



# 800 MHz CDMA Upmixer/Exciter

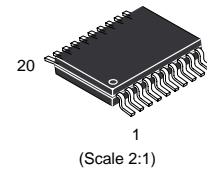
The MRFIC0954 is an integrated upmixer and exciter amplifier designed specifically for dual-mode CDMA/AMPS digital cellular radios. The exciter amplifier incorporates a temperature compensated linear gain control. The design utilizes Motorola's RF BiCMOS1 process to yield superior performance in a cost effective monolithic device.

- Designed for Dual-Mode Operation
  - Total Supply Current CDMA Mode = 55 mA Typical
  - Total Supply Current FM Mode = 35 mA Typical
- 30 dB Dynamic Range Gain Control on Exciter
- Upmixer Output IP<sub>3</sub> = 11 dBm Typical
- Exciter Output IP<sub>3</sub> = 28 dBm Typical
- Supply Voltage Range = 2.7 to 3.6 V
- Cascaded Adjacent Channel Power (P<sub>out</sub> = 6.0 dBm)
  - @ 885 kHz Offset = -60 dBc Typical
  - @ 1.98 MHz Offset = -72 dBc Typical

## MRFIC0954

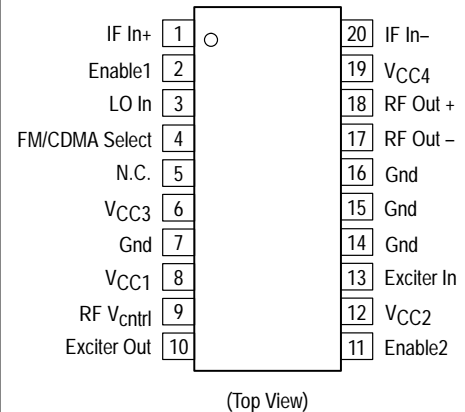
### 800 MHz DUAL-MODE CDMA/AMPS UPMIXER/EXCITER

#### SEMICONDUCTOR TECHNICAL DATA

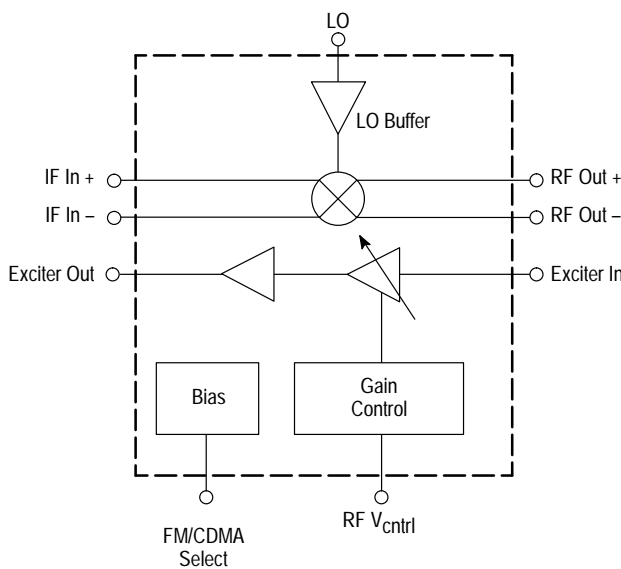


PLASTIC PACKAGE  
CASE 948M  
(TSSOP-20EP, Tape & Reel Only)

#### PIN CONNECTIONS



#### Simplified Block Diagram



This device contains 305 active transistors.

#### ORDERING INFORMATION

Device	Operating Temp Range	Package
MRFIC0954R2	T <sub>A</sub> = -40 to 85°C	TSSOP-20EP

**MAXIMUM RATINGS**

Rating	Symbol	Value	Unit
Supply Voltage	V <sub>CC</sub>	5.0	V
IF Input	IF In+, IF In-	10	dBm
LO Input	LO	10	dBm
Operating Temperature	T <sub>A</sub>	-40 to 85	°C
Storage Temperature	T <sub>stg</sub>	-65 to 150	°C

**NOTES:** 1. Maximum Ratings are those values beyond which damage to the device may occur. Functional operation should be restricted to the limits in the Recommended Operating Conditions and Electrical Characteristics tables or Pin Descriptions section.  
 2. Meets Human Body Model (HBM) ≤50 V and Machine Model (MM) ≤40 V. This device is rated Moisture Sensitivity Level (MSL) 4. ESD data available upon request.

