Stony Brook University

College of Engineering and Applied Sciences

ESE 342 - Communication Systems

Amplitude Modulator of a Tonal Message Using a Variable Gain Amplifier

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November 14, 2022

Table of Contents

List of Figures

1 Assignment

Design an amplitude modulator using a variable gain amplifier, such as the HMC694LPE. The baseband signal is given by

$$x(t) = 0.5cos(2\pi f_0 t) + 0.5cos(4\pi f_0 t)\ V \tag{1}$$

The carrier frequency is generated using a dielectric resonator oscillator with an output power of 15dBm at a frequency of 10GHz. The modulated signal should have a mean power of 15dBm with a modulation depth of ± 5 dB. Download the data sheets of the components from the manufacturer or distributor websites to design your modulator circuit to meet the specifications.

[f_0 = 1MHz]

2 Introduction

This report will lay out the design and construction of an Amplitude Modulator with a 10GHz carrier wave. The core of the modulator is a HMC694LPE from *Analog Devices*. Additionally, the design uses a OPA207 Operational Amplifier from *Texas Instruments*, a DRO10000A from *Z-Communications*, and a 30dB attenuator from *Mini-Circuits*. Resistances are assumed to be standard, according to the E24 standard. Common positive power rails are also assumed to be available, such as 5 volts, 10 volts, and 12 volts, with unlimited current draw for each rail. A standard impedance of 50Ω is also assumed throughout this project.

The final schematic is attached on the last page.

3 Dielectric Resonator Oscillator

Instead of using a Dielectric Resonator Oscillator (DRO), we have elected to use a Voltage Controlled Oscillator (VCO). In our research, we found VCOs to be more readily available over DROs. Additionally, the specific VCO used in this project, the DRO10000A from *Z-Communications*, offers a typical power of 0dBm. Thus, we can achieve our desired center power of 15dBm strictly using the Variable Gain Amplifier without any additional amplifiers. A 0dBm VCO was also chosen due to the power limit of 5dBm on the VGA. This does deviate from the assignment prompt, however, we feel as though the chosen method is superior to the original request. If we were to use a DRO at 15dBm, as originally requested, an attenuator would be required, adding complexity and cost to the project.

4 Variable Gain Amplifier

The HMC694LPE Variable Gain Amplifier has 3 core inputs/outputs that are essential to operation: RF In, RF Out, and Control Voltage. RF In will be connected to the DRO's output and has a maximum power rating of 5 dBm, according to the datasheet. The gain is altered by the Control Voltage, meaning that we can control the amplitude of the carrier wave. Thus, we can create an effective amplitude modulator with these two alone. However, we must alter our given inputs to match the specifications of the variable gain amplifier. You already saw an example of this alteration with the DRO and RF In. Let us now see how the signal received by Control Voltage has been manipulated.

4.1 Linear Region

The linear region, that is, the region in which a change in control voltage will linearly change the gain in decibels, is between -1.35V and -1.07V, corresponding to a gain of 20dB and 8dB of gain, respectively. This is especially useful now, since we can predictably alter the message wave without too much effort. Given that we want modulation depth of ± 5dB, and that our positive amplitude of 1 should correspond to 5dB, we can select 15 dB of gain as our midpoint, a control voltage of -1.21V. Thus, calculating 5dB up results in 20 dB of gain, with a control voltage of -1.34V. However, the negative portion of the message is 56.3% the size of its positive amplitude. Thus, our message should only reach -2.815dB from our calculated center point, or 12.185dBm, calculated from $.563 * 5dB$.

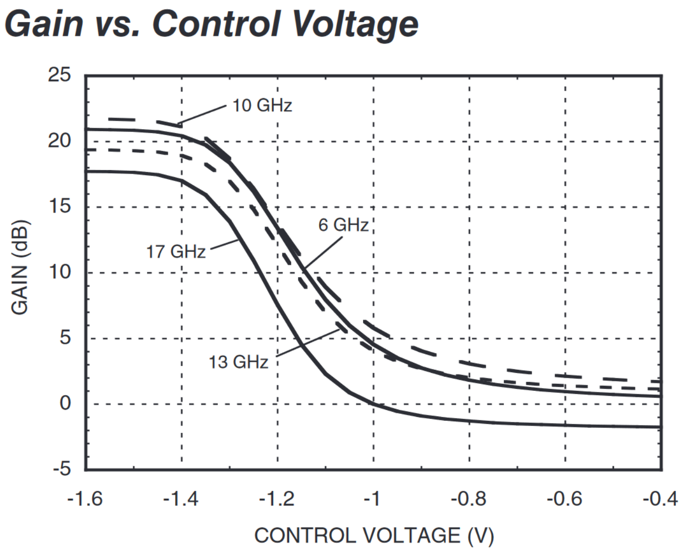


Figure 1: Gain vs Control Voltage of the HMC694LPE

5 Attenuator

It may be confusing that when analyzing the AM output before attenuation, it achieves the goal of ±5dB, however it is not centered at 15dBm. Rather, it is centered at 15dB. Since the HMC694LPE has an operational linear region between 12.2dB and 20dB. When we add this to a carrier wave of 0dBm, we cannot achieve the specifications. Therefore, this circuit must include attenuation to meet specifications. To achieve 15dBm from 15dBW, we must use the equation

$$30 + dB = dBm \tag{2}$$

to know how much attenuation we need. Solving this equation for $dBm = 15$,

$$dB = -15 \tag{3}$$

Therefore, we need to subtract 30dB in since we're at 15dB to achieve -15dBW or 15dBm.

6 Transforming the Message Wave

The message, given by (1) is shown below, between the bounds of 1V to -0.563V. However, as discussed previously, in order for the Variable Gain Amplifier to successfully encode the AM wave it needs the control voltage to vary between -1.34V and -1.21V. Thus, we need to transform the waveform. An Operational Amplifier, in this case an OPA207 from *Texas Instruments*, can configured as an inverting summing amplifier to take care of both summing and attenuation of the signal. The configuration of the amplifier is shown below. Conducting Nodal Analysis of the the inverting amplifier, we see that the output will end up being

$$V_{OUT} = -\frac{R2}{R1} * (V_1 + V_2) \tag{4}$$

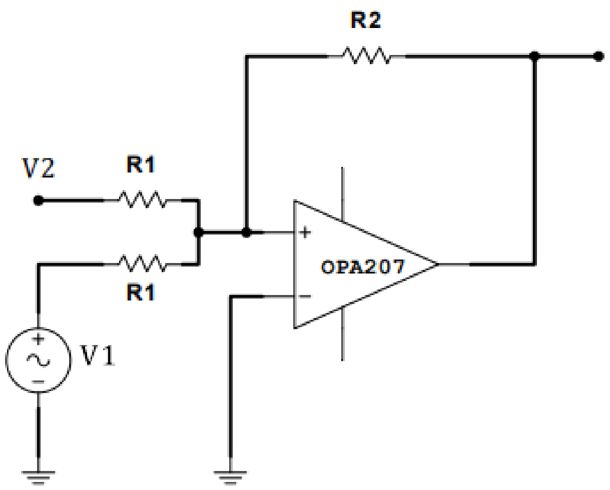


Figure 2: Inverting Summing Amplifier

7 Power

In order to provide power to everything, we can utilize the following current feedback Opamp-based virtual ground driver, provided from TangentSoft 2022. It provides up to 250mA of current and creates a virtual ground, allowing negative voltages, something we need for the HMC694LPE Variable Gain Amplifier.

