19-0586; Rev 1; 2/09

MAXIM

超声可变增益放大器

MAX2037

概述

MAX2037 8通道可变增益放大器(VGA)适用于高线性度、高动态范围和低噪声超声成像及多普勒应用。每个放大器都具有差分输入和输出，总增益范围的典型值是42dB。此外，VGA的等效输出噪声非常低，适合与12位的模数转换器(ADC)接口。

MAX2037 VGA经过优化的绝对增益误差小于±0.25dB，可保证通道间的超声波束成形聚焦误差最小。该器件的差分输出通过一个外部无源、抗混叠滤波器直接驱动超声ADC。每个放大器的输出端都有一个可切换箝位电路，用于限制输出信号，从而避免ADC过载或饱和。

经过优化的器件动态性能大大减小了失真，支持二次谐波成像。在V_{OUT} = 1.5V_{P-P}和f_{IN} = 5MHz时，二次谐波失真为-70dBc，按照超声规范的规定*，双音三阶交调失真为-52dBc。

MAX2037采用+5.0V电源供电，功耗只有120mW/通道。器件采用100引脚TQFP封装，带有裸焊盘，工作在0°C至+70°C温度范围。

应用

超声成像

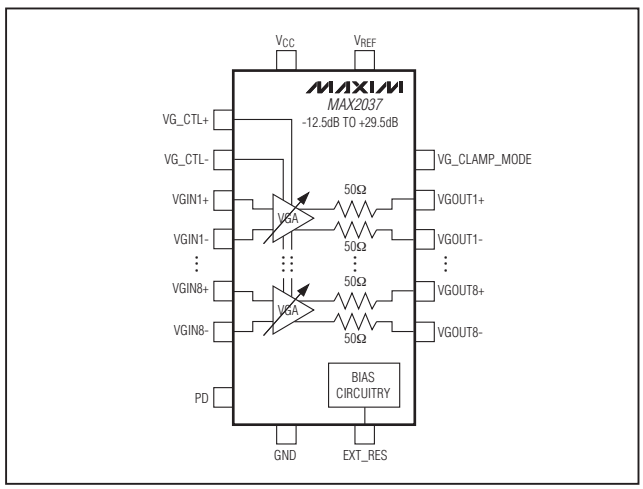
声纳系统

特性

- ♦ 具有8通道配置
- ♦ 高集成度可理想用于超声成像系统
- ♦ 与MAX2038超声VGA和连续波多普勒波束成形器件引脚兼容
- ♦ 最大增益、增益范围及等效输出噪声针对12位ADC应用进行优化
  - 最大增益：29.5dB
  - 总增益范围：42dB
  - 5MHz时具有22nV/√Hz的超低等效输出噪声
  - 与支持10位ADC的MAX2035/MAX2036引脚兼容
- ♦ 绝对增益误差为±0.25dB
- ♦ 可切换VGA输出箝位电路有效防止ADC过载
- ♦ 全差分VGA输出直接驱动ADC
- ♦ 可变增益范围高达42dB
- ♦ V_{OUT} = 1.5V_{P-P}和f_{IN} = 5MHz时，二次谐波失真是-70dBc
- ♦ V_{OUT} = 1.5V_{P-P}和f_{IN} = 5MHz时，超声规范规定*双音三阶交调失真为-52dBc
- ♦ 每通道功耗120mW

**请参见应用信息部分中的超声规范规定的IMD3。*

功能框图



定购信息

PART	TEMP RANGE	PIN-PACKAGE
MAX2037CCQ+D	0°C to +70°C	100 TQFP-EP†
MAX2037CCQ+TD	0°C to +70°C	100 TQFP-EP†

†EP = 裸焊盘。
+表示无铅(Pb)/符合RoHS标准的封装。
T = 卷带包装。
D = 防潮包装。

ABSOLUTE MAXIMUM RATINGS

V_{CC}, V_{REF} to GND .....-0.3V to +5.5V
Any Other Pins to GND.....-0.3V to (V_{CC} + 0.3V)
VGA Differential Input Voltage (VGIN_+ - VGIN_-).....8.0V_{P-P}
Analog Gain-Control Input Differential Voltage
(VG_CTL+ - VG_CTL-).....8.0V_{P-P}
Continuous Power Dissipation (T_A = +70°C)
100-Pin TQFP
(derated 45.5mW/°C above +70°C).....3636.4mW
Operating Temperature Range.....0°C to +70°C
Junction Temperature.....+150°C
θ_{JC} (Note 1) .....+2°C/W
θ_{JA} (Note 1) .....+22°C/W
Storage Temperature Range .....-40°C to +150°C
Lead Temperature (soldering, 10s) .....+300°C

Note 1: Package thermal resistances were obtained using the method described in JEDEC specification JESD51-7, using a four-layer board. For detailed information on package thermal considerations, refer to **www.maxim-ic.com.cn/thermal-tutorial**.

