

*ASSP for Telephone*

BIPOLAR

# Quadrature Modulator IC

(With 1.0 GHz Up-converter)

## MB54609

### ■ DESCRIPTION

The MB54609 is an intermediate-frequency (IF) quadrature modulator IC incorporating a 1.0-GHz up-converter optimized for use in digital mobile telecommunication systems such as GSM and PDC (Personal Digital Cellular).

The MB54609 incorporates a quadrature modulator for IF modulation, a transmission up-convert mixer, and a F/F type phase shifter as well, capable of handling IFs in a broad band.

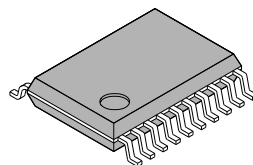
In addition, the MB54609 operates at a low power supply voltage of 3.0 V and a low power supply current of 18 mA (both as typical values), contributing to saving the power consumption of the device.

### ■ FEATURES

- Incorporating a high-performance transmission mixer covering the entire frequency band of up to 800 MHz used for PDC services (Maximum output frequency of 1.1 GHz)  
Maximum output frequency: 1.1 GHz, Output level: -9 dBm (typical)
- Externally connecting the quadrature modulator with the transmission mixer, allowing a bandpass filter (BPF) to be inserted in between  
The quadrature modulator output can drive a 50  $\Omega$  load.
- Flip-flop phase shifter capable of handling intermediate frequencies in the broad band (100 to 800 MHz)
- Operation at low voltage: 2.7 to 3.0 to 3.3 V
- Low current consumption  
During operating: 18.0 mA (typical)  
In power save mode: 0.6 mA (typical)
- Operating temperature range:  $T_a = -20$  to  $+85^\circ\text{C}$

### ■ PACKAGE

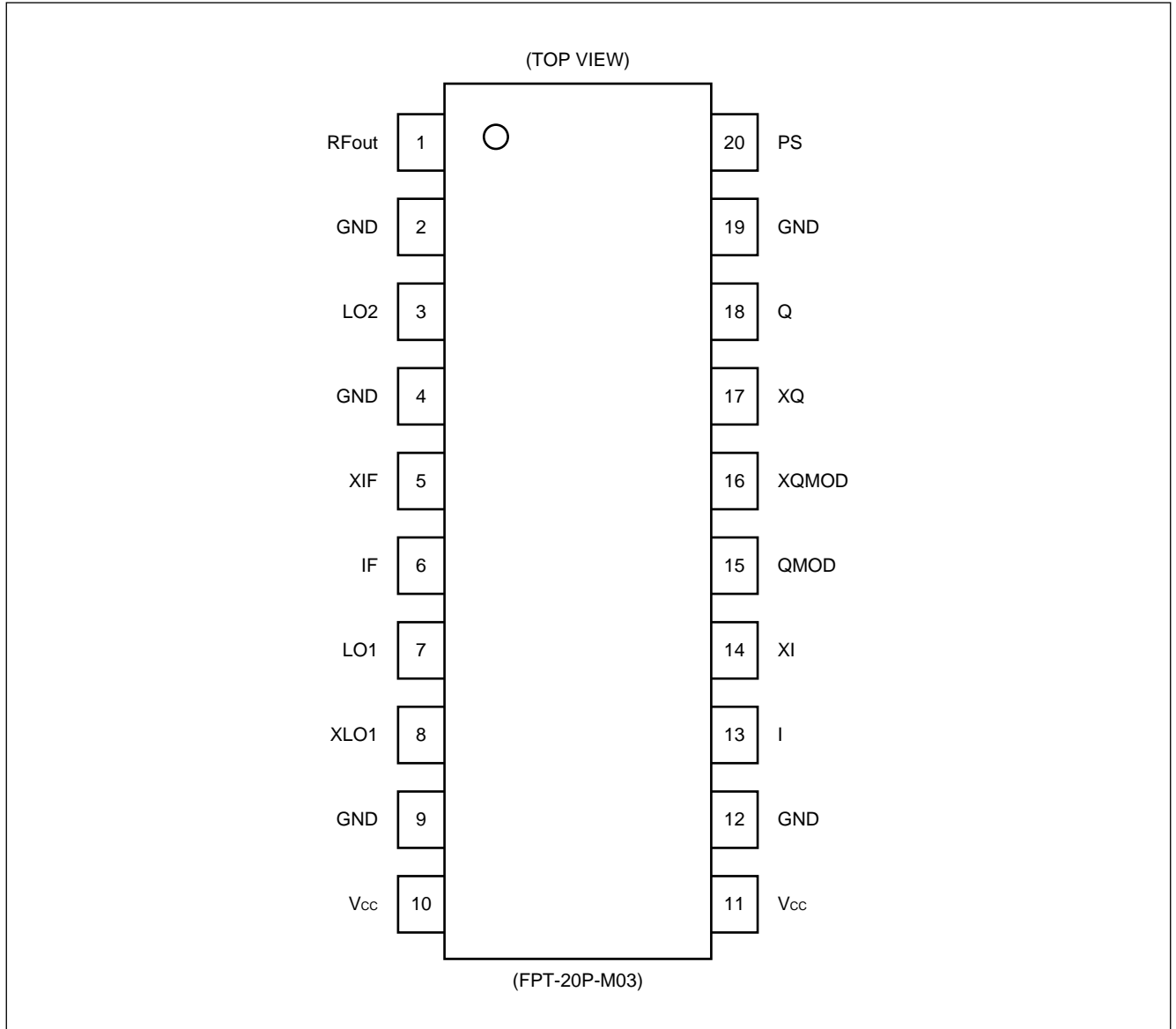
20-pin Plastic SSOP



(FPT-20P-M03)

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## ■ PIN ASSIGNMENT

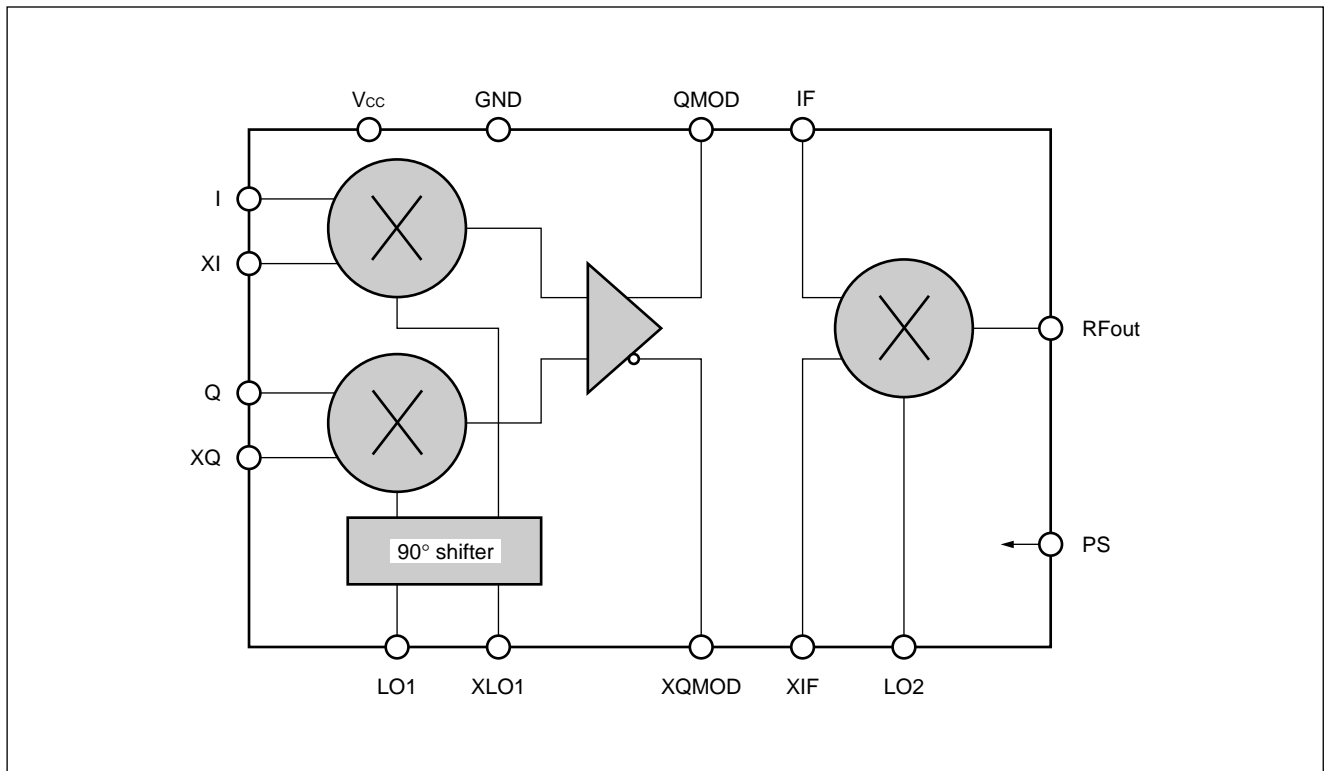


**■ PIN DESCRIPTION**

Pin no.	Pin name	Function	
1	RFout	Up-converter output pin	
2	GND	GND pin	
3	LO2	LO input pin for mixer	
4	GND	GND pin	
5	XIF	IF input complementary pin for mixer	
6	IF	IF input pin for mixer	
7	LO1	LO input pin for quadrature modulator	
8	XLO1	LO input complementary pin for quadrature modulator	
9	GND	GND pin	
10	V <sub>cc</sub>	Power supply pin	Power supply voltage must be applied to both pins.
11	V <sub>cc</sub>	Power supply pin	
12	GND	GND pin	
13	I	Baseband input (I) pin	
14	XI	Baseband input (I) complementary pin	
15	QMOD	Quadrature modulator IF output pin	
16	XQMOD	Quadrature modulator IF output complementary pin	
17	XQ	Baseband input (Q) complementary pin	
18	Q	Baseband input (Q) pin	
19	GND	GND pin	
20	PS	Power save mode control pin	

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## ■ BLOCK DIAGRAM



## ■ ABSOLUTE MAXIMUM RAGINGS (See WARNING)

Parameter	Symbol	Rating	Unit	Remarks
Power supply voltage	$V_{cc}$	-0.5 to 5.0	V	
Output voltage	$V_o$	-0.5 to $V_{cc} + 0.5$	V	
Input voltage	$V_i$	-0.5 to $V_{cc} + 0.5$	V	
Open collector applied voltage	$V_{oc}$	$V_{cc} \pm 0.3$ (-0.5 to 5.0)	V	RFout pin Do not leave this pin open.
Output current	$I_o$	$\pm 10$	mA	
Storage temperature	$T_{stg}$	-55 to +125	°C	

**WARNING:** Exceeding any of the above **Absolute Maximum Ratings** may cause permanent damage to the LSI. For normal operation, the device should be used under the recommended operating conditions. Exceeding any of the recommended conditions may adversely affect LSI reliability.

