MOTOROLA
"MC13143"

Ultra Low Power DC - 2.4 GHz Linear Mixer

MC13143

The MC13143 is a high compression linear mixer with single–ended RF input, differential IF output and differential LO inputs which consumes as little as 1.8 mW. A new circuit topology is used to achieve a high third order intermodulation intercept point, high linearity and high 1.0 dB output compression point while maintaining a linear 50 Ω input impedance. It is designed for Up or Down conversion anywhere from dc to 2.4 GHz.

ULTRA LOW POWER DC – 2.4 GHz LINEAR MIXER

SEMICONDUCTOR TECHNICAL DATA

Ultra Low Power: 1.0 mA @ V_{CC} = 1.8 to 6.5 V

- Wide Input Bandwidth: DC–2.4 GHz
- Wide Output Bandwidth: DC–2.4 GHz
- Wide LO Bandwidth: DC–2.4 GHz
- High Mixer Linearity: $P_{i1.0\ dB}$ = 3.0 dBm

Linearity Adjustment of up to IP_{3in} = 20 dBm

- 50 Ω Mixer Input
- Single–Ended Mixer Input
- Double Balanced Mixer Operation
- Differential Open Collector Mixer Output

8

1

D SUFFIX
PLASTIC PACKAGE
CASE 751
(SO–8)

ORDERING INFORMATION

Device	Operating Temperature Range	Package
MC13143D	T_A = –40 to 85°C	SO–8

MAXIMUM RATINGS (T_A = 25°C, unless otherwise noted.)

Rating	Symbol	Value	Unit
Power Supply Voltage	V_{CC}(max)	7.0	Vdc
Junction Temperature	T_{Jmax}	150	°C
Storage Temperature Range	T_{stg}	–65 to 150	°C

NOTE: ESD data available upon request.

PIN CONNECTIONS

Dec	1	8	RF
V_{CC}	2	7	V_{EE}
LO+	3	6	IF+
LO–	4	5	IF–

(Top View)

This device contains 29 active transistors.

LIFETIME BUY

LAST ORDER: 26JUN01   LAST SHIP: 26DEC01

RECOMMENDED OPERATING CONDITIONS

"MC13143" Rating	Symbol	Min	Typ	Max	Unit
Power Supply Voltage	V_{CC}	1.8	–	6.0	Vdc

DC ELECTRICAL CHARACTERISTICS (T_A = 25°C, V_{CC} = 3.0 V, f_{RF} = 1.0 GHz, Pin = –25 dBm.)

Characteristic	Symbol	Min	Typ	Max	Unit
Supply Current (Lin Control Current = 0)	I_{CC1}	–	1.0	–	mA
Supply Current (Lin Control Current = 1.6 mA)	I_{CC2}	–	4.1	–	mA

AC ELECTRICAL CHARACTERISTICS (T_A = 25°C, V_{CC} = 3.0 V, f_{RF} = 1.0 GHz, Pin = –25 dBm.)

Characteristic	Symbol	Min	Typ	Max	Unit
Mixer Voltage Conversion Gain ($R_P = R_L$ = 800 Ω)	VG_C	–	9.0	–	dB
Mixer Power Conversion Gain ($R_P = R_L$ = 800 Ω)	PG_C	–3.5	–2.6	–1.5	dB
Mixer Input Return Loss	Γin_{mx}	–	–20	–	dB
Mixer SSB Noise Figure	NF_{SSB}	–	14	15	dB
Mixer 1.0 dB Compression Point (Mx Lin Control Current = 1.6 mA)	$Pin_{-1.0\ dB}$	–1	0	–	dBm
Mixer Input Third Order Intercept Point (d_f = 1.0 MHz, $I_{control}$ = 1.6 mA)	$IP3_{in}$	–	16	–	dBm
LO Drive Level	LO_{in}	–	–5.0	–	dBm
LO Leakage to Mixer IF Outputs	P_{LO-IF}	–	–33	–25	dB
Mixer Input Feedthrough Output	P_{RFm-IF}	–	–25	–	dB
LO Leakage to Mixer Input	P_{LO-RFm}	–	–40	–25	dB
Mixer Input Leakage to LO	P_{RFm-LO}	–	–35	–	dB

Figure 1. Test Circuit

TYPICAL PERFORMANCE CURVES

"MC13143"

