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MOTOROLA

MC13146

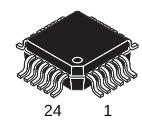
Low Power Integrated Transmitter for ISM Band Applications

The MC13146 is an integrated RF transmitter targeted at ISM band applications. It features a 50 Ω linear Mixer with linearity control, voltage controlled oscillator, divide by 64/65 dual modulus Prescaler and Low Power Amplifier (LPA). Together with the receiver chip (MC13145) and either baseband chip (MC33410 or MC33411A/B), a complete 900 MHz cordless phone system can be implemented. This device may be used in applications up to 1.8 GHz.

- Low Distortion LPA: $P_{out\_1\ dB}$ Compression Point ≈ 10 dBm
- High Mixer Linearity: IIP3 = 10 dBm
- 50 Ω Mixer Input Impedance
- Differential Open Collector Mixer Output
- Low Power 64/65 Dual Modulus Prescaler (MC12054 type)
- 2.7 to 6.5 V Operation, Low Current Drain (25 mA @ 2.0 GHz)
- Powerdown Mode: <60 µA
- Usable up to 1.8 GHz

LOW POWER DC – 1.8 GHz TRANSMITTER

SEMICONDUCTOR TECHNICAL DATA

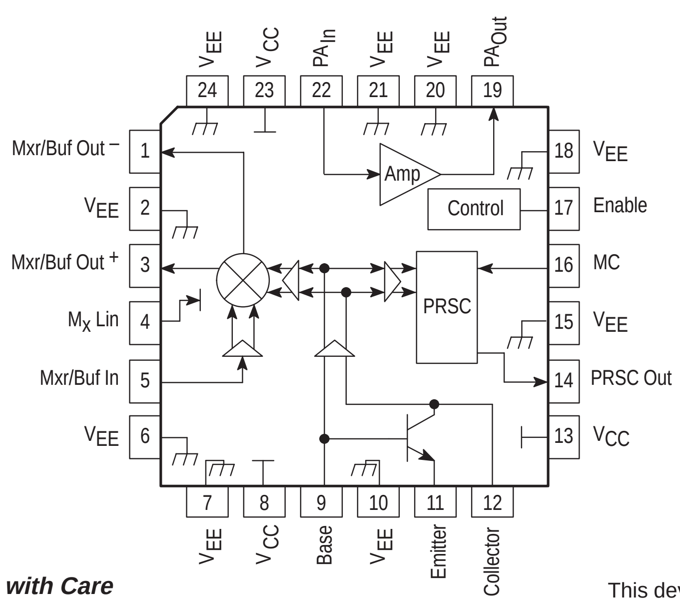


FTA SUFFIX
PLASTIC PACKAGE
CASE 977
(LQFP–24)

ORDERING INFORMATION

Device	Operating Temperature Range	Package
MC13146FTA	T_A = –20 to 70°C	LQFP–24

PIN CONNECTIONS



ESD Sensitive — Handle with Care

This device contains 268 active transistors.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Power Supply Voltage	V_{CC}(max)	7.0	Vdc
Junction Temperature	T_J(max)	150	°C
Storage Temperature Range	T_{stg}	–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, Electrical Characteristics tables or Pin Descriptions section.
2. Meets Human Body Model (HBM) ≤100 V and Machine Model (MM) ≤25 V. ESD data available upon request.

RECOMMENDED OPERATING CONDITIONS

Characteristic	Symbol	Min	Typ	Max	Unit
Power Supply Voltage (TA = 25°C)	VCC VEE	2.7 –	– 0	6.5 –	Vdc Vdc
RF Frequency Range	f_{RF}	1.0	–	2500	MHz
Ambient Temperature Range	T_A	–20	–	70	°C
Maximum Input Signal Level – with no damage – with minor performace degradation	P_{IF}	 – –	 –10 15	 – –	 dBm dBm

TRANSMITTER DC ELECTRICAL CHARACTERISTICS (T_A = 25°C, V_{CC} = 3.6 Vdc, no input signal, unless otherwise noted)

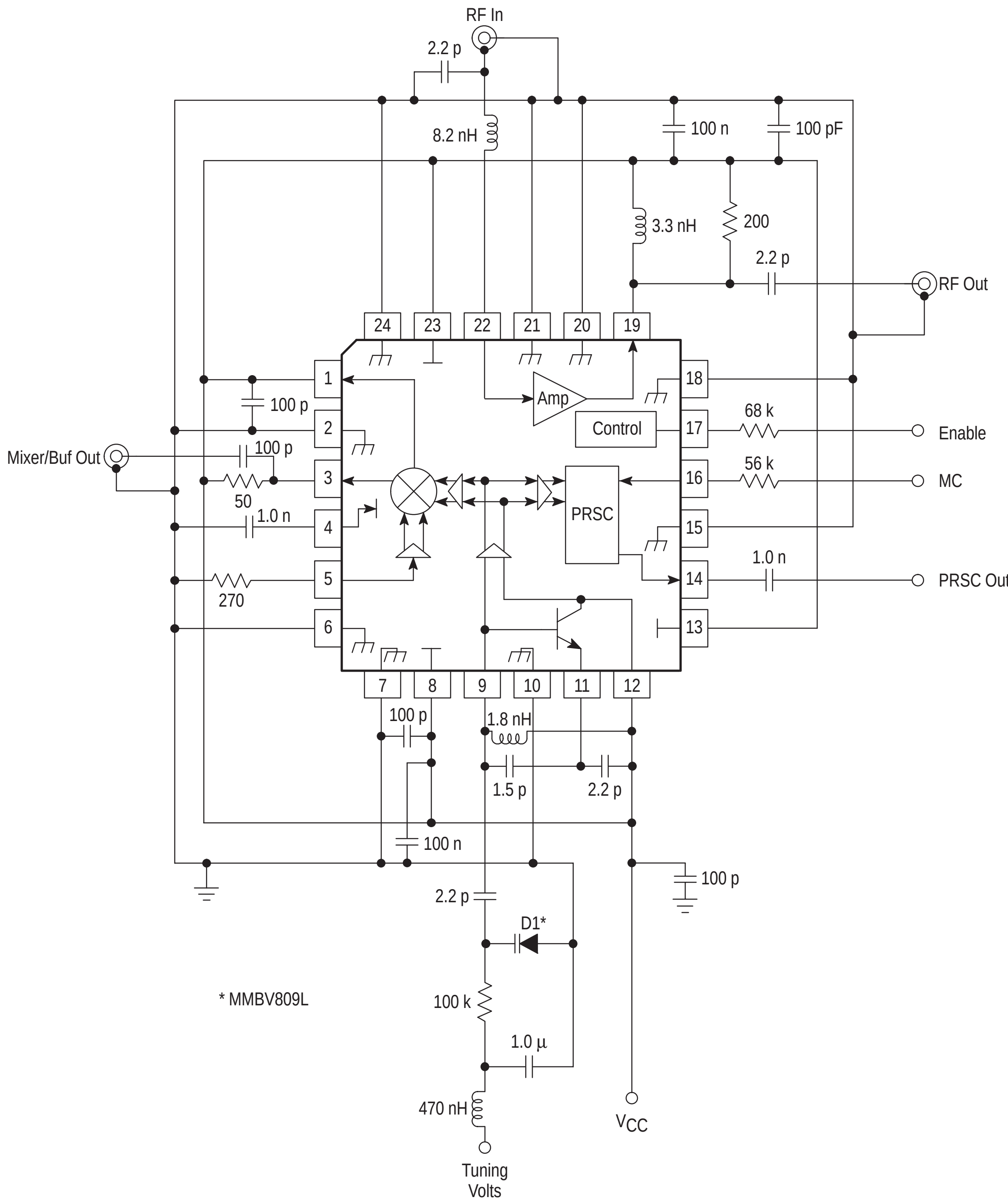
Characteristic	Symbol	Min	Typ	Max	Unit
Total Supply Current (Enable = V_{CC})	I_{total}	15	18	21	mA
Power Down Current (Enable = V_{EE})	I_{total}	-	30	100	µA
MC Current Input (High)	I_{ih}	70	100	130	µA
MC Current Input (Low)	I_{il}	–130	–100	–70	µA
Input high voltage	V_{ih}	V_{CC} – 0.4	–	–	V
Input low voltge	V_{il}	–	–	0.4	V
Input Current	I_{in}	–50	–	50	µA