**RECOMMENDED OPERATING CONDITIONS**

Characteristic	Symbol	Min	Typ	Max	Unit
Supply Voltage	V <sub>CC</sub>	2.7	-	3.6	V
RF Frequency Range	f <sub>RF</sub>	800	-	960	MHz
IF Frequency Range	f <sub>IF</sub>	70	-	250	MHz
LO Frequency Range	f <sub>LO</sub>	600	-	1200	MHz
Gain Control Voltage Range	V <sub>ctrl</sub>	0.1	-	1.7	V

**ELECTRICAL CHARACTERISTICS** (V<sub>CC</sub> = 2.7 V, P<sub>LO</sub> = -15 dBm @ 967 MHz, P<sub>IF</sub> = -21 dBm (differential) @ 130 MHz, V<sub>Enable</sub> = V<sub>TxEnable</sub> = 2.4 V, T<sub>A</sub> = 25°C, Test Circuit in Figure 1, unless otherwise noted.)

Characteristic	Symbol	Min	Typ	Max	Unit
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**CASCADE PERFORMANCE** (Filter included between RF Out and Exciter input. Filter has an insertion loss of 4.0 dB) For CDMA mode FM/CDMA Select = 2.7 V. For FM mode FM/CDMA Select = 0 V.

Output Power CDMA Mode (V <sub>ctrl</sub> = 1.7 V) FM Mode (P <sub>IF</sub> = -12 dBm (differential) ) CDMA Mode (V <sub>ctrl</sub> = 1.3 V)	P <sub>out</sub>	6.0 11 3.0	10 14 7.0	- - -	dBm
Dynamic Range (RF V <sub>ctrl</sub> = 0.1 to 1.7 V)	DR	25	38	-	dB
Adjacent Channel Power (CDMA Mode, P <sub>out</sub> = 6.0 dBm, P <sub>IF</sub> = -21 dBm (differential) ) @ 885 kHz Offset @ 1.98 MHz Offset	ACPR	- -	-60 -72	-52 -62	dBc
Supply Current CDMA Mode, P <sub>IF</sub> = -21 dBm (differential), P <sub>out</sub> = 6.0 dBm (set by V <sub>ctrl</sub> ) FM Mode, P <sub>IF</sub> = -12 dBm (differential), P <sub>out</sub> = 11 dBm (set by V <sub>ctrl</sub> )	I <sub>CC</sub>	- -	55 35	70 50	mA

**MIXER SECTION**

Conversion Gain	GC	-	7.0	-	dB
Noise Figure	NF	-	15	-	dB
Output Third Order Intercept Point	OIP3	-	11	-	dBm

**EXCITER SECTION**

Gain (No Attenuation)	GC	-	28	-	dB
Noise Figure	NF	-	5.0	-	dB
AGC Dynamic Range	DR	25	38	-	dB
Output Third Order Intercept Point	OIP3	-	25	-	dBm

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PIN FUNCTION DESCRIPTION

Pin	Function	Description	Voltage On (V)	Voltage Off (V)
1	IF In+	Mixer IF input pin. Input impedance is 500 Ω.	-24 dBm (Typ)	
2	Enable 1 (See Table 1)	Enable pin. A logic "High" (>2.4 V) enables entire chip and "Low" (<0.4 V) <b>disables chip.</b>	2.4 to 3.6	0 to 0.4
3	LO In	Mixer LO input pin.	-15 dBm (Typ)	
4	FM/CDMA Select	FM/CDMA select pin. Logic "High" (>2.4 V) selects CDMA mode for increased linearity and output power. "Low" (<0.4 V) selects FM mode for reduced current consumption.		
5	N.C.	No Connection		
6	VCC3	Supply Voltage.	2.7 to 3.6	
7	Gnd	Ground connection.	-	
8	VCC1	Supply Voltage	2.7 to 3.6	
9	RF AGC Control Voltage	RF AGC control pin. A 30 dB dynamic range can be achieved by adjusting voltage from 0.1 V (low gain) to 1.7 V (high gain).	0.1 to 1.7	
10	Exciter Out	RF exciter amplifier output pin.	-	
11	Enable 2 (See Table 1)	Tx Enable pin. A logic "High" (>2.4 V) enables Tx path and "Low" (<0.4 V) <b>disables Tx path except LO Buffer.</b>	2.4 to 3.6	0 to 0.4
12	VCC2	Supply Voltage	2.7 to 3.6	
13	Exciter In	RF exciter amplifier input pin.	-	
14	Gnd	Ground connection.	-	
15	Gnd	Ground connection.	-	
16	Gnd	Ground connection.	-	
17	RF Out-	Mixer RF output pin.		
18	RF Out+	Mixer RF output pin.		
19	VCC4	Supply Voltage	2.7 to 3.6	
20	IF In-	Mixer IF input pin. Input impedance is 500 Ω.	-24 dBm (Typ)	