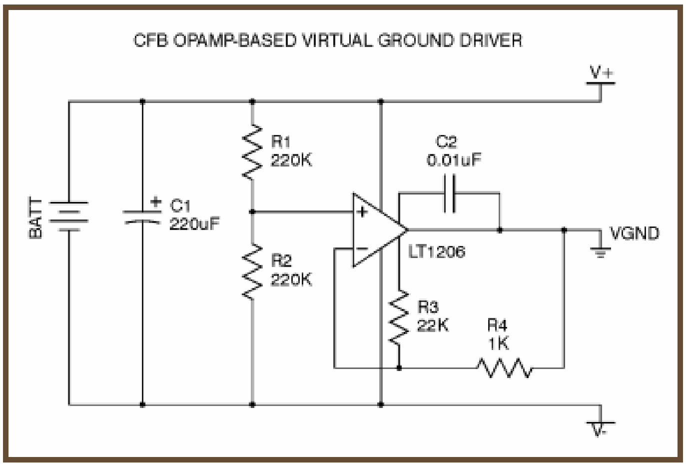


Figure 3: Current Feedback Operational Amplifier Virtual Ground Driver

We must also verify that this power supply can provide the maximum current required by the circuit. We can check all the essential components in this system. All information in the following table has been found from their respective datasheets:

Manufacturer	Component	Datasheet Reference	Max. Current Draw
Z-Communications	DRO10000A	Power Supply Req.: Supply Current	26 mA
Analog Devices	HMC694LPE	Total Supply Current	175 mA
Texas Instruments	OPA 207	Short Circuit Current	40 mA
Mini-Circuits	YAT-30A+	N/A	0mA

Summing the four main power intensive components in this circuit results in 241 mA of maximum current draw. This is cutting it a little close to the maximum current that the power supply can provide, but since it still is within spec, we will assume this power supply to work just fine.

YAT-30A+ Note: The YAT-30A+ is specified in the datasheet that it can take signals up to 1W. The input AM wave reaches up to 20dBm, satisfying this condition. Therefore, it requires no current from the power supply.

8 Simulation

8.1 DRO10000A Voltage Controlled Oscillator

The Dielectric Resonator Oscillator was simulated by its mathematical output in MATLAB. Given that our DRO outputs 0 dBm at 10GHz, we can plot and visualize the carrier frequency. Since we are given the frequency, we can assume the sinusoidal aspect of the wave to be

$$carrierWave = cos(2\pi f_0 t), \quad f_0 = 10GHz \tag{5}$$

Following that, we must determine amplitude. We can use the simple power equation

$$P = \frac{{V_{\text{peak}}}^2}{2} \tag{6}$$

We can also define the power of the signal to be

$$P = 10^{\frac{P_{\text{dBm}}}{20}} * cos(2\pi f_0 t) \tag{7}$$

Putting it all together, we get the following equation representing the DRO:

$$V_{\text{peak}} = (\sqrt{2 * 10^{\frac{P_{\text{dBm}}}{20}}}) * cos(2\pi f_0 t) \tag{8}$$

Thus, in MATLAB, we can use the following line:

```
carrierWave = sqrt(2*10^(carrierdBm/20))*cos(2*pi*carrierFrequency*t);
```

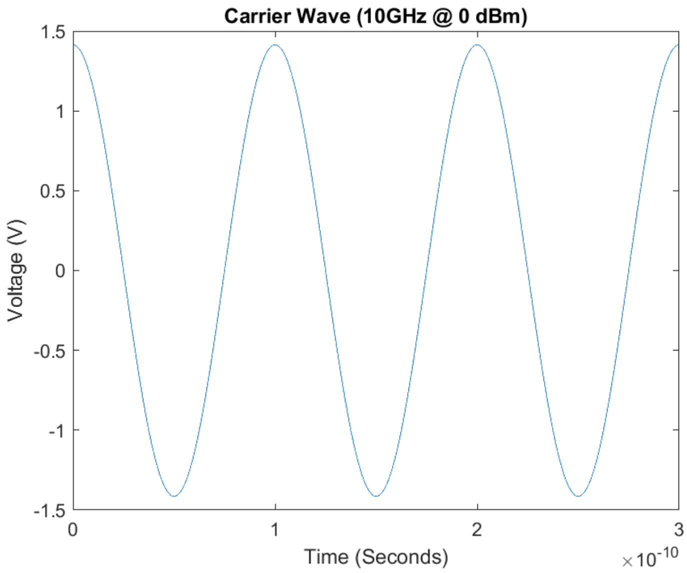
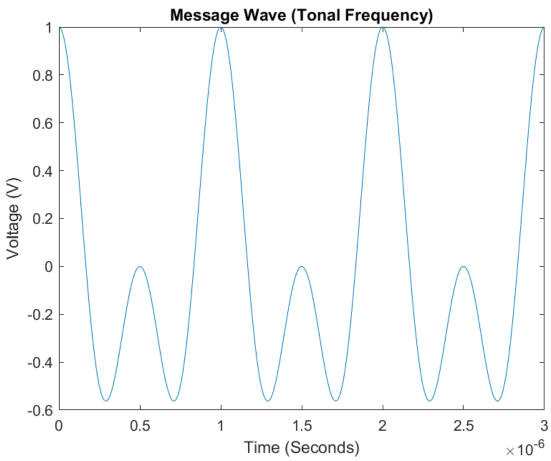


Figure 4: Simulation of a 10GHz signal at 0dBm

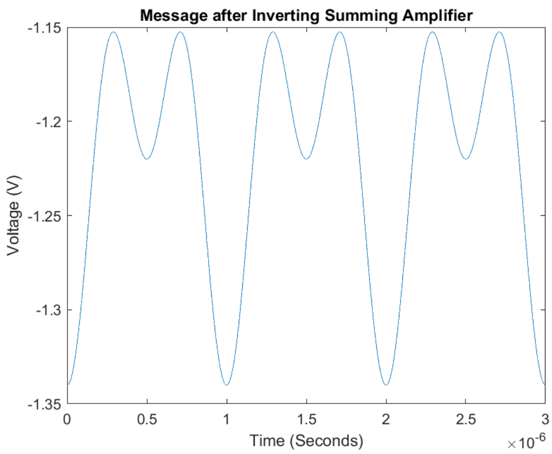
8.2 OPA207 Inverting Summing Amplifier

Through nodal analysis, we have derived equation (4). Thus, simulating the inverting summing amplifier is as simple as plugging in our computed values.

```
messageWave = -(R2/R1)*((messageWave)+(DCOffset))
```



