SBOS185D – JANUARY 2001 – REVISED MARCH 2003

Dual, VARIABLE GAIN AMPLIFIER with Input Buffer

FEATURES

- GAIN RANGE: 40dB
- 40MHz BANDWIDTH
- LOW CROSSTALK: 70dB at Max Gain, 5MHz
- HIGH-SPEED VARIABLE GAIN ADJUST
- POWER SHUTDOWN MODE
- HIGH IMPEDANCE INPUT BUFFER

APPLICATIONS

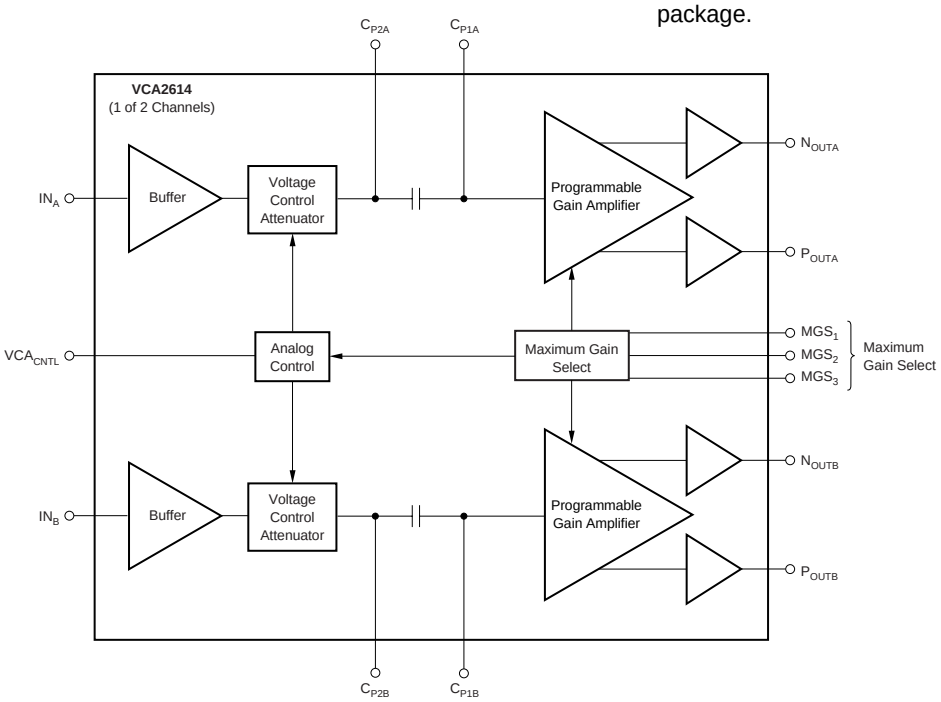
- ULTRASOUND SYSTEMS
- GAMMA CAMERAS
- WIRELESS RECEIVERS
- TEST EQUIPMENT

DESCRIPTION

The VCA2614 is a highly integrated, dual receive channel, Variable Gain Amplifier (VGA) with analog gain control.

The VCA2614's VGA section consists of two parts: the Voltage Controlled Attenuator (VCA) and the Programmable Gain Amplifier (PGA). The gain and gain range of the PGA can be digitally programmed. The combination of these two programmable elements results in a variable gain ranging from 0dB up to a maximum gain as defined by the user through external connections. The single-ended unity gain input buffer provides predictable high input impedance. The output of the VGA can be used in either a single-ended or differential mode to drive high-performance Analog-to-Digital Converters (ADCs). A separate power-down pin reduces power consumption.

The VCA2614 also features low crosstalk and outstanding distortion performance. The combination of low noise and gain range programmability makes the VCA2614 a versatile building block in a number of applications where noise performance is critical. The VCA2614 is available in a TQFP-32 package.



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ABSOLUTE MAXIMUM RATINGS[1]

Power Supply ($+V_S$)	+6V
Analog Input	–0.3V to ($+V_S$ + 0.3V)
Logic Input	–0.3V to ($+V_S$ + 0.3V)
Case Temperature	+100°C
Junction Temperature	+150°C
Storage Temperature	–40°C to +150°C

NOTE: (1) Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. Exposure to absolute maximum conditions for extended periods may affect device reliability.

ELECTROSTATIC DISCHARGE SENSITIVITY

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

PACKAGE/ORDERING INFORMATION

PRODUCT	PACKAGE-LEAD	PACKAGE DESIGNATOR[1]	SPECIFIED TEMPERATURE RANGE	PACKAGE MARKING	ORDERING NUMBER	TRANSPORT MEDIA, QUANTITY
VCA2614Y	TQFP-32 Surface-Mount	PBS	–40°C to +85°C	VCA2614Y	VCA2614Y/250	Tape and Reel, 250
"	"	"	"	"	VCA2614Y/2K	Tape and Reel, 2000

NOTE: (1) For the most current specifications and package information, refer to our web site at www.ti.com.

ELECTRICAL CHARACTERISTICS

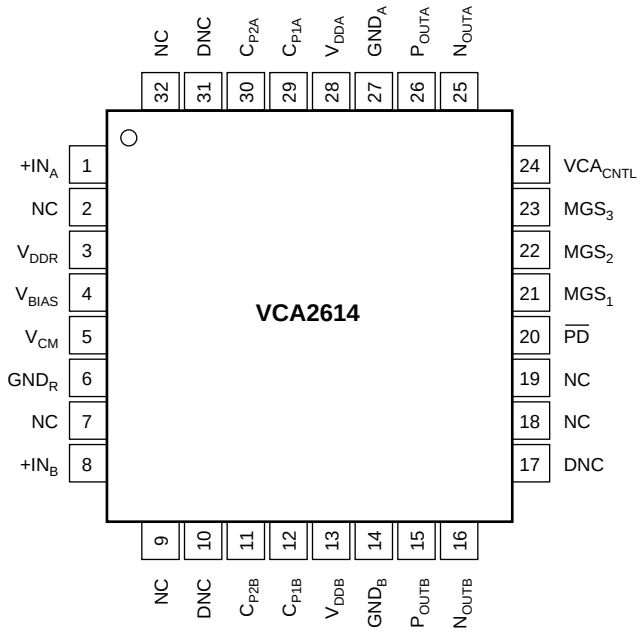
At T_A = +25°C, V_{DD} = 5V, load resistance = 500Ω on each output to ground differential output (2Vp-p), MGS = 011, and f_{IN} = 5MHz, unless otherwise noted.

PARAMETER	CONDITIONS	VCA2614Y MIN	VCA2614Y TYP	VCA2614Y MAX	UNITS
BUFFER					
Input Resistance			600		kΩ
Input Capacitance			5		pF
Input Bias Current			1		nA
Maximum Input Voltage			1		Vp-p
Input Voltage Noise	MGS = 111, PGA Gain = 44.2dB, R_S = 50Ω		4.8		nV/√Hz
Input Current Noise	Independent of Gain		350		fA/√Hz
Noise Figure	R_F = 550Ω, PGA Gain = 44.2dB, R_S = 75Ω		13		dB
Bandwidth			100		MHz
PROGRAMMABLE VARIABLE GAIN AMPLIFIER					
Peak Input Voltage			1		Vp-p
–3dB Bandwidth			40		MHz
Slew Rate			300		V/µs
Output Signal Range	R_L ≥ 500Ω Each Side to Ground		2.5 ±1		V
Output Impedance	f = 5MHz		1		Ω
Output Short-Circuit Current			±40		mA
3rd-Harmonic Distortion	f = 5MHz, V_{OUT} = 2Vp-p, VCA_{CNTL} = 3.0V	–45	–60		dBc
2nd-Harmonic Distortion	f = 5MHz, V_{OUT} = 2Vp-p, VCA_{CNTL} = 3.0V	–45	–50		dBc
Overload Performance (2nd-Harmonic Distortion)	Input Signal = 1Vp-p, MGS = 111, VCA_{CNTL} = 2V		–40 to –45		dB
Time Delay			5		ns
IMD, 2-Tone	V_{OUT} = 2Vp-p, f = 9.95MHz		–59		dBc
Crosstalk			70		dB
Group Delay Variation	1MHz < f < 10MHz, Full Gain Range		13		ns
ACCURACY					
Gain Slope			10.5		dB/V
Gain Error				±2[1]	dB
Output Offset Voltage			±50		mV
GAIN CONTROL INTERFACE					
Input Voltage (VCA_{CNTL}) Range			0.2 to 3.0		V
Input Resistance			1		MΩ
Response Time	40dB Gain Change, MGS = 111		0.2		µs
POWER SUPPLY					
Specified Operating Range		4.75	5.0	5.25	V
Power Dissipation	Operating, Each Channel		120	150	mW
Power-Down			9.2		mW

NOTE: (1) Referenced to best fit dB-linear curve.