Table 1. Enable Truth Table

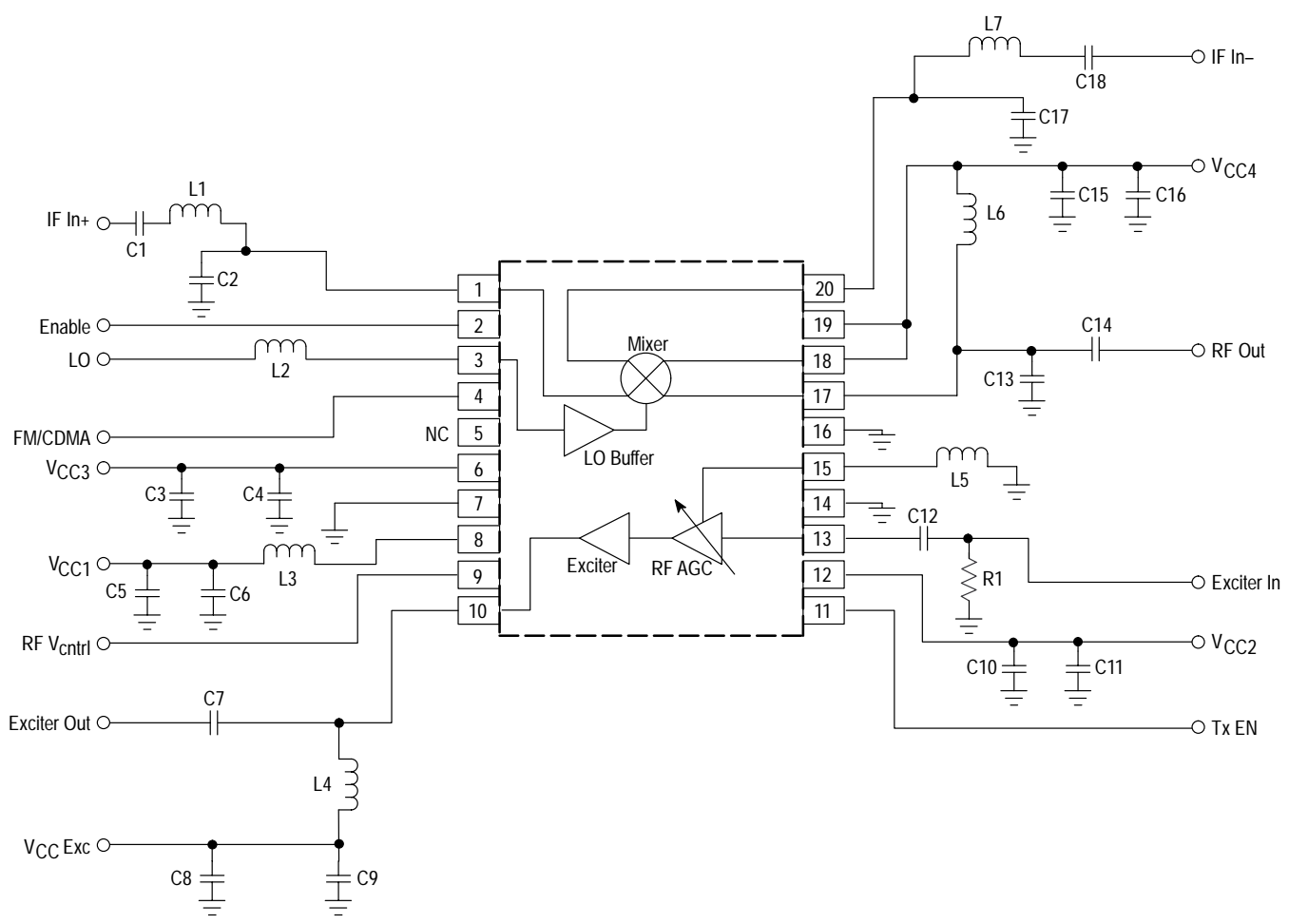
Enable 1	Enable 2	Mode
0	0	Disabled
0	1	Not Applicable
1	0	Standby Mode: Disables mixer/exciter, except LO buffer
1	1	Tx Enabled

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Figure 1. Applications Circuit



C1, C18	1.0 nF	L1, L7	220 nH
C2, C17	4.7 pF	L2	15 nH
C3, C5, C8, C11, C16	10 nF	L3, L4, L6	6.8 nH
C4, C6, C9, C10, C12, C15	100 pF	L5	1.0 nH
C7	4.3 pF		
C13	1.6 pF	R1	100 Ω
C14	1.3 pF		

- NOTES:**
1. IF ports matched to 50 Ω for testing purposes.
  2. L3 and C6 form part of RFAGC/Exciter interstage match.
  3. L5 can be varied to change gain.