(a) Original Message vs Time



(b) After the Inverting Summing OpAmp

Figure 5: Message Wave before and after the inverting summing op-amp

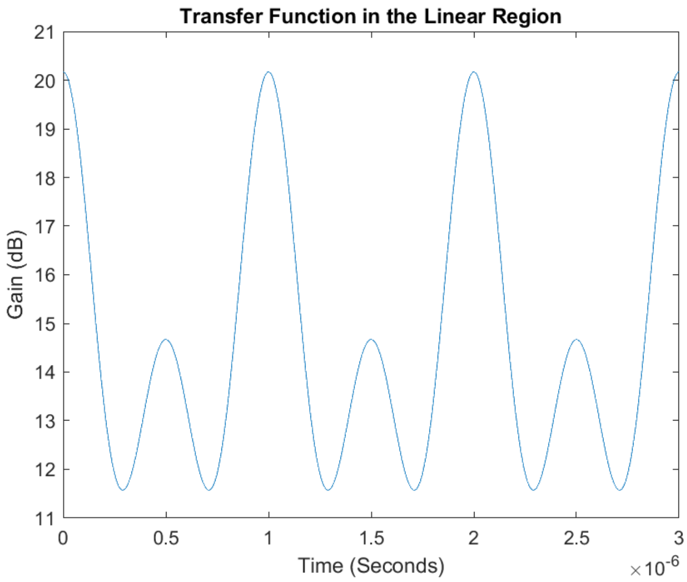


Figure 6: Message Gain as a function of time

8.3 HMC694LPE Variable Gain Amplifier

Linear Region Gain As mentioned in 4.1, we found that the linear region of the Variable Gain Amplifier would be the most useful. As Control Voltage varies, so too does the gain of the VGA, linearly. Thus, to simulate, we must determine the slope and the y-intercept. Instead of manually computing, we made the choice to recompute this regression everytime. If ever a more accurate regression was necessary, it would be as simple as slotting more datapoints into our model.

```
transferFuncDataPoints = [-1.34 -1.22 -1.1;
                          20    15    9]; %A 2d array with datapoints about the
↪   transfer function.
             % Voltage  Gain(dB)  Used to calculate the transfer function
             %To make the transfer function more accurate, take more
             %measurements of the graph "Gain vs Control Voltage" on
             %datasheet
%Peform Linear Regression using the noted date points to create the
%transfer function
regressionX = transferFuncDataPoints(1,:);
regressionY = transferFuncDataPoints(2,:);
mdl = fitlm(regressionX, regressionY);

%Extracted coefficients in the form y=mx+b
m = mdl.Coefficients{2, 1}; %Has units of dB/V
b = mdl.Coefficients{1, 1}; %Has units of dB
fprintf("The regression is calcualted to be y = %fx + %f\n", m, b);

%The linear regression transfer function represents the Analog Variable
%Gain Amplifier. The regression will match the control voltage to its
%corresponding gain (dB). Thus, we will pass the equation into the transfer
%function.
transferFunctionGain = m * messageWave + b;
```

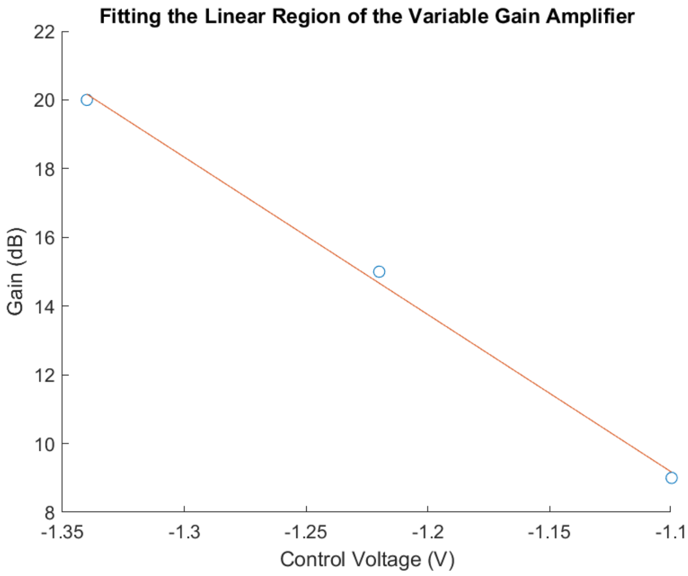


Figure 7: Regression plotted against the measured values

Amplifier Once obtaining the gain produced by the control voltage, we need to add it to our original carrier wave and convert back into voltage.

```
AMWaveV = carrierWave .* 10.^(transferFunctionGain/20);
```

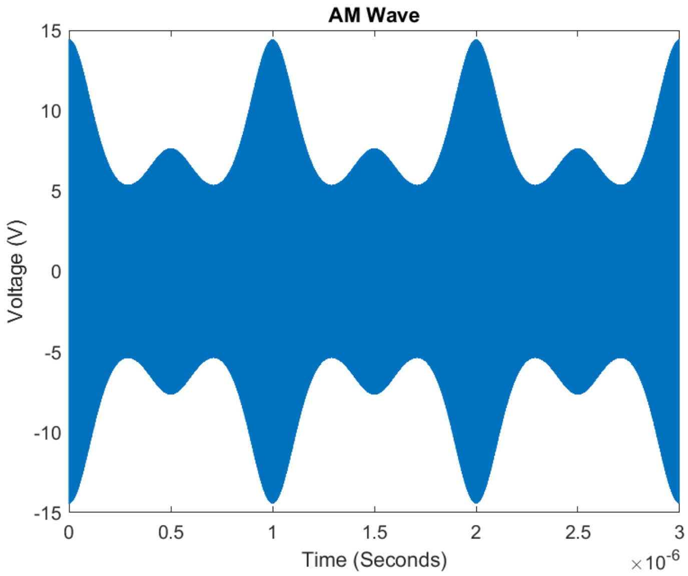


Figure 8: The Amplitude Modulated Wave

8.4 YAT-30A+

Though we now have an amplitude modulated wave, it doesn't conform to 15dBm. Thus running the signal through the 30dB attenuator nets the following waveform:

```
FinalWave = AMWaveV ./10.^(30/20);
```

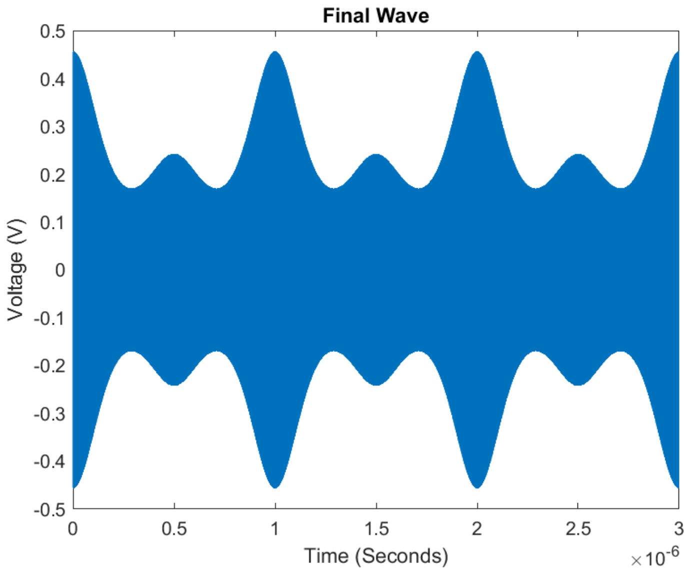


Figure 9: The final attenuated Amplitude Modulated Wave

9 Startup Sequence

As specified in the HMC694LP4 datasheet, there needs to be a startup before it is fully operational. This requires a Voltmeter to measure the voltage across the Shunt Resistor connecting the 5V power rail to Vdd1, Vdd2, and Vdd3. The Voltmeter must read 0.17V to achieve a Idd of 170mA across the 1Ω Shunt Resistor.

1. Flip the Single Pull Double Throw switch on the control voltage to -2V
2. Adjust the potentiometer while reading the voltage across the resistor to get a voltage of 0.17V
3. Flip the Single Pull Double Throw switch back to the OPA207

10 Conclusion

10.1 Error

It should be noted that there were errors in simulating the circuit.

10.1.1 Message after Inverting Summing Amplifier

Looking at Figure 5b, the maximum peak is theoretically -1.1V, instead we see it is approximately -1.15V.

10.1.2 Message Gain

Looking at Figure 6, we expect the peak of the function to reach 20dB and the ”smaller hump” to reach 15dB, however the simulation makes it slightly off (about 0.2dB off). This error poses some concern as it implies that it persists on the final AM wave.

10.1.3 Final Wave

When calculating for the voltage peak, the result should be approximately 0.45V given that the power is at the 20dBm peak. As for the center, it comes out to be approximately 0.25V at 15dBm.

10.2 Comments

In regards to Figure 5b, swinging up to -1.15V still meets design constraints, since we're interested in the maximum swing going down to be within 5dB. As for Figure 6, we can use Figure 9 as a litmus for how adverse the error's effect is. Although this design isn't ideal, seeing that the peak and center are close to theoretical in Figure 9, implies that the errors mentioned are trivial at best.