PIN CONFIGURATION

Top View **TQFP**



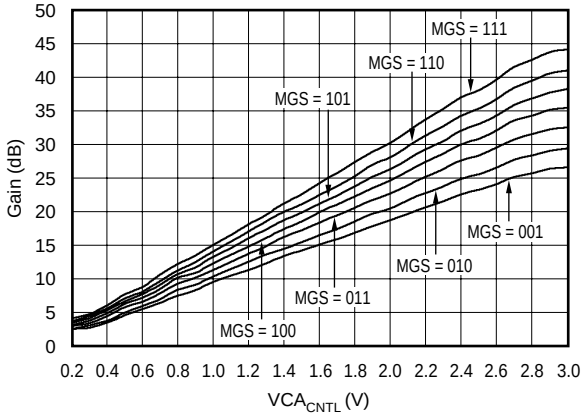
PIN DESCRIPTIONS

PIN	DESIGNATOR	DESCRIPTION	PIN	DESIGNATOR	DESCRIPTION
1	$+IN_A$	Input Channel A	17	DNC	Do Not Connect
2	NC	No Internal Connection	18	NC	No Internal Connection
3	V_{DDR}	Internal Reference Supply	19	NC	No Internal Connection
4	V_{BIAS}	Bias Voltage	20	$\overline{PD}$	Power Down (Active LOW)
5	V_{CM}	Common-Mode Voltage	21	MGS_1	Maximum Gain Select 1 (MSB)
6	GND_R	Internal Reference Ground	22	MGS_2	Maximum Gain Select 2
7	NC	No Internal Connection	23	MGS_3	Maximum Gain Select 3 (LSB)
8	$+IN_B$	Input Channel B	24	VCA_{CNTL}	VCA Analog Control
9	NC	No Internal Connection	25	N_{OUTA}	Negative VCA Output Channel A
10	DNC	Do Not Connect	26	P_{OUTA}	Positive VCA Output Channel A
11	C_{P2B}	Coupling Capacitor Channel B	27	GND_A	Ground Channel A
12	C_{P1B}	Coupling Capacitor Channel B	28	V_{DDA}	+5V Supply Channel A
13	V_{DDB}	+5V Supply Channel B	29	C_{P1A}	Coupling Capacitor Channel A
14	GND_B	Ground Channel B	30	C_{P2A}	Coupling Capacitor Channel A
15	P_{OUTB}	Positive Output Channel B	31	DNC	Do Not Connect
16	N_{OUTB}	Negative Output Channel B	32	NC	No Internal Connection

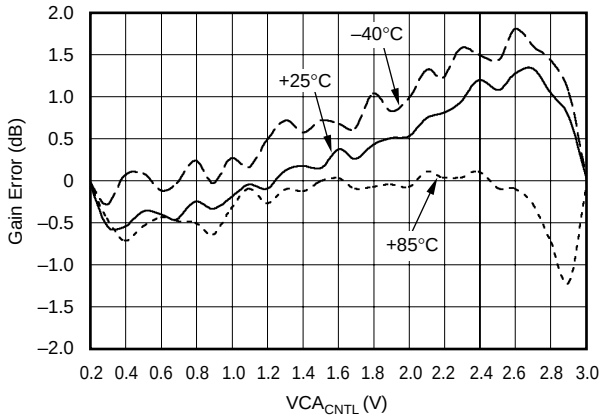
TYPICAL CHARACTERISTICS

At T_A = +25°C, V_{DD} = 5V, load resistance = 500Ω on each output to ground, differential output (2Vp-p) MGS = 011, and f_{IN} = 5MHz, unless otherwise noted.