**Figure 2. Power Conversion Gain and
Supply Current versus Supply Voltage**
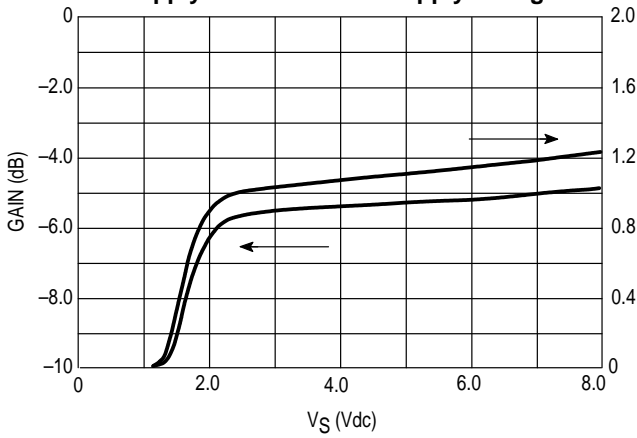
**Figure 3. Noise Figure and Gain
versus LO Power**

f_{RF} = 900 MHz
f_{LO} = 950 MHz
Test Circuit
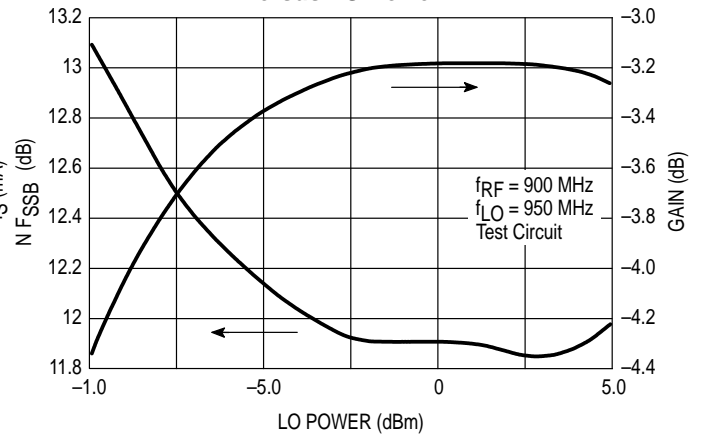
**Figure 4. Mixer Input Return Loss
versus RF Input Frequency**
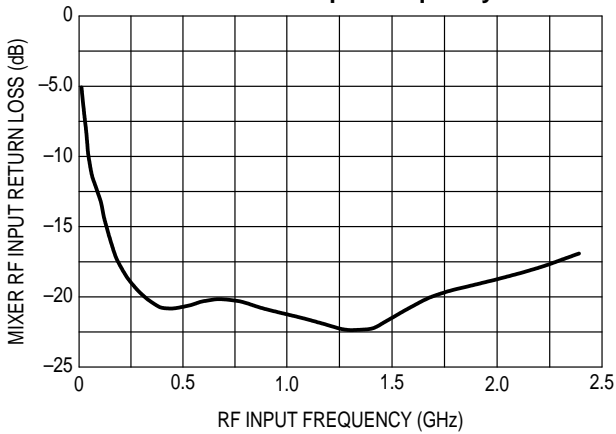
**Figure 5. Power Conversion Gain and Supply
Current versus RF Input Power**

V = 5.0 Vdc
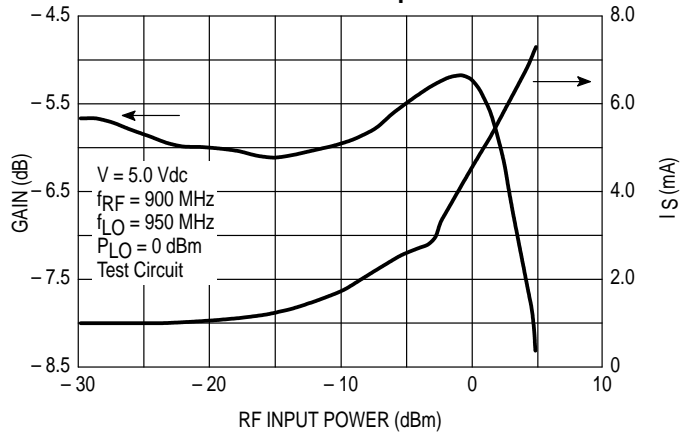f_{RF} = 900 MHz
f_{LO} = 950 MHz
P_{LO} = 0 dBm
Test Circuit