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Figure 2. Gain versus Frequency (FM Mode)

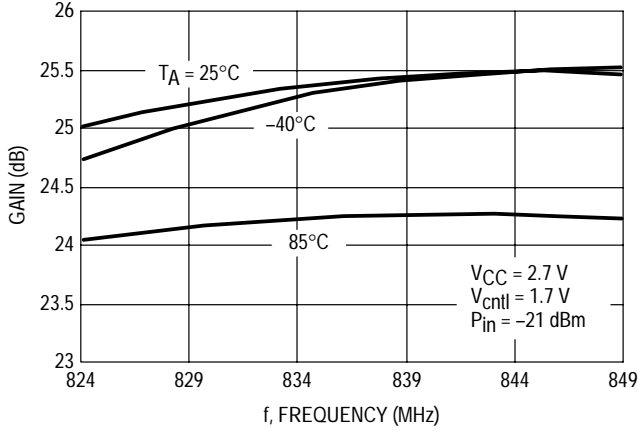


Figure 3. Gain versus Frequency (CDMA Mode)

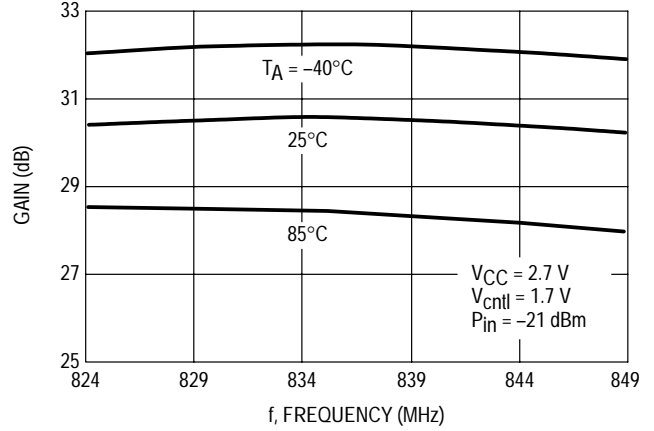


Figure 4. Gain versus LO Power (FM Mode)

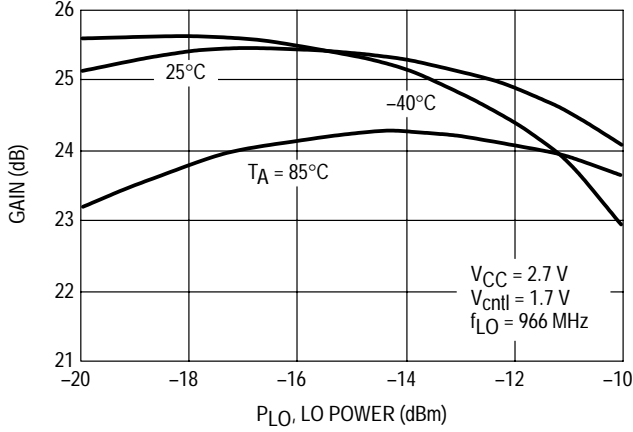


Figure 5. Gain versus LO Power (CDMA Mode)

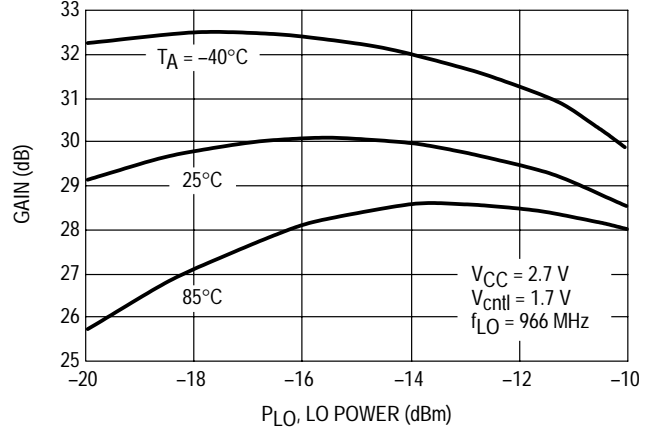


Figure 6. LO Feedthrough versus Control Voltage (FM Mode)