An inventor is one who can see the applicability of means to supply demand five years before it is obvious to those skilled in the art. - Reginald Aubrey Fessenden

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Appendix

A Matlab Code

```
clf
%Graph Parameters
periods = 3 %Will visualize 3 periods of the message frequency
resolution = 0.0000001 %This is the resolution of the wave. Smaller number =
↪ better resolution. Recommended at least 0.0001

%Inputs to the equations
carrierdBm = 0;      %dBm
DCOffset = 10.167; %Volts
R1 = 10000
R2 = 1200
messageFrequency = 1000000;       %The frequency for the message is 1MHz
carrierFrequency = 10000000000; %The frequency for the carrier wave is 10GHz
impedance = 50;      %Ohms
transferFuncDataPoints = [-1.34 -1.22 -1.1;
                          20    15   9]; %A 2d array with datapoints about the
↪ transfer function.
             % Voltage  Gain(dB)  Used to calculate the transfer function
             %To make the transfer function more accurate, take more
             %measurements of the graph "Gain vs Control Voltage" on
             %datasheet


%Formulas%
T=1/messageFrequency; %Obtains the period of the message frequency
t = 0:resolution*T:periods*T; %Creates the vector that represents the time
carrierWave = ((sqrt(2*10^(carrierdBm/20))*cos(2*pi*carrierFrequency*t))); %The
↪ carrier wave as Vpeak
messageWave = .5*cos(2*pi*messageFrequency*t) + .5*cos(4*pi*messageFrequency*t);
↪ %Tonal Message


%The carrier Frequency vs time
plot(t, carrierWave);
title("Carrier Wave (10GHz @ 5 dBm)")
xlabel("Time (Seconds)");
ylabel("Voltage (V)");
ax = gcf;
exportgraphics(ax, "CarriervTime.png");

%The message vs time
plot(t, messageWave);
title("Message Wave (Tonal Frequency)")
xlabel("Time (Seconds)");
ylabel("Voltage (V)");
ax = gcf;
exportgraphics(ax, "MessagevTime.png");

%Peform Linear Regression using the noted date points to create the
%transfer function
regressionX = transferFuncDataPoints(1,:);
regressionY = transferFuncDataPoints(2,:);
mdl = fitlm(regressionX, regressionY);
```

```
title("Linear Region: Gain vs Control Voltage (Transfer Function) HMC694LP4")
xlabel("Control Voltage [V]");
ylabel("Gain [dB]");
ax = gcf;
exportgraphics(ax, "LinearRegion.png");

%Extracted coefficients in the form y=mx+b
m = mdl.Coefficients{2, 1}; %Has units of dB/V
b = mdl.Coefficients{1, 1}; %Has units of dB
fprintf("The regression is calcualted to be y = %fx + %f\n", m, b);

%Plot the fit of the linear regression
scatter(regressionX, regressionY);
hold on
fitX = [regressionX(1, 1):0.01:regressionX(1, end)];
%dataPoints = -1.34:0.01:-1.1
fitY = m*fitX + b
plot(fitX, fitY)
title("Fitting the Linear Region of the Variable Gain Amplifier")
xlabel("Control Voltage (V)");
ylabel("Gain (dB)");
ax = gcf;
exportgraphics(ax, "LinearRegression.png");

hold off
%Now, let's attenuate the Message Frequency and DC offset
%This is representative of the inverting
%summing amplifier, which will sum
%messageWave = (-.22/1.5625) * messageWave - 1.2108
messageWave = -(R2/R1)*((messageWave)+(DCOffset))
plot(t, messageWave);
title("Message after Inverting Summing Amplifier")
xlabel("Time (Seconds)");
ylabel("Voltage (V)");
ax = gcf;
exportgraphics(ax, "AfterInverting.png");

%The linear regression transfer function represents the Analog Variable
%Gain Amplifier. The regression will match the control voltage to its
%corresponding gain (dB). Thus, we will pass the equation into the transfer
%function.
transferFunctionGain = m * messageWave + b;
plot(t, transferFunctionGain);
title("Transfer Function in the Linear Region")
xlabel("Control Voltage (V)");
ylabel("Gain (dB)");
ax = gcf;
exportgraphics(ax, "Message Gain.png");
%Once we have that, let's add it to the corresponding wave from the local
%oscillator. I'm going to transfer everything into dBms so that we can add
%it up.

AMWaveV = carrierWave .* 10.^(transferFunctionGain/20);
plot(t, AMWaveV);
title("AM Wave")
xlabel("Time (Seconds)");
ylabel("Voltage (V)");
```

```
ax = gcf;
exportgraphics(ax, "AMWave.png");

%This is still centered at 15dB, not 15dBm
%Therefore, we attenuate it with 30dBm, giving us this equation

FinalWave = AMWaveV ./10.^(30/20);
plot(t,FinalWave);
title("Final Wave")
xlabel("Time (Seconds)");
ylabel("Voltage (V)");
ax = gcf;
exportgraphics(ax, "FinalWave.png");
```