**Figure 6. Noise Figure and Gain
versus RF Frequency**
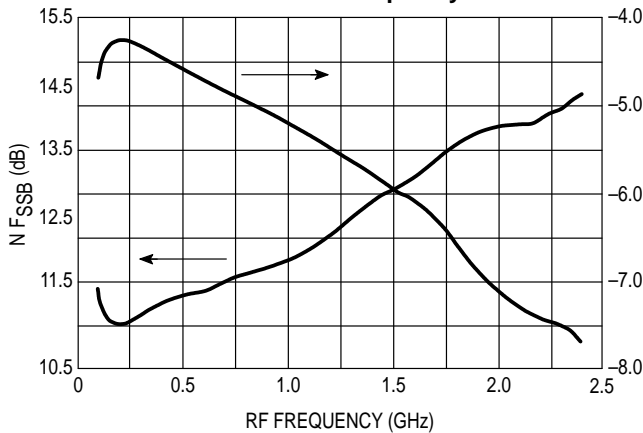
**Figure 7. IIP3, Gain, Supply Current
versus Mixer Linearity Control Current**

V_S = 5.0 Vdc
f_{RF} = 900 MHz
f_{LO} = 950 MHz

IIP3 (dBm)

I_S(mA)

GAIN(dB)

MIXER LINEARITY CONTROL CURRENT, $I_{Mx\ Lin\ Cont}$ (A)

MOTOROLA RF/IF DEVICE DATA

3

"MC13143"

Table 1. Mixer Scattering Parameters
(V_{DD} = 3.0 V, T_A = 25°C, Mixer Enable = 3.0 V, 50 Ω System)

f (MHz)	RF Input S_{11}		IF Input S_{11}		LO Input S_{11}	
	$|S_{11}|$	φ	$|S_{11}|$	φ	$|S_{11}|$	φ
50	0.343	178.00	0.951	−1.73	0.420	−178.56
100	0.344	174.95	0.932	−2.81	0.436	−179.65
150	0.344	173.59	0.923	−3.81	0.445	178.10
200	0.339	172.00	0.913	−4.04	0.452	176.53
250	0.339	169.86	0.894	−4.43	0.452	174.69
300	0.338	167.81	0.874	−4.49	0.454	173.45
350	0.334	165.65	0.865	−3.83	0.461	171.72
400	0.329	163.54	0.857	−2.79	0.462	169.68
500	0.310	159.65	0.881	−1.19	0.453	165.85
600	0.287	157.53	0.912	−1.85	0.451	162.65
700	0.271	162.46	0.938	−3.58	0.435	160.21
800	0.274	164.71	0.948	−5.39	0.437	159.31
900	0.292	165.39	0.953	−7.24	0.445	156.21
1000	0.308	164.23	0.953	−9.35	0.441	153.57
1100	0.312	162.28	0.951	−11.39	0.429	151.50
1200	0.318	161.86	0.944	−13.30	0.437	152.31
1300	0.330	158.99	0.936	−15.62	0.455	148.48
1400	0.334	156.41	0.927	−17.82	0.473	146.94
1500	0.340	153.93	0.920	−21.62	0.490	141.96
1600	0.336	151.75	0.905	−26.05	0.493	140.27
1700	0.342	150.94	0.886	−30.44	0.495	134.93
1800	0.358	148.01	0.886	−36.09	0.497	133.41
1900	0.358	144.62	0.840	−41.80	0.506	129.67
2000	0.355	141.73	0.820	−46.92	0.510	126.17
2100	0.357	139.48	0.798	−53.04	0.511	122.55
2200	0.364	137.30	0.787	−59.14	0.516	119.69
2300	0.367	134.21	0.783	−63.19	0.520	116.45
2400	0.367	130.92	0.786	−67.03	0.511	111.51
2500	0.370	128.16	0.808	−69.65	0.494	109.01
2600	0.367	125.48	0.816	−73.04	0.483	107.63
2700	0.371	123.33	0.828	−73.38	0.487	107.26

MC13143

CIRCUIT DESCRIPTION

General "MC13143"

The MC13143 is a double–balanced Mixer. This device is designated for use as the frontend section in analog and digital FM systems such as Wireless Local Area Network (LAN), Digital European Cordless Telephone (DECT), PHS, PCS, GPS, Cellular, UHF and 800 MHz Special Mobile Radio (SMR), UHF Family Radio Services and 902 to 928 MHz cordless telephones. It features a mixer linearity control to preset or auto program the mixer dynamic range, an enable function and a wideband IF so the IC may be used either as a down converter or an up converter.