TRANSMITTER AC ELECTRICAL CHARACTERISTICS (T_A = 25°C, V_{CC} = 3.6 Vdc, Enable = 3.6 Vdc, per Test Circuit shown in Figure 1, unless otherwise noted)

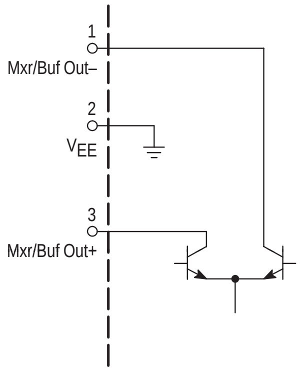
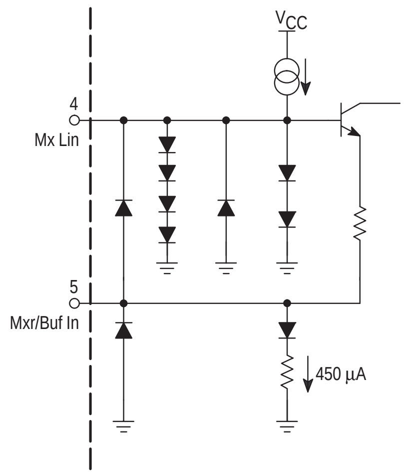
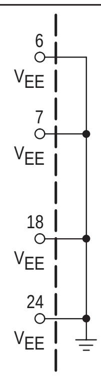
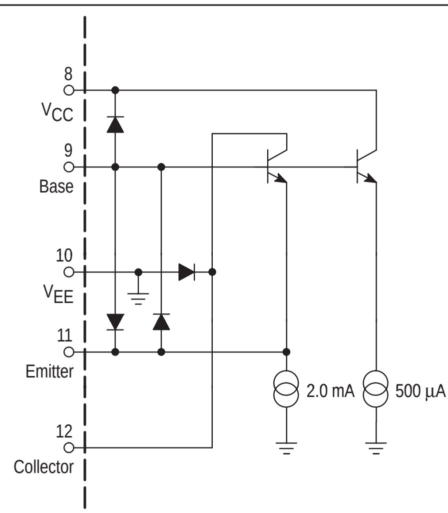
Characteristics	Input Pin	Measure Pin	Symbol	Min	Typ	Max	Unit
Amplifier Output Power (with external matching) @ 950 MHz; P_{in} = –19 dBm	PA_{in}	PA_{out}	$P_{A\_}P_O$	–4.5	–3.3	–2.1	dBm
Amplifier 1.0 dB Compression Point (@ 950 MHz = f_{IF_out})	PA_{in}	PA_{out}	$P_{1dBC.Pt.}$	–	8.0	–	dBm
Amplifier Output Harmonics (with external matching) @ 950 MHz; P_{in} = –19 dBm 2nd 3rd	PA_{in}	PA_{out}	 P_{A-2f} P_{A-3f}	 –25 –35	 –37 –52	 – –	dBc
Mixer/Buffer Output (@ 950 MHz = f_{osc}; Mixer input (Pin 5) pulled through 270 Ω resistor)		Buf_out+	P_{Mx/Buf_out}	–19	–18	–17	dBm
PLL Setup Time [Note 1]	MC	$PRSC_{out}$	T_{PLL}	-	10	–	nS
Mixer Input Third Order Intercept Point			IIP3	–	10	–	dBm
VCO Phase Noise (@ 10 kHz offset)		Buf_out+		–	–80	–	dBc/Hz
Prescalar Output Level (10 k || 8.0 pF Load)		$PRSC_{out}$		400	–	600	mVpp

NOTES: 1. MC input (50%) to $PRSC_{out}$ rising output (50%) for proper modulus selection.
2. Typical performance parameters indicate the potential of the device under ideal operation conditions.

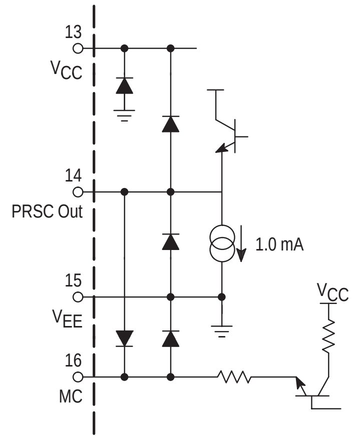
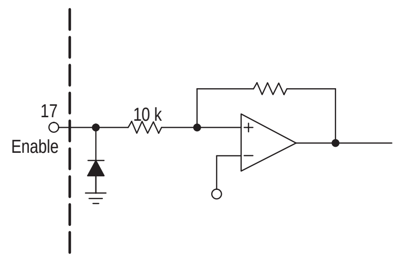
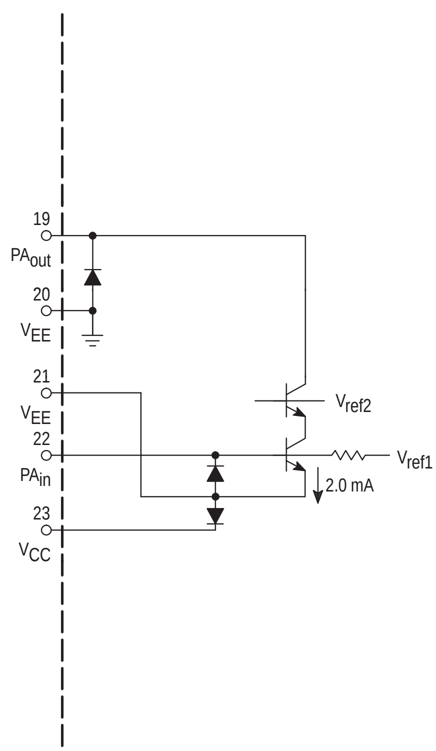
Figure 1. Test Circuit