Note: Although the MB54609 contains an antistatic element to prevent electrostatic breakdown and the circuitry has been improved in electrostatic protection, observe the following precautions when handling the device:

- When storing or carrying the device, put it in a conductive case.
- Before handling the device, check that the jigs and tools to be used have been uncharged (grounded) as well as yourself. Use a conductive sheet on the working bench.
- Before fitting the device into or removing it from the socket, turn the power supply off.
- When handling (such as transporting) the MB54609 mounted board, protect the leads with a conductive sheet.

■ RECOMMENDED OPERATING CONDITIONS

Parameter	Symbol	Value			Unit	Remarks
		Min.	Typ.	Max.		
Power supply voltage	V <sub>CC</sub>	2.7	3.0	3.3	V	
Input voltage	V <sub>I</sub>	GND	—	V <sub>CC</sub>	V	
Open collector applied voltage	V <sub>OC</sub>	V <sub>CC</sub> - 0.2	—	V <sub>CC</sub> + 0.2	V	RFout pin. Do not leave this pin open.
Operating temperature	T <sub>a</sub>	-20	—	+85	°C	

■ ELECTRIC CHARACTERISTICS

(T<sub>CC</sub> = 3.0 V, T<sub>a</sub> = +25°C)

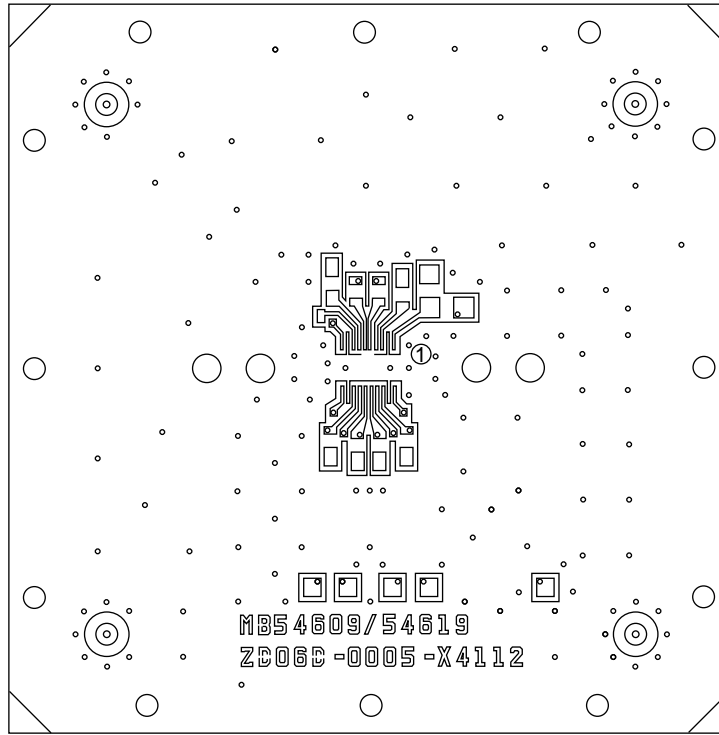
Parameter		Symbol	Value			Unit	Remarks	
			Min.	Typ.	Max.			
Power supply current		I <sub>CC</sub>	—	18.0	23.5	mA	DC current (Input with no AC signal)	
Power supply current in power save mode		I <sub>CCPS</sub>	—	0.6	0.9	mA	DC current (Input with no AC signal)	
Shifter input LO1	Operating band	f <sub>LO1</sub>	100	400	800	MHz		
	Input level	P <sub>LO1</sub>	-15	—	-5	dBm		
Baseband input	Operating band	f <sub>BB</sub>	DC	—	10	MHz		
	Input amplitude	V <sub>BB</sub>	—	—	1.2	V <sub>pp</sub>		
	Offset voltage	V <sub>OS</sub>	1.5	1.6	1.7	V	External offset voltage value	
	Offset current	I <sub>OS</sub>	—	3.0	—	μA	Input Imp. converted value = 533 kΩ	
Mixer input LO2	Operating band	f <sub>LO2</sub>	—	750	1100	MHz		
	Input level	P <sub>LO2</sub>	—	—	0	dBm		
Mixer output RFout	Operating band	f <sub>RF</sub>	—	950	1100	MHz	f <sub>RF</sub> = f <sub>LO2</sub> ± f <sub>LO1</sub> /2	
	Output level	P <sub>RF</sub>	—	-9	—	dBm	—	f <sub>LO1</sub> = 400 MHz (-15 dBm) f <sub>LO2</sub> = 750 MHz (-5 dBm)
Modulation precision	Amplitude deviation	A <sub>ERR</sub>	—	1.3	—	%	RMS value	f <sub>RF</sub> = 950 MHz output QMOD/Mix direct connection V <sub>BB</sub> = 1 V <sub>pp</sub>
	Phase deviation	P <sub>ERR</sub>	—	0.82	—	deg.	RMS value	
	Vector error	V <sub>ERR</sub>	—	1.9	—	%	RMS value	
Carrier suppression		CS	—	-40	-30	dBc	With external offset unadjusted	

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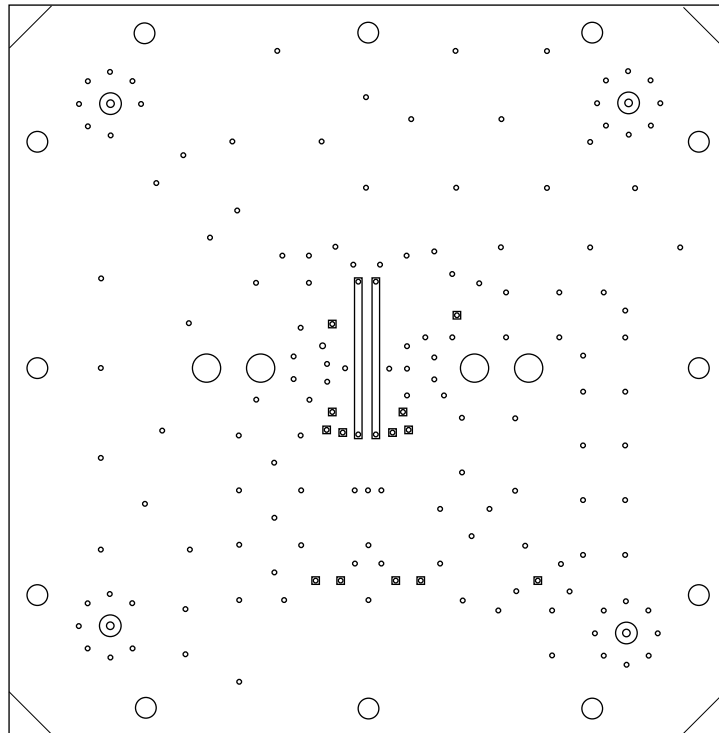
## ■ EVALUATION BOARD (Reference Example)

- Material: BT resin BT-HL870 (Dielectric constant [1 MHz] = 3.4 to 3.6)
- Thickness: 4 layers, 1.6 mm (Copper thickness: External layer = 18  $\mu\text{m}$ , Internal layer = 70  $\mu\text{m}$ )
- Plating: electroless gold plating

### • Layer 1 (front surface)



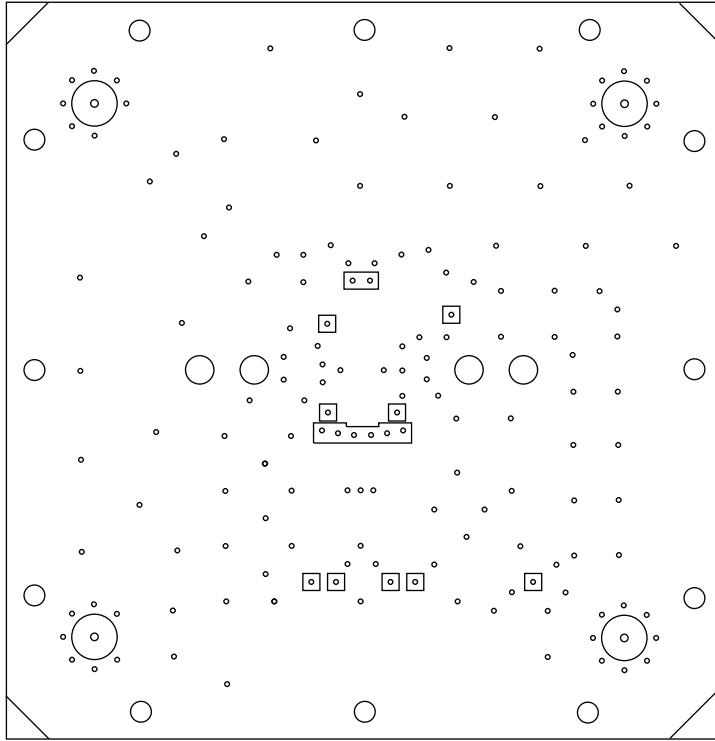
### • Layer 2



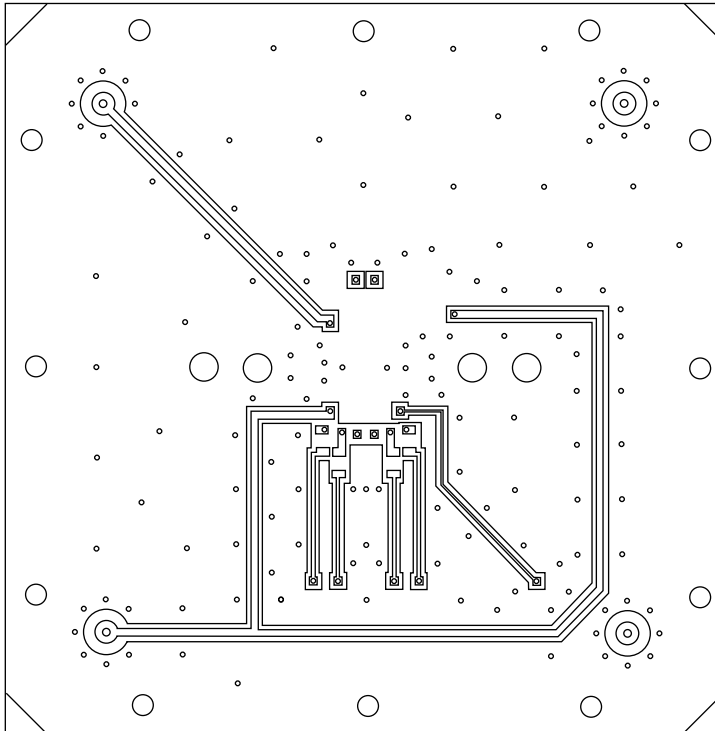
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• Layer 3