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

DC ELECTRICAL CHARACTERISTICS

(Figure 2, V_{CC} = V_{REF} = 4.75V to 5.25V, V_{CM} = (3/5)V_{REF}, T_A = 0°C to +70°C, V_{GND} = 0, PD = 0, no RF signals applied, capacitance to GND at each of the VGA differential outputs is 60pF, differential capacitance across the VGA outputs is 10pF, R_L = 1kΩ. Typical values are at V_{CC} = V_{REF} = 5V, T_A = +25°C, unless otherwise noted.) (Note 2)

PARAMETER	SYMBOL	CONDTIONS		MIN	TYP	MAX	UNITS
Supply Voltage Range	V_{CC}			4.75	5	5.25	V
V_{CC} External Reference Voltage Range	V_{REF}	(Note 3)		4.75	5	5.25	V
Total Power Supply Current		Refers to V_{CC} supply current plus V_{REF} current	PD = 0		204	231	mA
			PD = 1		27	33	
V_{CC} Supply Current	I_{VCC}				192	216	mA
V_{REF} Current	I_{REF}				12	15	mA
Current Consumption per Amplifier Channel		Refers to V_{CC} supply current			24	27	mA
Differential Analog Control Voltage Range		Minimum gain			+2		V_{P-P}
		Maximum gain			-2		
Differential Analog Control Common-Mode Voltage	V_{CM}			2.85	3.0	3.15	V
Analog Control Input Source/Sink Current					4.5	5	mA
LOGIC INPUTS							
CMOS Input High Voltage	V_{IH}			2.0			V
CMOS Input Low Voltage	V_{IL}					0.8	V

AC ELECTRICAL CHARACTERISTICS

(Figure 2, V_{CC} = V_{REF} = 4.75V to 5.25V, V_{CM} = (3/5)V_{REF}, T_A = 0°C to +70°C, V_{GND} = 0, PD = 0, VG_CLAMP_MODE = 1, f_{RF} = 5MHz, capacitance to GND at each of the VGA differential outputs is 60pF, differential capacitance across the VGA outputs is 10pF, R_L = 1kΩ. Typical values are at V_{CC} = V_{REF} = 5V, T_A = +25°C, unless otherwise noted.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Full-Scale Bandwidth	f-1.3dB	V_{OUT} = 1.5V_{P-P}, 1.3dB bandwidth, gain = 10dB	Differential output capacitance is 10pF, capacitance to GND at each single-ended output is 60pF, R_L = 1kΩ		18		MHz
			No capacitive load R_L = 1kΩ		29		
Small Signal Bandwidth	f-1.3dB	V_{OUT} = 1.5mV_{P-P}, 1.3dB bandwidth, gain = 10dB			30		MHz
Differential Input Resistance	R_{IN}			170	200	230	Ω
Input Effective Capacitance	C_{IN}	f_{RF} = 10MHz, each input to ground			15		pF
Differential Output Resistance	R_{OUT}				100		Ω
Maximum Gain					+29.5		dB
Minimum Gain					-12.5		dB
Gain Range					42		dB
Absolute Gain Error		T_A = +25°C, full gain range 0% to 100%, V_{REF} = 5V			±0.25	±1.5	dB
VGA Gain Response Time		40dB gain change to within 1dB final value			1		µs
Input-Referred Noise		VG_CTL set for maximum gain, no input signal			2		nV/√Hz
Output-Referred Noise		VG_CTL set for +10dB of gain	No input signal		22		nV/√Hz
			V_{OUT} = 1.5V_{P-P}, 1kHz offset		55		
Second Harmonic	HD2	VG_CLAMP_MODE = 1, VG_CTL set for +10dB of gain, f_{RF} = 5MHz, V_{OUT} = 1.5V_{P-P}			-70		dBc
		VG_CLAMP_MODE = 1, VG_CTL set for +10dB of gain, f_{RF} = 10MHz, V_{OUT} = 1.5V_{P-P}		-55	-65		
Third-Order Intermodulation Distortion	IMD3	VG_CLT set for +10dB of gain, f_{RF1} = 5MHz, f_{RF2} = 5.01MHz, V_{OUT} = 1.5V_{P-P}, V_{REF} = 5V (Note 4)		-40	-52		dBc

AC ELECTRICAL CHARACTERISTICS (continued)

(Figure 2, V_{CC} = V_{REF} = 4.75V to 5.25V, V_{CM} = (3/5)V_{REF}, T_A = 0°C to +70°C, V_{GND} = 0, PD = 0, VG_CLAMP_MODE = 1, f_{RF} = 5MHz, capacitance to GND at each of the VGA differential outputs is 60pF, differential capacitance across the VGA outputs is 10pF, R_L = 1kΩ. Typical values are at V_{CC} = V_{REF} = 5V, T_A = +25°C, unless otherwise noted.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Channel-to-Channel Crosstalk		V_{OUT} = 1V_{P-P} differential, f_{RF} = 10MHz, VG_CTL set for +10dB of gain		-80		dB
Maximum Output Voltage at Clamp ON		VG_CLAMP_MODE = 0, VG_CTL set for +20dB of gain, 350mV_{P-P} differential input		2.4		V_{P-P} differential
Maximum Output Voltage at Clamp OFF		VG_CLAMP_MODE = 1, VG_CTL set for +20dB of gain, 350mV_{P-P} differential input		2.8		V_{P-P} differential

Note 2: Specifications at T_A = +25°C and T_A = +70°C are guaranteed by production test. Specifications at T_A = 0°C are guaranteed by design and characterization.

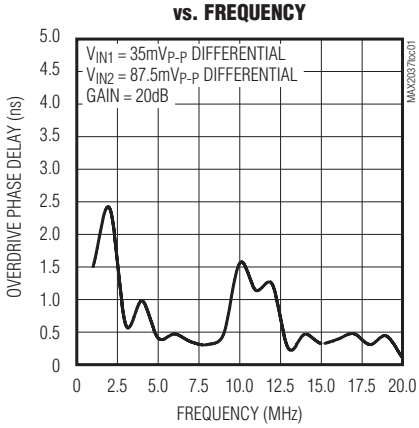
Note 3: Noise performance of the device is dependent on the noise contribution from the supply to V_{REF}. Use a low noise supply for V_{REF}. V_{CC} and V_{REF} can be connected together to share the same supply voltage if the supply for V_{CC} exhibits low noise.