PIN FUNCTION DESCRIPTION

Pin	Symbol/Type	Description	Description
1, 3	Mxr/Buf Out–, Mxr/Buf Out+		**Mixer/Buffer Outputs** The Mixer/Buffer is a differential open collector configuration which designed to use over a wide frequency range for up conversion as well as direct conversion. Differential to single–ended circuit configuration and matching options are discussed in the Circuit Description section. 6.0 dB of additional Mixer gain can be achieved by conjugately matching the outputs at the desired RF frequency.
2	V_{EE}		**V_{EE}, Negative Supply** This pin is V_{EE} supply for the mixer IF output. In the application PC board this pin is tied to a common V_{EE} trace with other V_{EE} pins.
4	Mx Lin		**Mixer Linearity Control** The mixer linearity control circuit accepts approximately 0 to 200 µA control current to set the dynamic range of the mixer. An Input Third Order Intercept Point, IIP3 of 17 dBm may be achieved at 200 µA of control current.
5	Mxr/Buf In		**Mixer/Buffer Input** The mixer input impedance is broadband 50 Ω for applications up to 2.4 GHz.
6, 7, 18, 24	V_{EE}		**V_{EE}, Negative Supply** These pins are substrate connections on the IC. In the application PC board these pins are tied to a common V_{EE} trace with other V_{EE} pins.
8	V_{CC}		**V_{CC}, Supply Voltage** Two V_{CC} pins are provided for the Local Oscillator and LO Buffer Amplifier. The operating supply voltage range is from 2.7 Vdc to 6.5 Vdc. In the PCB layout, the V_{CC} trace must be kept as wide as feasible to minimize inductive reactances along the trace. V_{CC} should be decoupled to V_{EE} at the IC pin.
9	Base		**On–board VCO Transistor** The transistor has the emitter, base, collector, V_{CC} and V_{EE} pins available. Internal biasing which is compensated for stability over temperature is provided. It is recommended that the base pin is pulled up to V_{CC} through an RFC chosen for the particular oscillator center frequency. The application circuit shows a Colpitts oscillator configuration.
10	V_{EE}		
11	Emitter		
12	Collector		

PIN FUNCTION DESCRIPTION (continued)

Pin	Symbol/Type	Description	Description
13	V_{CC}		**V_{CC}, Supply Voltage**
14	PRSC Out		**Prescaler Output** The prescaler output provides 500 mVpp drive to the F_{in} Pin of a PLL synthesizer. Conjugately matching the interface will increase the drive delivered to the PLL input.
15	V_{EE}		**V_{EE}, Negative Supply**
16	MC		**Dual Modulus Control Current Input** This requires a current input of typically 200 µApp.
17	Enable		**Transmitter Enable** Enable the transmitter by pulling the pin up to V_{CC}.
19	PA_{out}		**PA Out** The output is an open collector of the cascode transistor low power amplifier (LPA); it is externally biased. The output may be conjugately matched with a shunt L, and series L and C network.
20, 21	V_{EE}		**V_{EE}, Negative Supply** V_{EE} pin is taken to an ample dc ground plane through a low impedance path. The path should be kept as short as possible. A two sided PCB is implemented so that ground returns can be easily made through via holes.
22	PA_{in}		**PA In** The input is the base of the common emitter transistor. Minimum external matching is required to optimize the input return loss and gain.
23	V_{CC}		**V_{CC}, Positive Supply** V_{CC} pin is taken to the incoming positive battery or regulated dc voltage through a low impedance trace on the PCB. It is decoupled to V_{EE} ground at the pin of the IC.

CIRCUIT DESCRIPTION

General

The MC13146 consists of a low power amplifier, a 50 Ω linear mixer with linearity control, divide by 64/65 dual modulus prescaler and LPA. This device is designated for use as the low power transmitter in analog and digital FM systems such as UHF and 800 MHz Special Mobile Radio (SMR), UHF Family Radio Services, PCS 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 mixer output so the IC may be used either as an upconverter or for a direct conversion source. Additional details are covered in the Pin by Pin Description which shows the equivalent internal circuit and external circuit requirements.

Current Regulation/Enable

The device features temperature compensating, voltage independent current regulators which are controlled by the enable function in which "high" powers up the IC.

Mixer: General

The mixer is a 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 has been achieved. The mixer has a 50 Ω single–ended RF input and open collector differential outputs. An onboard Local Oscillator transistor has the emitter, base and collector pinned out to implement a low phase noise VCO in various configurations. Additionally, a buffered prescaler output is provided for operation with a low frequency synthesizer. For direct conversion applications the input of the mixer may be terminated to ground through a 120 to 330 Ω resistor.

Local Oscillator/Voltage Control Oscillator

The on–chip transistor operates with coaxial transmission line or LC resonant elements to over 1.8 GHz. Biasing is done with a temperature/voltage compensated current source in the emitter. A RFC from V_{CC} to the base is recommended.

The transistor can be operated in the classic Colpitts, Clapp, or Hartley configuration. The application circuit (Figure 8) depicts a parallel resonant VCO which can cover the entire 902 to 928 MHz frequency band with phase noise of approximately –80 dBc/Hz at a 10 kHz offset (see Figure 2). For this configuration, the LO will be driven with approximately 100 mVrms, and the frequency of oscillation can be approximated by:

$$F_{OSC} = \frac{1}{\left(2\pi\sqrt{\left(\frac{C1\ C2}{C1+C2}\right)\left(\frac{C3\ Cv}{C3+Cv} + 3.6\ pF\right)(L1 + 1.8\ nH)}\right)}$$

where Cv is the equivalent capacitance of the varactor at the control voltage.

For higher frequency operation, a series tuned oscillator configuration is recommended. Table 1 contains the S–parameters for the VCO transistor in a common collector configuration. This information is useful for designing a VCO at other operating frequencies or for various other oscillator topologies.

The output power (at Mix/Buf Out) can be varied by adjusting the value of R5 as illustrated in Figures 3 and 4. Figure 5 shows the typical operating window for the prescaler.

Figure 2. Typical Tuning Performance

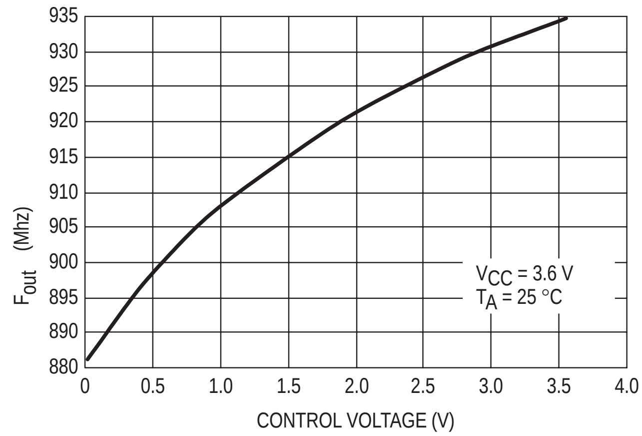


Figure 3. Mixer/Buffer Output versus 1st LO Input

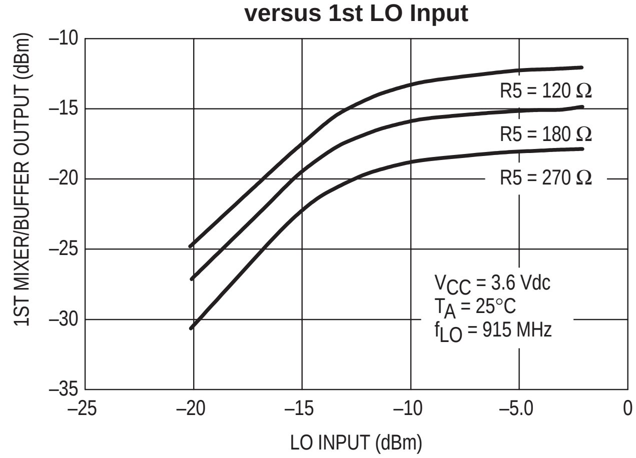


Figure 4. Test Circuit for Figure 3.