• Layer 4  
(rear surface)

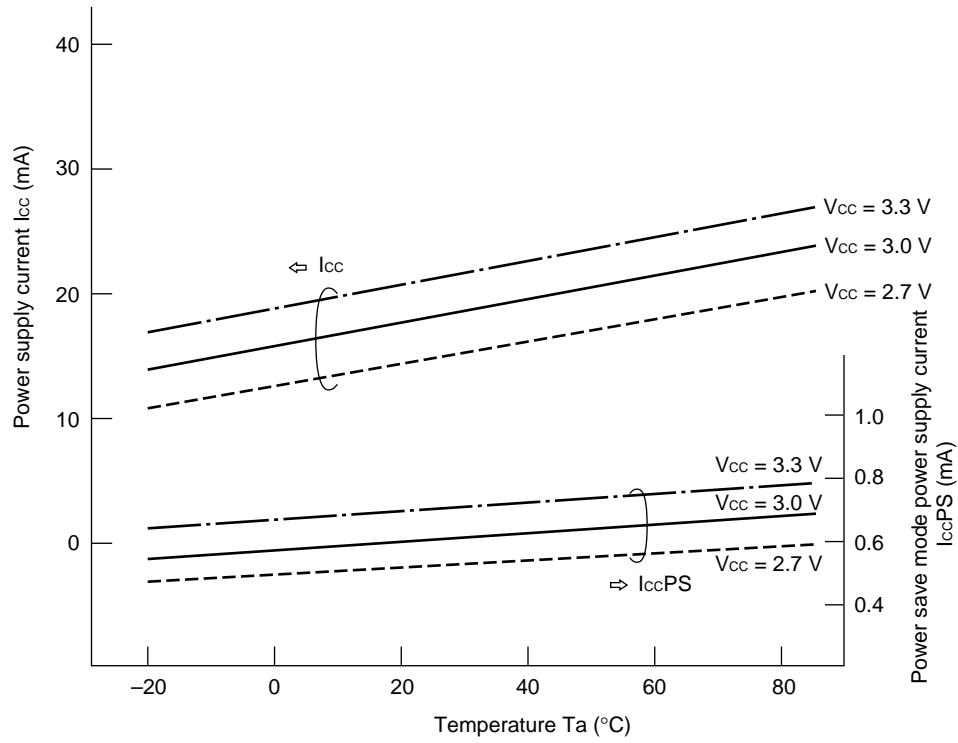


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## ■ MEASUREMENT DATA (Reference Values)

\* : Application-common characteristics

- DC characteristics (test circuit 1)  
@ Input with no AC signal



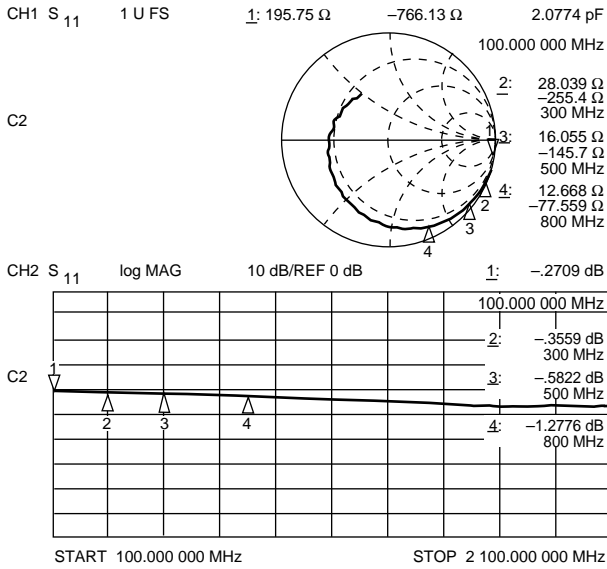
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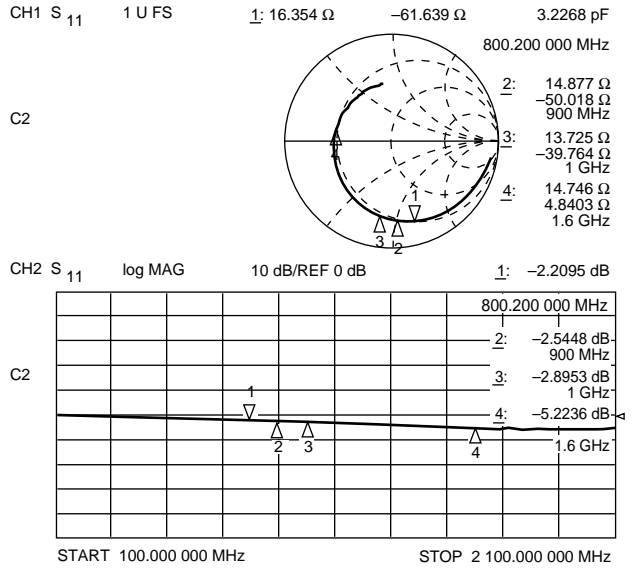
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• **Input impedance (Only IC: test circuit 4)**  
 @ Impedance from IC pin end

• **LO1**

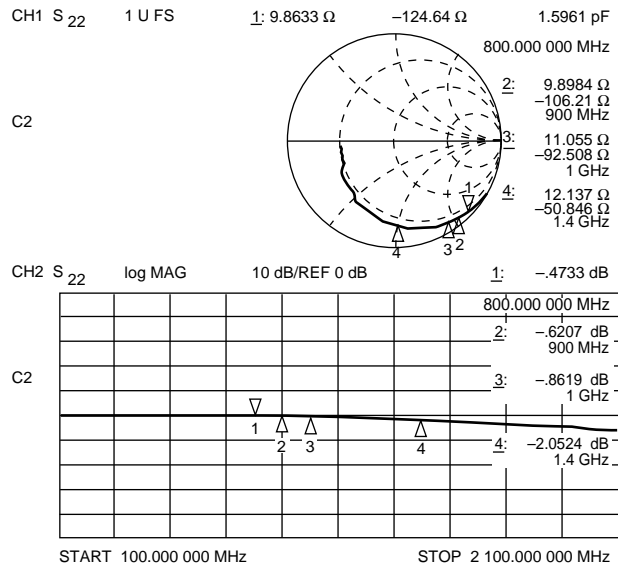


• **LO2**



• **Output impedance (Only IC: test circuit 4)**  
 @ Impedance from IC pin end

• **RFout**

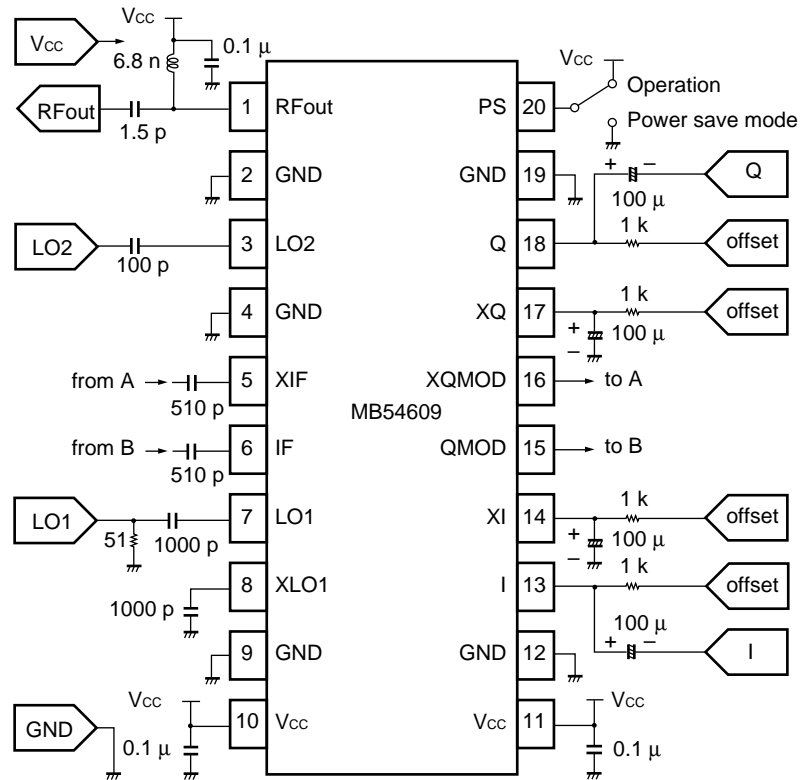


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## ■ 800-MHz PDC APPLICATION MEASUREMENT DATA (Reference Values)

Parameter	Symbol	Measurement result	Unit	Condition	Test circuit
Baseband input signal	f <sub>BB</sub>	42	kbps	$\pi/4$ DQPSK, Root-Nyquist filter ( $\alpha = 0.5$ )	—
	V <sub>BB</sub>	1.0	V <sub>pp</sub>	Single-end input	—
Shifter input signal LO1	f <sub>LO1</sub>	400	MHz	—	—
	P <sub>LO1</sub>	-15	dBm	—	—
Mixer input signal LO2	f <sub>LO2</sub>	750	MHz	—	—
	P <sub>LO2</sub>	-5	dBm	—	—
Mixer output signal RFout	f <sub>RF</sub>	950	MHz	f <sub>RF</sub> = f <sub>LO2</sub> + f <sub>LO1</sub> /2	—
	P <sub>RF</sub>	-8.4	dBm	SSB value	1
Return loss	RL <sub>LO1</sub>	-17	dB	f <sub>LO1</sub> = 400 MHz	3
	RL <sub>LO2</sub>	-2	dB	f <sub>LO2</sub> = 750 MHz	
	RL <sub>RF</sub>	-12	dB	f <sub>RF</sub> = 950 MHz	
Modulation precision	A <sub>ERR</sub>	1.3	%	RMS Magnitude Error	2
	P <sub>ERR</sub>	0.82	deg.	RMS Phase Error	
	V <sub>ERR</sub>	1.9	%	RMS Vector Error	
Carrier suppression	CS	-34.5	dBc	—	2