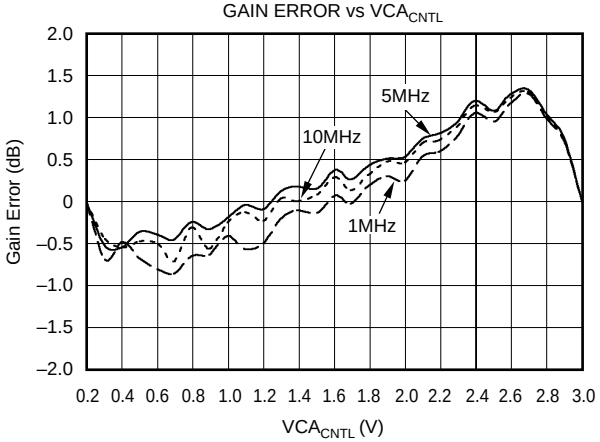
GAIN vs VCA_{CNTL}



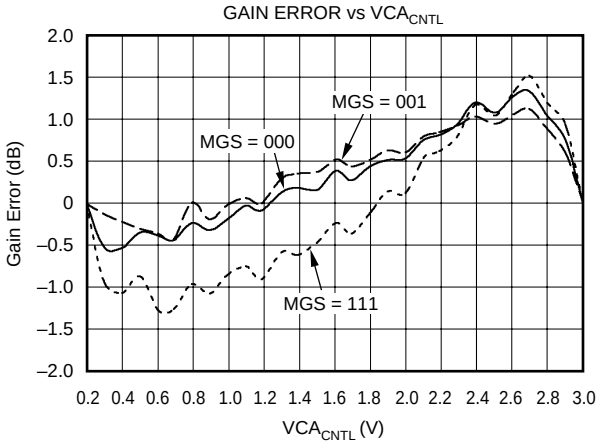
GAIN ERROR vs TEMPERATURE



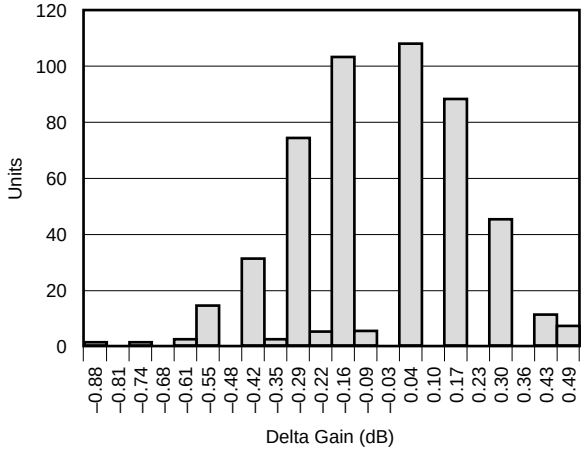
GAIN ERROR vs VCA_{CNTL}



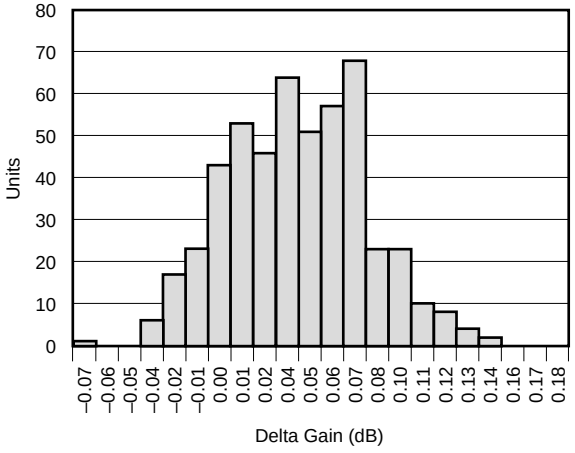
GAIN ERROR vs VCA_{CNTL}



GAIN MATCH: CHA to CHB, VCA_{CNTL} = 0.2V



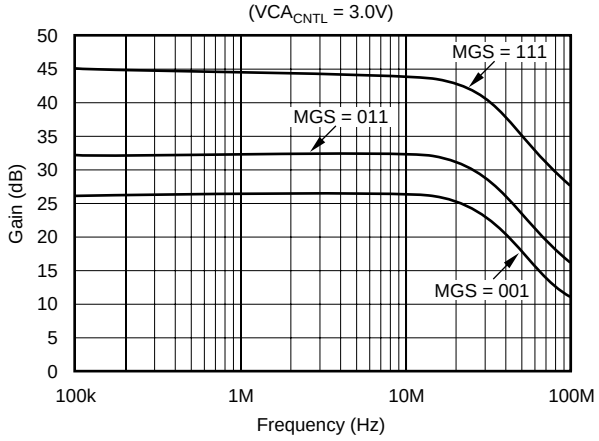
GAIN MATCH: CHA to CHB, VCA_{CNTL} = 3.0V



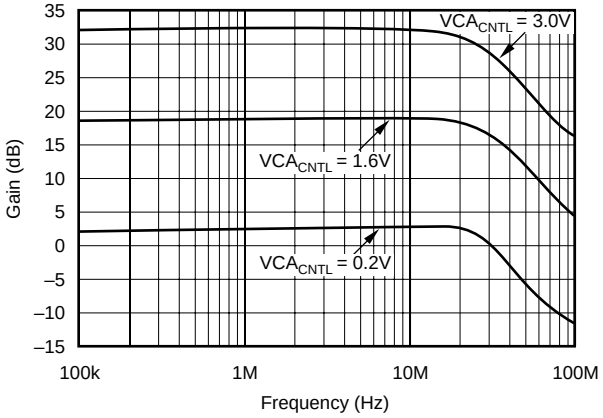
TYPICAL CHARACTERISTICS (Cont.)

At T_A = +25°C, V_{DD} = 5V, load resistance = 500Ω on each output to ground, differential output (2Vp-p) MGS = 011, and f_{IN} = 5MHz, unless otherwise noted.

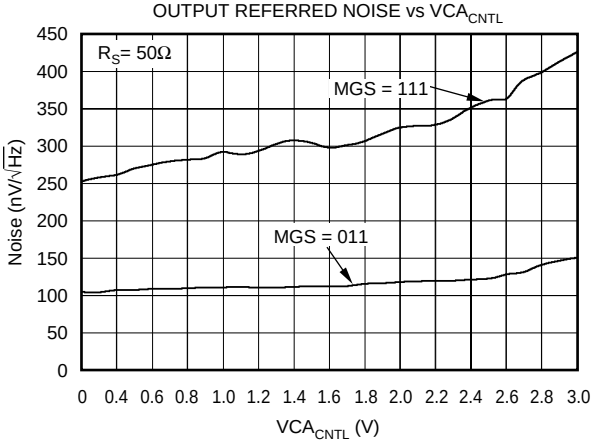
GAIN vs FREQUENCY
(VCA_{CNTL} = 3.0V)



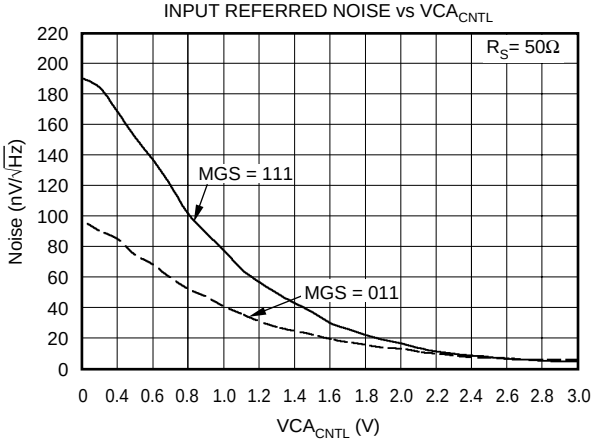
GAIN vs FREQUENCY



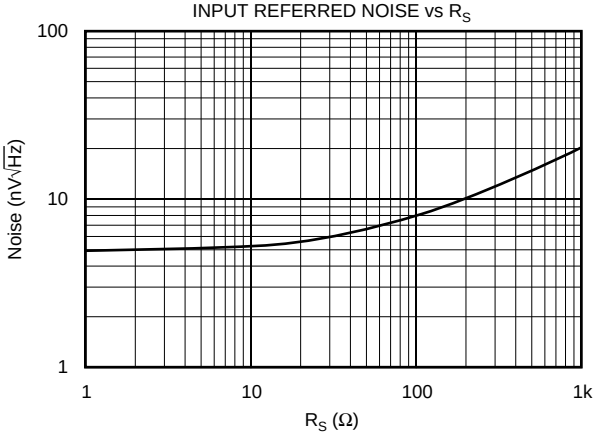
OUTPUT REFERRED NOISE vs VCA_{CNTL}



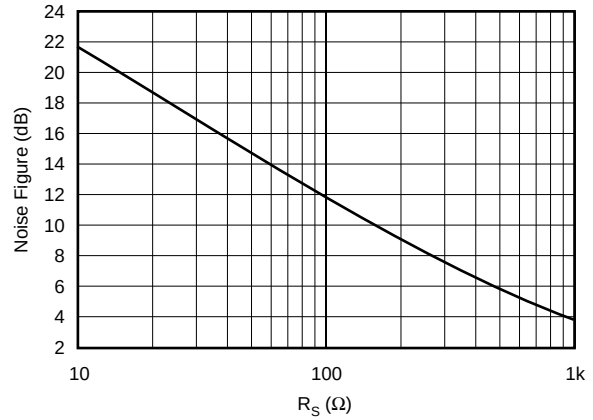
INPUT REFERRED NOISE vs VCA_{CNTL}



INPUT REFERRED NOISE vs R_S



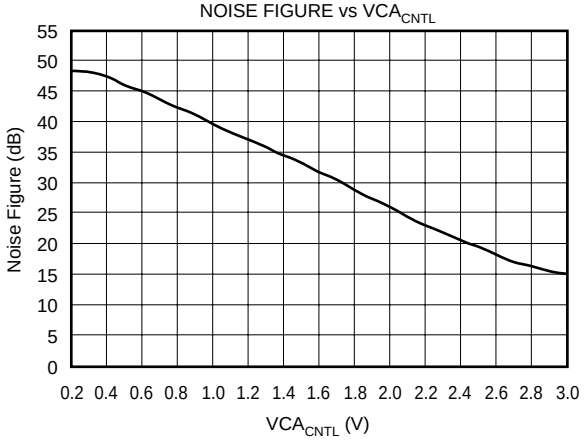
NOISE FIGURE vs R_S



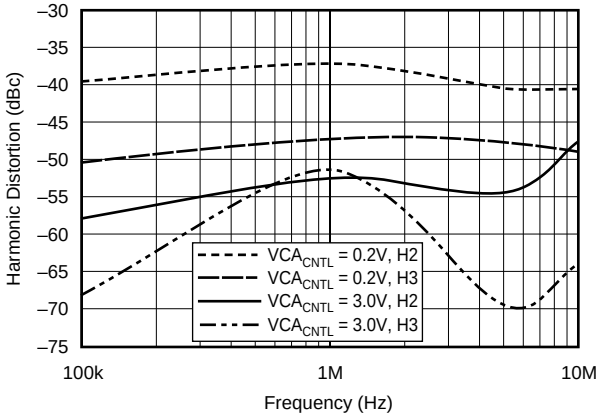
TYPICAL CHARACTERISTICS (Cont.)