Current Regulation

Temperature compensating voltage independent current regulators provide typical supply current at 1.0 mA with no mixer linearity control current.

Mixer

The mixer is a unique and patented double–balanced four quadrant multiplier biased class AB allowing for programmable linearity control via an external current source. An input third order intercept point of 20 dBm may be achieved. All 3 ports of the mixer are designed to work up to 2.4 GHz. The mixer has a 50 Ω single–ended RF input and open collector differential IF outputs (see Internal Circuit Schematic for details). The linear gain of the mixer is approximately –5.0 dB with a SSB noise figure of 12 dB.

Local Oscillator

The local oscillator has differential input configuration that requires typically –10 dBm input from an external source to achieve the optimal mixer gain.

Figure 8. MC13143 Internal Circuit*
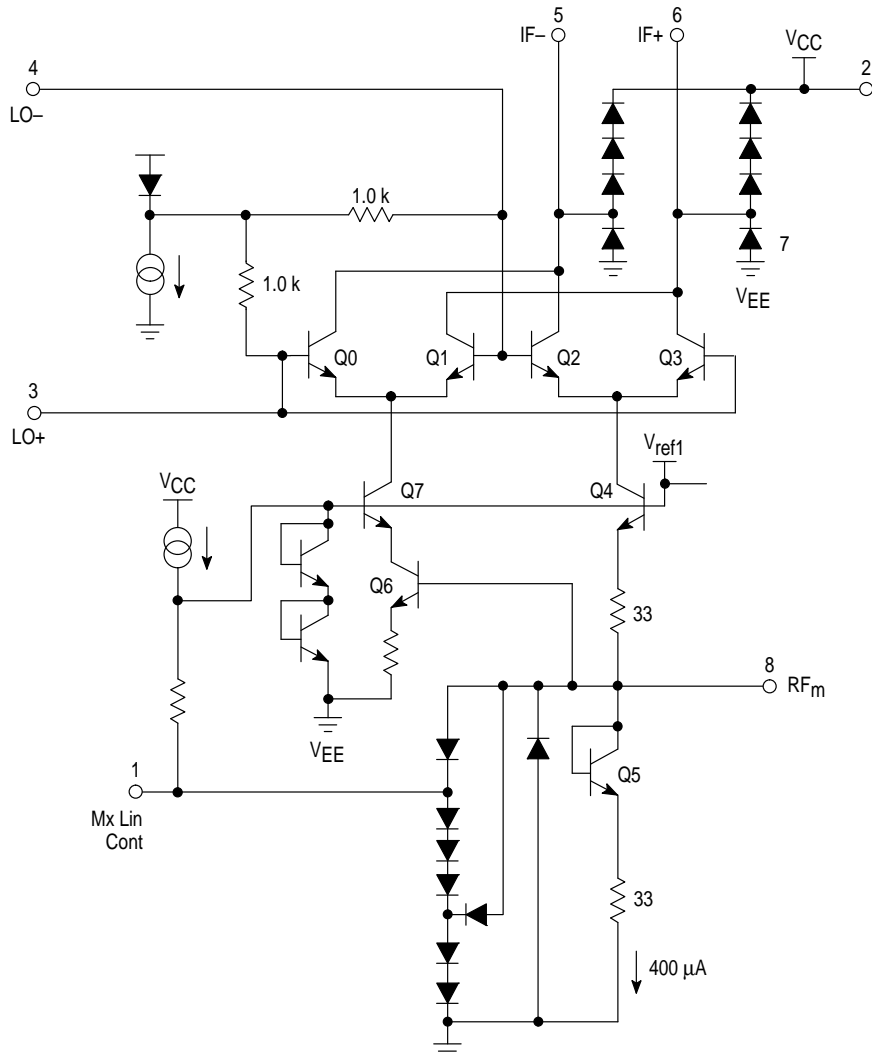
NOTE: * The MC13143 uses a unique and patented circuit topology.

MOTOROLA RF/IF DEVICE DATA

APPLICATIONS INFORMATION

Evaluation PC Board

The evaluation PCB is very versatile and is intended to be used across the entire useful frequency range of this device. The PC board is laid out to accommodate all SMT components on the circuit side (see Circuit Side Component Placement View).

