AVT-51663 and AVT-53663 Darlington Amplifiers for Broadband Applications (DC to 6 GHz)

AVAGO TECHNOLOGIES

Application Note 5474

Introduction

The Avago Technologies AVT-5X663 Darlington amplifiers are low cost, high dynamic range and easy-to-use InGaP HBT MMIC utility gain block amplifiers. These high linearity Darlington amplifiers are made possible by an advanced InGaP HBT (Hetero-junction Bipolar Transistor) technology that offers state-of-art reliability, temperature stability, and performance consistency making them a reliable gain block solution. The amplifiers are housed in SC-70 (SOT-363) packages. They use a Darlington pair configuration for broadband performance up to 2 GHz.

Avago offers a series of AVT devices with a range of OIP3 and gain specifications. Table 1 is a quick reference to the performance of the AVT series measured at 900 MHz and 2 GHz with a 50Ω impedance board. This information can also be obtained from the individual device datasheets.

This application note will discuss the AVT low gain products mainly, the AVT-51663 and AVT-53663. These two AVT products provide a nominal gain of about 19.5 dB, and good input and output return losses (>10 dB). These parts are differentiated by their linearity performance. For instance, the AVT-53663 has an OIP3 of +26.2 dBm and OP1dB of +15.1 dBm while the AVT-51663 has an OIP3 of +25 dBm and OP1dB of +12.9 dBm. Both of the products exhibit broad bandwidth and good gain flatness, which makes them useful in Cellular, PCS, WLL base station, Wireless Data, Fiber Optic Systems, CATV and ISM applications.

Table 1. AVT-5x663 specifications

Symbol	Unit	AVT-50663	AVT-51663	AVT-52663	AVT-53663
Frequency	MHz		900		
Vdd	V		5		
Idd	mA	36	37	45	48
Gain	dB	15.8	21.7	16.1	21.8
IRL	dB	-21.9	-14.8	-21.9	-16.5
ORL	dB	-19.1	-14.9	-19.1	-17.3
OIP3	dBm	+26.4	+25.8	+30.2	+28.9
OP1dB	dBm	+13	+13.3	+15.6	+16
NF	dB	3.7	2.8	3.6	2.9
Gain Flatness (DC to 2 GHz)	dB	± 0.67	± 2.7	± 0.67	± 2.7

Symbol	Unit	AVT-50663	AVT-51663	AVT-52663	AVT-53663
Frequency	MHz		2000		
Vdd	V		5		
Idd	mA	36	37	45	48
Gain	dB	15.3	19.6	15.5	19.5
IRL	dB	-15.4	-10.8	-15.9	-12
ORL	dB	-14.4	-11.8	-15.2	-13.4
OIP3	dBm	+25	+25	+27.7	+26.2
OP1dB	dBm	+12.5	+12.9	+15	+15.1
NF	dB	4	3.2	4	3.2
Gain Flatness (DC to 2 GHz)	dB	±0.67	± 2.7	± 0.67	± 2.7

AVT-51663 and AVT-53663 Product Overview

The AVT-5X663 is housed in a 6-lead (SOT-363) surface mount plastic package with the dimensions of 2.25 x 1.35 x 1.0 mm^3. The footprint and pin configurations are shown in Figure 1.

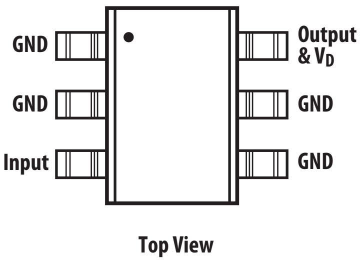

Figure 1. Top view of AVT-5X663

Table 2 shows the pin configuration and description for both the AVT-51663 and AVT-53663. AVT products are very easy to use. For most applications, all that is required is to apply 30 to 50 mA to the RF output pin. The RF input and RF output ports of AVT products are closely matched to a 50 Ω impedance.

Table 2. Pin configuration of the AVT-5X663

Pin	Label	Description
3	RF In	RF Input of device
6	RF Out & Vdd	RF Output of device Voltage supply for device
1, 2, 4, 5	GND	Grounding for the device

AVT-5X663 Demonstration Board

a) PCB Layout

A recommended AVT-5X663 PCB pad layout for the miniature SOT-363 package is shown in Figure 2.

Starting with the package layout in Figure 2, an RF layout similar to that in Figure 4 is a good starting point for coplanar waveguide designs using the AVT-51663 and AVT-53663 amplifiers.

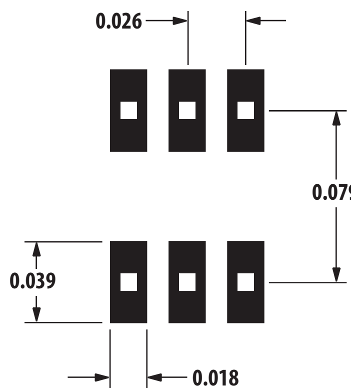

Figure 2. PCB Pad Layout for the AVT-5X663 (Package dimensions in inches)

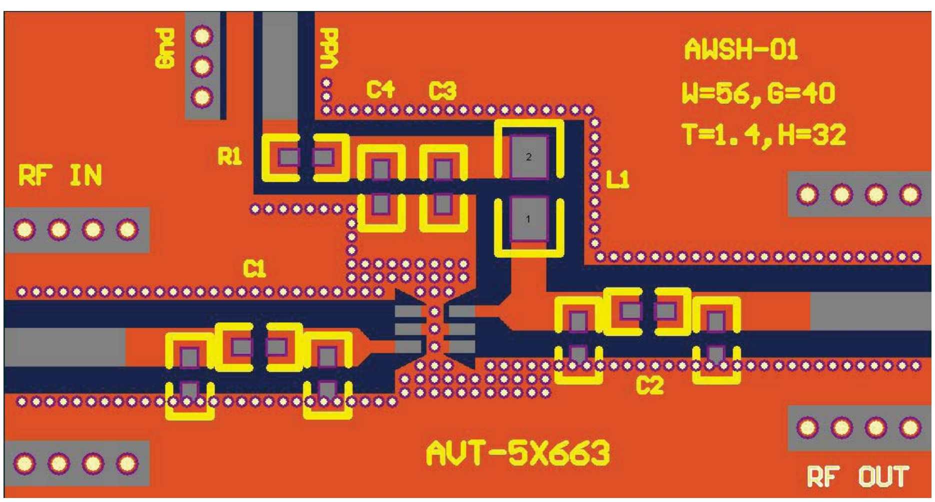

Figure 3. Top view of the AVT series demonstration board

b) PCB Materials

This layout is a coplanar waveguide design (solid ground plane on the backside of the circuit board) with 50 Ω interfaces for the RF input and output. The circuit is fabricated on 32 mil thick RF4 dielectric material. The amplifier and related components are assembled onto the printed circuit board as shown in Figure 6.