Note 4: See the *Ultrasound-Specific IMD3 Specification* in the *Applications Information* section.

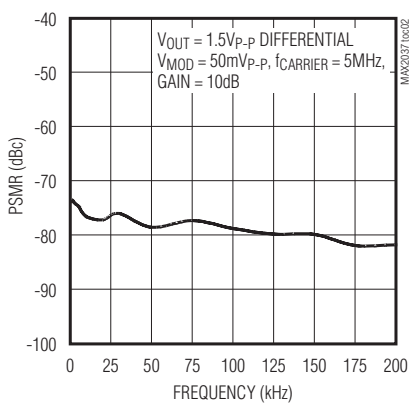
典型工作特性

(Figure 2, V_{CC} = V_{REF} = 4.75V to 5.25V, V_{GND} = 0, PD = 0, VG_CLAMP_MODE = 1, f_{RF} = 5MHz, capacitance to GND at each of the VGA differential outputs is 60pF, differential capacitance across the VGA outputs is 10pF, R_L = 1kΩ, T_A = 0°C to +70°C. Typical values are at V_{CC} = V_{REF} = 5V, T_A = +25°C, unless otherwise noted.)

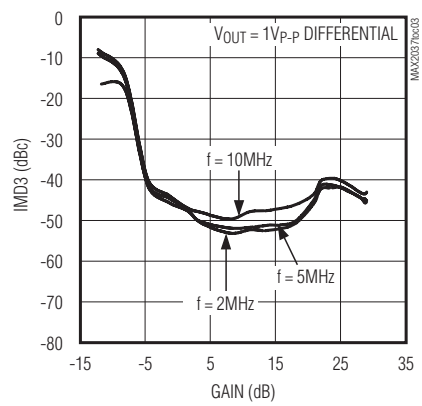
OVERDRIVE PHASE DELAY vs. FREQUENCY



POWER SUPPLY MODULATION RATIO



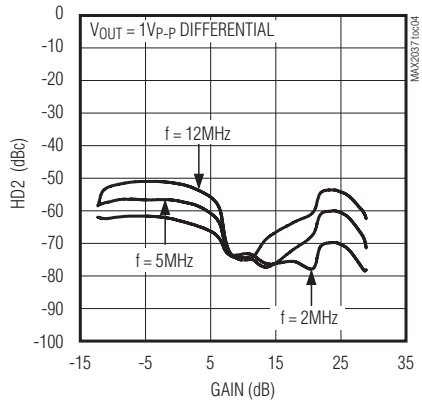
TWO-TONE ULTRASOUND-SPECIFIC IMD3 vs. GAIN



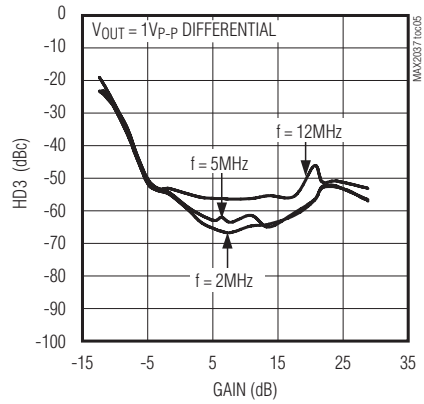
典型工作特性(续)

(Figure 2, V_{CC} = V_{REF} = 4.75V to 5.25V, V_{GND} = 0, PD = 0, VG_CLAMP_MODE = 1, f_{RF} = 5MHz, capacitance to GND at each of the VGA differential outputs is 60pF, differential capacitance across the VGA outputs is 10pF, R_L = 1kΩ, T_A = 0°C to +70°C. Typical values are at V_{CC} = V_{REF} = 5V, T_A = +25°C, unless otherwise noted.)