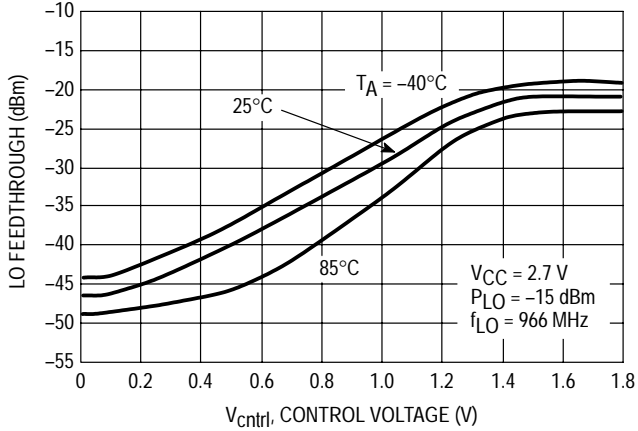
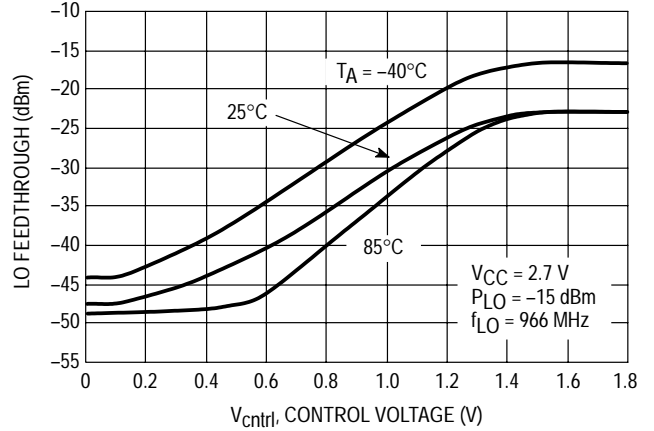


Figure 7. LO Feedthrough versus Control Voltage (CDMA Mode)



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Figure 8. Output Power versus Control Voltage (FM Mode)

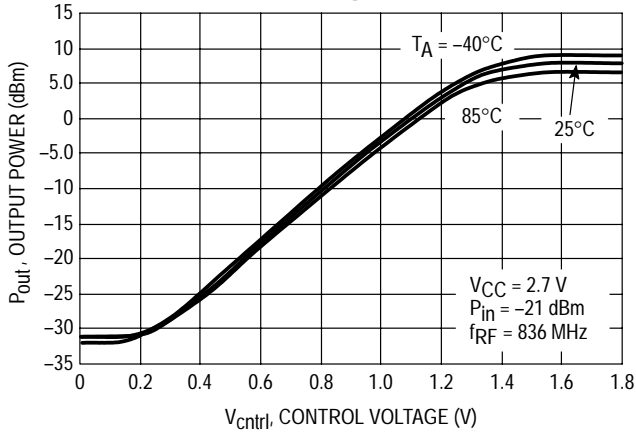


Figure 9. Output Power versus Control Voltage (CDMA Mode)

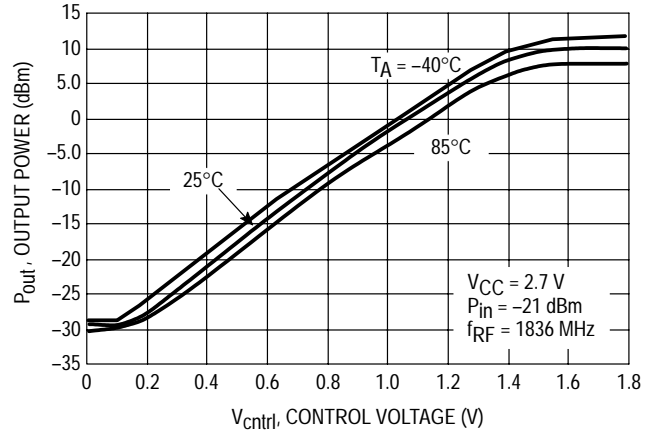


Figure 10. Adjacent Channel Power versus Control Voltage (CDMA Mode)

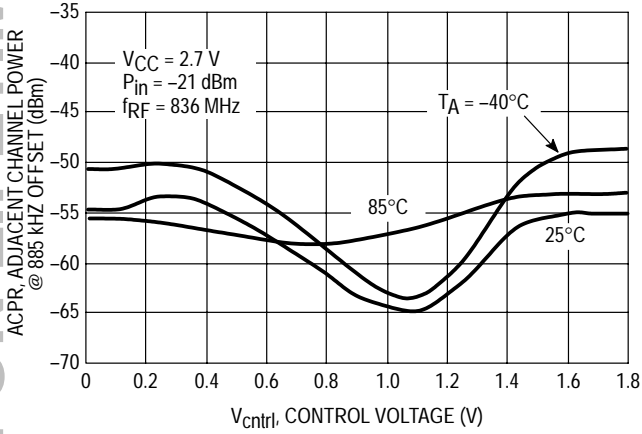
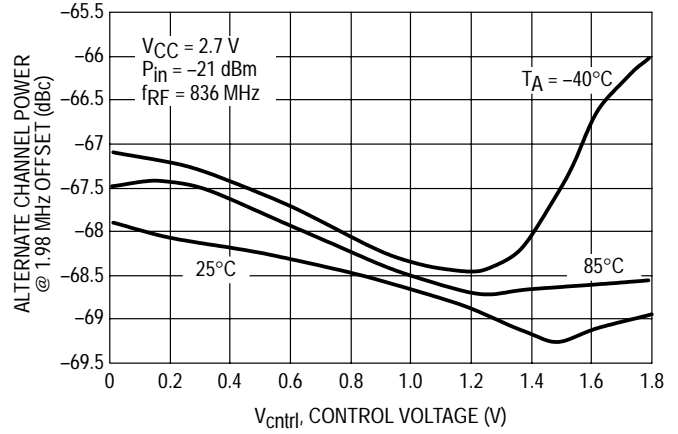