This demonstration board is a two layer PCB using 30 mil FR4 material. The 34 mil total board thickness allows the SMA connectors (EF Johnson 142-0701-881) to be easily slipped on over the edges of the PCB. DC pin headers are soldered at the top edge of the top layer board. Figure 3 sows the stacking structure of the PCB.

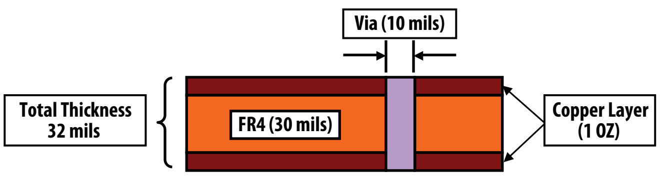

Figure 4. Stacking structure for the AVT-5X663 demonstration board

c) PCB Grounding

The demonstration uses plated through holes (vias) to bring ground to the topside of the circuit where needed. Multiple vias are used to reduce the inductance of the path to ground. A combined ground at Pin 1, Pin 2, Pin 4 and Pin 5 is used to bring the grounding circuit from the top plane to the bottom plane using multiple 10 mil via holes. Multiple vias are used to reduce the inductance of the path to ground.

AVT-5X663 Application Circuit

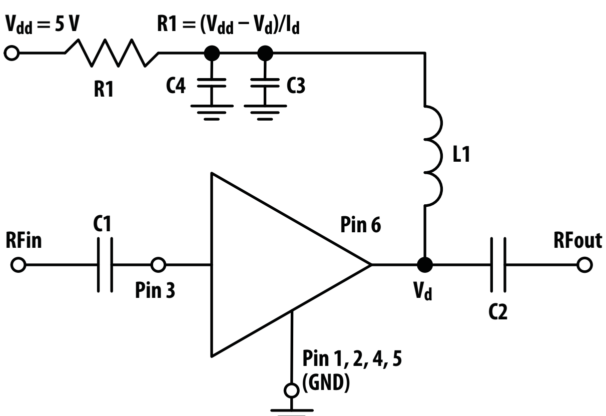

Figure 5. AVT-51663 / 53663 application circuit

As shown in Figure 5, both the AVT-51663 and AVT-53663 require series coupling capacitor C1 at the input and C2 at output side. The value of C1 and C2 are selected to provide a low reactance relative to 50 Ω at the lowest operating frequency. For a circuit tuned for 1900 MHz operation, the calculations to determine the values for C1 and C2 are:

X_C = 1 / jωC, where ω = 2πf

= 1 / (j x 2π x 1900 x 10^6 x C, assume X_C = 2 Ω (Short at 1900 MHz)

C = 1 / (2π x 1900 x 10^6 x 2)

= 42 pF (47 pF was chosen for C1 and C2 at 1900 MHz)

Resistor R1 sets the voltage and Idd bias current at Pin 6. R1 is used to drop the voltage at Pin 6. The calculation to determine the value for R1 is:

R1 = (Vdd – Vd) / Id

Where:

Vdd = The power supply voltage applied to R1 (volts)

Vd = The device voltage (V), which is available from the data sheet

Id = The quiescent bias current drawn by the device which is available from the data sheet

L1 is an RF choke and has been chosen to give a reactance of about 10 times the impedance at the bias injection point. The calculation to determine the value for L1, at an operating frequency of 1900 MHz, is:

X_L = jωL, where ω = 2πf

= j x (2π x 1900x10^6) x L, assume X_L = 150 Ω (High impedance at 1900 MHz)

L = 150 / [2π x 1900 x 10^6]

= 12.5 nH (3.3 nH was chosen for L1 for a 1900MHz frequency of operation after tuning on the demonstration board)

C4 is a low frequency bypass capacitor for the Vdd line. C3 reduces the external noise from the Vdd line.

AVT-5X663 Demonstration Board Placement and Bill of Material

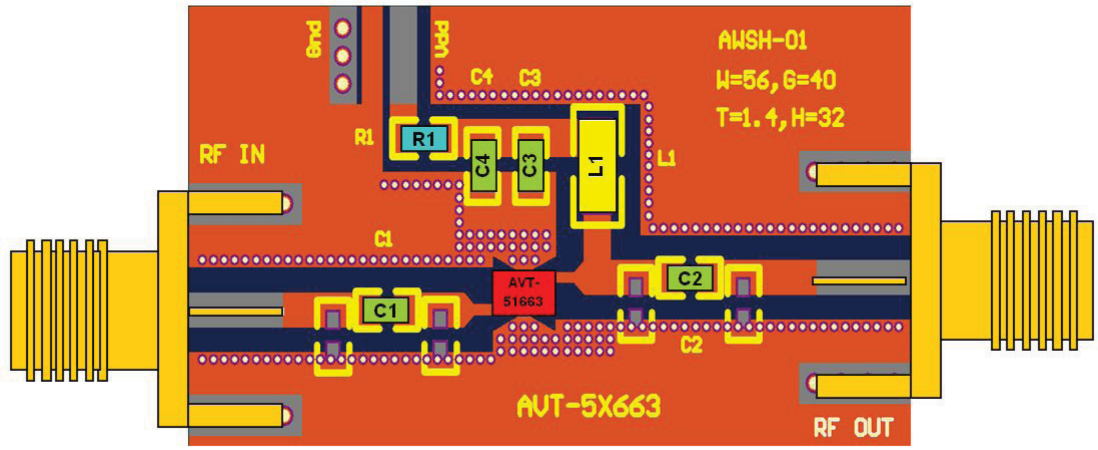

Figure 6. A complete demonstration board for the AVT-51663 and AVT 53663 amplifiers

Although the AVT-51663 and AVT-53663 are broadband Darlington pair amplifiers, they can be optimized at four narrowband frequencies, for example 450 MHz, 900 MHz, 1900 MHz and 2500 MHz. Tables 3 and 4 show the component values for each frequency.