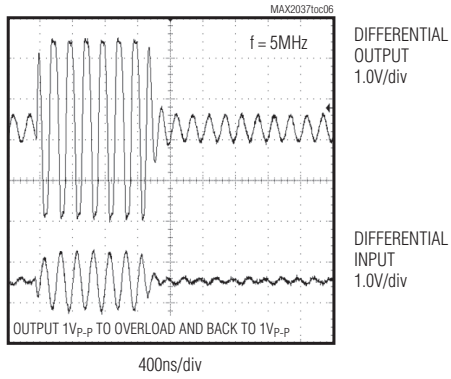
SECOND HARMONIC DISTORTION vs. GAIN



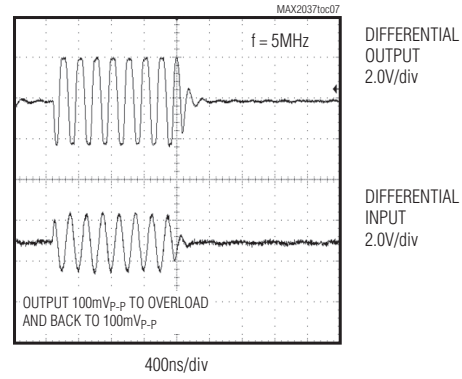
THIRD HARMONIC DISTORTION vs. GAIN



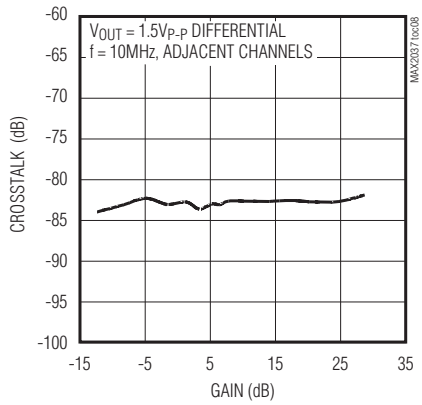
OVERLOAD RECOVERY TIME



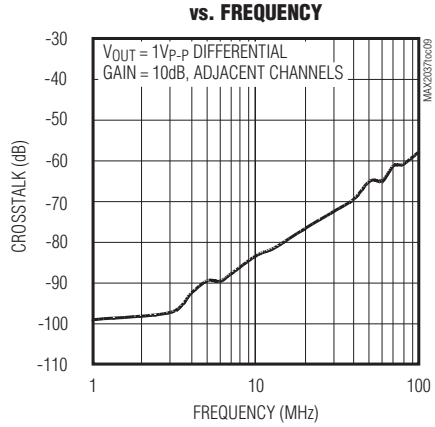
OVERLOAD RECOVERY TIME



CHANNEL-TO-CHANNEL CROSSTALK vs. GAIN



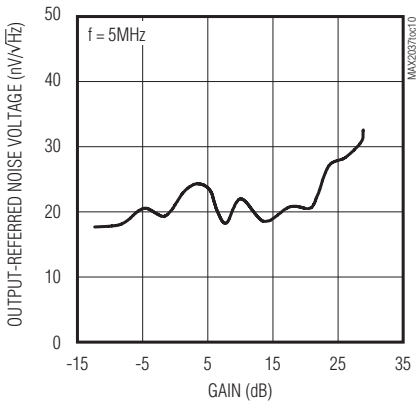
CHANNEL-TO-CHANNEL CROSSTALK vs. FREQUENCY



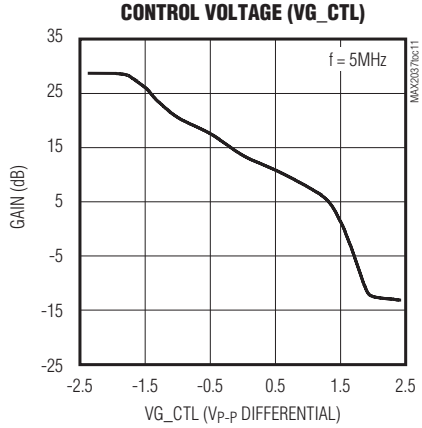
典型工作特性(续)

(Figure 2, V_{CC} = V_{REF} = 4.75V to 5.25V, V_{GND} = 0, PD = 0, VG_CLAMP_MODE = 1, f_{RF} = 5MHz, capacitance to GND at each of the VGA differential outputs is 60pF, differential capacitance across the VGA outputs is 10pF, R_L = 1kΩ, T_A = 0°C to +70°C. Typical values are at V_{CC} = V_{REF} = 5V, T_A = +25°C, unless otherwise noted.)

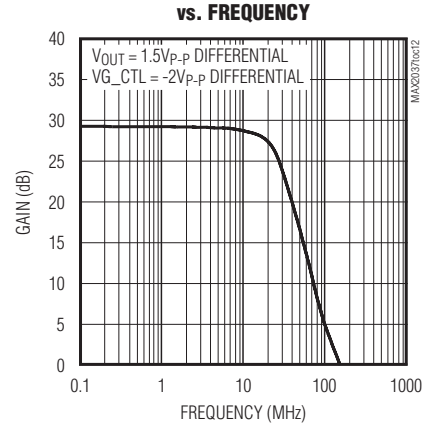
OUTPUT-REFERRED NOISE VOLTAGE vs. GAIN



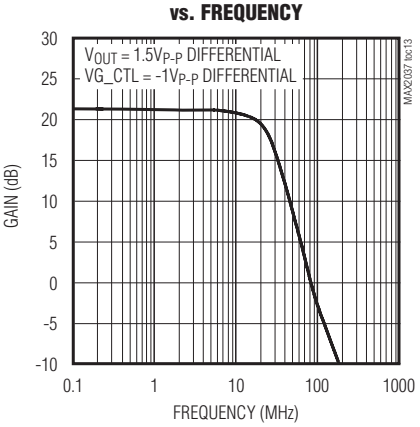
GAIN vs. DIFFERENTIAL ANALOG CONTROL VOLTAGE (VG_CTL)