B Schematic: Power Supply

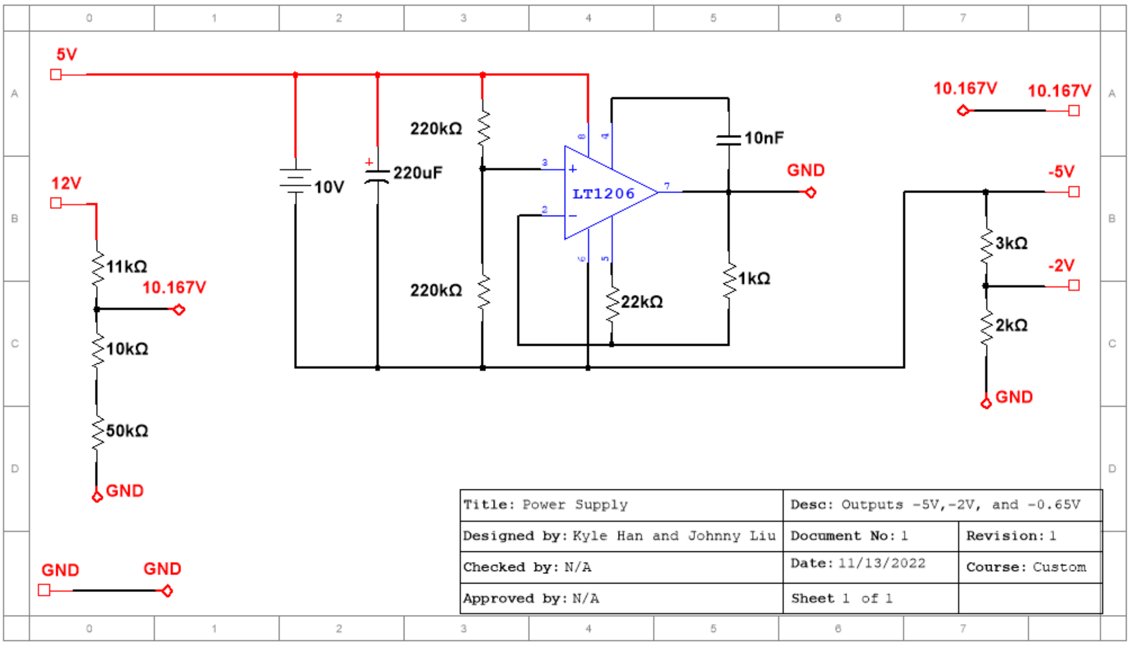


Figure 10: Power Supply Circuit to obtain 10.167V, -2V, and -5V

C Schematic: Amplitude Modulator

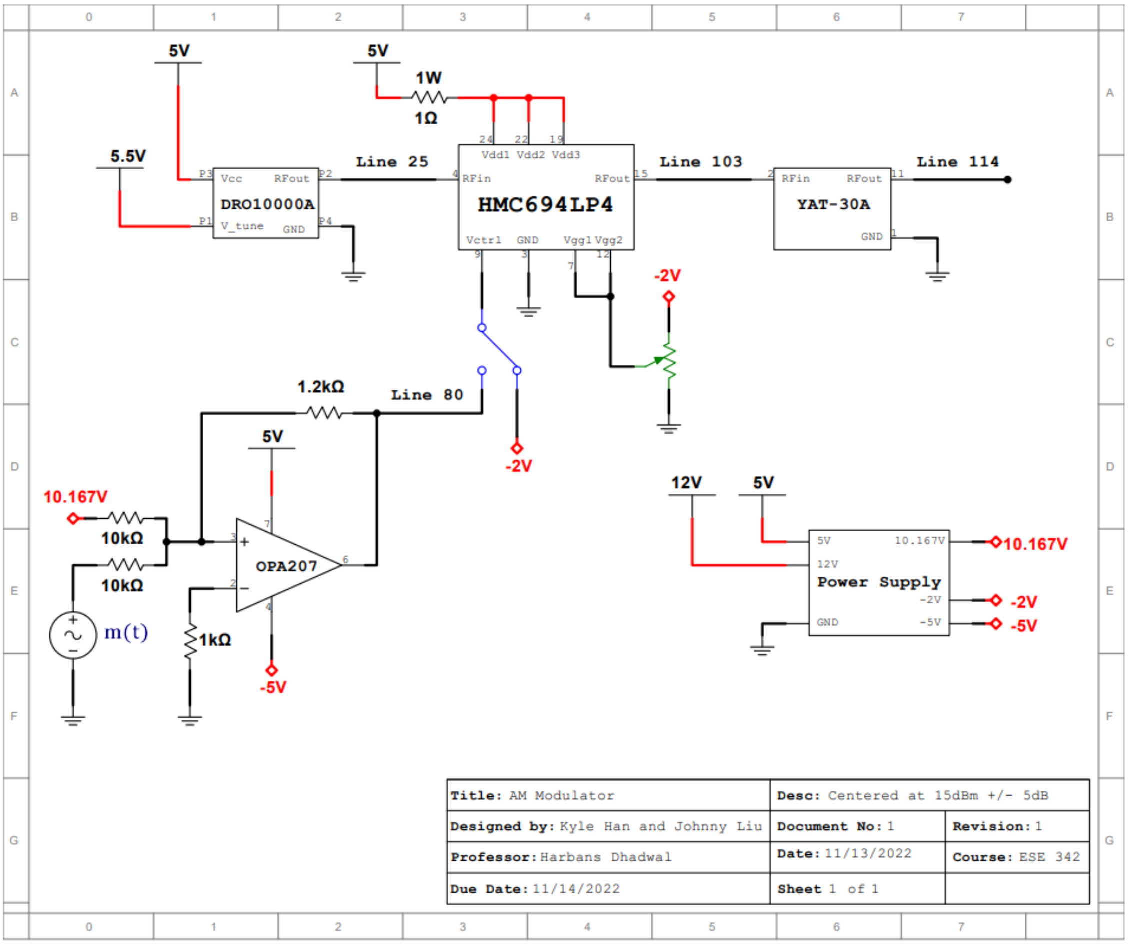


Figure 11: Amplitude Modulator Circuit for 15dBm ±5dB swing. Labelled wires for inputs and outputs for

https://www.overleaf.com/project/636a79a82392e04240efe040

D Datasheets

Z~Communications

DRO10000A

Rev A1

TEL: (858) 621-2700
URL: www.zcomm.com
EMAIL: applications@zcomm.com

Voltage-Controlled Oscillator Surface Mount Module

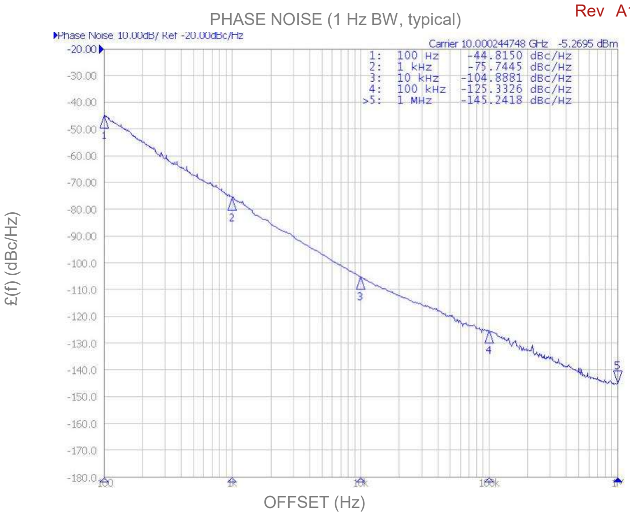
Applications

Radar Equipment
Test Instrumentation

Application Notes

AN-101: Mounting and Grounding
AN-102: Output Loading
AN-107: Manual Soldering

PHASE NOISE (1 Hz BW, typical)



Performance Specifications	Min	Typ	Max	Units
Oscillation Frequency Range	10000		10000	MHz
Phase Noise @ 10 kHz offset (1 Hz BW)		-102		dBc/Hz
Harmonic Suppression (2nd)		-25	-20	dBc
Tuning Voltage	0		12	Vdc
Tuning Sensitivity (avg.)		0.5		MHz/V
Power Output	-3	0	3	dBm
Load Impedance		50		Ω
Input Capacitance			50	pF
Pushing			1	MHz/V
Pulling (dB Return Loss, Any Phase)			2	MHz
Operating Temperature Range	-40		85	°C
Package Style		SDRO		

Power Supply Requirements	Min	Typ	Max	Units
Supply Voltage (Vcc, nom.)		5		Vdc
Supply Current (Icc)		20	26	mA

Additional Notes

It is not recommended to solder the ground plane under the DRO. Only the outside castellations shall be soldered.

LFSuffix = RoHS Compliant. All specifications are subject to change without notice.

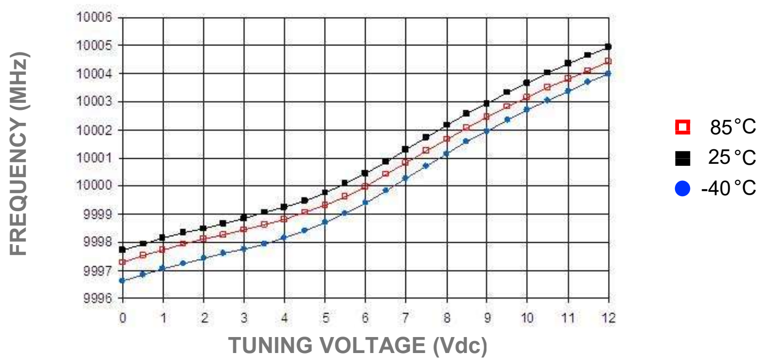
FRM-S-002 B

Z~Communications, Inc.