Table 3. AVT-51663 Bill of Material

		Freq (MHz)				Broadband
Item	**Unit**	**450**	**900**	**1900**	**2500**	**(DC to 2 GHz)**
C1	pF	1000	100	47	15	100
C2	pF	1000	100	47	15	100
C3	pF	100				
C4	pF	2200				
R1	Ω	30				
L1	nH	180	27	3.3	1.6	Ferrite Bead [Murata: BLM 18HE152SN1D]

Table 4. AVT-53663 Bill of Material

		Freq (MHz)				Broadband
Item	**Unit**	**450**	**900**	**1900**	**2500**	**(DC to 2 GHz)**
C1	pF	1000	100	47	15	100
C2	pF	1000	100	47	15	100
C3	pF	100				
C4	pF	2200				
R1	Ω	24				
L1	nH	180	27	3.3	2.2	Ferrite Bead [Murata: BLM 18HE152SN1D]

AVT-51663 & AVT-53663 Measured Performance

a) Gain Flatness Measurement

The gain flatness for both of the parts is measured from the populated demonstration board with external matching components, as shown in Figure 6, using the BOM for the Gain Flatness column in Table 3. The AVT-51663 is biased at a Vdd of 5 V, Id of 36 mA and the AVT-53663 is biased at a Vdd of 5 V, Id of 45 mA.

From Figure 7, both devices have good gain flatness of ± 2 dB from 50 MHz up to 1GHz. The low frequency is limited by the choke and the capacitors.

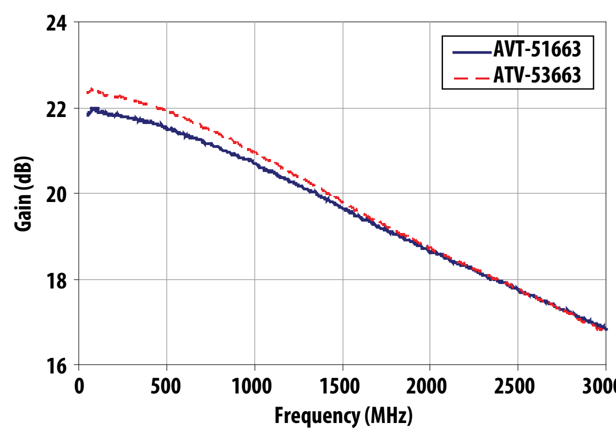

Figure 7. Glat flatness comparison between the AVT-51663 and AVT-53663

b) RF Performance for Different Matching Frequencies.

The AVT-51663 is biased at a Vdd of 5 V and Id of 36 mA. The AVT-53663 is biased at a Vdd of 5 V and Id of 45 mA. Table 5 shows measured performance at four frequencies using the demonstration board shown in Figure 6.

i) RF performance tuned at 450 MHz

The RF performance summary of the for AVT-51663 and AVT-53663 at a design frequency of 450 MHz is shown in the Table 5, and the performance over frequency is shown in Figures 8 to 12.

Table 5. AVT-51663 and AVT-53663 measured performance at 450MHz

		Tuned Frequency @ 450 MHz	
Item	**Unit**	**AVT-51663**	**AVT-53663**
Vdd	V	5	
Idd	mA	37	45
Gain	dB	21.8	22.2
IRL	dB	-17.6	-15.9
ORL	dB	-16.5	-15.5
ISO	dB	-24.2	-24.6
OIP3	dBm	+25.8	+28.9
OP1dB	dBm	+13.6	+15.8