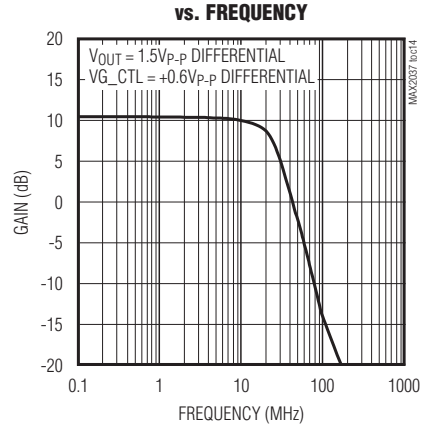
LARGE-SIGNAL BANDWIDTH vs. FREQUENCY



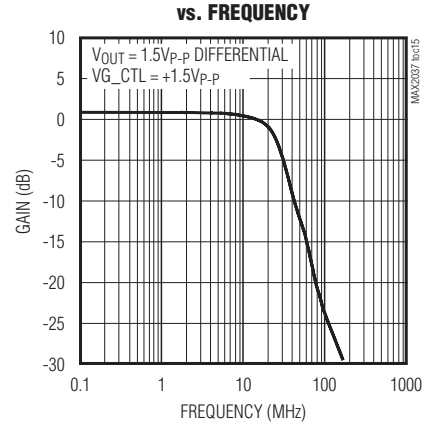
LARGE-SIGNAL BANDWIDTH vs. FREQUENCY



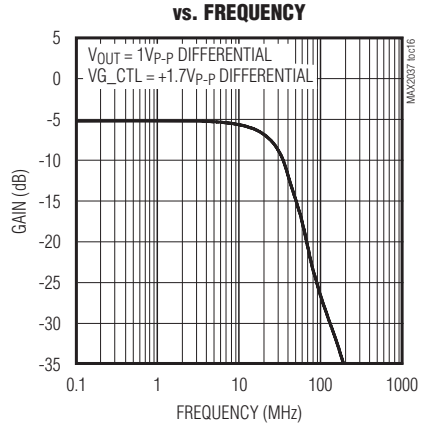
LARGE-SIGNAL BANDWIDTH vs. FREQUENCY



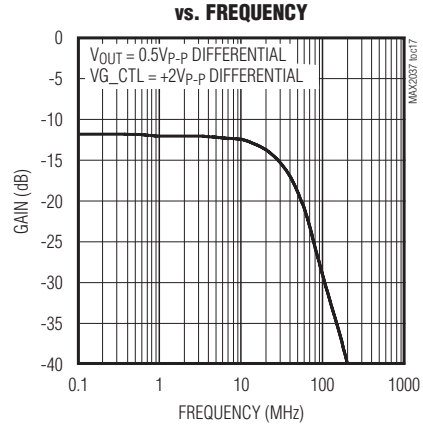
LARGE-SIGNAL BANDWIDTH vs. FREQUENCY



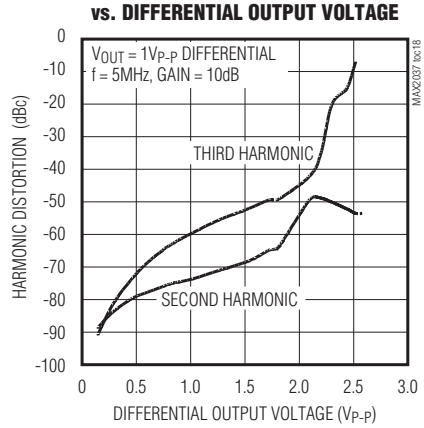
LARGE-SIGNAL BANDWIDTH vs. FREQUENCY



LARGE-SIGNAL BANDWIDTH vs. FREQUENCY



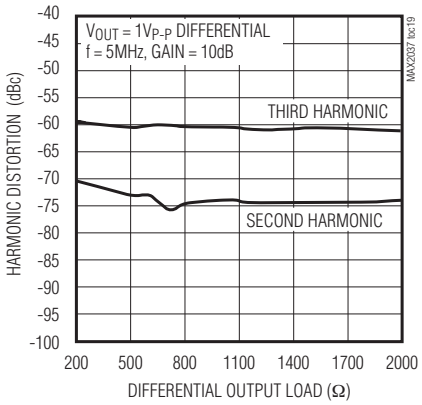
HARMONIC DISTORTION vs. DIFFERENTIAL OUTPUT VOLTAGE



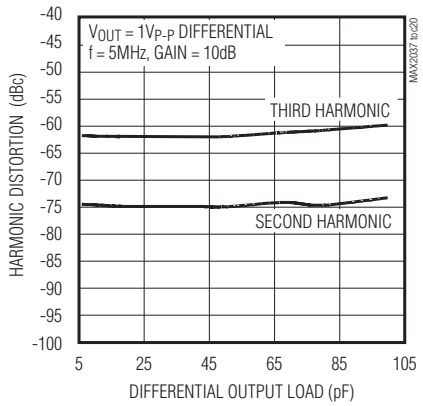
典型工作特性(续)

(Figure 2, V_{CC} = V_{REF} = 4.75V to 5.25V, V_{GND} = 0, PD = 0, VG_CLAMP_MODE = 1, f_{RF} = 5MHz, capacitance to GND at each of the VGA differential outputs is 60pF, differential capacitance across the VGA outputs is 10pF, R_L = 1kΩ, T_A = 0°C to +70°C. Typical values are at V_{CC} = V_{REF} = 5V, T_A = +25°C, unless otherwise noted.)