Figure 11. Alternate Channel Power versus Control Voltage (CDMA Mode)



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### Design Philosophy

The MRFIC0954 has three operating states, enable, standby, and disable. These states are controlled by the truth table shown in Table 1. The device is fully operational during the enable state and the bias level can be selected. A high bias current for CDMA or a lower bias current for Analog (or CDMA at lower powers) can be selected via the FM/CDMA pin. In the high current CDMA mode, the quiescent current is increased to maximize the linearity of the device. In the lower current bias, the quiescent current is optimized for efficiency in the Analog mode. This lower bias point is also useful in lower power CDMA operation. The standby mode can be used to reduce current consumption during Voice Activity Factoring. In the standby mode, the LO buffer remains on to prevent VCO pulling and the bandgap reference bias circuit remains on to assure rapid device turn on. Current consumption in standby mode is 10 mA typical. The disable mode is used to turn the MRFIC0954 completely off. Leakage current in this mode is only a few microamps.

The mixer is a double-balanced “Gilbert-cell” design with a balanced LO buffer amplifier. The input and output of the mixer are differential. However, the linearity is high enough to tie one output to  $V_{CC}$  and use the other as a single-ended output. Used this way it provides around 7.0 dB of gain and typically draws 20 mA quiescent current in CDMA mode and 16 mA in Analog Mode. An external filter is required between the mixer and RF AGC amplifier to reduce RX band noise.

Figure 1 shows the applications circuit for the MRFIC0954. In this circuit, the IF ports of the mixer have been matched to 50  $\Omega$  for testing purposes. In the actual application, the differential IF ports of the mixer would be impedance matched to an IF SAW filter. The differential impedance of the mixer IF ports is 1600  $\Omega$ . The RF output of the mixer is configured as a single ended output. DC current to the open collector output of the mixer is provided by inductor, L6 (6.8 nH). Inductor L6 is also part of the matching circuit with C13 (1.6 pF), C14 (1.3 pF) and C15 (100 p).

The RF AGC amplifier is a single-ended cascode design employing the standard “current steering” method of gain control. It’s ground is brought out through pin number 15 so inductance can be added to degenerate the gain for a lower noise floor. With 2.0 to 3.0 nH of external inductance, the maximum gain is around 13 dB. It typically draws 9.0 mA quiescent current in CDMA mode and 3.0 mA in Analog mode. The RF  $V_{ctrl}$  signal is buffered with an on-chip OpAmp then preconditioned with temperature compensation and dB/V linearization before being applied to the RF AGC amplifier.

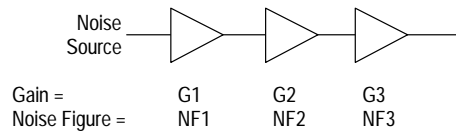
Inductor L3 (6.8 nH) and capacitor C6 (100 pF) are for the interstage match between the RF AGC and the exciter amplifier.

The exciter amplifier is a simple common emitter design. It is grounded directly to the exposed pad which results in 12 dB of gain. It typically draws 24 mA bias current in CDMA mode and 8.0 mA in Analog mode. Inductor L4 (6.8 nH),

capacitor C7 (4.3 pF), and C9 (100 pF) provide the output matching. L4 also provides a DC current path for the open collector output.