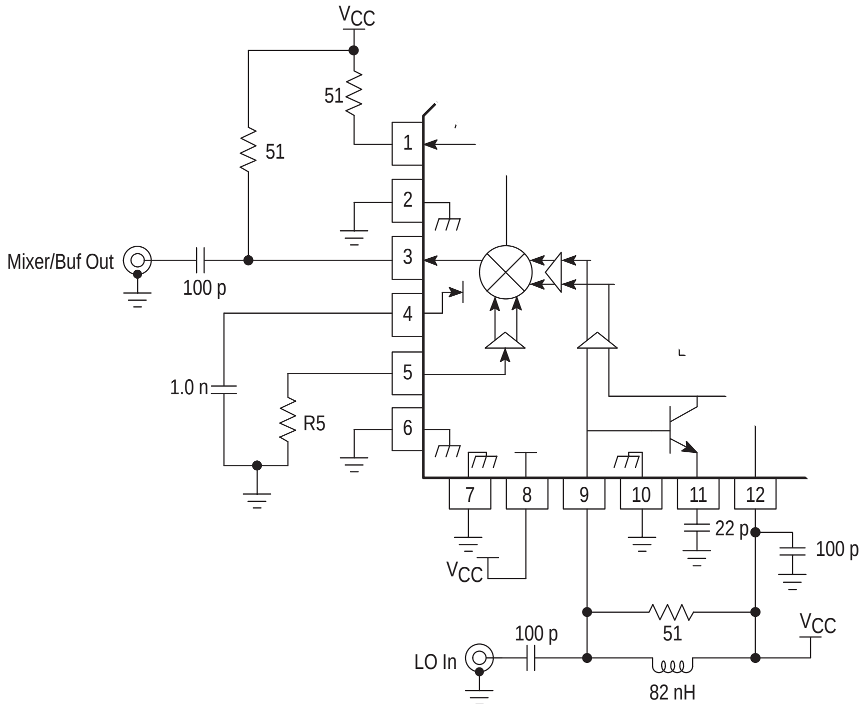
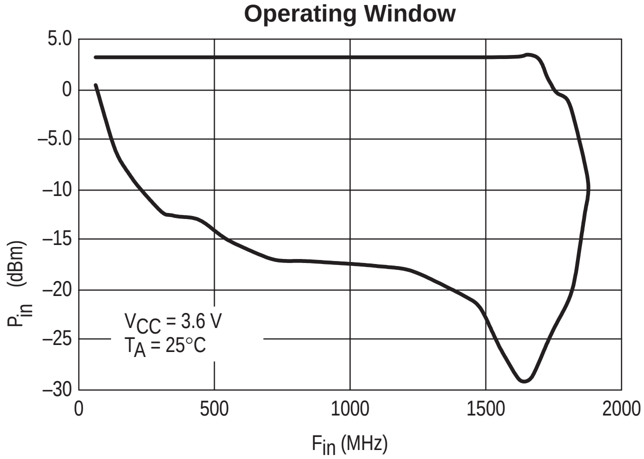


Figure 5. Typical Prescaler Operating Window



Mixer/Buffer Input

The Mixer/Buf In pin is a broadband, 50 Ω input used to drive the IF port of the mixer (see Table 2, S11 parameters).The Mixer/Buf In pin can be used in one of three modes:

1. A IF signal can be applied to this pin and up–converted to the desired RF frequency.
2. A resistor can be connected to ground, controlling the RF output power.
3. A resistor can be connected to V_{CC}, disabling the entire mixer.

The linear gain of the Mixer/Buf when used as a buffer is approximately –5.0 to –8.0 dB.

Mixer/Buffer Outputs

The mixer outputs (Mixer/Buf Out + and Mixer/Buf Out –) are balanced, open collector. A shunt resistor of 200 Ω minimum to V_{CC} is recommended for stability.

The outputs can be used as a single–ended driver or connected in a balanced–to–unbalanced configuration. If the single–ended driver configuration is used, the unused output must be tied directly to V_{CC}. For the balanced–to–unbalanced configuration, an additional 3.0 to 6.0 dB of power gain can be achieved. Conjugate matching is easily accomplished to the desired load by the addition of a shunt and series element (see Table 2, S22 parameters).

Low Power Amplifier (LPA)

The LPA is internally biased at low supply current (approximately 2.0 mA emitter current) for optimal low power operation, yielding a 10 dBm 1.0 dB output power compression point. Input and output matching may be achieved at various frequencies using few external components (see Table 3 S–parameters). Typical power gain is 16 dB with the input/output conjugately matched to the source/load impedance. A minimum 200 Ω shunt resistor from the output to V_{CC} is recommended for stability.