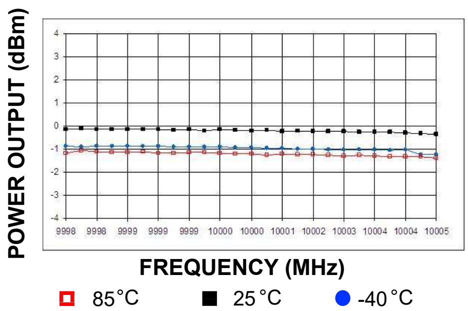
Voltage-Controlled Oscillator
Surface Mount Module

DRO10000A
Rev A1

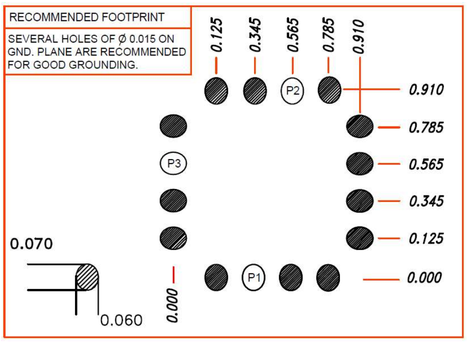
Tuning Curve, typ.



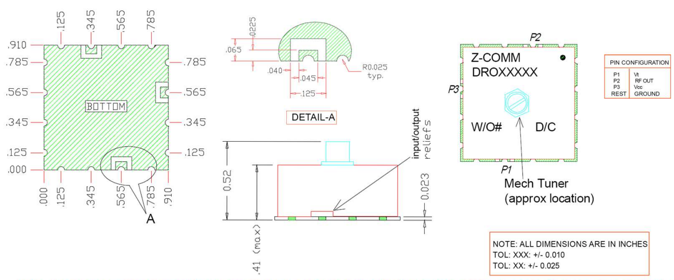
Power Curve, typ.



Footprint



Physical Dimensions



Note: It is not recommended to solder the ground plane under the DRO. Only the outside castellations require soldering for assembly.

LFSuffix = RoHS Compliant. All specifications are subject to change without notice.

FRM-S-002 B

ANALOG DEVICES

RoHS EARTH FRIENDLY

HMC694LP4 / 694LP4E

v02.1108

GaAs MMIC ANALOG VARIABLE GAIN AMPLIFIER, 6 - 17 GHz

Typical Applications

The HMC694LP4(E) is ideal for:

- Point-to-Point Radio
- Point-to-Multi-Point Radio
- EW & ECM
- X-Band Radar
- Test Equipment

Features

Wide Gain Control Range: 23 dB

Single Control Voltage

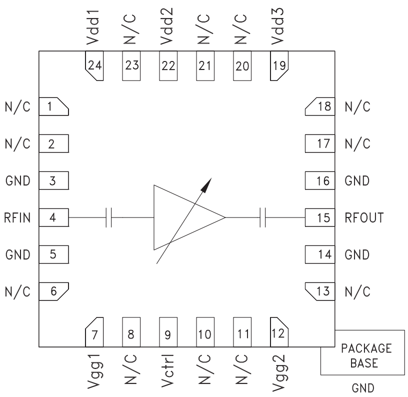
Output IP3 @ Max Gain: +30 dBm

Output P1dB: +22 dBm

No External Matching

24 Lead 4x4 mm SMT Package: 16 mm^2

Functional Diagram



General Description

The HMC694LP4(E) is a GaAs MMIC PHEMT analog variable gain amplifier which operates between 6 and 17 GHz. Ideal for microwave radio applications, the amplifier provides up to 22 dB of gain, output P1 dB of up to +22 dBm, and up to +30 dBm of output IP3 at maximum gain, while requiring only 175 mA from a +5V supply. A gate bias pin (Vctrl) is provided to allow variable gain control up to 23 dB. Gain flatness is excellent making the HMC694LP4E ideal for EW, ECM and radar applications. The HMC694LP4E is housed in a RoHS compliant 4x4 mm QFN leadless package and is compatible with high volume surface mount manufacturing.

Electrical Specifications, T_A = +25°C, Vdd1, 2, 3= 5V, Vctrl= -2V, Idd= 170 mA*

Parameter	Min.	Typ.	Max.	Min.	Typ.	Max.	Units
Frequency Range		6 - 10			10 - 17		GHz
Gain	19	22		14	18		dB
Gain Flatness		±1			±1.5		dB
Gain Variation Over Temperature		0.015			0.015		dB/ °C
Gain Control Range		23			20		dB
Noise Figure		6	7.5		6	6.5	dB
Input Return Loss		15			8		dB
Output Return Loss		10			8		dB
Output Power for 1 dB Compression (P1dB)	19	21		21	22		dBm
Saturated Output Power (Psat)		22			23		dBm
Output Third Order Intercept (IP3)		30			30		dBm
Total Supply Current (Idd)		175			175		mA

*Set Vctrl = -2V and then adjust Vgg1, 2 between -2V to 0V (typ. -0.8V) to achieve Idd = 170mA typical.

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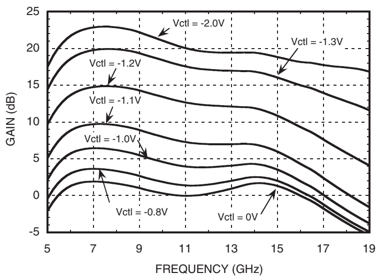
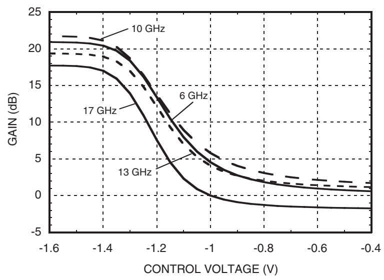
GaAs MMIC ANALOG VARIABLE GAIN AMPLIFIER, 6 - 17 GHz