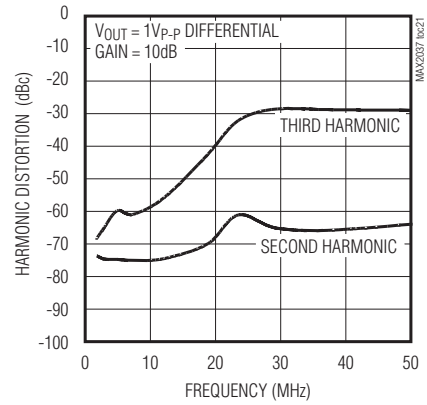
HARMONIC DISTORTION vs. DIFFERENTIAL OUTPUT LOAD RESISTANCE



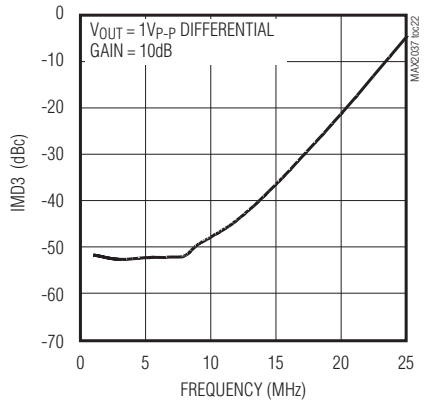
HARMONIC DISTORTION vs. DIFFERENTIAL OUTPUT LOAD CAPACITANCE



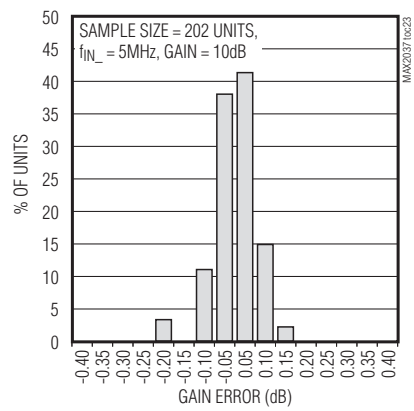
HARMONIC DISTORTION vs. FREQUENCY



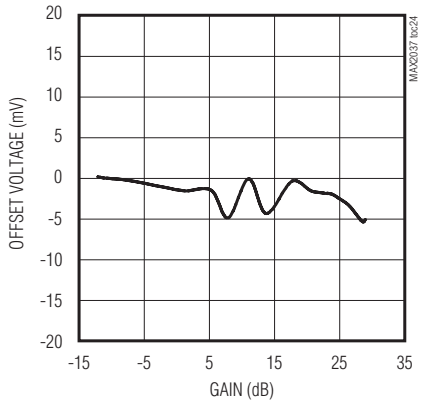
TWO-TONE ULTRASOUND-SPECIFIC IMD3 vs. FREQUENCY



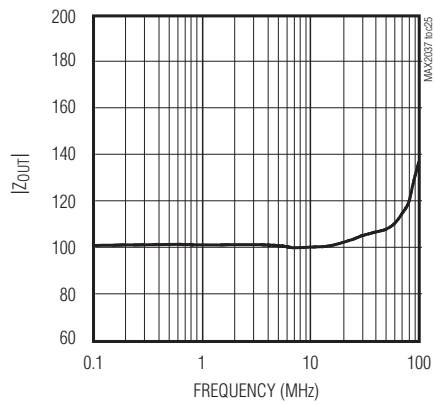
GAIN ERROR HISTOGRAM



OUTPUT COMMON-MODE OFFSET VOLTAGE vs. GAIN



DIFFERENTIAL OUTPUT IMPEDANCE MAGNITUDE vs. FREQUENCY



引脚说明

引脚	名称	功能
1, 2, 5, 6, 7, 10, 11, 12, 19, 20, 21, 24, 25, 26, 29, 30, 31, 34, 35, 36, 41, 43, 44, 45, 47, 48, 51, 55, 58, 59, 64, 65, 66, 69, 73, 76, 79, 80, 81, 83, 84, 85, 88–92, 96, 97, 98	GND	地。
3	VGIN3-	VGA通道3反相差分输入。
4	VGIN3+	VGA通道3同相差分输入。
8	VGIN4-	VGA通道4反相差分输入。
9	VGIN4+	VGA通道4同相差分输入。
13	EXT_C1	外部补偿，通过一个4.7µF电容接地。
14	EXT_C2	外部补偿，通过一个4.7µF电容接地。
15	EXT_C3	外部补偿，通过一个4.7µF电容接地。
16, 39, 42, 46, 54, 72, 82, 87	V_{CC}	5V电源，在尽可能靠近引脚处将每个V_{CC}端通过0.1µF电容旁路至地。
17	VGIN5-	VGA通道5反相差分输入。
18	VGIN5+	VGA通道5同相差分输入。
22	VGIN6-	VGA通道6反相差分输入。
23	VGIN6+	VGA通道6同相差分输入。
27	VGIN7-	VGA通道7反相差分输入。
28	VGIN7+	VGA通道7同相差分输入。
32	VGIN8-	VGA通道8反相差分输入。
33	VGIN8+	VGA通道8同相差分输入。
37, 93	V_{REF}	5V基准电源，在尽可能靠近引脚处通过0.1µF电容旁路至GND。注意：器件的噪声性能取决于V_{REF}端的电源噪声，V_{REF}端要使用低噪声电源。如果V_{CC}电源噪声低的话，可以将V_{REF}和V_{CC}连接在一起，使用同一电源。
38	EXT_RES	外部电阻，通过一个7.5kΩ电阻接地。
40	PD	关断开关，器件在PD为高电平时处于关断模式，PD为低电平时正常工作。
49	VGOUT8+	VGA通道8同相差分输出。
50	VGOUT8-	VGA通道8反相差分输出。
52	VGOUT7+	VGA通道7同相差分输出。
53	VGOUT7-	VGA通道7反相差分输出。
56	VGOUT6+	VGA通道6同相差分输出。
57	VGOUT6-	VGA通道6反相差分输出。
60	VGOUT5+	VGA通道5同相差分输出。

引脚说明(续)

引脚	名称	功能
61	VGOUT5-	VGA通道5反相差分输出。
62	VG_CTL-	VGA模拟增益控制反相输入。
63	VG_CTL+	VGA模拟增益控制同相输入。
67	VGOUT4+	VGA通道4同相差分输出。
68	VGOUT4-	VGA通道4反相差分输出。
70	VGOUT3+	VGA通道3同相差分输出。
71	VGOUT3-	VGA通道3反相差分输出。
74	VGOUT2+	VGA通道2同相差分输出。
75	VGOUT2-	VGA通道2反相差分输出。
77	VGOUT1+	VGA通道1同相差分输出。
78	VGOUT1-	VGA通道1反相差分输出。
86	VG_CLAMP_MODE	VGA箝位模式使能，VG_CLAMP_MODE为低电平时使能VGA箝位，VGA箝位后差分输出的典型值是2.4V_{P-P}。VG_CLAMP_MODE为高电平时禁止VGA箝位。
94	VGIN1-	VGA通道1反相差分输入。
95	VGIN1+	VGA通道1同相差分输入。
99	VGIN2-	VGA通道2反相差分输入。
100	VGIN2+	VGA通道2同相差分输入。
—	EP	裸焊盘，内部连接至GND，通过多个过孔连接到地层。

