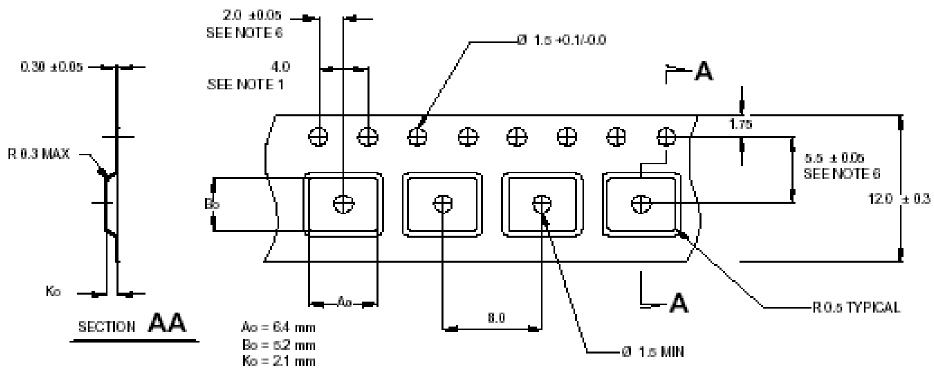
[2] Darrel Hill, John Parsey, "Motorola Digital DNA™ Laboratory, 2100 E. Elliot Rd., Tempe, Arizona 85284

[3] N.L. Wang, W.J.Ho, J.A. Higgins, "AlGaAs/GaAs HBT Linearity Characteristics", Trans. Microwave Theory Tech., pp.1845-1850, vol. 42, no.10, Oct. 1994

TAPE AND REEL SPECIFICATION
SOT-89

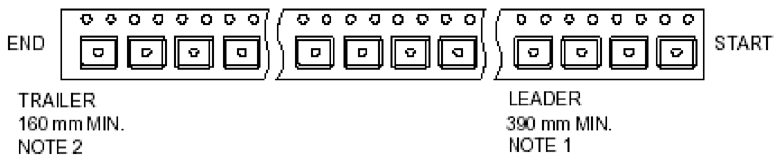
1. EMBOSSED TAPE.

2. TAPE DIMENSIONS. (ALL DIMENSIONS ARE IN MILLIMETERS)



1. 10 SPROCKET HOLE PITCH CUMULATIVE TOLERANCE ± 0.2.
2. CAMBER NOT TO EXCEED 1 mm IN 100 mm.
3. MATERIAL: BLACK CONDUCTIVE POLSTYRENE.
4. Ao AND Bo MEASURED ON A PLANE 0.3 mm ABOVE THE BOTTOM OF THE POCKET.
5. Ko MEASURED FROM A PLANE ON THE INSIDE BOTTOM OF THE POCKET TO THE TOP SURFACE OF THE CARRIER.
6. POCKET POSITION RELATIVE TO SPROCKET HOLE MEASURED AS TRUE POSITION OF POCKET, NOT POCKET HOLE.

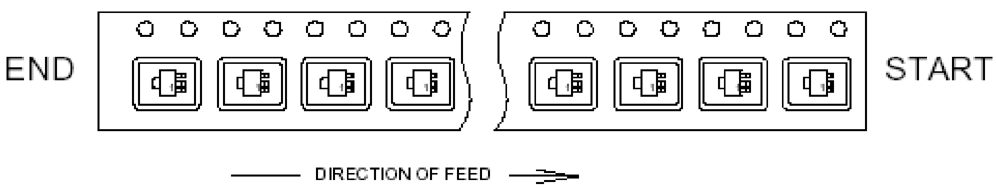
3. TAPE LEADER AND TRAILER DIMENSIONS



1. THERE SHALL BE A LEADER OF 230 mm MINIMUM WHICH MAY CONSIST OF CARRIER AND/OR COVER TAPE FOLLOWED BY A MINIMUM OF 160 mm OF EMPTY CARRIER TAPE SEALED WITH COVER TAPE.
2. THE TRAILER OF 160 mm MUST BE SEALED WITH COVER TAPE AND MUST RELEASE FROM THE REEL HUB UPON COMPLETION, WITHOUT DAMAGE.

Acrobat

4. COMPONENT ORIENTATION.



5. REEL DIMENSIONS