### • External circuit constants (with the IC mounted on the evaluation board)

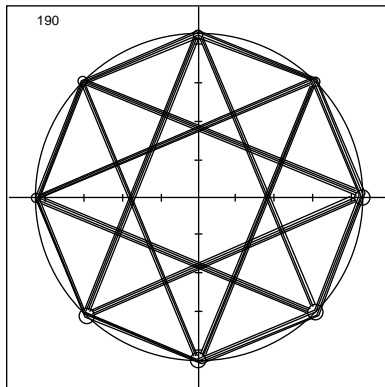


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- **Modulation precision and output spectrum (test circuit 2)**  
 @ Baseband signal:  $\pi/4$  DQPSK, 42 kbps, 1.0 Vpp, PN 15, Root-Nyquist filter  $\alpha = 0.5$   
 Input signals: LO1 = 400 MHz, -15 dBm; LO2 = 750 MHz, -5 dBm  
 Output signal: RFout = 950 MHz

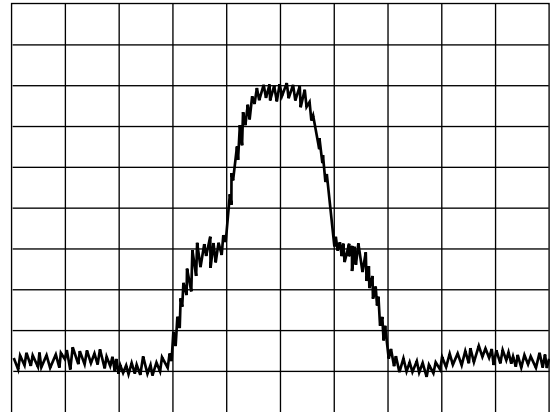
• **Modulation precision**



RMS Vector	Error =	1.927%
Peak Vector	Error =	4.234%
RMS Magnitude	Error =	1.290%
Peak Magnitude	Error =	3.364%
RMS Phase	Error =	0.821 degs
Peak Phase	Error =	-2.240 degs
Carrier Freq	Offset =	8.561e+03 Hz
Carrier Phase	Offset =	157.455 degs
Carrier Leak	=	-32.429 dB
Bias Vector	=	( 2.305, 0.634)%
Gravity Center	=	(-4.635, 10.356)%

VG: 5.000e-01 V/Div  
 Baseband Filter: RtNyq (0.5000) Rectangle Len = 64 OSR = 4.761905

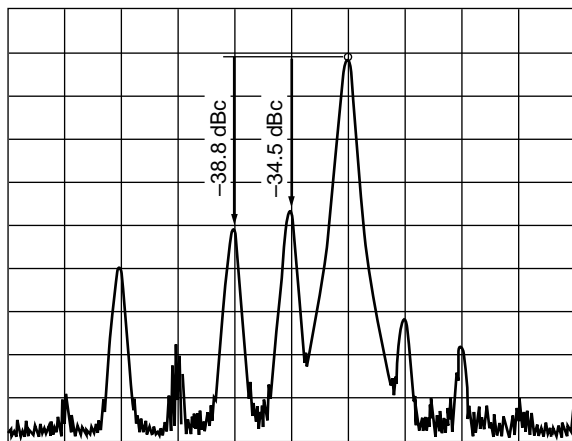
• **Output spectrum**



CENTER = 950 MHz  
 SPAN = 200 kHz  
 RBW = 3 kHz VBW = 100 Hz SWP = 3 s  
 ATT = 10 dB  
 REF = 0 dBm 10 dB/div.

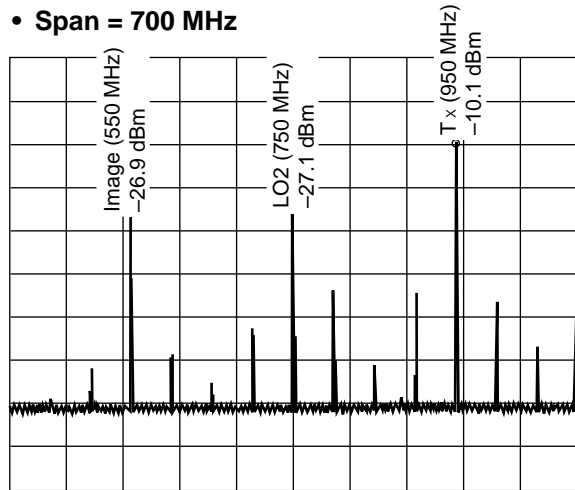
- **Spectrum (test circuit 2)**  
 @ Baseband signal:  $\pi/4$  DQPSK, 42 kbps, 1.0 Vpp, 0000, Root-Nyquist filter  $\alpha = 0.5$   
 Input signals: LO1 = 400 MHz, -15 dBm; LO2 = 750 MHz, -5 dBm  
 Output signal: RFout = 950 MHz

• **Span = 240 kHz**



CENTER = 950 MHz  
 SPAN = 26.2 kHz  
 RBW = 300 Hz VBW = 300 Hz SWP = 1.3 s  
 ATT = 10 dB  
 REF = 0 dBm 10 dB/div.

• **Span = 700 MHz**



CENTER = 750 MHz  
 SPAN = 700 MHz  
 RBW = 1 MHz VBW = 3 kHz SWP = 1.1 s  
 ATT = 10 dB  
 REF = 10 dBm 10 dB/div.

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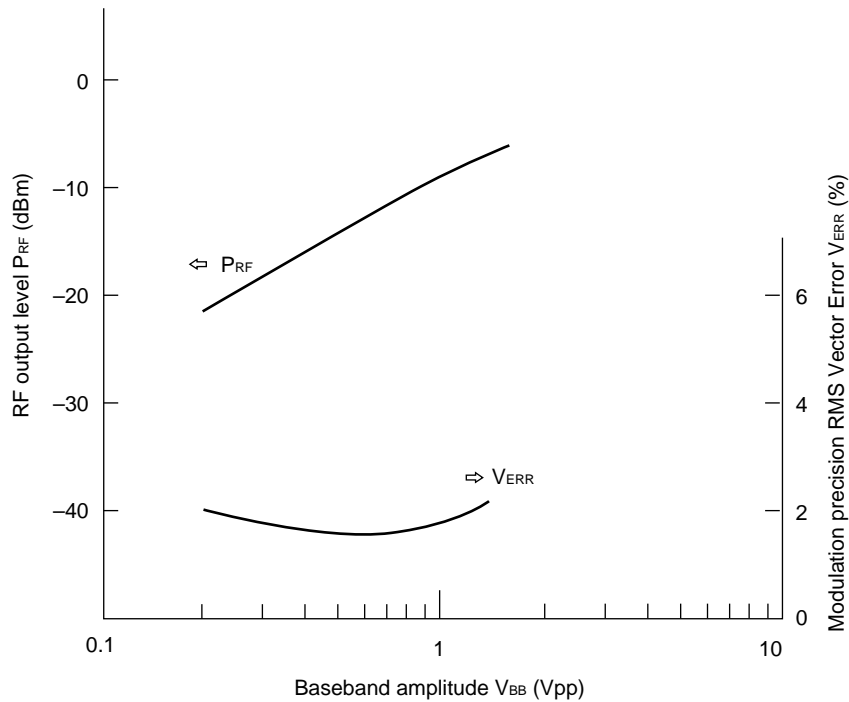
- RF output level dependent on baseband amplitude

( $P_{RF}$ : test circuit 1, Modulation precision: test circuit 2)

@ Baseband signal of test circuit 2:  $\pi/4$  DQPSK, 42 kbps, 1.0 Vpp, PN 15, Root-Nyquist filter  $\alpha = 0.5$

Input signals of test circuits 1 and 2: LO1 = 400 MHz, -15 dBm; LO2 = 750 MHz, -5 dBm

Output signal: RFout = 950 MHz



- RF output level dependent on LO1 and LO2 input levels

( $P_{RF}$ : test circuit 1, Modulation precision: test circuit 2)

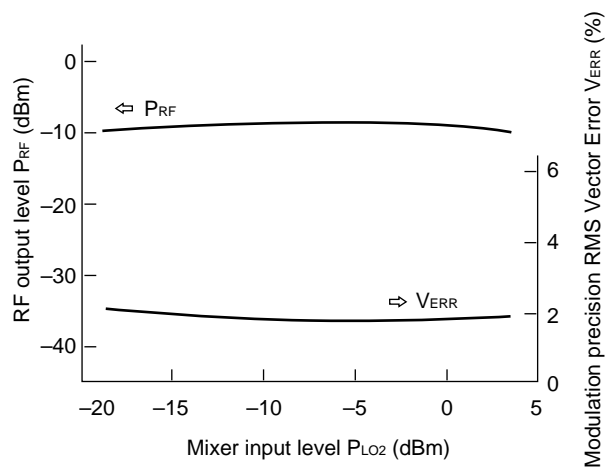
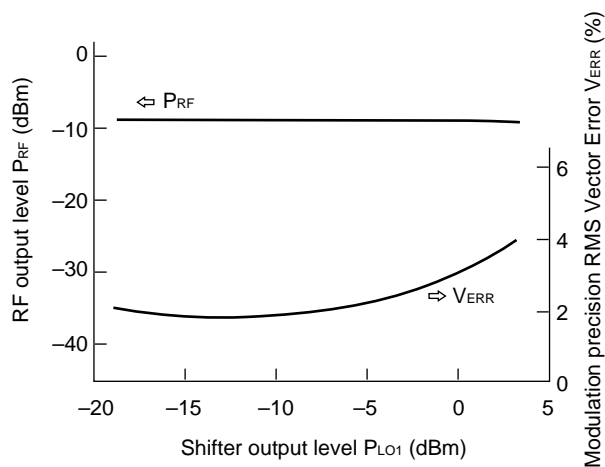
@ Baseband signal of test circuit 2:  $\pi/4$  DQPSK, 42 kbps, 1.0 Vpp, PN 15, Root-Nyquist filter  $\alpha = 0.5$

Input signals of test circuits 1 and 2: LO1 = 400 MHz, -15 dBm; LO2 = 750 MHz, -5 dBm

Output signals of test circuits 1 and 2: RFout = 950 MHz

- RF output level dependent on LO1 input level  
(@  $P_{LO2} = -5$  dBm)