Component Selection

The evaluation PC board is designed to accommodate specific components, while also being versatile enough to use components from various manufacturers. The circuit side placement view is illustrated for the components specified in the application circuit. The Component Placement View specifies particular components that were used to achieve the results shown in the typical curves and tables.

Mixer Input

The mixer input impedance is broadband 50 Ω for applications up to 2.4 GHz. It easily interfaces with a RF ceramic filter as shown in the application schematic.

Mixer Linearity Control

The mixer linearity control circuit accepts approximately 0 to 2.3 mA control current. An Input Third Order Intercept Point, IIP3 of 20 dBm may be achieved at 2.3 mA of control current (approximately 7.0 mA of additional supply current).

Local Oscillator Inputs

The differential LO inputs are internally biased at $V_{CC} - 1.0\ V_{BE}$; this is suitable for high voltage and high gain operation.

For low voltage operation, the inputs are taken to V_{CC} through 51 Ω.

IF Output

The IF is a differential open collector configuration which is designed to use over a wide frequency range for up conversion as well as down conversion.

Input/Output Matching

It is desirable to use a RF ceramic or SAW filter before the mixer to provide image frequency rejection. The filter is selected based on cost, size and performance tradeoffs. Typical RF filters have 3.0 to 5.0 dB insertion loss. The PC board layout accommodates both ceramic and SAW RF filters which are offered by various suppliers such as Siemens, Toko and Murata.

Interface matching between the RF input, RF filter and the mixer will be required. The interface matching networks shown in the application circuit are designed for 50 Ω interfaces.

Differential to single–ended circuit configuration is shown in the test circuit. 6.0 dB of additional mixer gain can be achieved by conjugately matching the output of the MiniCircuits transformer to 50 Ω at the desired IF frequency. With narrowband IF output matching the mixer performance is 3.0 dB gain and 12 dB noise figure (see Narrowband 49 and 83 MHz IF Output Matching Options). Typical insertion loss of the Toko ceramic filter is 3.0 dB. Thus, the overall gain of the circuit is 0 dB with a 15 dB noise figure.

Figure 9. Narrowband IF Output Matching with 16:1 Z Transformer and LC Network
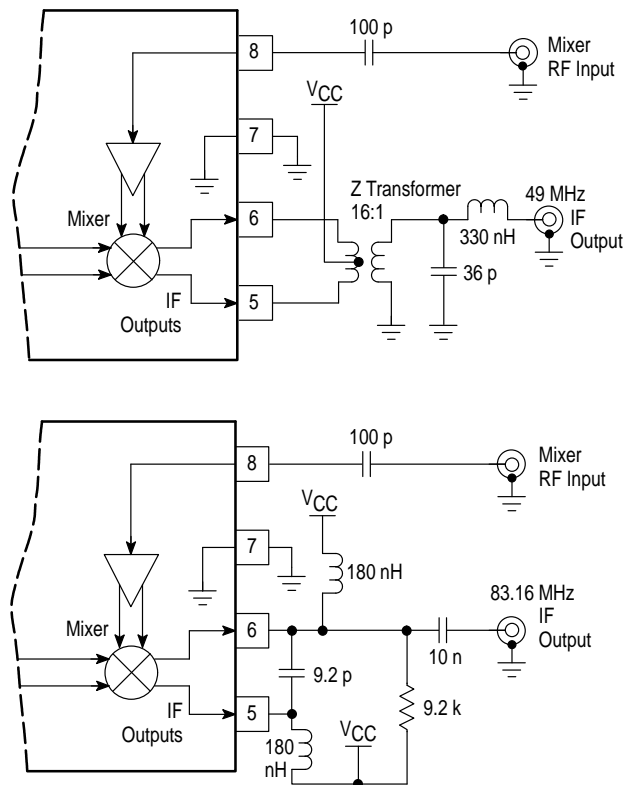
"MC13143"