### Noise Power Considerations

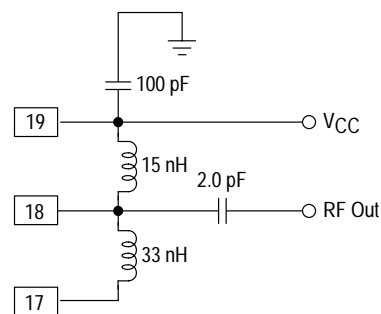
In CDMA systems, the handset is required to dynamically adjust its output power to specific levels. This requires a dynamic range of as much as 90 dB from the transmitter. Another key performance specification in CDMA systems is the output noise power, both in band and out of band. Noise power specifications has caused the noise figure of the transmitter to become an important system consideration. The cascaded noise figure of the transmitter can be analyzed with the same equation used in receiver analysis. The only difference is the noise source is from the transmitter (modulator) instead of the atmosphere.



$$NF_{\text{cascaded}} = NF_1 + \frac{NF_2 - 1}{G_1} + \frac{NF_3 - 1}{G_1 G_2}$$

This equation above shows that the cascaded noise figure is better if the gain is higher and the noise figure is lower for the stages close to the noise source. For this reason, it is advantageous to implement some of the gain control of a CDMA transmitter in the RF section. The MRFIC0954 integrates a RF AGC amplifier after the upmixer to improve the overall noise figure of the transmitter.

If better noise figure from the mixer is required, the mixer RF output can be operated differentially with the addition of a balun. Operating the mixer differentially will provide some noise cancellation and reduce the noise figure by 5.0 dB. Shown below is a lumped element balun that is effective in the cellular transmit band of 824 to 849 MHz.



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**Table 2. Scattering Parameters for Exciter Amplifier**  
( $V_{DD} = 2.7\text{ V}$ ,  $T_A = 25^\circ\text{C}$ ,  $R_F V_{ctrl} = 1.8\text{ V}$ ,  $50\ \Omega$  System)

f (MHz)	S <sub>11</sub>		S <sub>21</sub>		S <sub>12</sub>		S <sub>22</sub>	
	S <sub>11</sub>	∠φ	S <sub>21</sub>	∠φ	S <sub>12</sub>	∠φ	S <sub>22</sub>	∠φ
800	0.523	-31.46	18.463	-102.56	0.001	153.19	0.341	-26.37
810	0.522	-31.83	18.964	-107.12	0.001	152.15	0.360	-33.06
820	0.519	-31.84	19.412	-111.84	0.001	152.18	0.379	-39.48
830	0.515	-31.96	20.017	-121.57	0.001	143.30	0.413	-52.61
840	0.513	-31.90	20.214	-126.53	0.002	139.87	0.428	-58.96
850	0.512	-31.78	20.330	-131.59	0.001	140.14	0.445	-65.36
860	0.513	-31.62	20.228	-141.98	0.001	143.83	0.468	-77.72
870	0.510	-31.64	19.962	-147.12	0.002	140.02	0.476	-83.97
880	0.510	-31.45	19.593	-152.09	0.002	147.69	0.478	-89.94
890	0.514	-31.41	18.768	-161.40	0.002	139.58	0.486	-100.64
900	0.515	-31.50	18.161	-166.11	0.002	141.12	0.491	-105.67
910	0.514	-31.58	17.585	-170.50	0.002	124.24	0.489	-110.70
920	0.515	-31.83	16.353	-178.79	0.002	125.97	0.485	-119.67
930	0.517	-31.96	15.718	177.30	0.002	128.36	0.489	-124.16
940	0.518	-32.29	15.070	173.39	0.002	125.66	0.484	-128.24
950	0.517	-32.88	13.708	166.70	0.002	112.00	0.473	-135.30
960	0.518	-32.81	13.090	163.84	0.002	117.04	0.468	-138.41

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**Table 3. Scattering Parameters for Upmixer**  
(V<sub>DD</sub> = 2.7 V, T<sub>A</sub> = 25°C, 50 Ω System)

f (MHz)	IF In+		IF In-		f (MHz)	RF Out (Pin 17)	
	S <sub>11</sub>	∠φ	S <sub>11</sub>	∠φ		S <sub>11</sub>	∠φ
70	0.886	-5.66	0.885	-5.12	800	0.488	-60.15
80	0.883	-5.79	0.882	-5.29	810	0.487	-60.56
90	0.884	-6.15	0.881	-5.73	820	0.487	-61.04
100	0.879	-6.26	0.878	-5.74	830	0.488	-61.82
110	0.881	-6.74	0.881	-6.19	840	0.490	-62.20
120	0.877	-7.20	0.878	-6.43	850	0.487	-62.85
130	0.880	-7.23	0.879	-6.64	860	0.491	-63.72
140	0.876	-7.89	0.876	-7.20	870	0.492	-64.03
150	0.876	-8.11	0.875	-7.28	880	0.493	-64.38
160	0.878	-8.51	0.877	-7.57	890	0.497	-65.56
170	0.879	-8.84	0.879	-8.07	900	0.501	-65.98
180	0.877	-9.28	0.880	-8.26	910	0.503	-66.50
190	0.876	-9.81	0.878	-8.81	920	0.504	-68.66
200	0.876	-10.15	0.877	-9.21	930	0.504	-69.70
210	0.875	-10.52	0.876	-9.44	940	0.502	-69.91
220	0.877	-10.83	0.880	-9.78	950	0.503	-71.15
230	0.877	-11.58	0.877	-10.41	960	0.502	-70.74
240	0.878	-11.59	0.877	-10.41			
250	0.881	-12.29	0.879	-10.85			