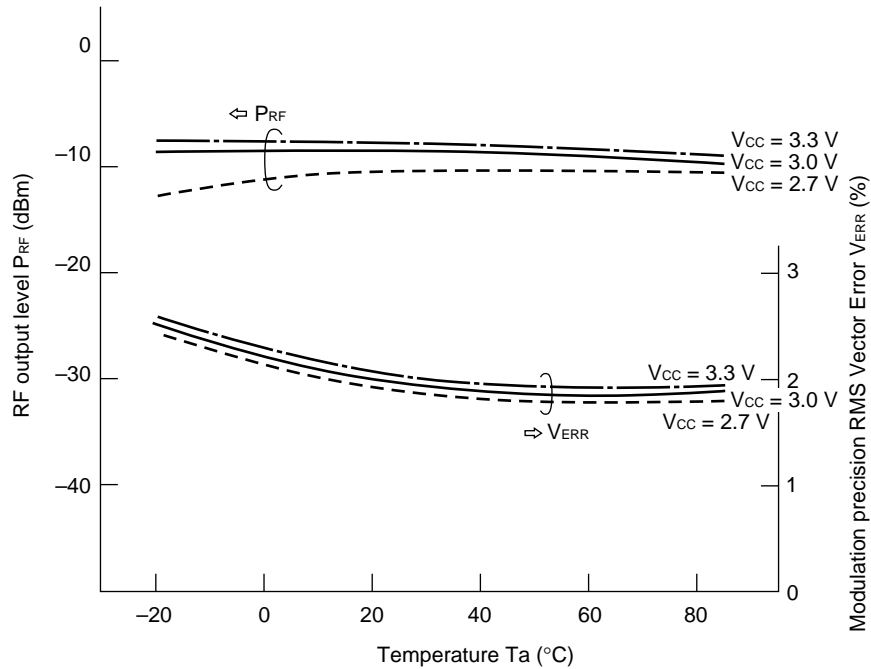
- RF output level dependent on LO2 input level  
(@  $P_{LO1} = -15$  dBm)



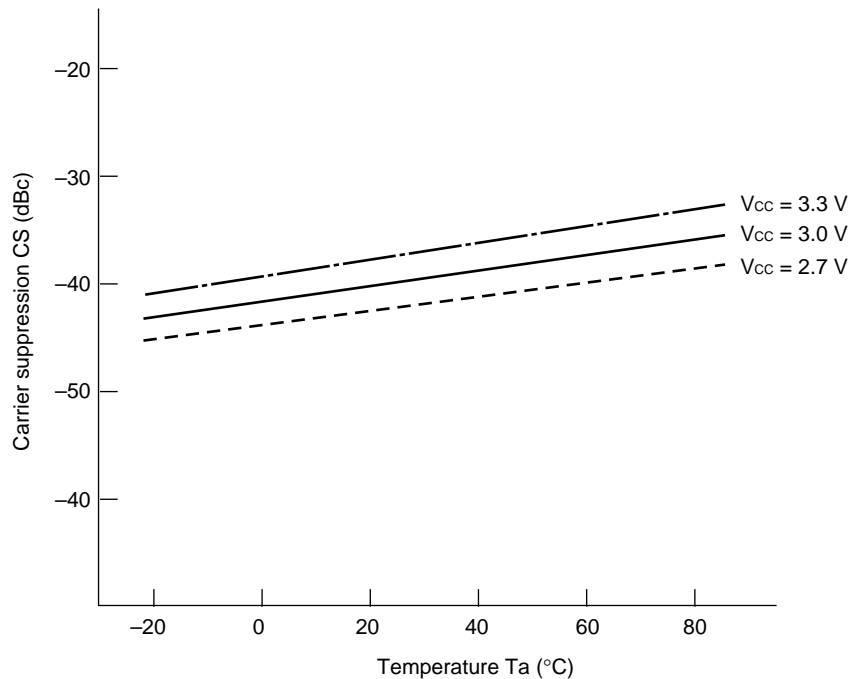
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- RF output level dependent on temperature (PRF: test circuit 1, Modulation precision: test circuit 2)
  - @ Baseband signal of test circuit 2:  $\pi/4$  DQPSK, 42 kbps, 1.0 Vpp, PN 15, Root-Nyquist filter  $\alpha = 0.5$
  - Input signals of test circuits 1 and 2: LO1 = 400 MHz, -15 dBm; LO2 = 750 MHz, -5 dBm
  - Output signals of test circuits 1 and 2: RFout = 950 MHz



- Carrier suppression dependent on temperature (test circuit 2)
  - @ Baseband signal:  $\pi/4$  DQPSK, 42 kbps, 1.0 Vpp, 0000, Root-Nyquist filter  $\alpha = 0.5$
  - Input signals: LO1 = 400 MHz, -15 dBm; LO2 = 750 MHz, -5 dBm
  - Output signal: RFout = 950 MHz



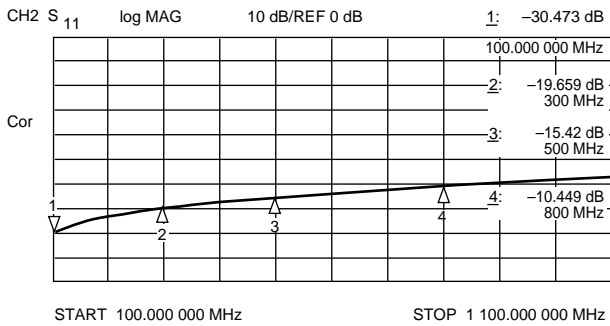
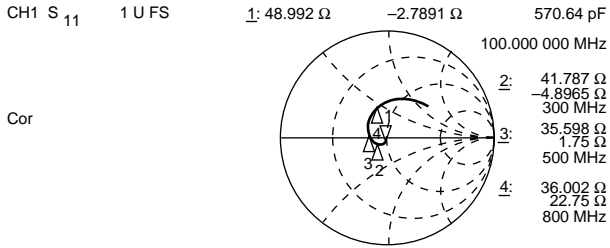
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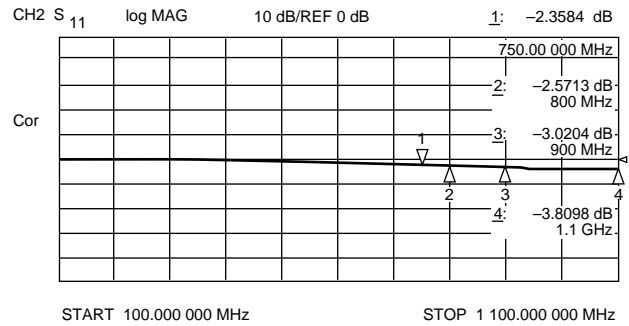
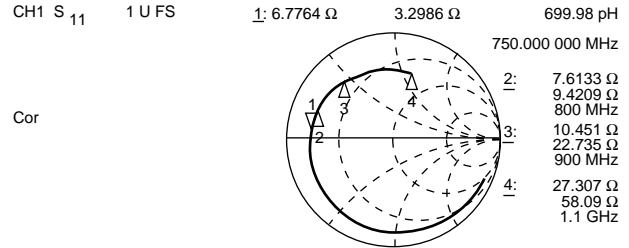
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- Input impedance (with components mounted: test circuit 3)  
@ Impedance including external components and evaluation board

## • LO1

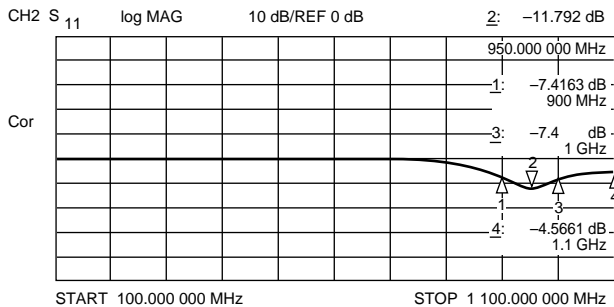
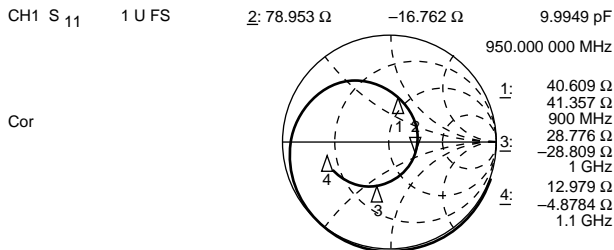


## • LO2



- Output impedance (with components mounted: test circuit 3)  
@ Impedance including external components and evaluation board

## • RFout

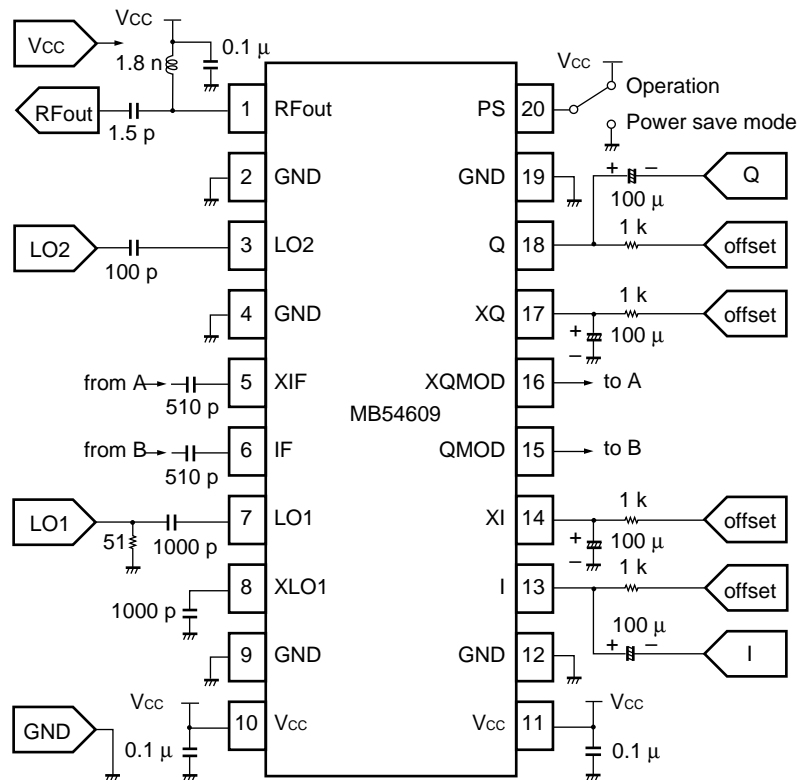


■ 1.5-GHz PDC APPLICATION MEASUREMENT DATA (Reference Values)