详细说明

MAX2037 VGA经过优化具有高线性度、大动态范围、低输出噪声等特性，是超声成像应用中的理想器件。VGA通道间的串扰在10MHz时为-80dB，VGA绝对增益误差小于±0.25dB，使超声系统中通道间的聚焦误差最小。每个VGA通道都包括模拟增益调整电路、具有差分输出(VGOUT_+，VGOUT_-)的缓冲器(用于驱动ADC)和差分输入端口(VGIN_+，VGIN_-)，可直接与MAX2034四通道LNA连接，请参考*功能框图*。

VGA可调增益范围为-12.5dB至+29.5dB，总动态范围可达42dB。VGA增益可通过差分增益控制输入端VG_CTL+和VG_CTL-调整。当差分增益控制输入电压为-2V时增益最大，为+2V时增益最小。差分模拟控制共模电压的典型值是3.0V。

VGA箝位

箝位电路限制VGA输出信号，避免ADC过载或饱和。将VG_CLAMP_MODE置为低电平时，可将VGA差分输出箝位至2.4V_{P-P}。VG_CLAMP_MODE为高电平时，禁止箝位功能。

关断

器件可通过PD控制进入关断模式，将PD置为逻辑高电平时器件处于关断模式。关断模式下器件消耗的总电流为27mA。将PD置为逻辑低电平时，器件正常工作。

过载恢复

成像系统中，超声波输入到缓冲器的信号幅度非常大，该器件经过优化可以在这样的条件下进行快速的过载恢复。从发送端引起过载到快速恢复的时间请参考*典型工作特性*。

应用信息

外部补偿

外部补偿用来旁路内部偏置。分别在EXT_C1、EXT_C2、EXT_C3 (引脚13、14、15)与地之间连接一个4.7µF的电容，电容须尽可能靠近引脚放置。

外部偏置电阻

EXT_RES处的外部偏置电阻用于设置内部偏压。将EXT_RES (引脚38)通过7.5kΩ电阻接地，电阻须尽可能靠近引脚放置。

模拟输入和输出耦合

典型应用中，MAX2037由一个低噪声放大器(如MAX2034)驱动，并通过一个分立式差分、抗混叠滤波器驱动ADC (如MAX1436 8路ADC)。MAX2037的差分输入阻抗典型值为200Ω。差分输出可以驱动1000Ω差分负载，差分输出电阻为100Ω。差分输出端具有大约3.0V的共模偏压。如果下一级电路具有不同的共模输入范围，差分输出可采用交流耦合。

超声规范规定的IMD3

与典型的通信规范不同，超声规范定义的双音IMD3指标对应的两个输入音具有不同的幅度。测试中，f_1代表肌肉等组织的反射波，f_2代表血液的反射波。后者一般比前者在幅度上低25dB，所以这种测量方式中，双音输入的其中一个比另一个低25dB。在超声应用中，IMD3产物($f_1 - (f_2 - f_1)$)表现为一个不希望产生的、错误的多普勒信号，见图1。

电路板布局

MAX2037的引脚排列经过优化后能够很方便地与相关的分立元件连接，实现紧凑的物理布局。通常情况下，该器件与几个类似器件一起构成多通道信号处理系统。

MAX2037采用TQFP-EP封装，其裸焊盘(EP)提供了一个与管芯之间的低热阻通路。设计PCB时，借助MAX2037的裸焊盘散热非常重要。此外，将裸焊盘通过一个低电感路径连接至电气地。裸焊盘**必须**直接或通过一系列电镀过孔焊接至PCB的地层。