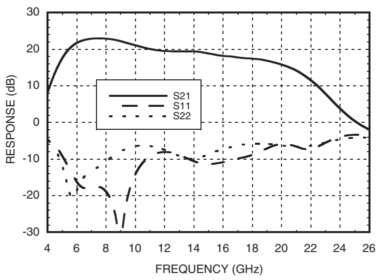
Control Voltage Range vs. Gain



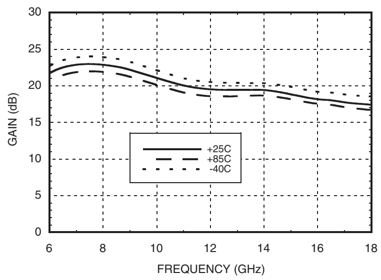
Gain vs. Control Voltage



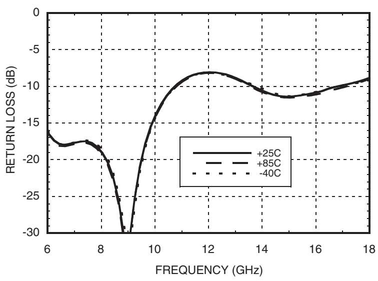
Broadband Gain & Return Loss



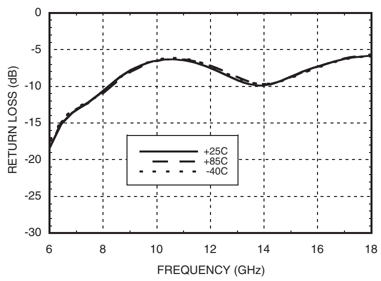
Gain vs. Temperature



Input Return Loss vs. Temperature

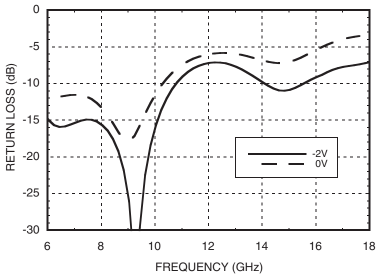


Output Return Loss vs. Temperature

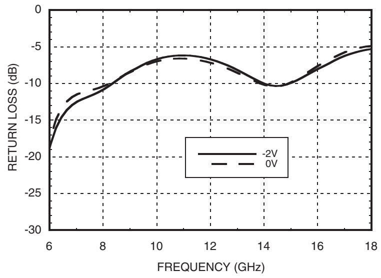


GaAs MMIC ANALOG VARIABLE GAIN AMPLIFIER, 6 - 17 GHz

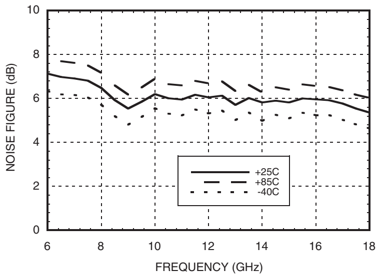
Return Loss @ Voltage Extreme



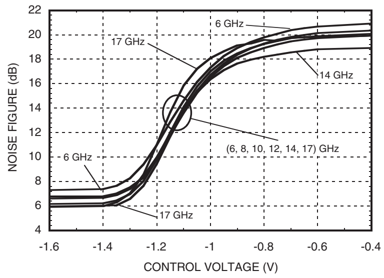
Output Return Loss @ Voltage Extreme



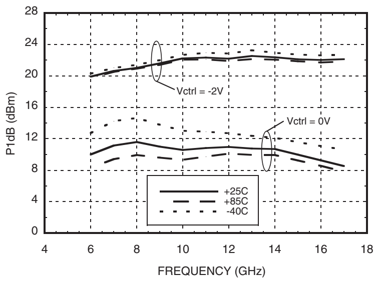
Noise Figure vs. Temperature



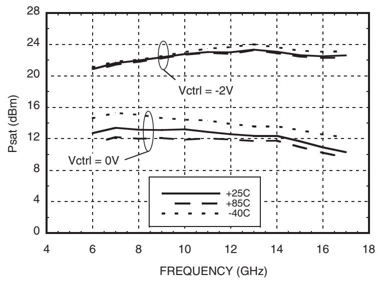
Noise Figure vs. CTRL



P1dB vs. Temperature



Psat vs. Temperature



[1] Tested with broadband bias tee on RF ports and C1 = 10,000pF
[2] C1, C6 and C8 = 100pF, L1 = 24nF

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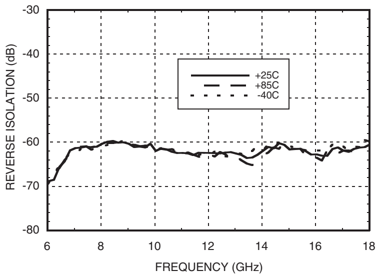
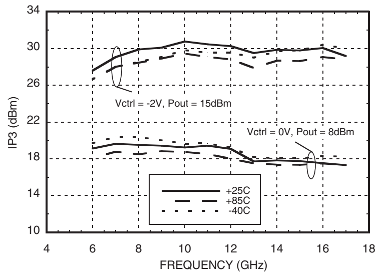
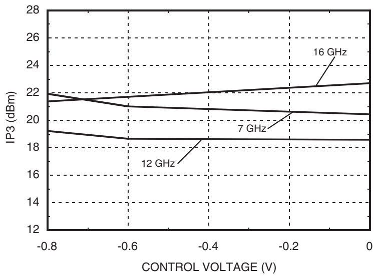
Reverse Isolation vs. Temperature



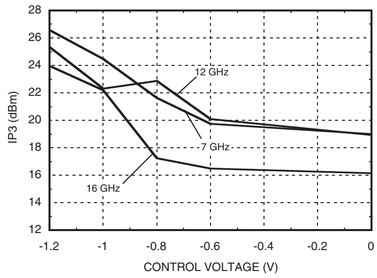
Output IP3 vs. Temperature



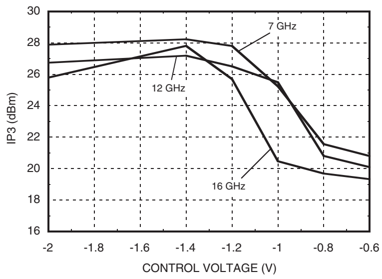
Output IP3 @ 0 dBm



Output IP3 @ 5 dBm



Output IP3 @ 10 dBm



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ANALOG DEVICES

HMC694LP4 / 694LP4E

v02.1108

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GaAs MMIC ANALOG VARIABLE GAIN AMPLIFIER, 6 - 17 GHz

Absolute Maximum Ratings

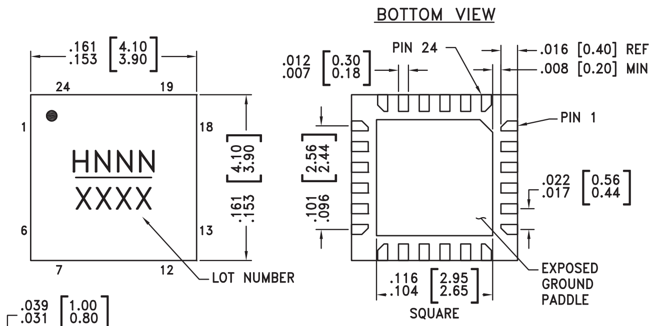
Drain Bias Voltage (Vdd1, 2, 3)	+5.5V
Gate Bias Voltage (Vgg1, 2)	-3 to 0V
Gain Control Voltage (Vctrl)	-3 to 0V
RF Power Input	+5 dBm
Channel Temperature	175 °C
Continuous Pdiss (T = 85 °C) (derate 10.2 mW/°C above 85 °C) [1]	0.92 W
Thermal Resistance (Channel to ground paddle)	97.6 °C/W
Storage Temperature	-65 to +150 °C
Operating Temperature	-40 to +85 °C

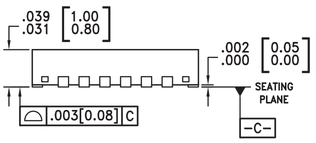
Bias Voltage

Vdd1,2,3 (V)	Idd Total (mA)
+5.0	170
Vgg1,2 (V)	Igg Total (mA)
0V to -2V	<3 μA

ELECTROSTATIC SENSITIVE DEVICE
OBSERVE HANDLING PRECAUTIONS

Outline Drawing





NOTES:
1. LEADFRAME MATERIAL: COPPER ALLOY
2. DIMENSIONS ARE IN INCHES [MILLIMETERS]
3. LEAD SPACING TOLERANCE IS NON-CUMULATIVE.
4. PAD BURR LENGTH SHALL BE 0.15mm MAXIMUM. PAD BURR HEIGHT SHALL BE 0.05mm MAXIMUM.
5. PACKAGE WARP SHALL NOT EXCEED 0.05mm.
6. ALL GROUND LEADS AND GROUND PADDLE MUST BE SOLDERED TO PCB RF GROUND.
7. REFER TO HITTITE APPLICATION NOTE FOR SUGGESTED LAND PATTERN.