Figure 10. Circuit Side Component Placement View
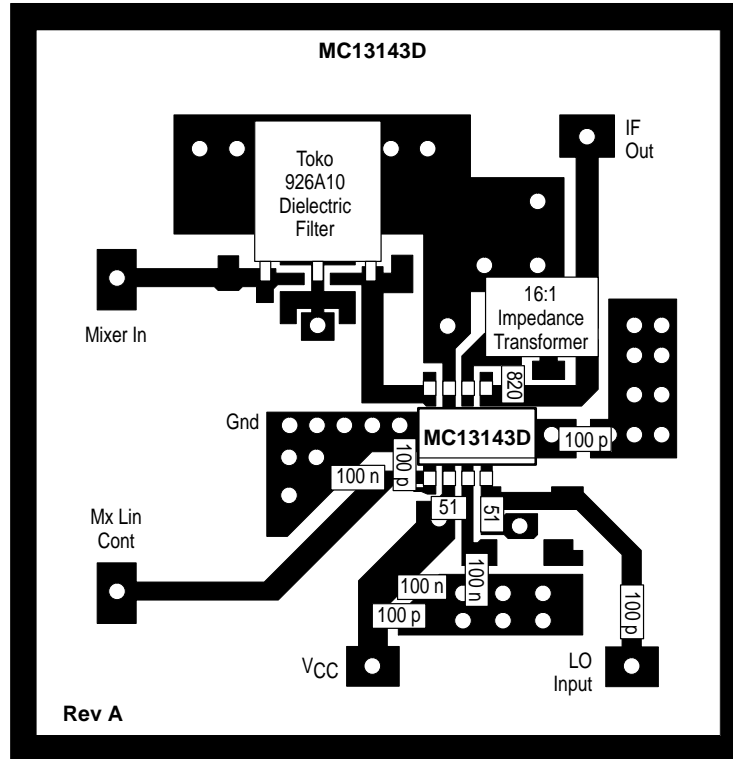
NOTES: 926.5 MHz preselect dielectric filter is Toko part # 4DFA–926A10; the 4DFA (2 and 3 pole SMD type) filters are available for applications in cellular and GSM, GPS, DECT, PHS, PCS and ISM bands at 902–928 MHz, 1.8–1.9 GHz at 2.4–2.5 GHz.

The PCB also accommodates a surface mount RF SAW filter in an eight or six pin ceramic package for the cellular base and handset frequencies. Recommended manufacturers are Siemens and Murata.

The PCB may also be used without a preselector filter; AC coupled to the mixer as shown in the test circuit schematic. All other external circuit components shown in the PCB layout above are the same as used in the test circuit schematic.

16:1 broadband impedance transformer is mini circuits part #TX16–R3T; it is in the leadless surface mount "TX" package. For a more selective narrowband match, a lowpass filter may be used after the transformer. The PCB is designed to accommodate lump inductors and capacitors in more selective narrowband matching of the mixer differential outputs to a single–ended output at a given IF frequency.

. The local oscillator may also be driven in a differential configuration using a coaxial transformer. Recommended sources are the Toko Balun transformers type B4F, B5FL and B5F (SMD component).

Figure 11. Circuit Side View

MC13143D

IF Out

Mixer In

Gnd

Mx Lin Cont

V$_{CC}$

LO Input

Rev A
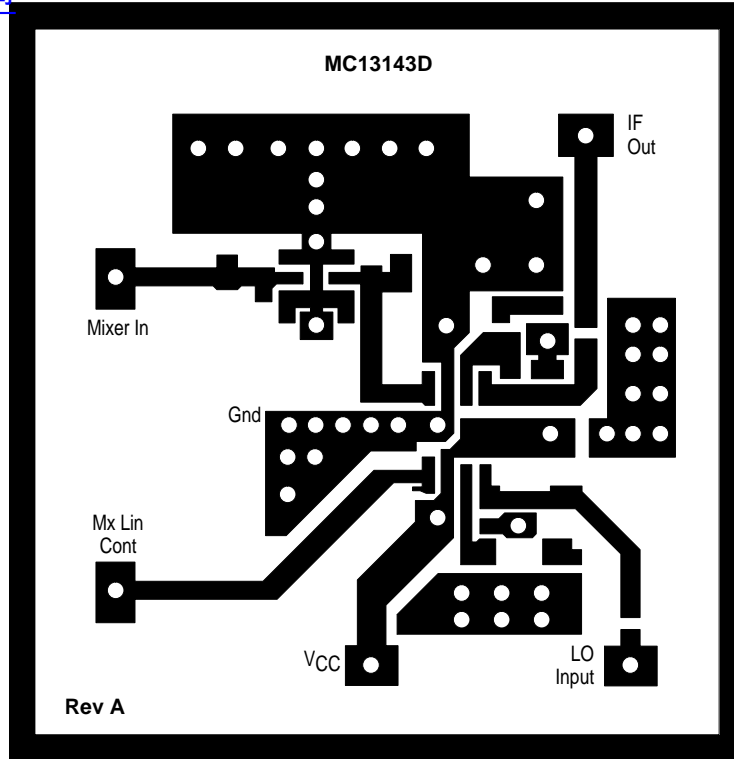
NOTES: Critical dimensions are 50 mil centers lead to lead in SO–8 footprint.
Also line widths to labeled ports excluding V$_{CC}$ are 50 mil.