Figure 6. I_{CC} versus Temperature

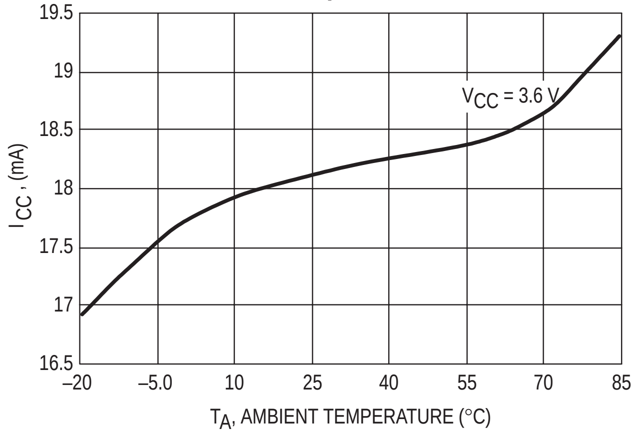


Figure 7. Output Power versus Temperature

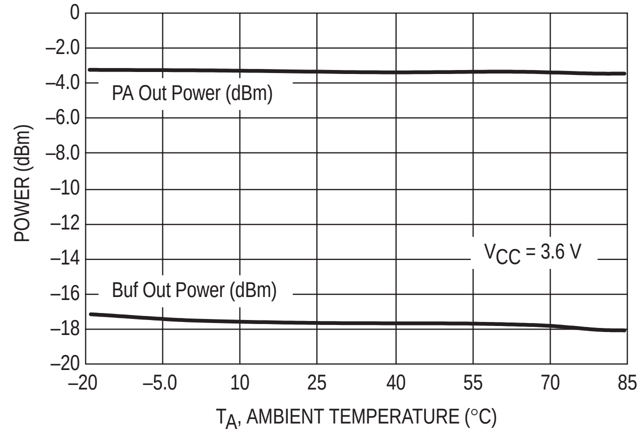
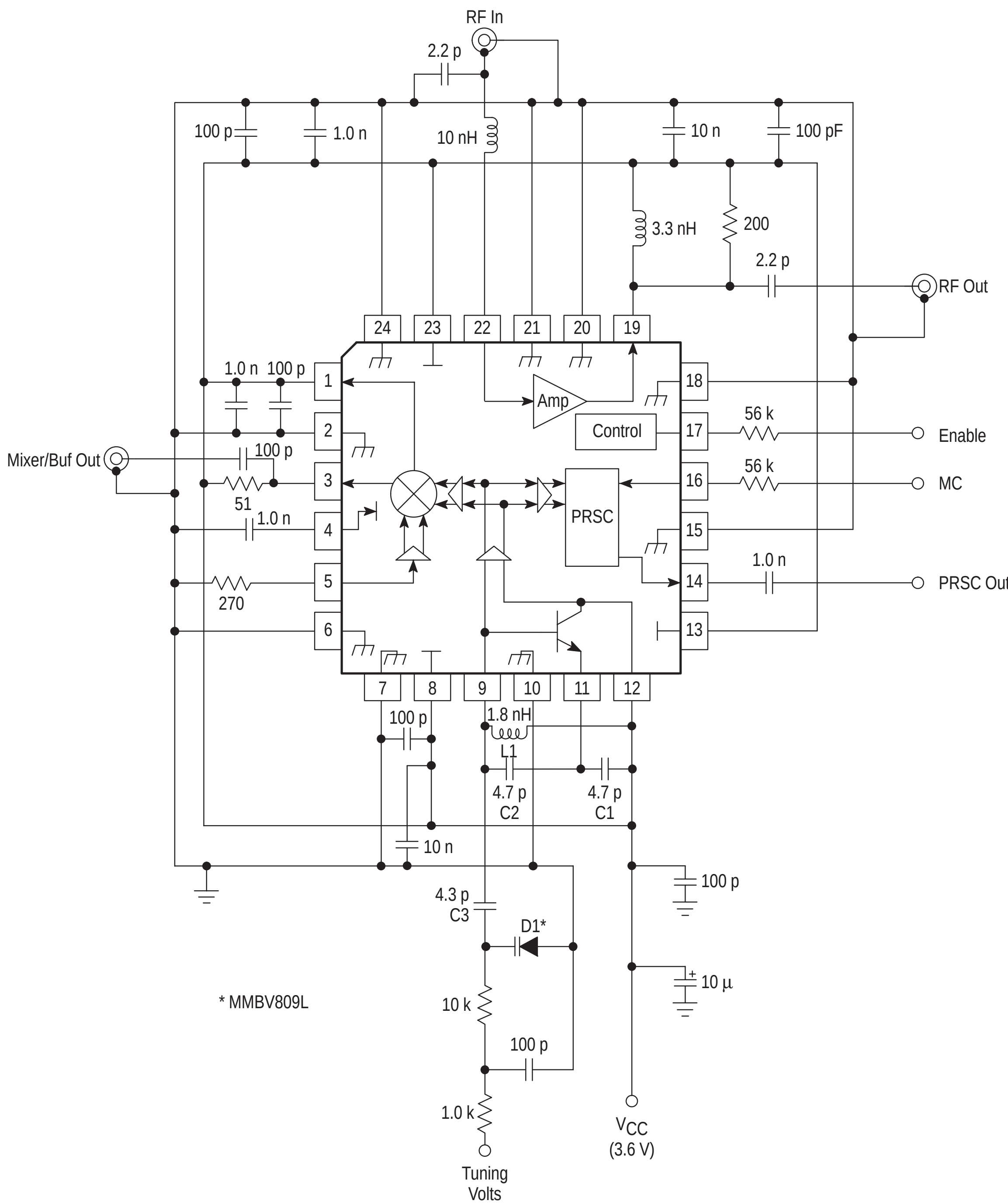


Figure 8. Applications Circuit



* MMBV809L

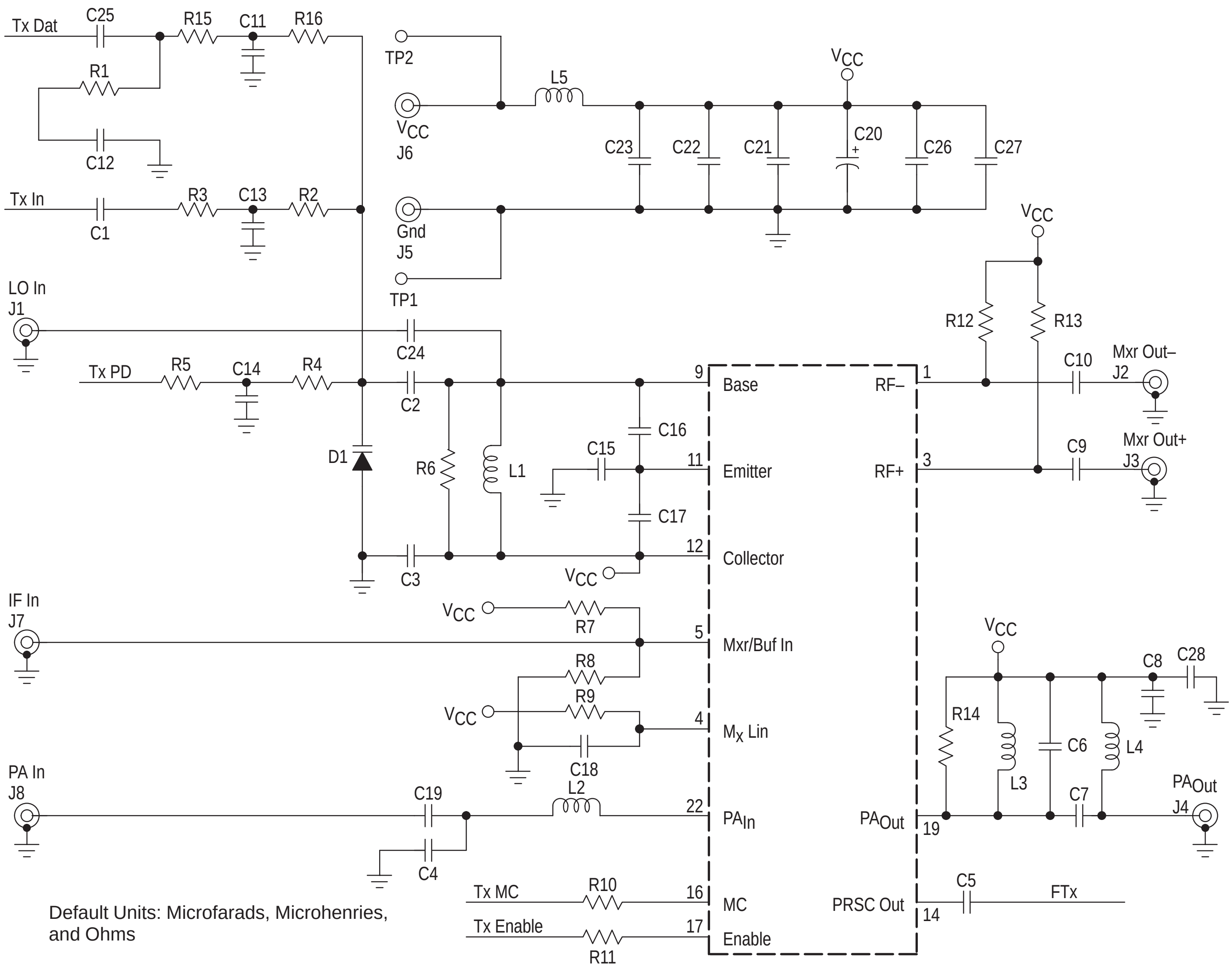
Evaluation PCB

The evaluation PCB is a versatile board which allows the MC13146 to be configured as a basic transmitter, or to characterize individual operating parameters.