At T_A = +25°C, V_{DD} = 5V, load resistance = 500Ω on each output to ground, differential output (2Vp-p) MGS = 011, and f_{IN} = 5MHz, unless otherwise noted.

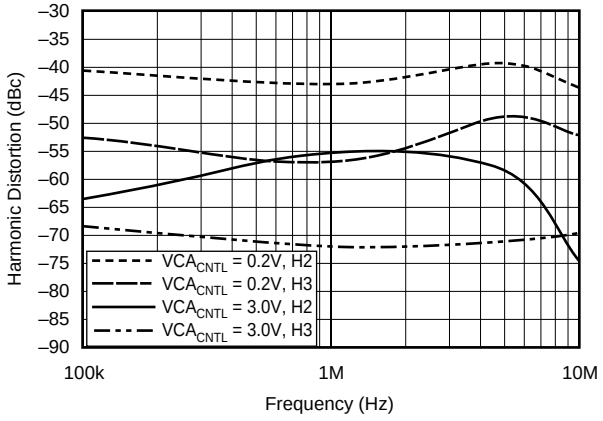
NOISE FIGURE vs VCA_{CNTL}



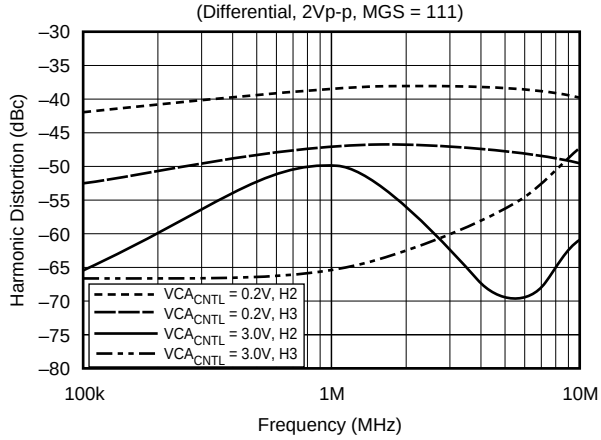
HARMONIC DISTORTION vs FREQUENCY
(Differential, 2Vp-p, MGS = 001)



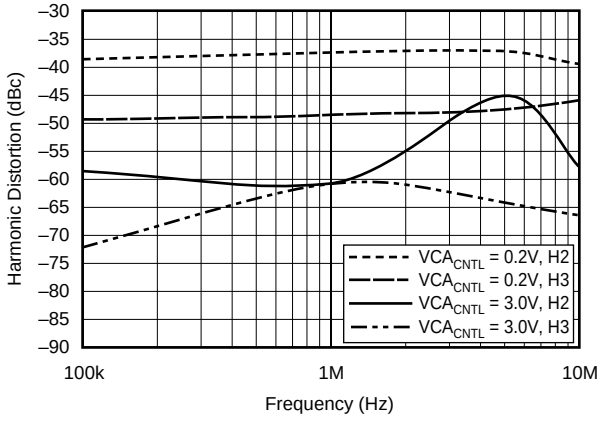
HARMONIC DISTORTION vs FREQUENCY
(Differential, 2Vp-p, MGS = 011)



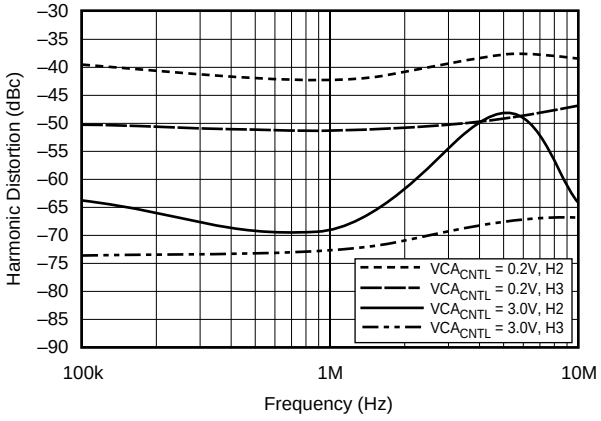
HARMONIC DISTORTION vs FREQUENCY
(Differential, 2Vp-p, MGS = 111)



HARMONIC DISTORTION vs FREQUENCY
(Single-Ended, 1Vp-p, MGS = 001)



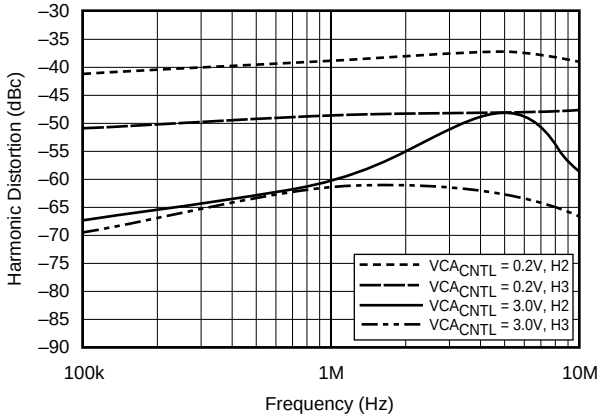
HARMONIC DISTORTION vs FREQUENCY
(Single-Ended, 1Vp-p, MGS = 011)



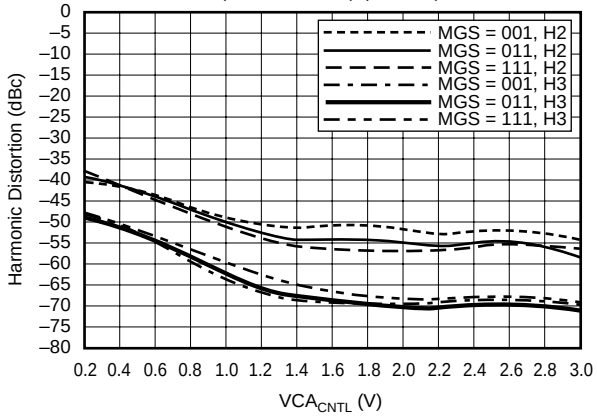
TYPICAL CHARACTERISTICS (Cont.)

At T_A = +25°C, V_{DD} = 5V, load resistance = 500Ω on each output to ground, differential output (2Vp-p) MGS = 011, and f_{IN} = 5MHz, unless otherwise noted.