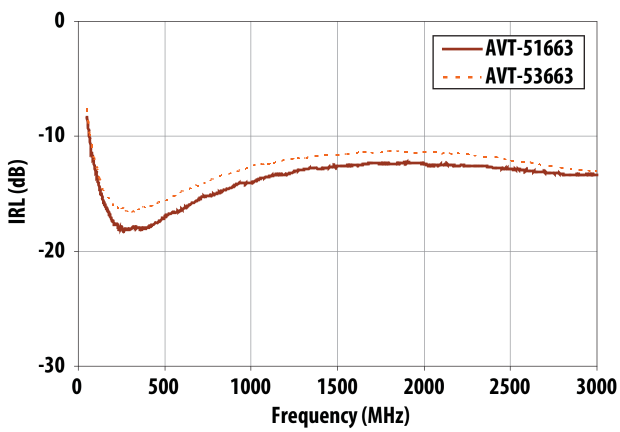

Figure 8. Measured IRL of the AVT-51663 and AVT-53663 at 450 MHz

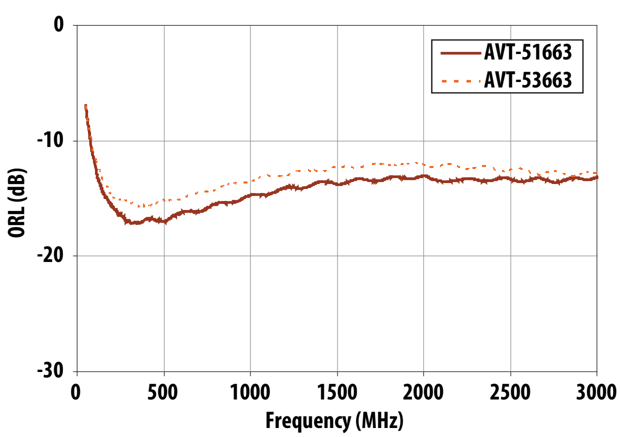

Figure 9. Measured ORL of the AVT-51663 and AVT-53663 at 450 MHz

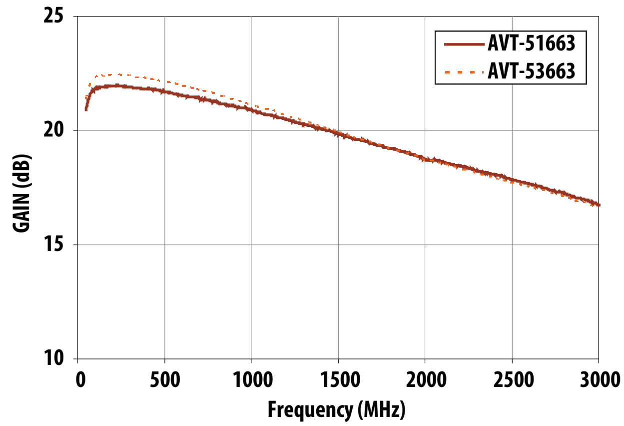

Figure 10. Measured gain of the AVT-51663 and AVT-53663 at 450 MHz

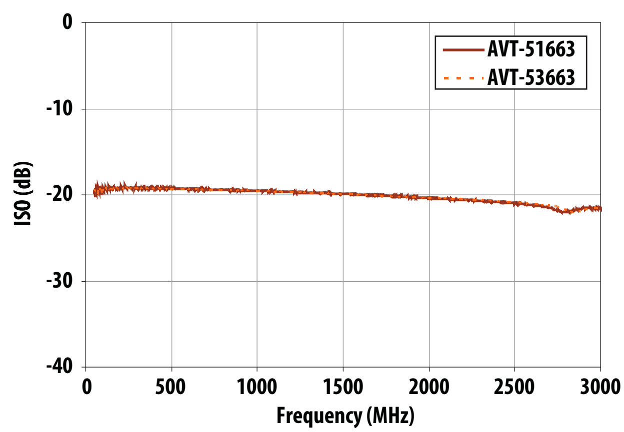

Figure 11. Measured isolation of the AVT-51663 and AVT-53663 at 450 MHz

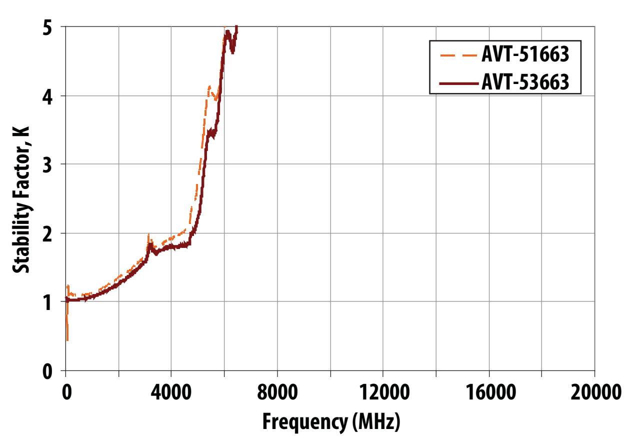

Figure 12. Measured stability, K, of the AVT-51663 and AVT-53663

ii) RF performance tuned at 900 MHz

The RF performance summary for the AVT-51663 and AVT-53663 at a design frequency of 900 MHz is shown in Table 6, and the performance over frequency is shown in Figures 13 to 18.

Table 6. AVT-51663 and AVT-53663 measured performance at 900 MHz

		Tuned Frequency @ 900 MHz	
Item	**Unit**	**AVT-51663**	**AVT-53663**
Vdd	V	5	
Idd	mA	37	45
Gain	dB	21.3	21.5
IRL	dB	-17.8	-17.6
ORL	dB	-19.2	-19.6
ISO	dB	-24.4	-24.5
OIP3	dBm	+27.2	+29.8
OP1dB	dBm	+14	+15.7