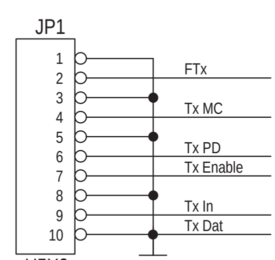
The general purpose schematic and associated parts list for the PCB is given in Figure 9. This parts list build–up is identical to the Test Circuit illustrated in Figure 1, although parameters can very significantly due to differences in PCB parasitics. Figures 10, 11, and 12 show the actual PCB component, ground and solder sides, respectively.

Please refer to AN1687/D and AN1691/D for additional details and applications for the device.

Figure 9. Evaluation PCB Schematic



Default Units: Microfarads, Microhenries, and Ohms



R1,R2,R3,R15,R16, C1,C11,C12,C13,C25, R6,R7,R9,L4,J1,J2,J7, C6,C10,C15,C24	No component	C16	1.5 p
R4	100 k	C17	2.2 p
R5,R12,C19	Short	C20	10 µ
R8	270	C28	10 n
R10	56 k	L1	1.8 n
R11	68 k	L2	8.2 n
R13	51	L3	3.3 n
R14	200	L5	RFC
C2	2.2 p	D1	MMBV809LT1
C3,C8,C9,C26,C27	100 p	J3,J4,J8	SMA EF Johnson 142–0701–851
C4, C7	2.2 p	J5,J6	Bananna Johnson Components 108–0902–001
C5,C18,C21,C22,C23	1.0 n	JP1	Header, 5x2
C14	1.0 µ	U1	MC13146FTA