Figure 12. Ground Side View

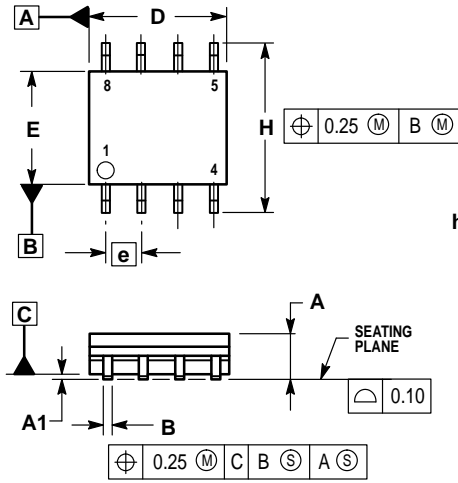**Rev A**

V$_{CC}$

LO Input

Mx Lin Cont

Mixer In

IF Out
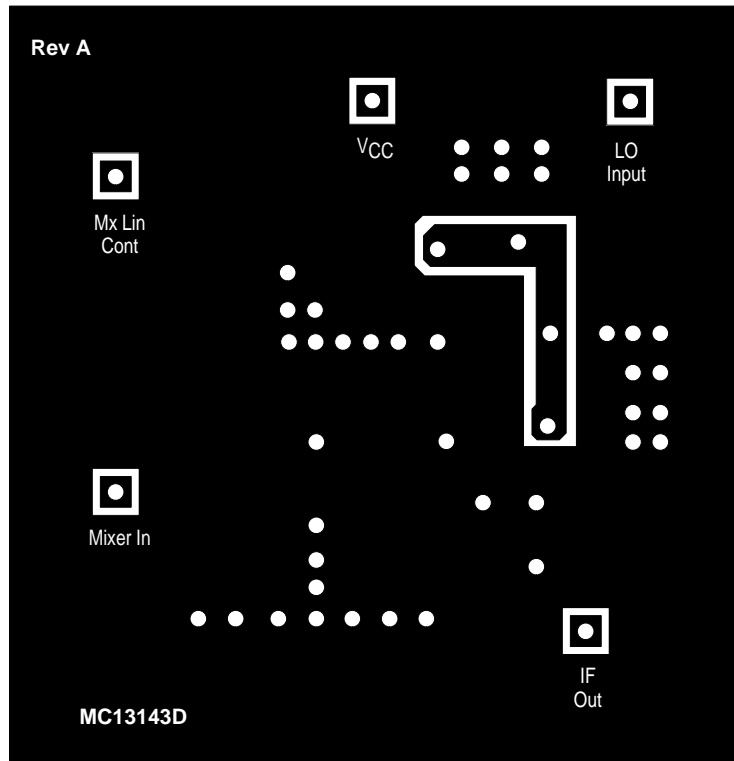
MC13143D

MC13143

OUTLINE DIMENSIONS

"MC13143"

D SUFFIX
PLASTIC PACKAGE
CASE 751–06
(SO–8)
ISSUE T

NOTES:
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
2. DIMENSIONS ARE IN MILLIMETER.
3. DIMENSION D AND E DO NOT INCLUDE MOLD PROTRUSION.
4. MAXIMUM MOLD PROTRUSION 0.15 PER SIDE.
5. DIMENSION B DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.127 TOTAL IN EXCESS OF THE B DIMENSION AT MAXIMUM MATERIAL CONDITION.

DIM	MILLIMETERS	
	MIN	MAX
A	1.35	1.75
A1	0.10	0.25
B	0.35	0.49
C	0.19	0.25
D	4.80	5.00
E	3.80	4.00
e	1.27 BSC	
H	5.80	6.20
h	0.25	0.50
L	0.40	1.25
θ	0 °	7 °

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