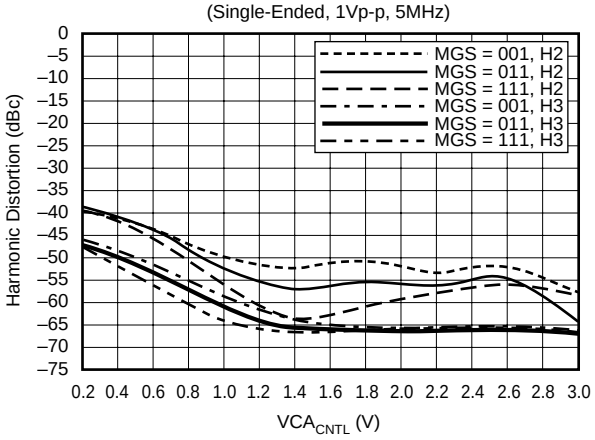
HARMONIC DISTORTION vs FREQUENCY
(Single-Ended, 1Vp-p, MGS = 111)



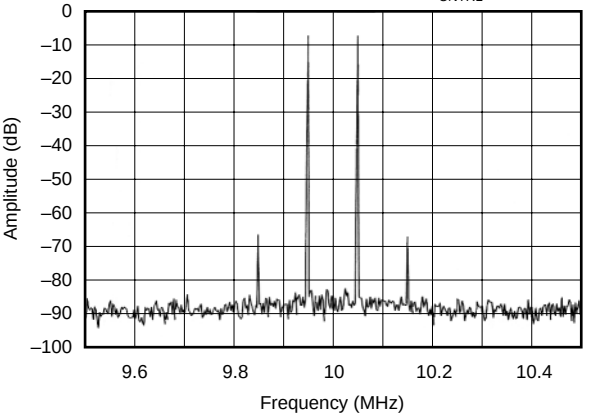
HARMONIC DISTORTION vs VCA_{CNTL}
(Differential, 2Vp-p, 5MHz)



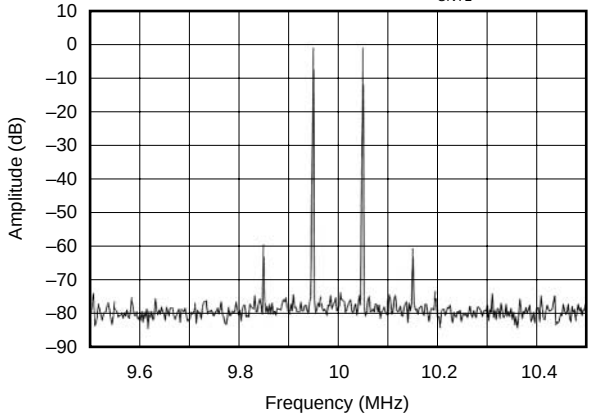
HARMONIC DISTORTION vs VCA_{CNTL}
(Single-Ended, 1Vp-p, 5MHz)



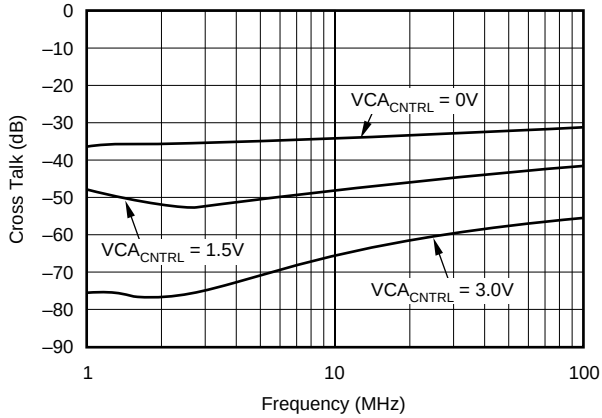
INTERMODULATION DISTORTION
(Single-Ended, 1Vp-p, f = 10MHz, VCA_{CNTRL} = 3.0V)



INTERMODULATION DISTORTION
(Differential, 2Vp-p, f = 10MHz, VCA_{CNTL} = 3.0V)



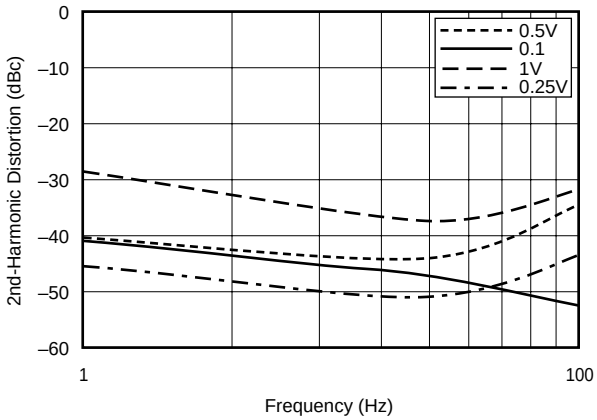
CROSSTALK vs FREQUENCY
(Differential, 2Vp-p, MGS = 011)



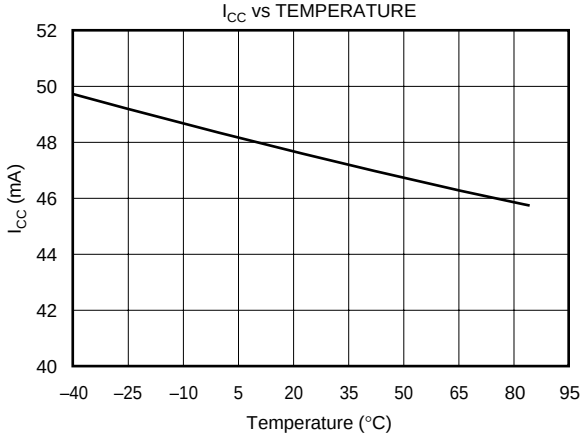
TYPICAL CHARACTERISTICS (Cont.)

At T_A = +25°C, V_{DD} = 5V, load resistance = 500Ω on each output to ground, differential output (2Vp-p) MGS = 011, and f_{IN} = 5MHz, unless otherwise noted.

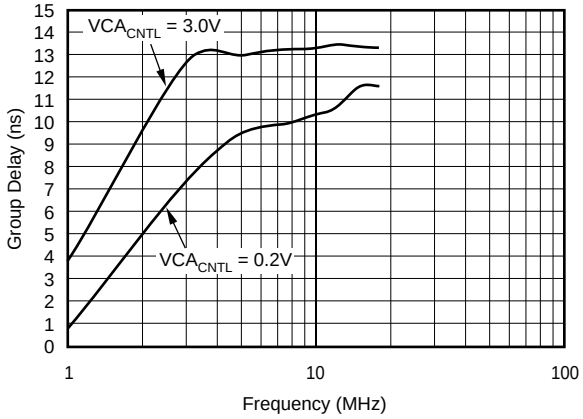
OVERLOAD DISTORTION vs FREQUENCY



I_{CC} vs TEMPERATURE



GROUP DELAY vs FREQUENCY



OVERVIEW

The VCA2614 is a dual-channel, VGA consisting of three primary blocks: an Input Buffer, a VCA, and a PGA (as shown in Figure 1). All stages are AC-coupled with the coupling into the PGA stage being made variable by placing an external capacitor between the C_{P1} and C_{P2} pins. This will be discussed further in the PGA section. By using the internal coupling into the PGA, the result is a high-pass filter characteristic with cutoff at approximately 75kHz. The output PGA naturally rolls off at around 40MHz, making the usable bandwidth of the VCA2614 between 75kHz and 40MHz.

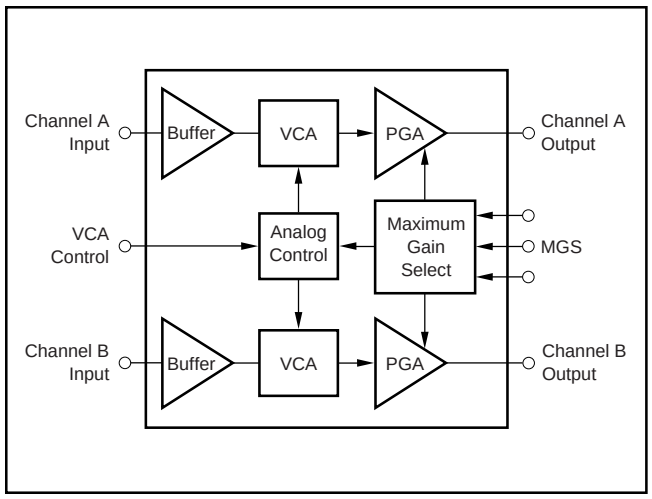


FIGURE 1. Simplified Block Diagram of the VCA2614.