Figure 10. MC13146 Evaluation PCB Component Side

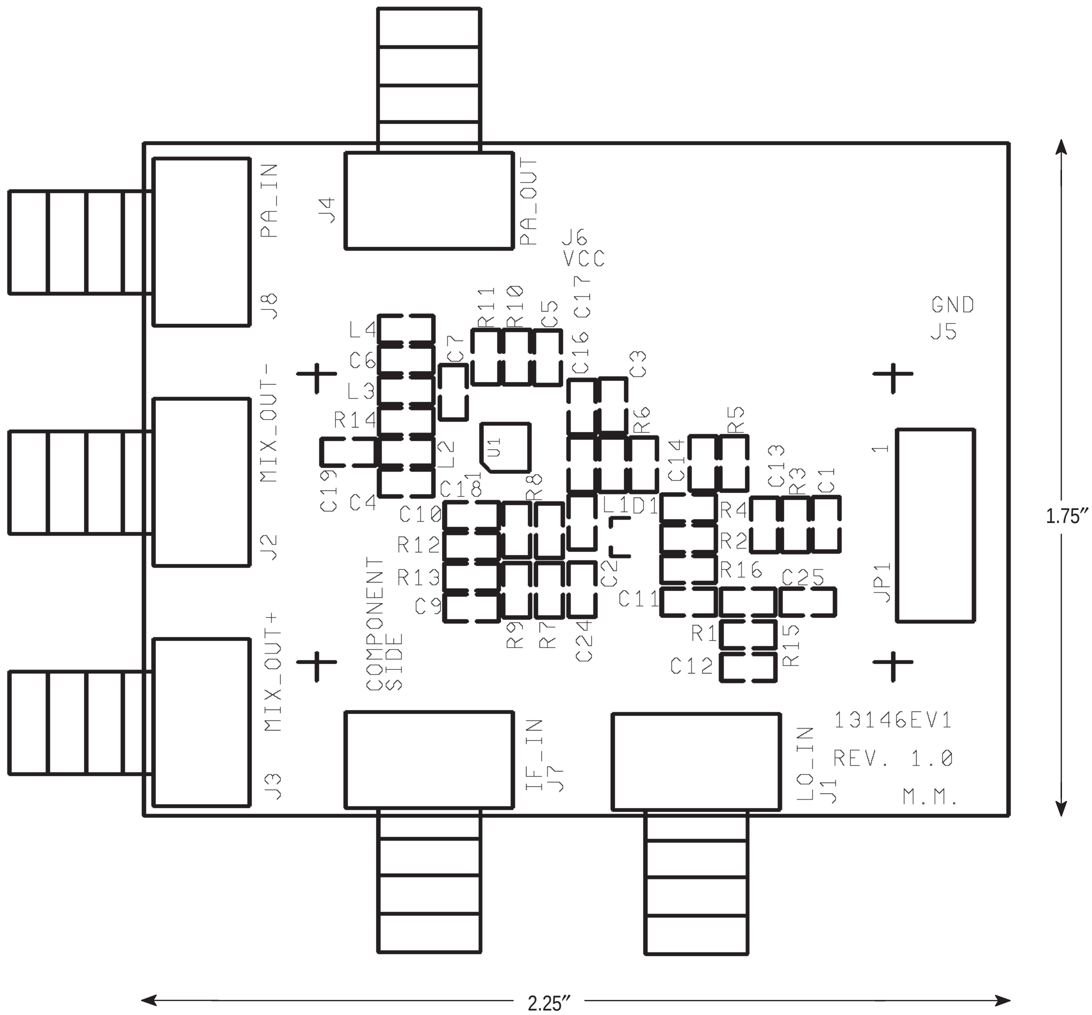


Figure 11. MC13146 Evaluation PCB Ground Plane

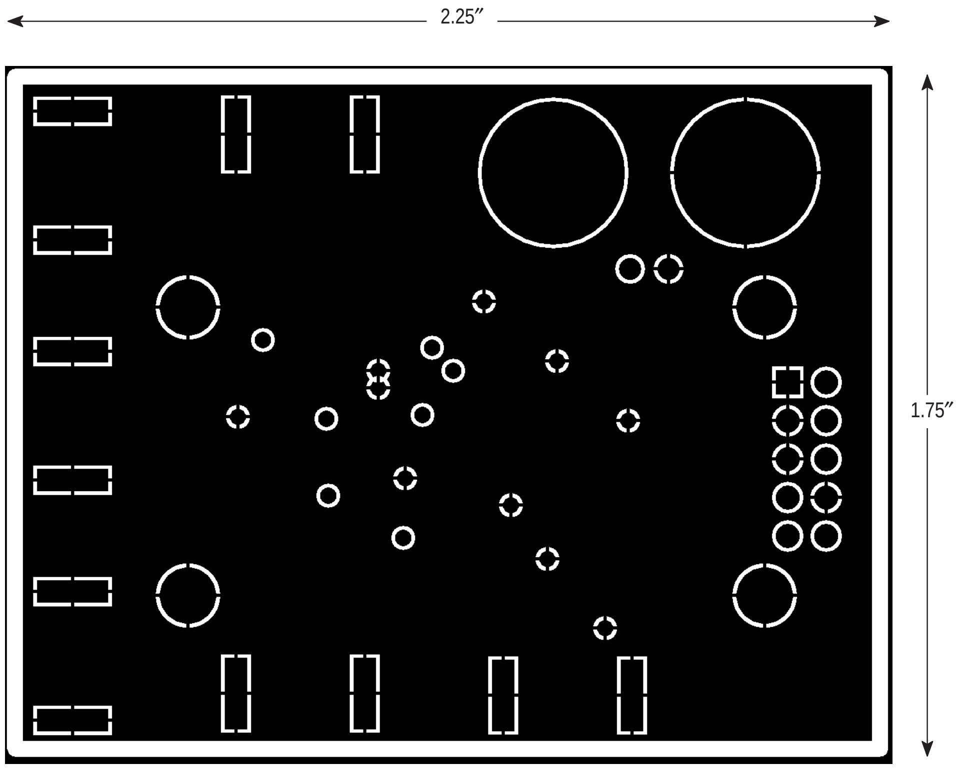


Figure 12. MC13146 Evaluation PCB Solder Side

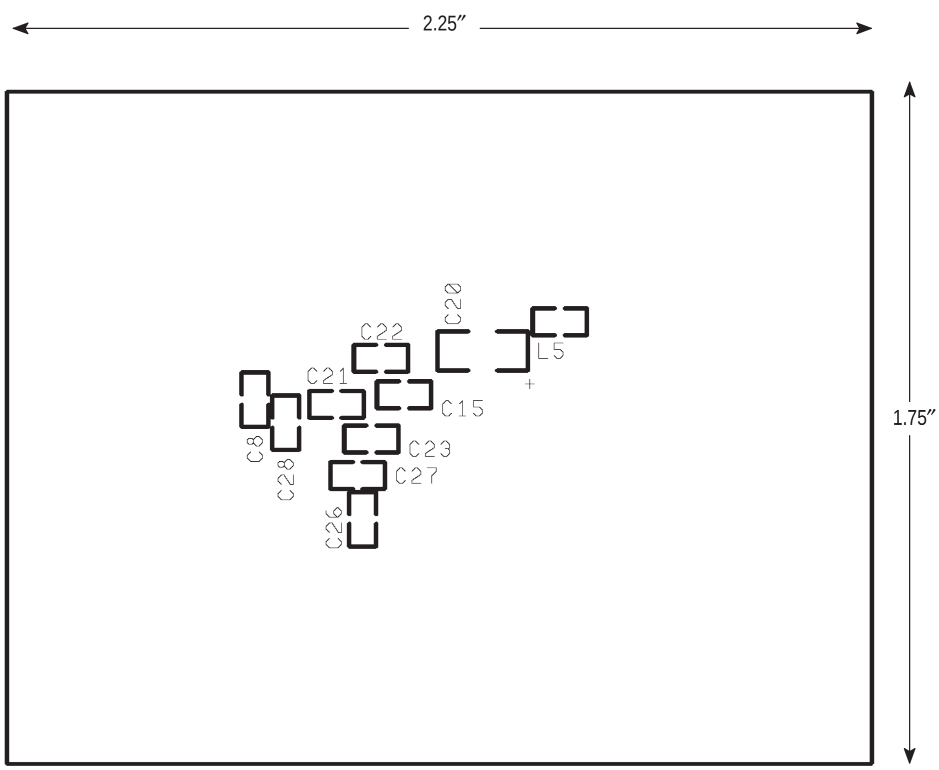


Table 1. VCO Transistor S–Parameters 3.6 Vdc; 50 Ω Load and Source Impedance; Common Collector

Freq (MHz)	S11 Mag	S11 Ang	S21 Mag	S21 Ang	S12 Mag	S12 Ang	S22 Mag	S22 Ang
25	0.99	–1	0.88	0	0.01	44	0.10	–7
50	0.99	–2	0.92	–1	0.02	61	0.09	–9
100	0.98	–5	0.95	–2	0.04	70	0.07	–37
150	0.98	–7	0.97	–3	0.06	73	0.07	–47
200	0.97	–10	1.04	–4	0.07	73	0.06	–86
300	0.95	–14	1.11	–8	0.10	71	0.09	–124
400	0.93	–19	1.23	–12	0.13	67	0.14	–149
450	0.92	–21	1.26	–14	0.15	66	0.15	–155
500	0.91	–23	1.30	–16	0.16	65	0.17	–159
600	0.86	–28	1.35	–20	0.19	61	0.20	–167
750	0.79	–37	1.46	–25	0.24	57	0.26	–172
800	0.79	–39	1.48	–26	0.25	56	0.28	–174
850	0.77	–42	1.48	–28	0.26	54	0.29	–177
900	0.74	–44	1.47	–31	0.28	52	0.28	–179
950	0.67	–49	1.53	–35	0.30	49	0.31	174
1000	0.61	–55	1.59	–38	0.33	47	0.34	171
1250	0.45	–81	1.61	–50	0.41	38	0.38	157
1500	0.35	–159	1.68	–67	0.53	16	0.38	134
1750	0.85	107	1.60	–100	0.57	–15	0.33	97
2000	1.02	76	1.17	–117	0.47	–32	0.18	86
2250	1.25	76	1.13	–125	0.55	–38	0.19	89
2500	1.58	53	0.84	–150	0.56	–64	0.09	57

Table 2. Mixer Input/Output S–Parameters: 200 Ω Pull–Up Resistor

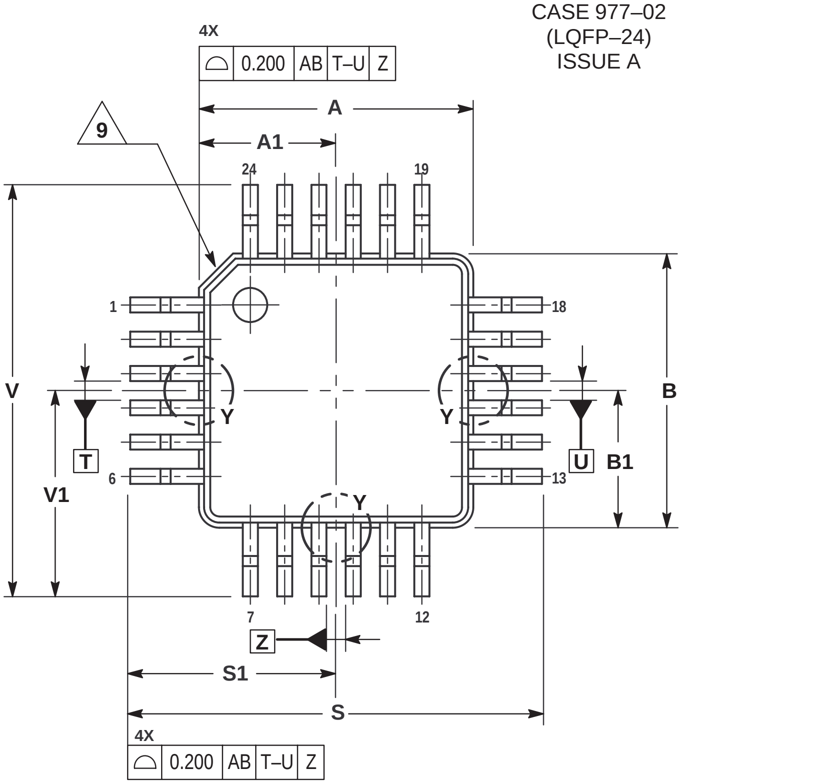
Freq (MHz)	S11 Mag	S11 Ang	S21 Mag	S21 Ang	S12 Mag	S12 Ang	S22 Mag	S22 Ang
50	0.11	176.8	0.43	–4.2	0.001	38.7	0.60	–1.9
100	0.11	177.9	0.43	–7.5	0.002	19.8	0.60	–3.5
200	0.11	179.4	0.42	–13.7	0.001	28.3	0.60	–6.7
300	0.10	179.5	0.42	–20.7	0.001	69.8	0.61	–9.9
400	0.10	177.2	0.42	–27.3	0.001	106.3	0.61	–13.2
450	0.11	174.9	0.41	–31.1	0.001	135.2	0.62	–14.8
500	0.10	177.7	0.42	–34.1	0.002	138.2	0.62	–16.6
600	0.09	174.3	0.42	–41.8	0.003	150.5	0.63	–20.0
700	0.09	167.2	0.41	–49.3	0.005	158.7	0.64	–23.5
750	0.08	162.8	0.41	–53.9	0.006	166.0	0.65	–25.2
800	0.08	156.6	0.40	–58.4	0.008	166.5	0.65	–26.9
850	0.06	152.3	0.40	–62.7	0.009	171.2	0.66	–28.7
900	0.05	145.2	0.39	–66.4	0.012	177.6	0.66	–30.3
950	0.04	131.1	0.38	–71.6	0.015	–179.7	0.67	–31.9
1000	0.02	101.1	0.38	–76.7	0.019	178.0	0.68	–33.7
1250	0.08	–41.5	0.27	–96.8	0.042	137.1	0.73	–43.2
1500	0.40	–87.6	0.24	–90.2	0.036	129.9	0.78	–53.3
1750	0.50	–144.1	0.30	–114.0	0.058	142.8	0.86	–63.8
2000	0.51	–173.5	0.22	–133.0	0.174	151.6	0.96	–81.3