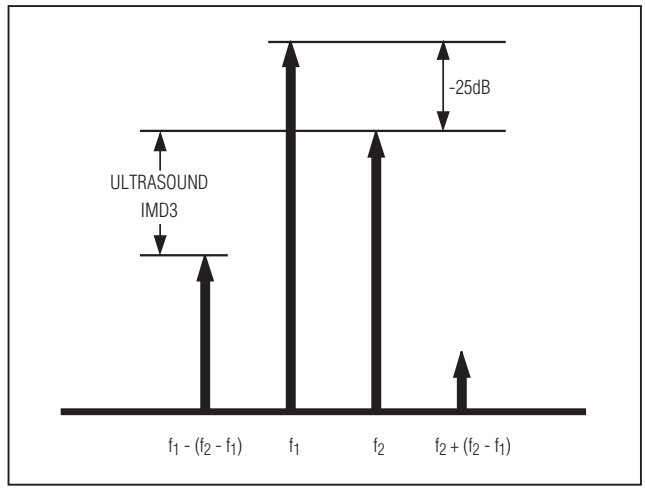


图1. 超声IMD3测量技术

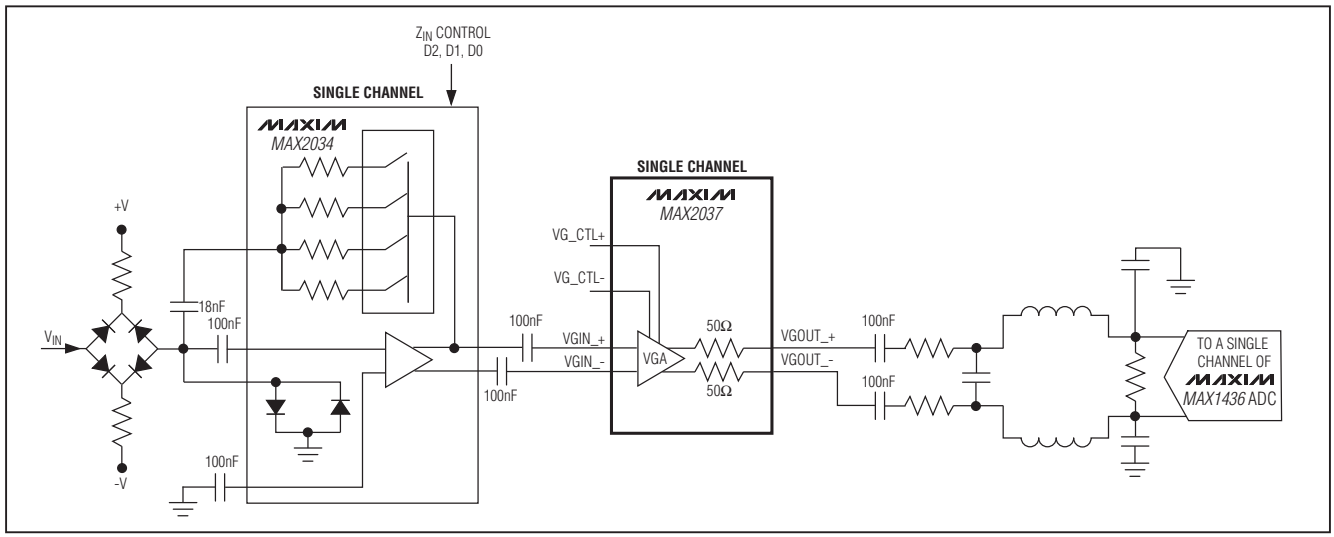
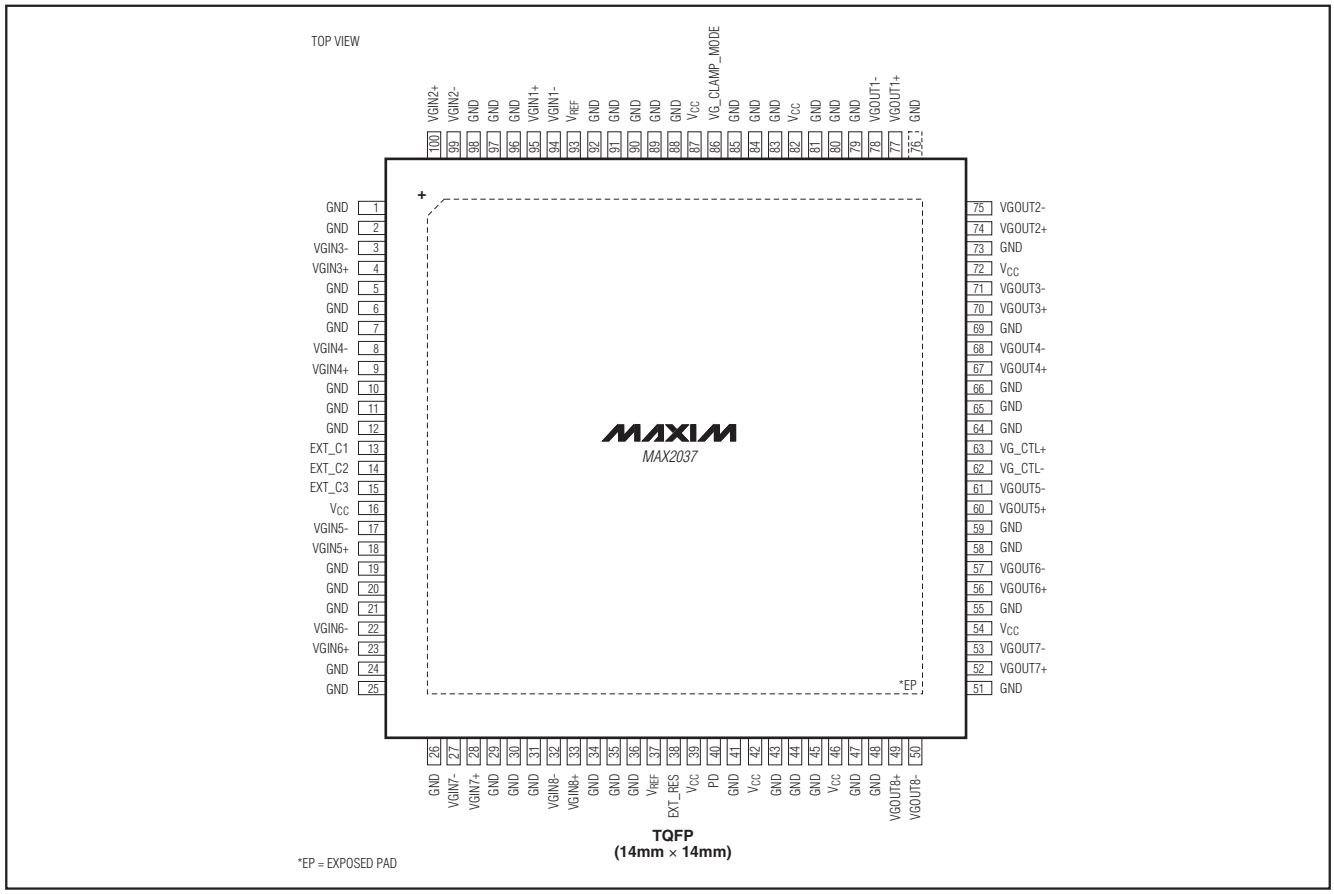


图2. 每个通道的超声成像典型应用

引脚配置



芯片信息

PROCESS: Silicon Complementary Bipolar

封装信息

如需最近的封装外形信息和焊盘布局，请查询 **www.maxim-ic.com.cn/packages**。

封装类型	封装编码	文档编号
100 TQFP-EP	C100E+3	**21-0116**

修订历史

修订次数	修订日期	说明	修改页
0	10/06	最初版本。	—
1	2/09	更新了多处内容。	1–7, 9, 12

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