INPUT BUFFER

The input buffer is a unity gain amplifier (gain of +1) with a bandwidth of 100MHz with an input resistance of approximately 600kΩ. The input buffer isolates the circuit driving the VCA2614 inputs from the internal VCA block, which would present a varying impedance to the input circuitry. To allow symmetrical operation of the input buffer, the input to the buffer must be AC-coupled through an external capacitor. The recommended value of the capacitor is 0.01µF. It should be noted that if the capacitor value were increased, the power-on time of the VCA2614 would be increased. If a decrease in the power-on time is needed, the value can be decreased to no less than 100pF.

VOLTAGE-CONTROLLED ATTENUATOR

The magnitude of the VCA input signal from the input buffer is reduced by a programmable attenuation factor, set by the analog VCA Control Voltage (VCA_{CNTL}) at pin 24. The maximum attenuation is programmable by using the three MGS bits (pins 21, 22, and 23). Figure 2 illustrates this dual-adjust characteristic.

The MGS bits adjust the overall range of attenuation and maximum gain while the VCA_{CNTL} voltage adjusts the actual attenuation factor. At any given maximum gain setting, the analog variable gain characteristic is linear in dB as a function of the control voltage, and is created as a piecewise approximation of an ideal dB-linear transfer function, see Figure 4. The VCA control circuitry is common to both channels of the VCA2614. The range for the VCA_{CNTL} input spans from 0V to 3V. Although overdriving the VCA_{CNTL} input above the recommended 3V maximum will not damage the part, this condition should be avoided.

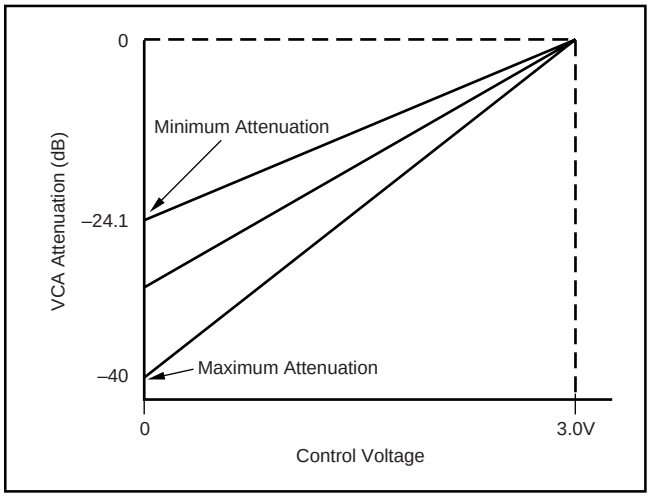


FIGURE 2. Swept Attenuator Characteristic.

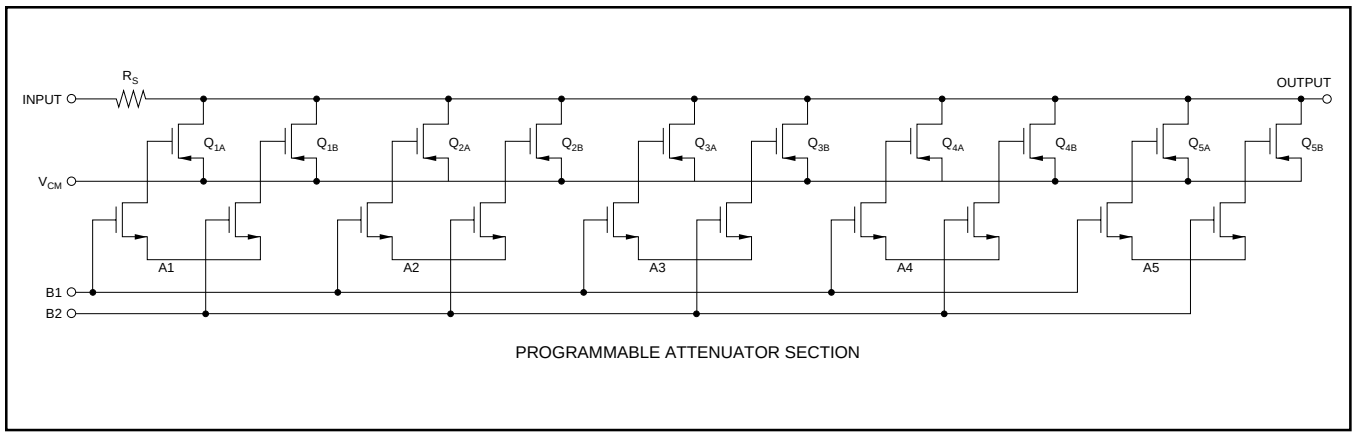


FIGURE 3. Programmable Attenuator Section.

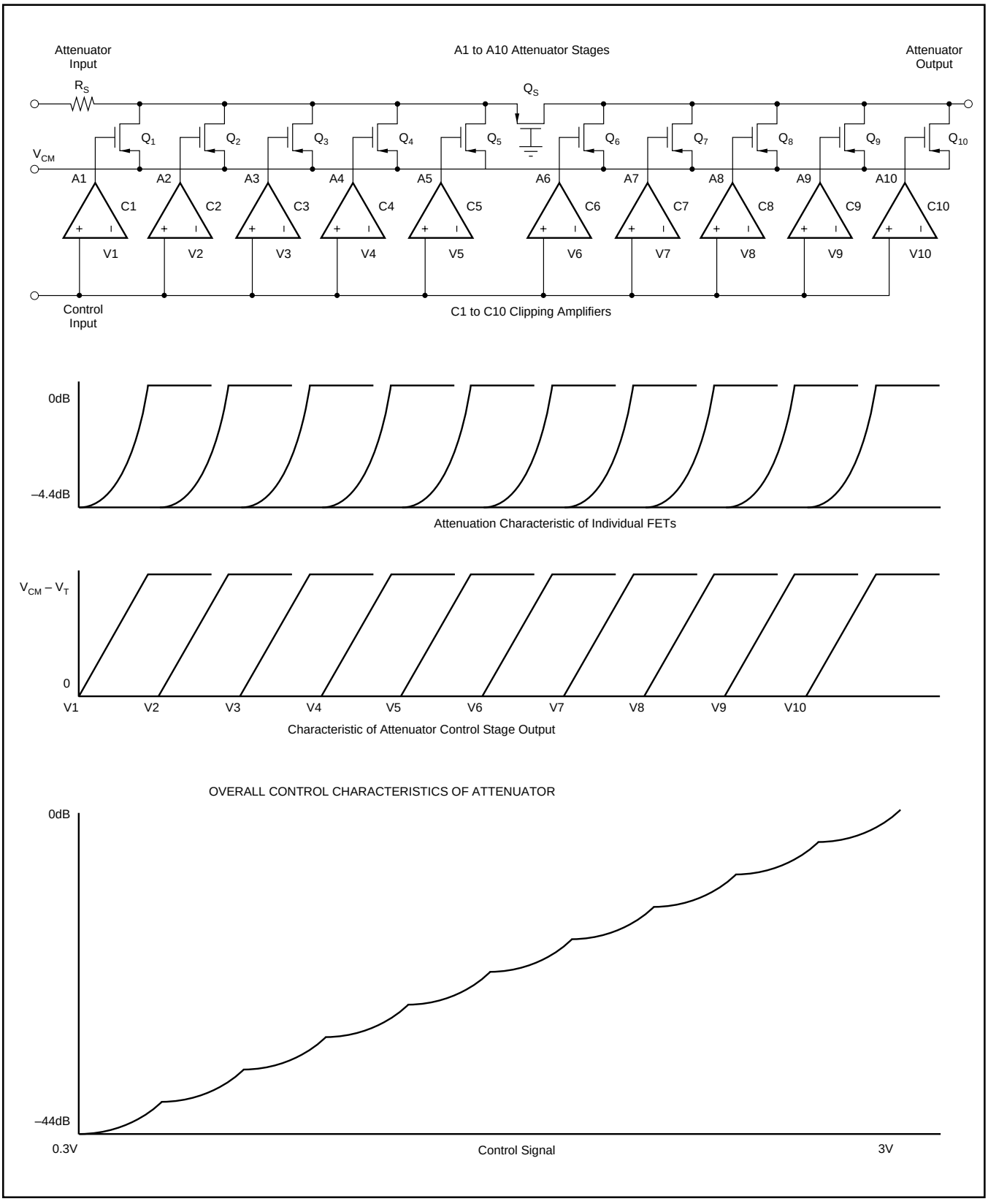


FIGURE 4. Piecewise Approximation to Logarithmic Control Characteristics.