• Measurement result

Parameter	Symbol	Measurement result	Unit	Condition	Test circuit
Baseband input signal	$f_{BB}$	42	kbps	$\pi/4$ DQPSK, Root-Nyquist filter ( $\alpha = 0.5$ )	—
	$V_{BB}$	1.0	Vpp	Single-end input	—
Shifter input signal LO1	$f_{LO1}$	356	MHz	—	—
	$P_{LO1}$	-5	dBm	—	—
Mixer input signal LO2	$f_{LO2}$	1619	MHz	—	—
	$P_{LO2}$	-5	dBm	—	—
Mixer output signal RFout	$f_{RF}$	1441	MHz	$f_{RF} = f_{LO2} + f_{LO1}/2$	—
	$P_{RF}$	-13.4	dBm	SSB value	1
Return loss	$RL_{LO1}$	-18	dB	$f_{LO1} = 356$ MHz	3
	$RL_{LO2}$	-6	dB	$f_{LO2} = 1619$ MHz	
	$RL_{RF}$	-14	dB	$f_{RF} = 1441$ MHz	
Modulation precision	$A_{ERR}$	1.6	%	RMS magnitude error	2
	$P_{ERR}$	0.90	deg.	RMS phase error	
	$V_{ERR}$	2.2	%	RMS vector error	
Carrier suppression	CS	-39.0	dBc	—	2

• External circuit constants (with the IC mounted on the evaluation board)



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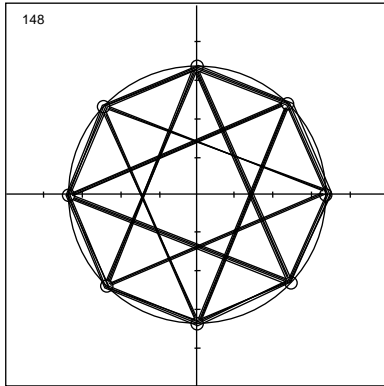
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- **Modulation precision and output spectrum (test circuit 2)**

@ Baseband signal:  $\pi/4$  DQPSK, 42 kbps, 1.0 Vpp, PN 15, Root-Nyquist filter  $\alpha = 0.5$   
 Input signals: LO1 = 356 MHz, -5 dBm; LO2 = 1619 MHz, -5 dBm  
 Output signal: RFout = 1441 MHz

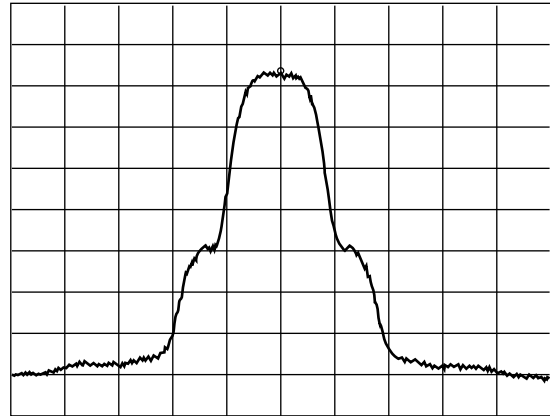
- **Modulation precision**



RMS Vector	Error =	2.243%
Peak Vector	Error =	4.552%
RMS Magnitude	Error =	1.597%
Peak Magnitude	Error =	3.756%
RMS Phase	Error =	0.902 degs
Peak Phase	Error =	-1.977 degs
Carrier Freq	Offset =	-1.454e+03 Hz
Carrier Phase	Offset =	7.417 degs
Carrier Leak	=	-33.001 dB
Bias Vector	= (	1.839, 1.275)%
Gravity Center	= (-1.295, 0.833)%	

VG: 7.000e-02 V/Div  
 Baseband Filter: RfNyq (0.500) Rectangle Len = 64 OSR = 4.761905

- **Output spectrum**

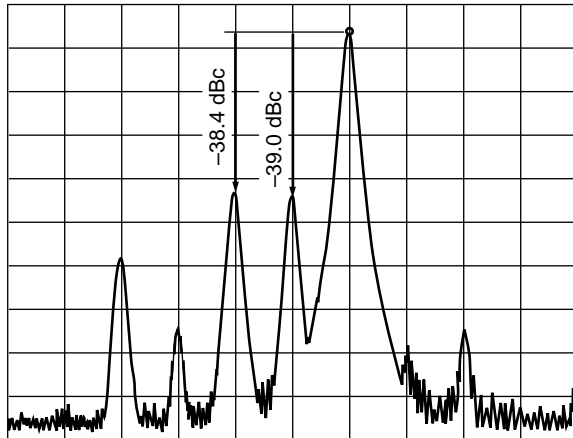


CENTER = 1441 MHz  
 SPAN = 200 kHz  
 RBW = 3 kHz VBW = 3 kHz SWP = 100 ms AVG = 128  
 ATT = 10 dB  
 REF = -10 dBm 10 dB/div.

- **Spectrum (test circuit 2)**

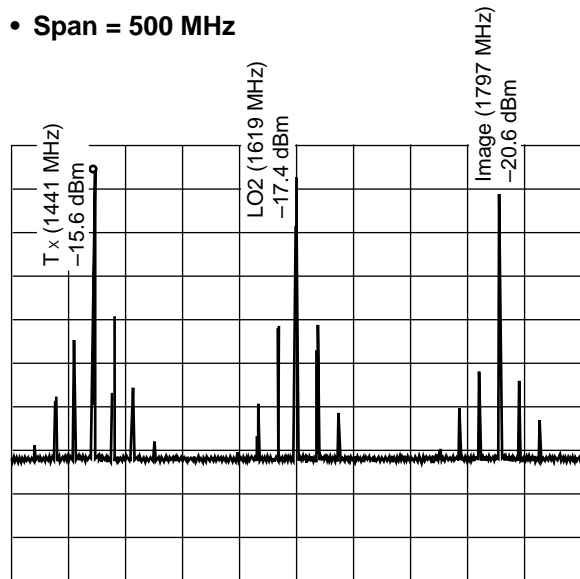
@ Baseband signal:  $\pi/4$  DQPSK, 42 kbps, 1.0 Vpp, 0000, Root-Nyquist filter  $\alpha = 0.5$   
 Input signals: LO1 = 356 MHz, -5 dBm; LO2 = 1619 MHz, -5 dBm  
 Output signal: RFout = 1441 MHz

- **Span = 26.2 kHz**



CENTER = 1441 MHz  
 SPAN = 26.2 kHz  
 RBW = 300 Hz VBW = 100 Hz SWP = 4 s  
 ATT = 10 dB  
 REF = -10 dBm 10 dB/div.

- **Span = 500 MHz**



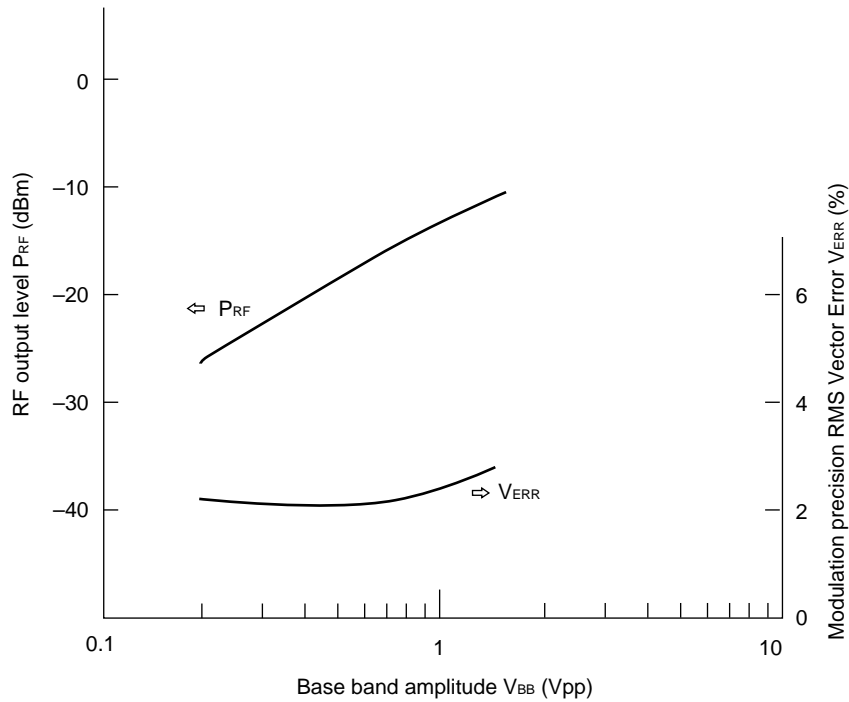
CENTER = 1619 MHz  
 SPAN = 500 MHz  
 RBW = 1 MHz VBW = 1 kHz SWP = 3 s  
 ATT = 10 dB  
 REF = -10 dBm 10 dB/div.

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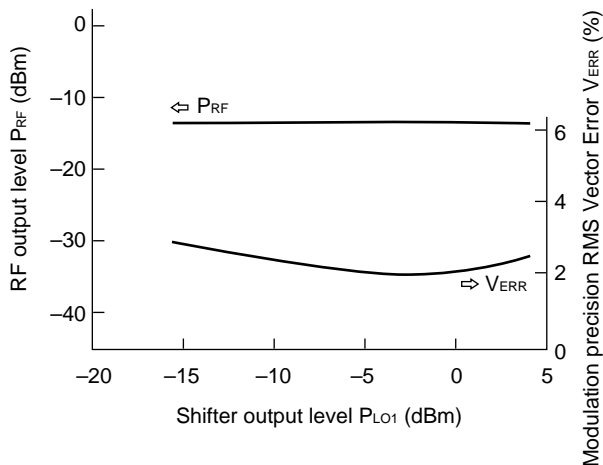
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- RF output level dependent on baseband amplitude  
 (P<sub>RF</sub>: test circuit 1, Modulation precision: test circuit 2)  
 @ Baseband signal of test circuit 2:  $\pi/4$  DQPSK, 42 kbps, 1.0 Vpp, PN 15, Root-Nyquist filter  $\alpha = 0.5$   
 Input signals of test circuits 1 and 2: LO1 = 356 MHz, -5 dBm; LO2 = 1619 MHz, -5 dBm  
 Output signals of test circuits 1 and 2: RFout = 1441 MHz

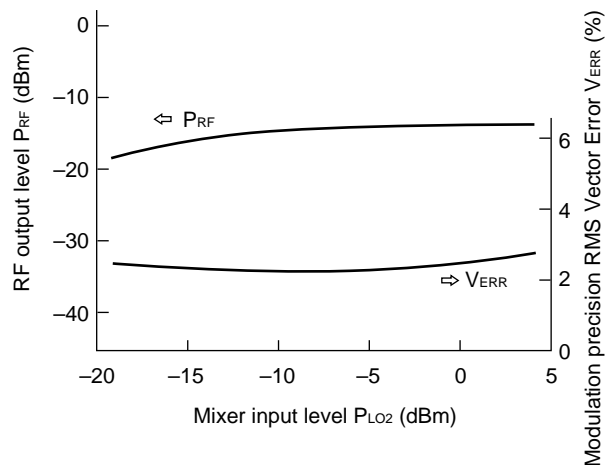


- RF output level dependent on LO1 and LO2 input levels  
 (P<sub>RF</sub>: test circuit 1, Modulation precision: test circuit 2)  
 @ Baseband signal of test circuit 2:  $\pi/4$  DQPSK, 42 kbps, 1.0 Vpp, PN 15, Root-Nyquist filter  $\alpha = 0.5$   
 Input signals of test circuits 1 and 2: LO1 = 356 MHz, -5 dBm; LO2 = 1619 MHz, -5 dBm  
 Output signals of test circuits 1 and 2: RFout = 1441 MHz