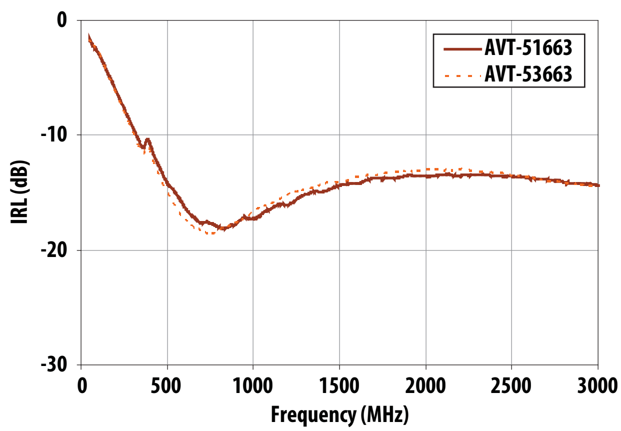

Figure 13. Measured IRL of the AVT-51663 and AVT-53663 at 900 MHz

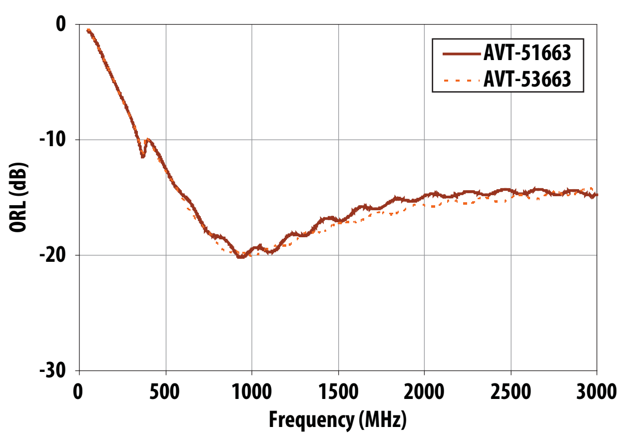

Figure 14. Measured ORL of the AVT-51663 and AVT-53663 at 900 MHz

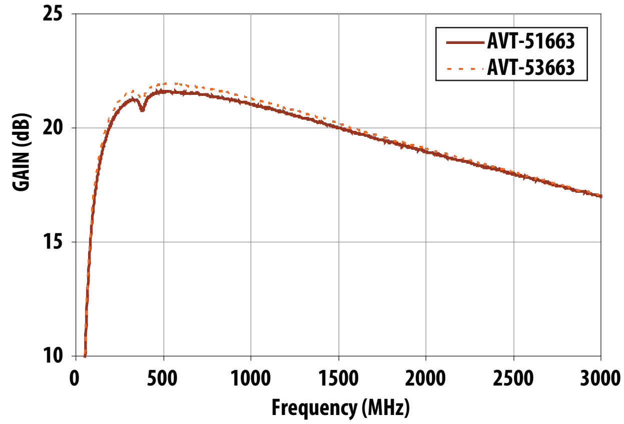

Figure 15. Measured gain of the AVT-51663 and AVT-53663 at 900 MHz

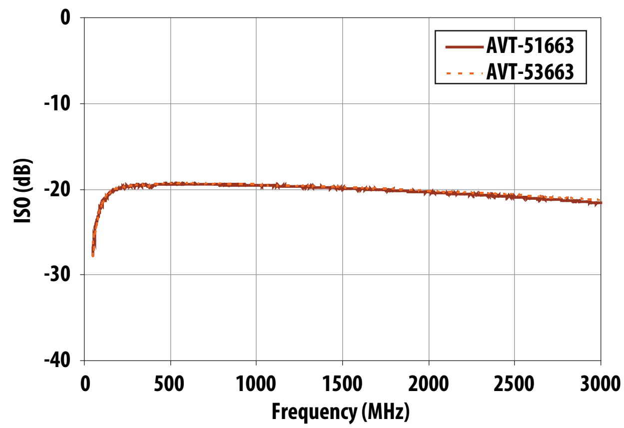

Figure 16. Measured isolation of the AVT-51663 and AVT-53663 at 900 MHz

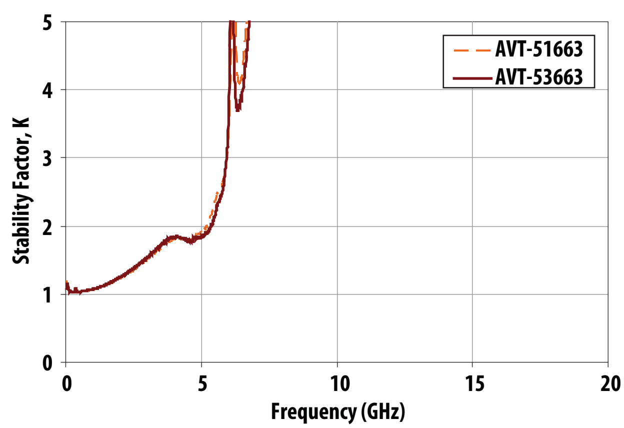

Figure 17. Measured stability, K, of the AVT-51663 and AVT-53663

iii) RF performance tuned at 1900 MHz

The AVT-51663 and AVT-53663 RF performance summary for a tuned frequency of 1900 MHz is shown in Table 7. The performance over frequency is shown in Figures 19 to 23.

Table 7. AVT-51663 and AVT-53663 measured performance at 1900 MHz

		Tuned Frequency @ 1900 MHz	
Item	**Unit**	**AVT-51663**	**AVT-53663**
Vdd	V	5	
Idd	mA	37	45
Gain	dB	19.2	19.3
IRL	dB	-21.8	-21
ORL	dB	-29.7	-19.6
ISO	dB	-25.1	-25.2
OIP3	dBm	+24.8	+27.8
OP1dB	dBm	+13.7	+14.5

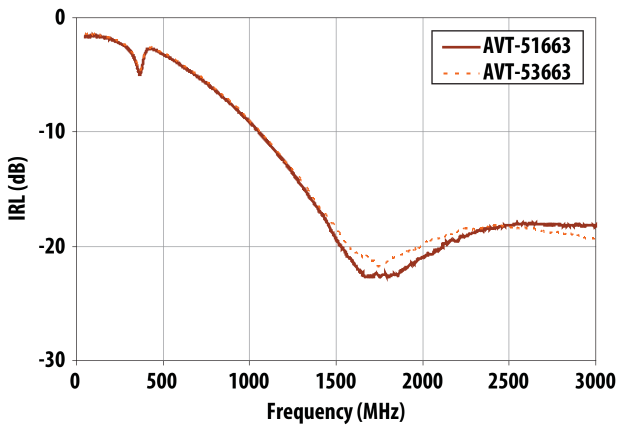

Figure 18. Measured IRL of the AVT-51663 and AVT-53663 at 1900 MHz

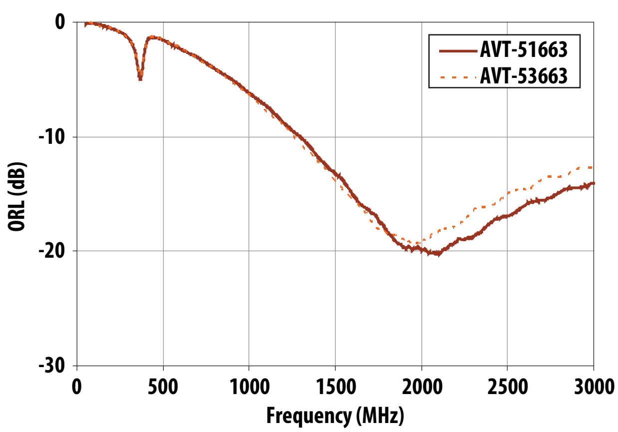

Figure 19. Measured ORL of the AVT-51663 and AVT-53663 at 1900 MHz

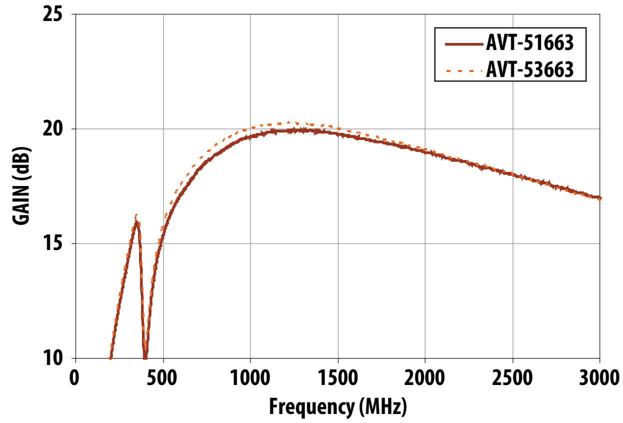

Figure 20. Measured gain of the AVT-51663 and AVT-53663 at 1900 MHz

Figures 18 and 22 shows that there is a small dip at 400 MHz; this is mainly due to the resonance from the bypass capacitors C3 and C4. This effect can be reduced by inserting a series resistor in between the bypass capacitors or by changing the C4 value.