PGA POST-AMPLIFIER

Figure 5 shows a simplified circuit diagram of the PGA block. As stated before, the input to the PGA is AC-coupled by an internal capacitor. Provisions are made so that an external capacitor can be placed in parallel with the internal capacitor, thus lowering the usable low-frequency bandwidth. The low-frequency bandwidth is set by the following equation:

$$\frac{1}{\left(2 \bullet \pi \bullet 500k\Omega \bullet \left(220pF + C_{EXTERNAL}\right)\right)}$$

where $C_{EXTERNAL}$ is the external capacitor value in picofarads.

Care should be taken to avoid using too large a value of capacitor, as this can increase the power-on delay time.

As described previously, the PGA gain is programmed with the same MGS bits that control the VCA maximum attenuation factor. Specifically, the maximum PGA gain at each MGS setting is the inverse (reciprocal) of the maximum VCA attenuation at that setting. Therefore, the VCA + PGA overall gain will always be 0dB (unity) when the analog VCA_{CNTL} input is set to 0V (the maximum attenuation for VCA). For VCA_{CNTL} = 3V (no attenuation), the VCA + PGA gain will be controlled by the programmed PGA gain. For clarity, the gain and attenuation factors are detailed in Table I.

The PGA architecture converts the single-ended signal from the VCA into a differential signal. Low input noise was also a requirement of the PGA design due to the large amount of signal attenuation that can be asserted before the PGA. At minimum VCA attenuation (used for small input signals), the input buffer noise dominates; at maximum VCA attenuation (large input signals), the PGA noise dominates. Note that if the PGA output is used single-ended, the apparent gain will be 6dB lower.

MGS SETTING	ATTENUATOR GAIN VCA_{CNTL} = 0.02V to 3V	ATTENUATOR + DIFFERENTIAL PGA GAIN
000	Not Valid	Not Valid
001	–24.1dB to 0dB	2.6dB to 26.7dB
010	–26.9dB to 0dB	2.6dB to 29.5dB
011	–29.5dB to 0dB	3.0dB to 35.6dB
100	–32.4dB to 0dB	3.1dB to 35.5dB
101	–34.8dB to 0dB	3.4dB to 38.3dB
110	–37.3dB to 0dB	3.7dB to 44.1dB
111	–40.0dB to 0dB	4.1dB to 44.2dB

TABLE I. MGS Settings.

LAYOUT CONSIDERATIONS

The VCA2614 is an analog amplifier capable of high gain. When working on a PCB layout for the VCA2614, it is recommended to utilize a solid ground plane that is connected to analog ground. This helps to maximize the noise performance of the VCA2614.

Adequate power-supply decoupling must be used in order to achieve the best possible performance. Decoupling capacitors on the VCA_{CNTL} voltage should also be used to help minimize noise. Recommended values can be obtained from the layout diagram of Figure 6.

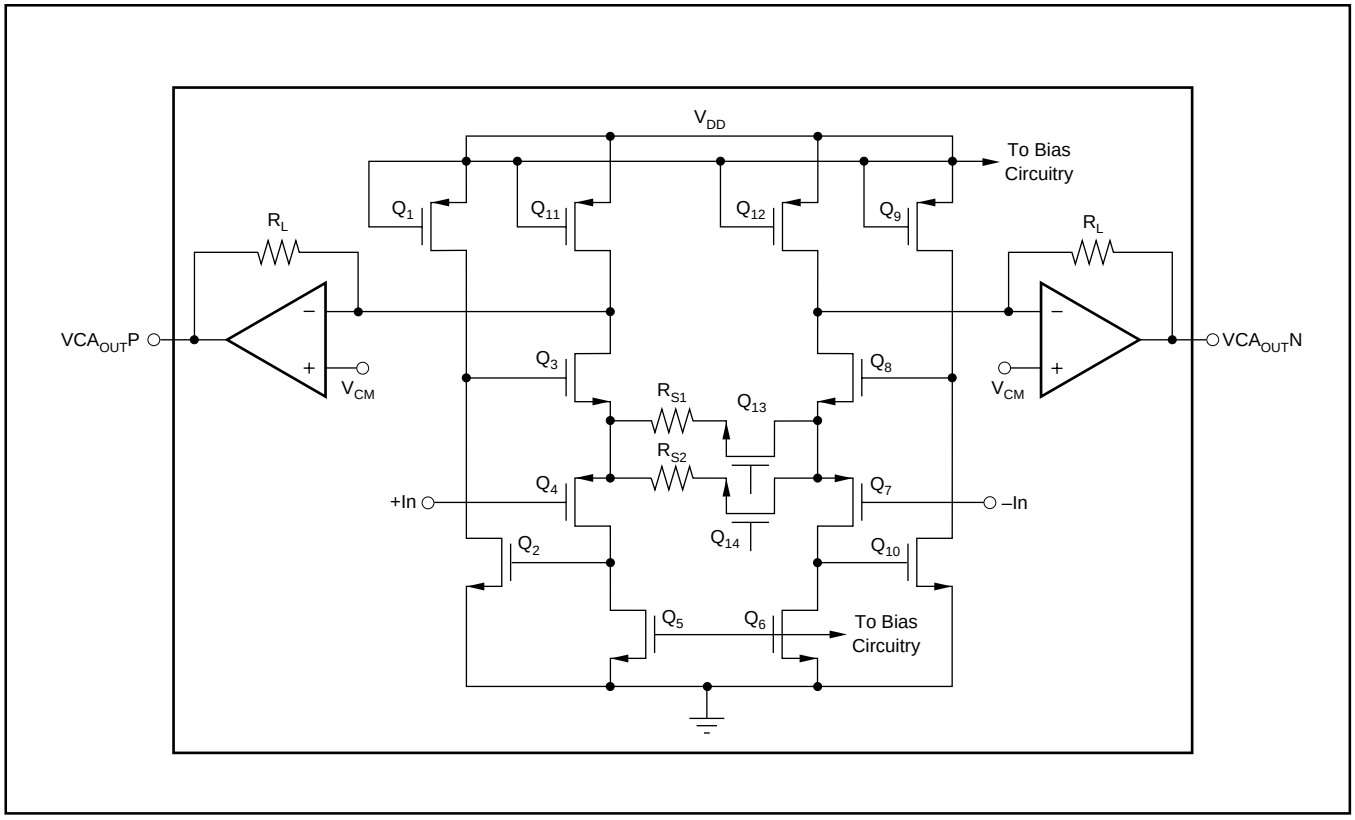


FIGURE 5. Simplified Block Diagram of the PGA Section with the VCA2614.