- RF output level dependent on LO1 input level  
 (@ P<sub>LO2</sub> = -5 dBm)



- RF output level dependent on LO2 input level  
 (@ P<sub>LO1</sub> = -5 dBm)



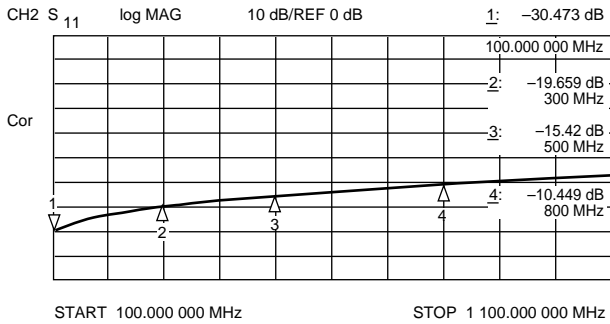
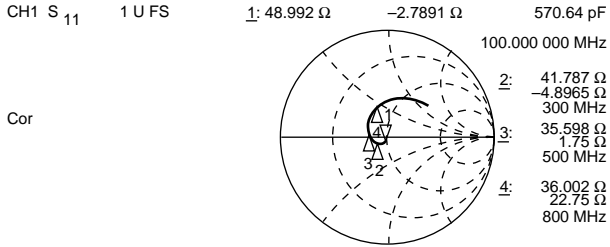
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# MB54609

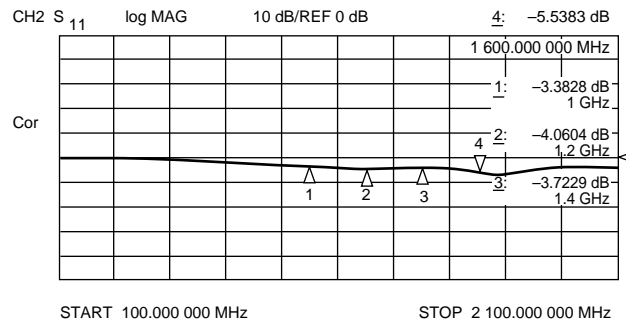
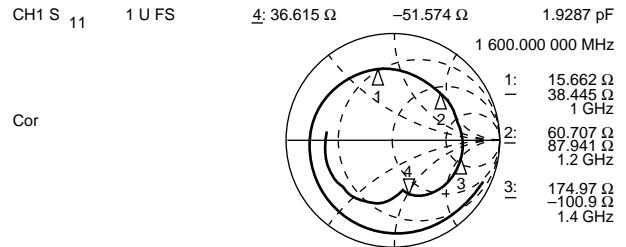
(Continued)

- Input impedance (with components mounted: test circuit 3)  
@ Impedance including external components and evaluation board

## • LO1

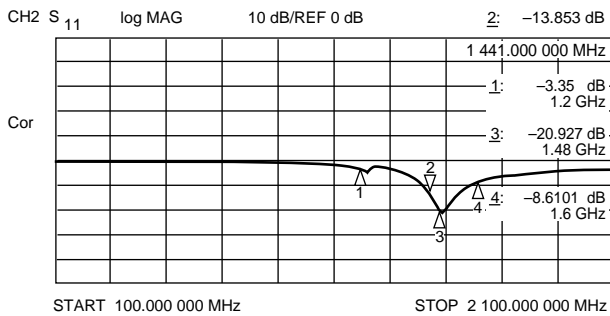
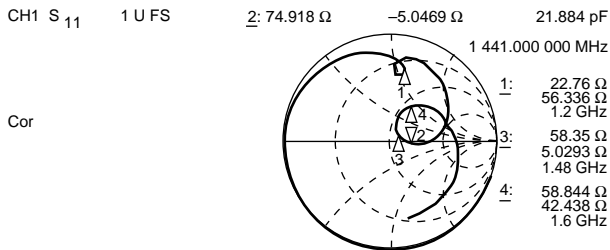


## • LO2

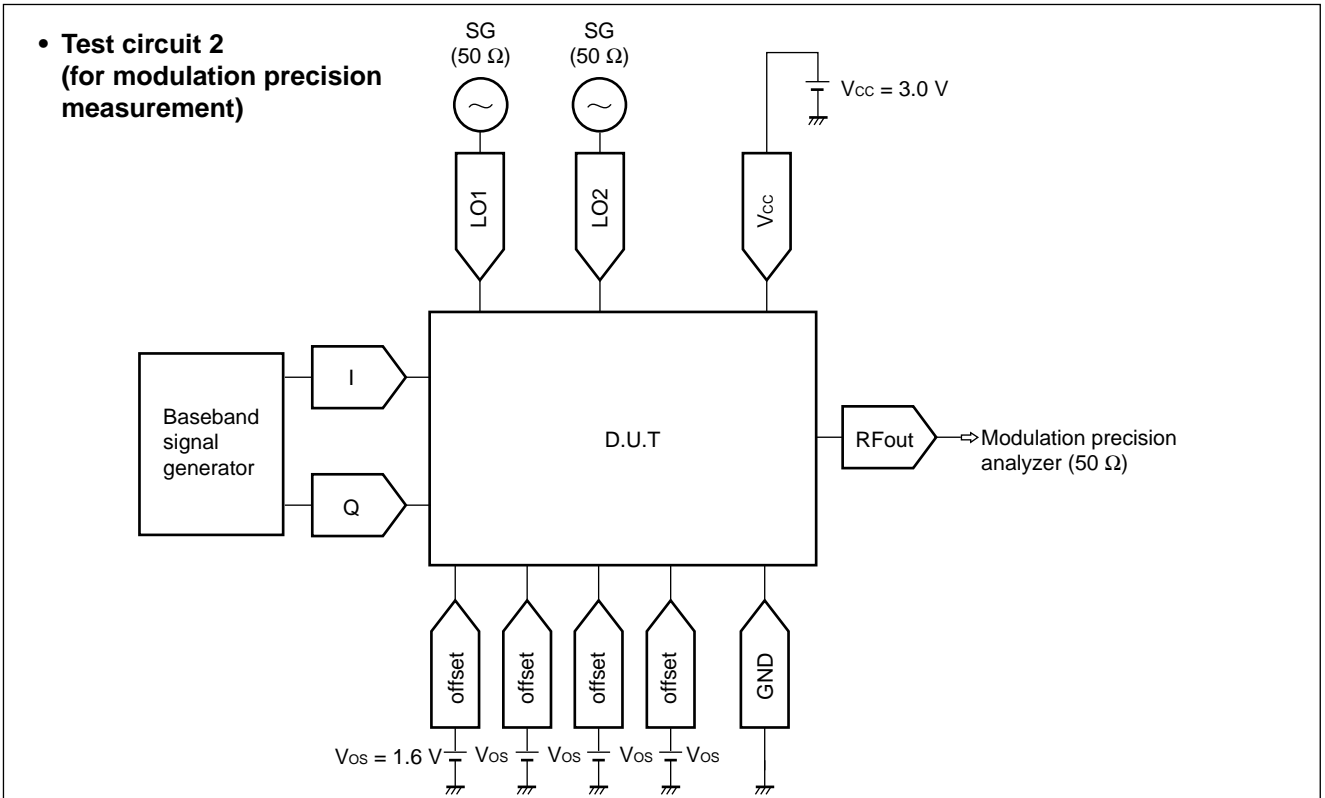
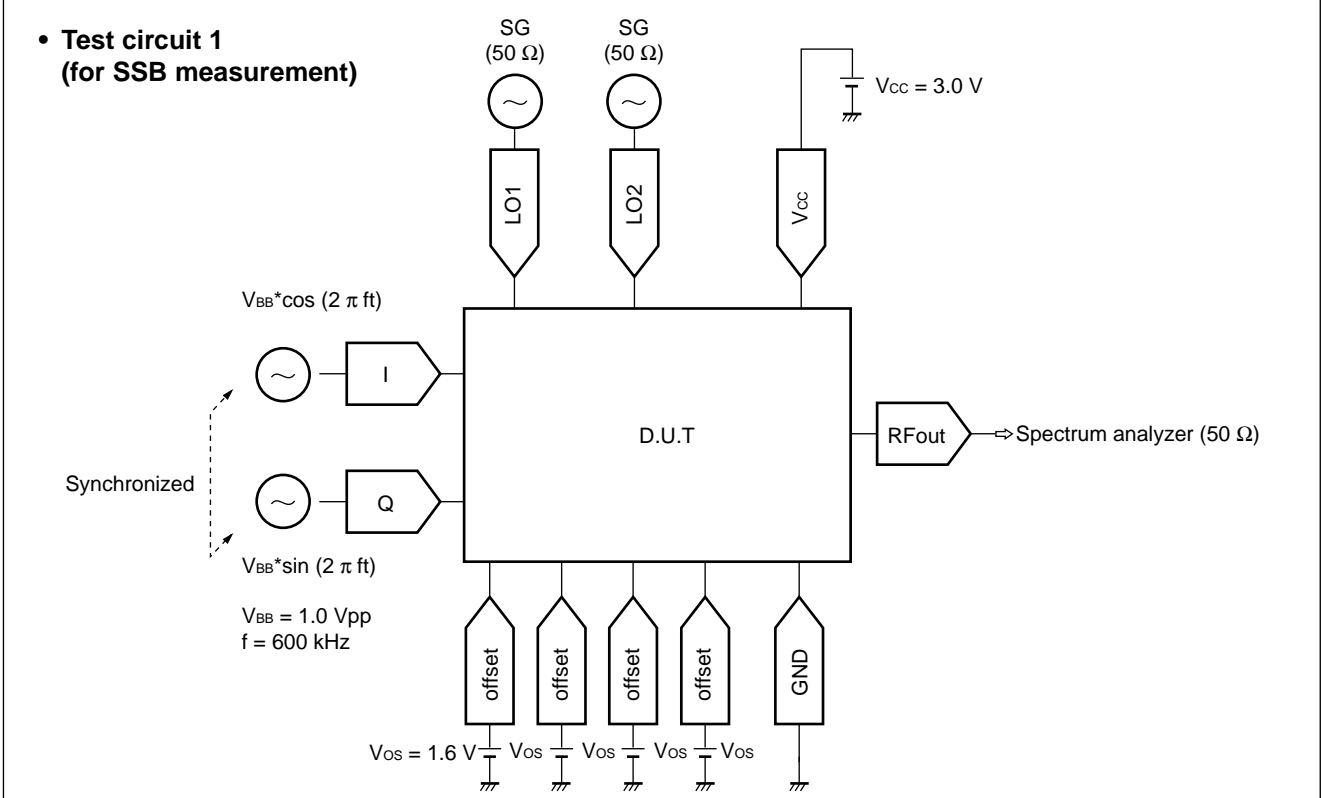