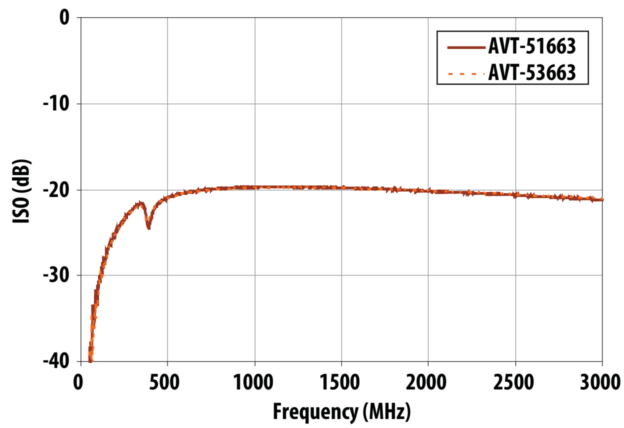

Figure 21. Measured isolation of the AVT-51663 and AVT-53663 at 1900 MHz

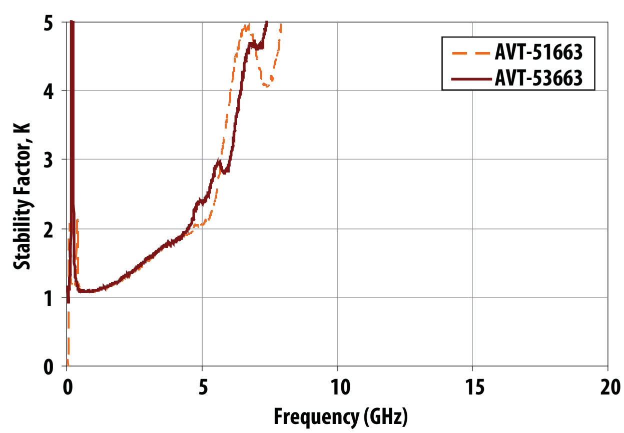

Figure 22. Measured stability, K, of the AVT-51663 and AVT-53663

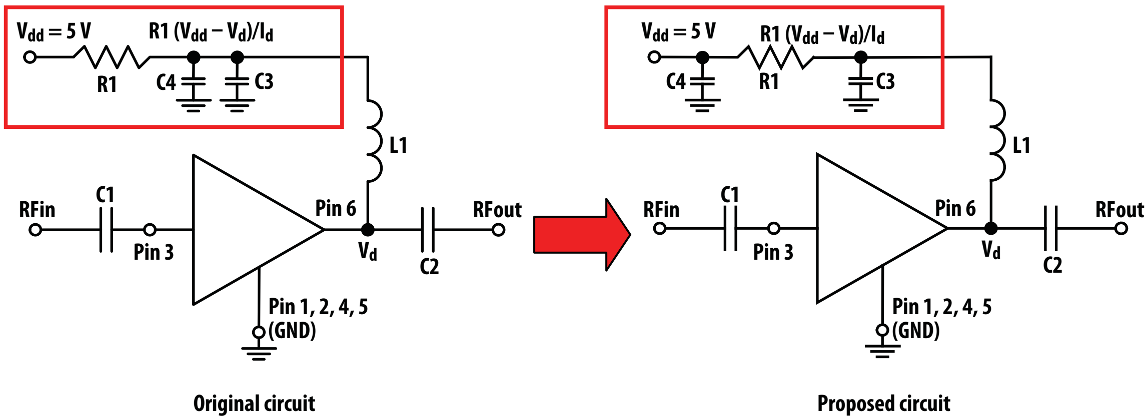

Figure 23. Changing the C4 location to form a π network

The dip at 400MHz can be eliminated by either changing the C4 value from 2200 pF to 220 pF or by changing the location of C4 by moving the R1 resistor in between C3 and C4 to form a π network, as shown in Figure 24. This π network will remove the effect of the resonance formed by C3 and C4 in the actual circuit configuration by placing a resistor in between the C3 and C4 capacitors.

Figures 24 to 27 show that the dip at 400 MHz has been removed by changing the value of C4 and also by shifting the location of C4 in the original circuitry.