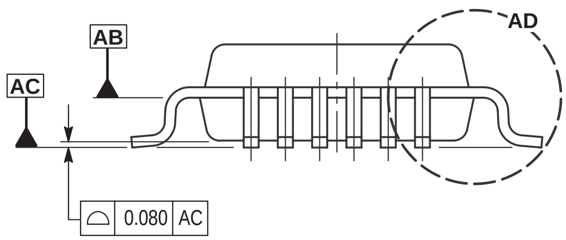
Table 3. LPA S–Parameters: 200 Ω Pull–Up Resistor

Freq (MHz)	S11 Mag	S11 Ang	S21 Mag	S21 Ang	S12 Mag	S12 Ang	S22 Mag	S22 Ang
200	0.76	–26.0	9.3	148.1	0.0006	73.3	0.60	–12.4
300	0.71	–37.5	8.5	135.2	0.0011	74.4	0.60	–18.5
400	0.67	–47.2	7.6	124.5	0.0011	79.6	0.61	–24.6
450	0.64	–51.7	7.2	118.6	0.0010	66.0	0.62	–28.3
500	0.62	–55.4	6.9	114.2	0.0011	45.4	0.62	–31.6
600	0.58	–63.7	6.3	105.3	0.0012	16.7	0.64	–38.8
700	0.54	–72.1	5.6	95.2	0.0016	–20.9	0.66	–45.6
750	0.52	–74.6	5.4	91.8	0.0013	–36.9	0.66	–48.5
800	0.51	–77.9	5.2	87.7	0.0023	–50.8	0.67	–52.6
850	0.49	–80.3	5.0	83.8	0.0033	–63.6	0.68	–56.1
900	0.49	–83.5	4.7	79.6	0.0044	–78.7	0.68	–60.3
950	0.48	–85.4	4.5	77.2	0.0060	–90.3	0.68	–63.2
1000	0.48	–88.8	4.3	74.7	0.0082	–97.6	0.68	–65.8
1250	0.51	–102.7	3.7	58.8	0.0249	–136.6	0.73	–74.6
1500	0.48	–119.7	3.3	37.6	0.0273	172.0	0.90	–87.7
1750	0.47	–130.0	2.7	20.5	0.0290	166.5	0.97	–103.7
2000	0.51	–136.7	2.2	–1.1	0.0386	164.1	1.01	–119.1

OUTLINE DIMENSIONS

FTA SUFFIX
PLASTIC PACKAGE
CASE 977–02
(LQFP–24)
ISSUE A

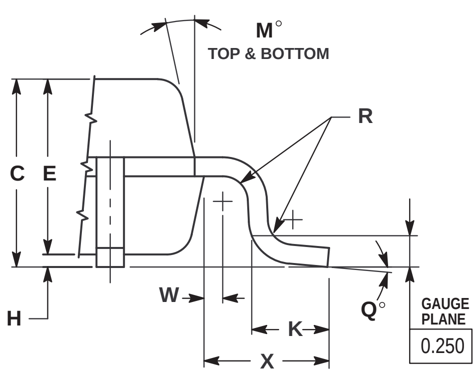




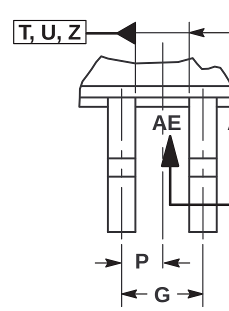
NOTES:

1. CONTROLLING DIMENSION: MILLIMETER.
2. DIMENSIONS AND TOLERANCES PER ASME Y14.5M, 1994.
3. DATUM PLANE AB IS LOCATED AT BOTTOM OF LEAD AND IS COINCIDENT WITH THE LEAD WHERE THE LEAD EXITS THE PLASTIC BODY AT THE BOTTOM OF THE PARTING LINE.
4. DATUMS T, U, AND Z TO BE DETERMINED AT DATUM PLANE AB.
5. DIMENSIONS S AND V TO BE DETERMINED AT DATUM PLANE AC.
6. DIMENSIONS A AND B DO NOT INCLUDE MOLD PROTRUSION. ALLOWABLE PROTRUSION IS 0.250 PER SIDE. DIMENSIONS A AND B DO INCLUDE MOLD MISMATCH AND ARE DETERMINED AT DATUM PLANE AB.
7. DIMENSION D DOES NOT INCLUDE DAMBAR PROTRUSION. DAMBAR PROTRUSION SHALL NOT CAUSE THE D DIMENSION TO EXCEED 0.350.
8. MINIMUM SOLDER PLATE THICKNESS SHALL BE 0.0076.
9. EXACT SHAPE OF EACH CORNER IS OPTIONAL.

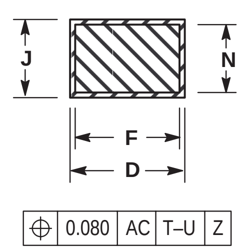
DIM	MILLIMETERS MIN	MILLIMETERS MAX
A	4.000 BSC	
A1	2.000 BSC	
B	4.000 BSC	
B1	2.000 BSC	
C	1.400	1.600
D	0.170	0.270
E	1.350	1.450
F	0.170	0.230
G	0.500 BSC	
H	0.050	0.150
J	0.090	0.200
K	0.500	0.700
M	12° REF	
N	0.090	0.160
P	0.250 BSC	
Q	0°	7°
R	0.150	0.250
S	6.000 BSC	
S1	3.000 BSC	
V	6.000 BSC	
V1	3.000 BSC	
W	0.200 REF	
X	1.000 REF	



DETAIL AD



DETAIL Y



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