- Output impedance (with components mounted: test circuit 3)  
@ Impedance including external components and evaluation board

## • RFout



■ TEST CIRCUITS (Reference Examples)

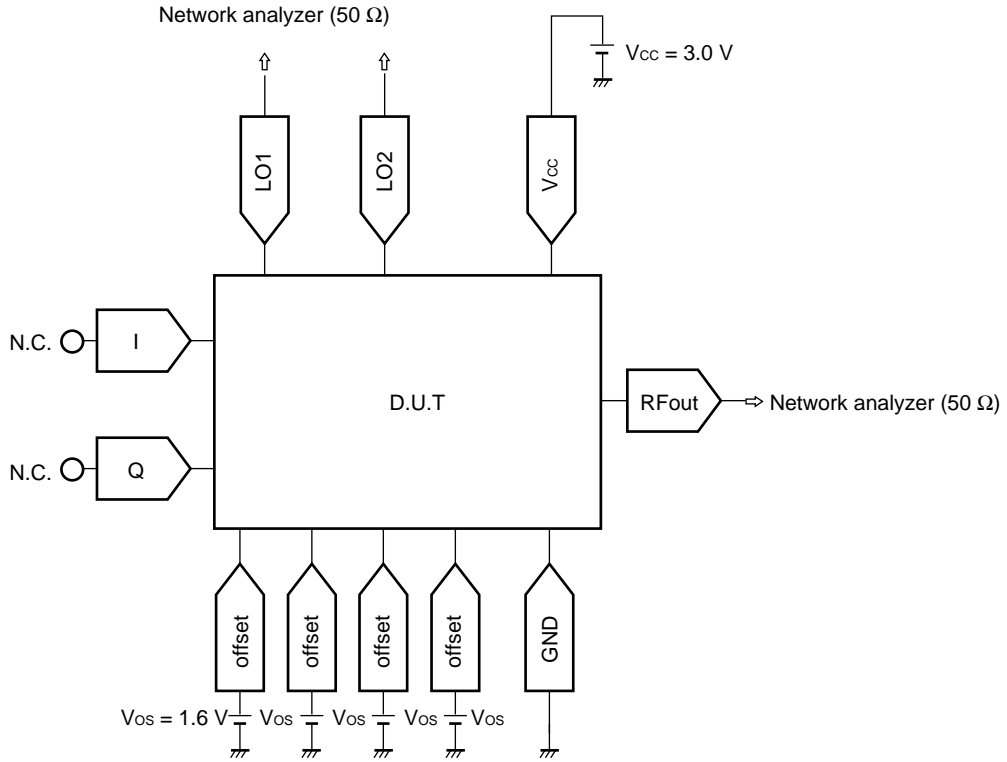


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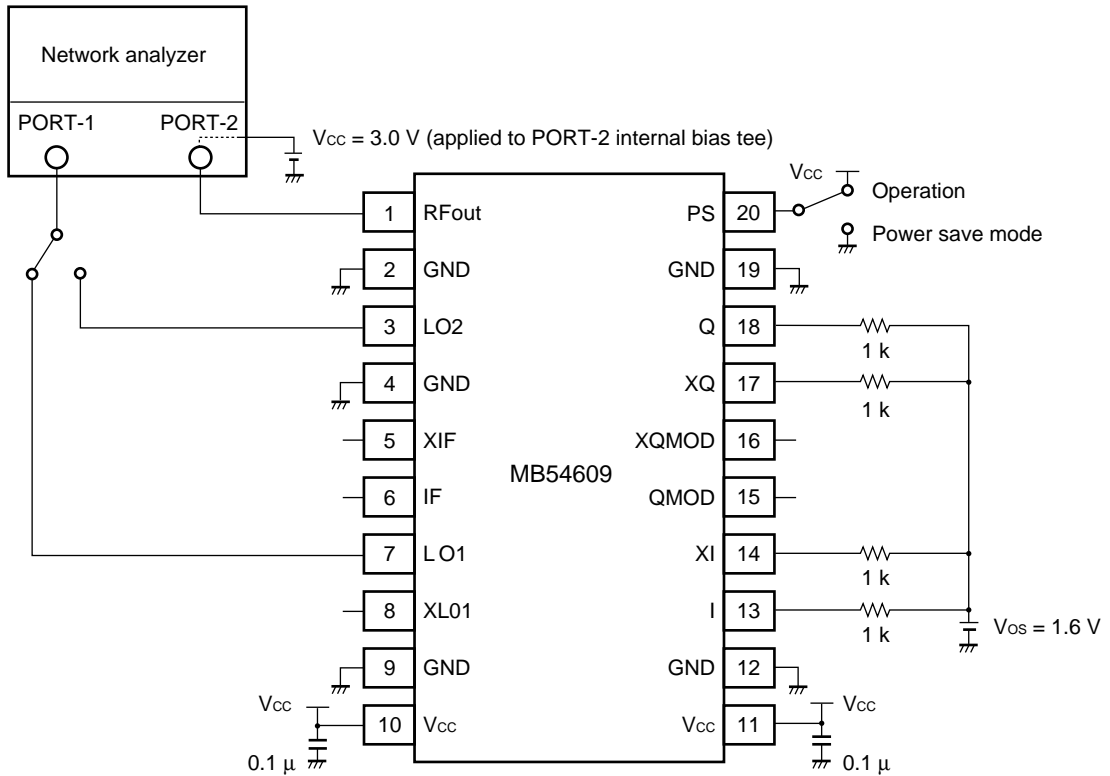
# MB54609

(Continued)

• Test circuit 3 (for impedance measurement with components mounted)



• Test circuit 4 (for measurement of impedance of only IC)



**■ ORDERING INFORMATION**

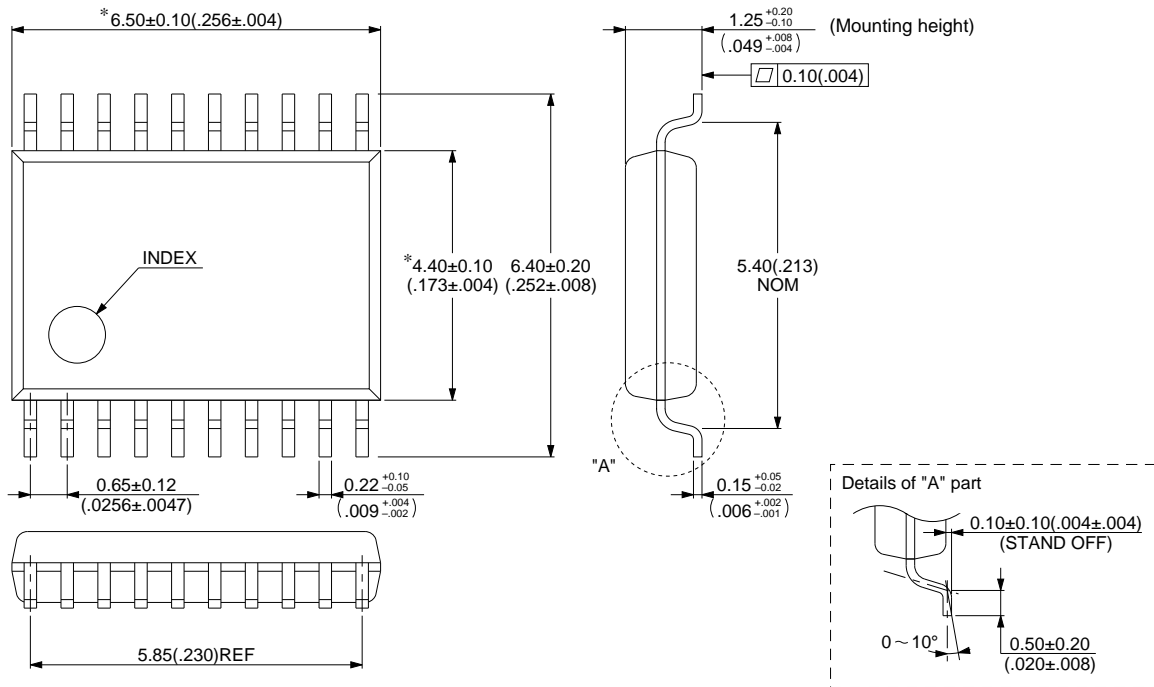
Part number	Package	Remarks
MB54609PFV	20-pin Plastic SSOP (FPT-20P-M03)	

# MB54609

## ■ PACKAGE DIMENSION

20-pin Plastic SSOP  
(FPT-20P-M03)

\*: These dimensions do not include resin protrusion.



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Dimensions in mm (inches)

# FUJITSU LIMITED

*For further information please contact:*

## **Japan**

FUJITSU LIMITED  
Corporate Global Business Support Division  
Electronic Devices  
KAWASAKI PLANT, 4-1-1, Kamikodanaka  
Nakahara-ku, Kawasaki-shi  
Kanagawa 211-88, Japan  
Tel: (044) 754-3763  
Fax: (044) 754-3329

## **North and South America**

FUJITSU MICROELECTRONICS, INC.  
Semiconductor Division  
3545 North First Street  
San Jose, CA 95134-1804, U.S.A.  
Tel: (408) 922-9000  
Fax: (408) 432-9044/9045

## **Europe**

FUJITSU MIKROELEKTRONIK GmbH  
Am Siebenstein 6-10  
63303 Dreieich-Buchsschlag  
Germany  
Tel: (06103) 690-0  
Fax: (06103) 690-122

## **Asia Pacific**

FUJITSU MICROELECTRONICS ASIA PTE. LIMITED  
#05-08, 151 Lorong Chuan  
New Tech Park  
Singapore 556741  
Tel: (65) 281-0770  
Fax: (65) 281-0220

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