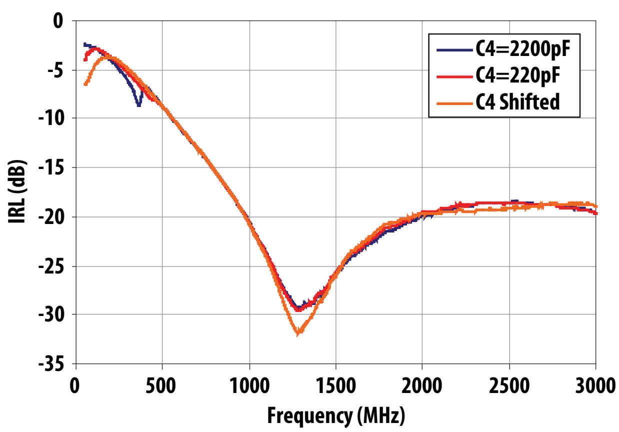

Figure 24. IRL comparison with three different configurations

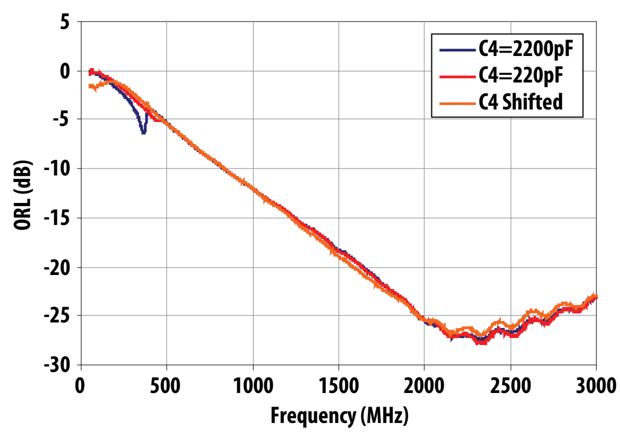

Figure 25. ORL comparison with three different configurations

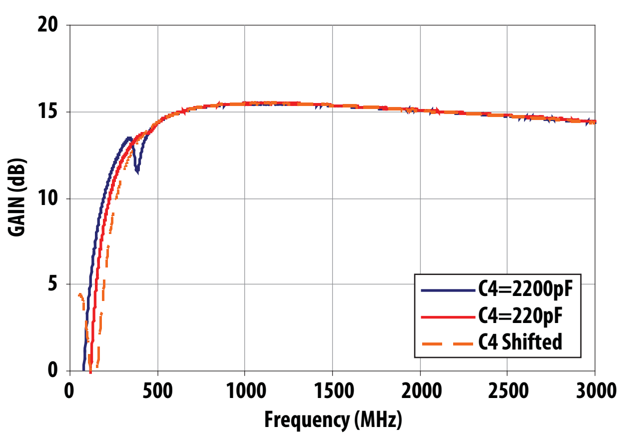

Figure 26. GAIN comparison with three different configurations

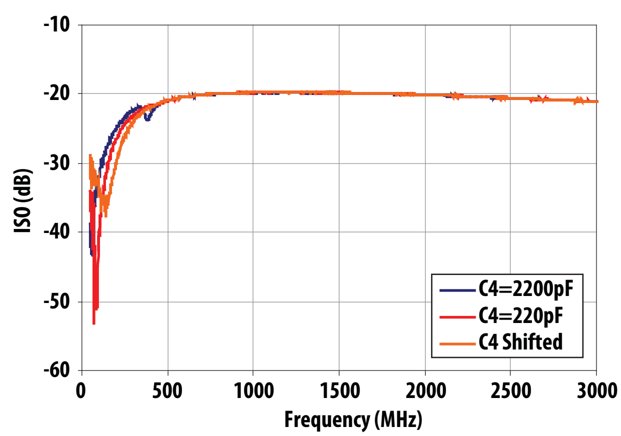

Figure 27. ISO comparison with three different C4 configurations

iv) RF performance tuned at 2500MHz

The summary of the RF performance for the AVT-51663 and AVT-53663 tuned at 2500 MHz is shown in Table 8. The performance over frequency is shown in Figures 28 to 32.

Table 8. AVT-51663 and AVT-53663 measured performance at 2500 MHz

		Tuned Frequency @ 2500 MHz	
Item	**Unit**	**AVT-51663**	**AVT-53663**
Vdd	V	5	
Idd	mA	37	45
Gain	dB	17.9	17.9
IRL	dB	-17.6	-18.9
ORL	dB	-16.6	-14.7
ISO	dB	-25.8	-25.8
OIP3	dBm	+23	+24
OP1dB	dBm	+12	+13.7

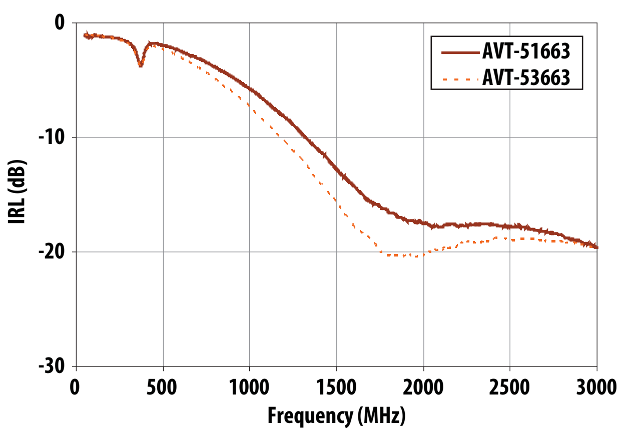

Figure 28. Measured IRL of the AVT-51663 and AVT-53663 at 2500 MHz

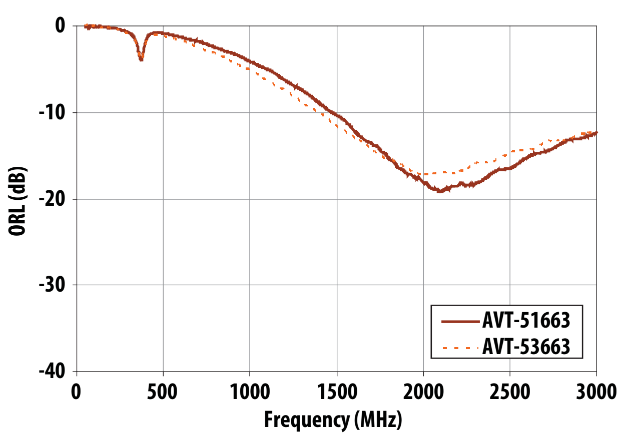

Figure 29. Measured ORL of the AVT-51663 and AVT-53663 at 2500 MHz

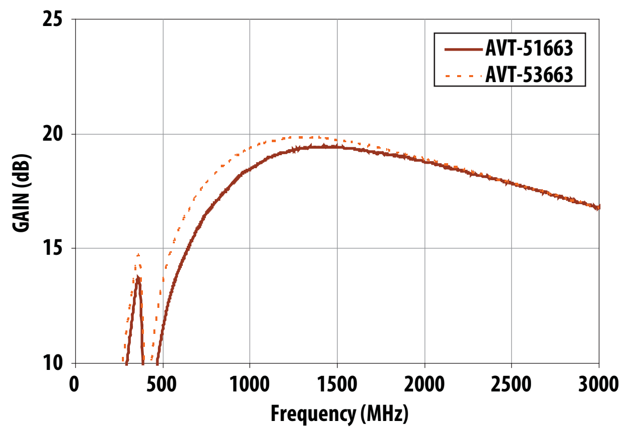

Figure 30. Measured gain of the AVT-51663 and AVT-53663 at 2500 MHz

These figures show that there is a small dip at 400 MHz. This is mainly due to the resonance of the bypass C3 and C4 capacitors. This effect can be removed by inserting a series resistor in between the bypass capacitors.