f (MHz)	LO In		f (MHz)	LO In		f (MHz)	LO In	
	S <sub>11</sub>	∠φ		S <sub>11</sub>	∠φ		S <sub>11</sub>	∠φ
600	0.820	-18.93	810	0.802	-24.40	1020	0.785	-30.28
610	0.819	-19.00	820	0.800	-24.55	1030	0.784	-30.09
620	0.817	-19.35	830	0.802	-24.75	1040	0.786	-30.63
630	0.815	-19.60	840	0.804	-25.22	1050	0.786	-30.91
640	0.820	-19.87	850	0.804	-25.13	1060	0.784	-31.10
650	0.814	-20.06	860	0.802	-25.86	1070	0.780	-31.60
660	0.813	-20.49	870	0.799	-26.14	1080	0.783	-31.85
670	0.816	-20.61	880	0.801	-26.36	1090	0.782	-31.99
680	0.815	-20.82	890	0.797	-26.72	1100	0.775	-32.54

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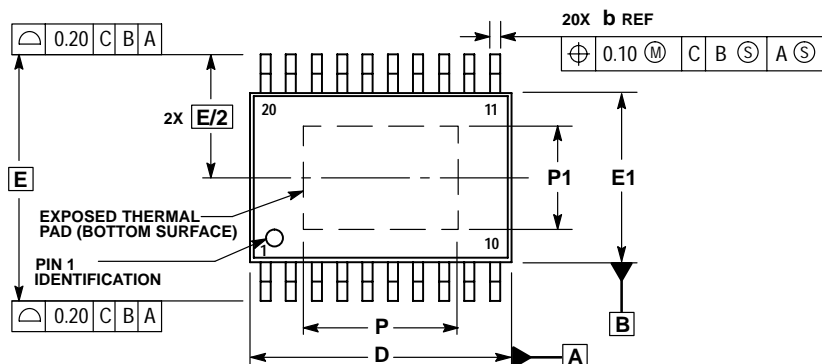
**Freescale Semiconductor, Inc.**  
NOTES

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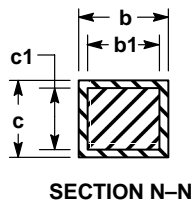
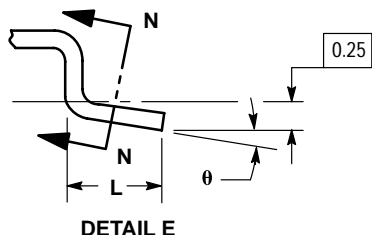
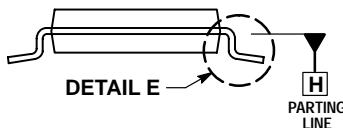
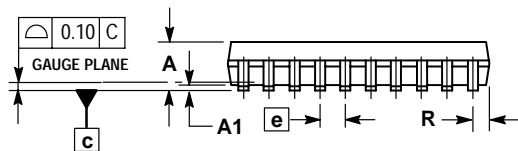
OUTLINE DIMENSIONS

PLASTIC PACKAGE  
CASE 948M-01  
(TSSOP-20EP)  
ISSUE O



NOTES:

- 1 DIMENSIONS ARE IN MILLIMETERS.
- 2 INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M, 1994.
- 3 DIMENSION D DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS. MOLD FLASH OR GATE BURRS SHALL NOT EXCEED 0.15 PER SIDE.
- 4 DIMENSION E1 DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSION. INTERLEAD FLASH OR PROTRUSION SHALL NOT EXCEED 0.25 PER SIDE.
- 5 DIMENSION b DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.08 TOTAL IN EXCESS OF THE b DIMENSION AT MAXIMUM MATERIAL CONDITION.
- 6 TERMINAL NUMBERS ARE SHOWN FOR REFERENCE ONLY.
- 7 DIMENSIONS D AND E1 ARE TO BE DETERMINED AT DATUM PLANE H.



DIM	MILLIMETERS	
	MIN	MAX
A	---	1.20
A1	0.00	0.10
b	0.19	0.30
b1	0.19	0.25
c	0.09	0.20
c1	0.09	0.16
D	6.40	6.60
E	6.40 BSC	
E1	4.30	4.50
e	0.65 BSC	
L	0.50	0.75
P	---	4.80
P1	---	3.00
R	0.27	0.37
θ	0°	8°


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