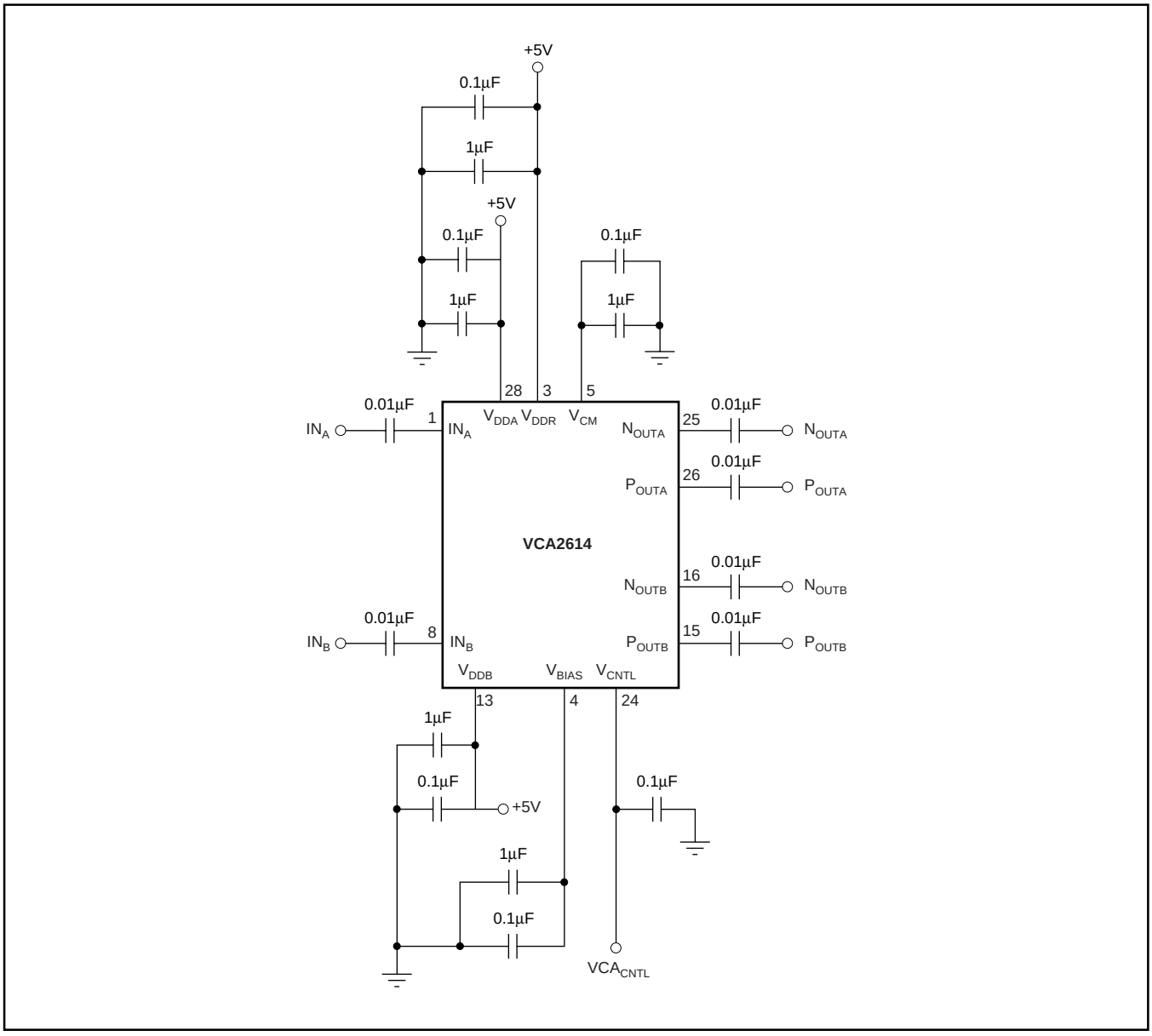
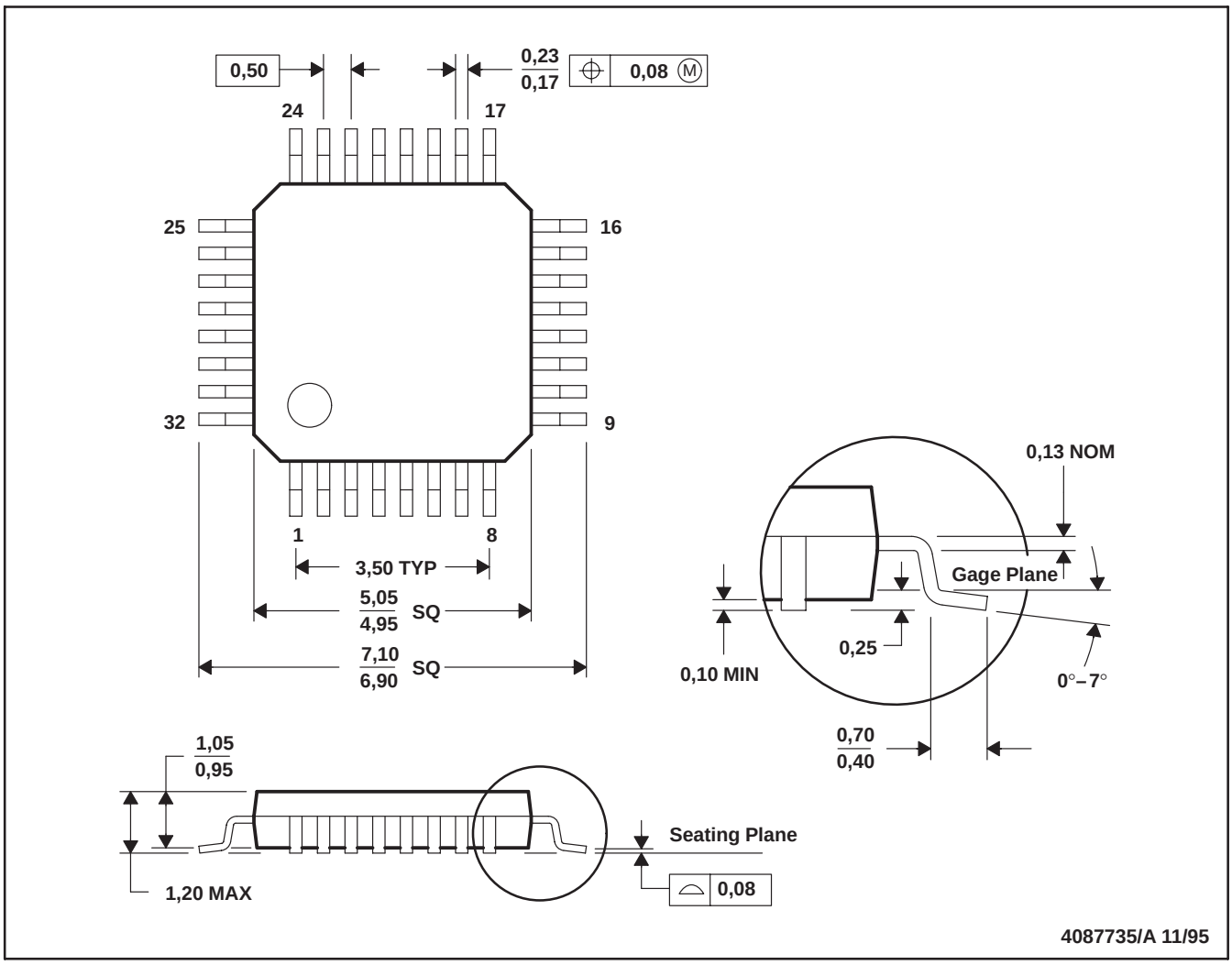


FIGURE 6. VCA2614 Layout.

PACKAGE DRAWING

PBS (S-PQFP-G32) **PLASTIC QUAD FLATPACK**



NOTES: A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)
VCA2614Y/250	ACTIVE	TQFP	PBS	32	250	None	CU SNPB	Level-3-220C-168 HR
VCA2614Y/2K	ACTIVE	TQFP	PBS	32	2000	None	CU SNPB	Level-3-220C-168 HR

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - May not be currently available - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
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(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDECindustry standard classifications, and peak solder temperature.

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