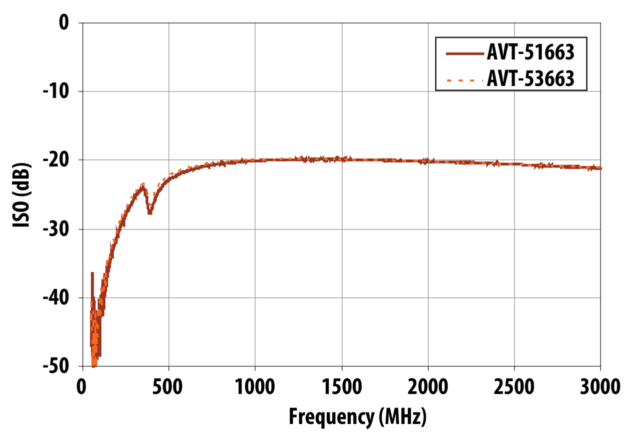

Figure 31. Measured isolation of the AVT-51663 and AVT-53663 at 2500 MHz

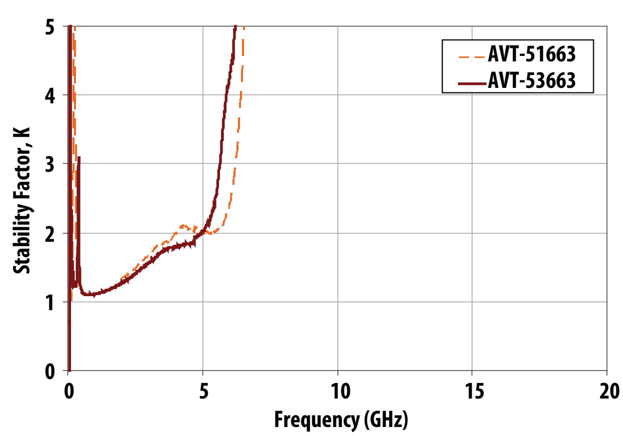

Figure 32. Measured Stability, K of AVT-51663 & AVT-53663

The AVT-53663 has 2 dB higher OIP3 and P1dB than the AVT-51663, as shown in Figure 33 and Figure 34 respectively. Figure 35 shows the NF performance for both parts. Both parts show identical NF performance trends over frequency.

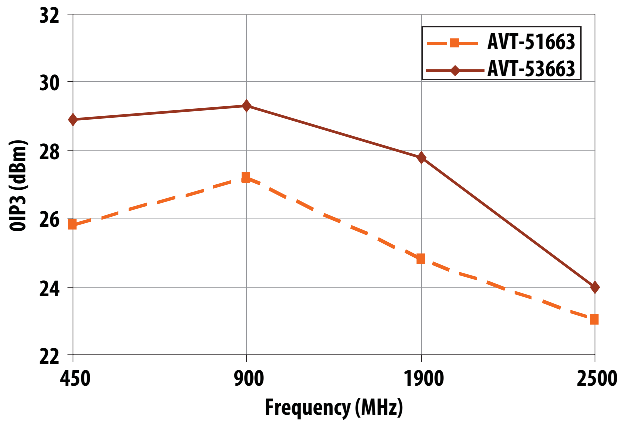

Figure 33. AVT-51663 and AVT-53663 comparison for for OIP3 performance

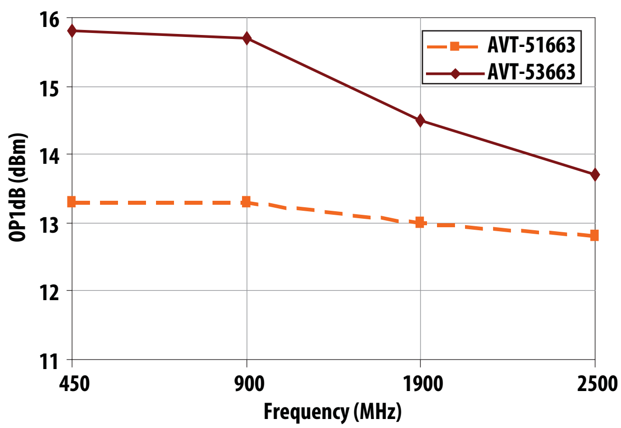

Figure 34. AVT-51663 and AVT-53663 comparison for OP1dB performance

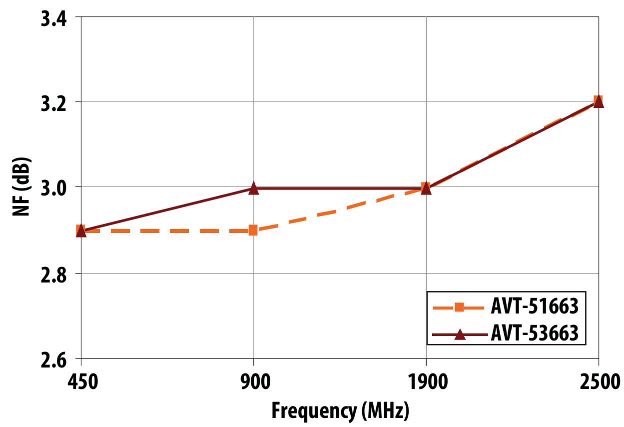

Figure 35. AVT-51663 and AVT-53663 comparison for NF performance

Conclusion

The actual performance of the AVT RFIC mounted on the demonstration board may not exactly match the data sheet specifications. This is because the data sheet measurements are obtained using a broadband board and broadband Bias Tee, while the performance in this application note is obtained using a broadband board with narrowband lumped components. The board's material, passive components and connectors on the actual application board introduce losses and parasitics that degrade the board's device performance, especially at higher frequencies. Some variation on measured results is also to be expected because of the normal manufacturing distribution of products.

References

Application Note for ADA-4543 +1.9 dBm Output P1dB Avago Darling Amplifier – AN1369.

For product information and a complete list of distributors, please go to our web site: **www.avagotech.com**

AV02-2513EN - June 3, 2010