Package Information

Part Number	Package Body Material	Lead Finish	MSL Rating	Package Marking [3]
HMC694LP4	Low Stress Injection Molded Plastic	Sn/Pb Solder	MSL1 [1]	H694 XXXX
HMC694LP4E	RoHS-compliant Low Stress Injection Molded Plastic	100% matte Sn	MSL1 [2]	H694 XXXX

[1] Max peak reflow temperature of 235 °C
[2] Max peak reflow temperature of 260 °C
[3] 4-Digit lot number XXXX

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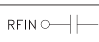
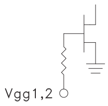
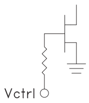
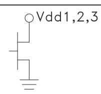
GaAs MMIC ANALOG VARIABLE GAIN AMPLIFIER, 6 - 17 GHz

Pin Descriptions

Pad Number	Function	Description	Interface Schematic
1, 2, 6, 8, 10, 11, 13, 17, 18, 20, 21, 23	N/C	No Connection	
3, 5, 14, 16	GND	Die bottom must be connected to RF/DC ground.	
4	RFIN	This pad is AC coupled and matched to 50 Ohm.	
7, 12	Vgg1, 2	Gate control for amplifier. Adjust voltage to achieve typical Idd. Please follow “MMIC Amplifier Biasing Procedure” application note.	
9	Vctrl	Gain control Voltage for the amplifier. See assembly diagram for required external components.	
15	RFOUT	This pad is AC coupled and matched to 50 Ohm.	
19, 22, 24	Vdd1, 2, 3	Drain Bias Voltage for the amplifier. See assembly diagram for required external components	

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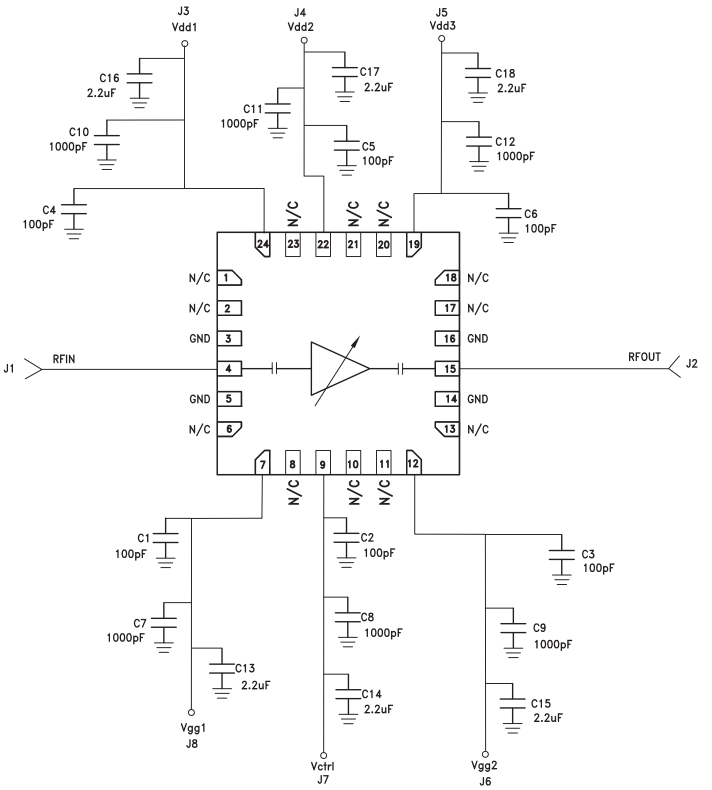
GaAs MMIC ANALOG VARIABLE GAIN AMPLIFIER, 6 - 17 GHz

Application Circuit



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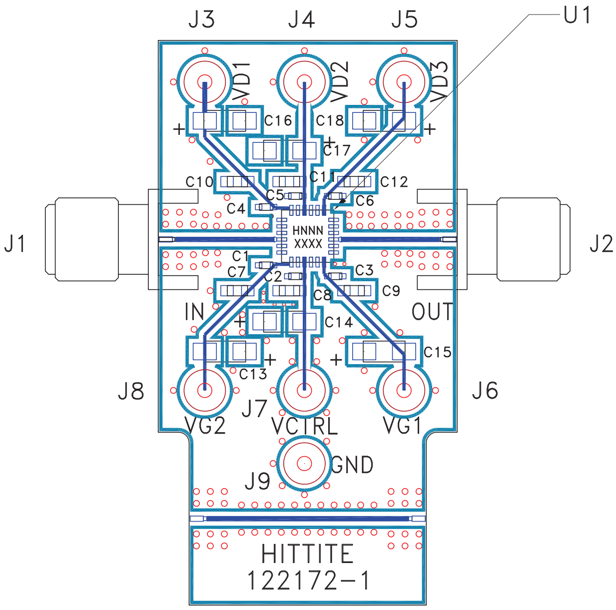
Evaluation PCB



List of Materials for Evaluation PCB 122174 [1]

Item	Description
J1, J2	PCB Mount SMA RF Connectors
J3 - J9	DC Pin
C1 - C6	100 pF Capacitor, 0402 Pkg.
C7 - C12	1000 pF Capacitor, 0603 Pkg.
C13 - C18	2.2 µF Capacitor, CASE A
U1	HMC694LP4(E) Variable Gain Amplifier
PCB [2]	122172 Evaluation PCB

[1] Reference this number when ordering complete evaluation PCB

[2] Circuit Board Material: Arlon 25FR

The circuit board used in the application should use RF circuit design techniques. Signal lines should have 50 Ohm impedance while the package ground leads and exposed paddle should be connected directly to the ground plane similar to that shown. A sufficient number of via holes should be used to connect the top and bottom ground planes. The evaluation circuit board shown is available from Hittite upon request.

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OPA207 Low-Power, High-Precision, Low-Noise, Rail-to-Rail Output Operational Amplifier

1 Features

- Ultra-low offset voltage: 150 µV (maximum)
- Ultra-low drift: ±1 µV/°C (maximum)
- Gain bandwidth: 1 MHz (typical)
- Slew rate: 3.6 V/µs (typical)
- High open-loop gain: 130 dB (minimum)
- High common-mode rejection: 115 dB (minimum)
- High power-supply rejection: 5µV/V (maximum)
- Low bias current: 2.8 nA (maximum)
- Wide supply range: ±2.25 V to ±18 V
- Low quiescent current: 375 µA (maximum)
- Replaces OP-07, OP-77, and OP-177

2 Applications

- Analog input module
- Battery test
- Data acquisition (DAQ)
- Pressure transmitter
- Temperature transmitter

3 Description

The OPA207 precision operational amplifier (op amp) replaces the industry standard OP-07, OP-77 and OP–177 amplifiers. The OPA207 offers improved noise, wider output voltage swing, and is twice as fast with half the quiescent current of the industry standard alternatives. Features include ultra-low input offset voltage and drift, low input bias current, high common-mode rejection ratio, and high power-supply rejection ratio.

The OPA207 op amp operates over a wide power-supply-voltage range, from ±2.25 V to ±18 V, with excellent performance. High performance is maintained as the amplifiers swing to their specified limits.

The OPA207 operational amplifier is easy to use and free from phase inversion and the overload problems found in some other operational amplifiers. The OPA207 is stable in unity gain and provide excellent dynamic behavior over a wide range of load conditions.

Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
OPA207	SOIC (8)	4.90 mm × 3.91 mm
	VSSOP (8)	3.00 mm × 3.00 mm
	SOT-23 (5)	2.90 mm × 1.60 mm

(1) For all available packages, see the package option addendum at the end of the data sheet.

Ultra-Low 0.1-Hz to 10-Hz Noise

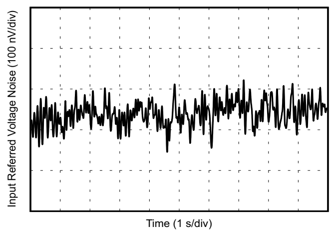


Table of Contents

4 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision C (March 2019) to Revision D	Page
• Changed SOT-23 (DBV) package from preview to production data (active)	1
• Added specifications for new DBV package	4

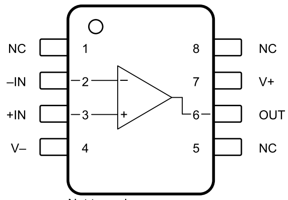
Changes from Revision B (March 2019) to Revision C	Page
• Added input offset voltage specification for OPA207DGK	5
• Added input offset voltage drift specification for OPA207DGK	5

Changes from Revision A (December 2018) to Revision B	Page
• Added content for first release of production-data data sheet for VSSOP (DGK) package	1

Changes from Original (December 2017) to Revision A	Page
• Added content re: 5-pin SOT-23 package for Advance Information	1

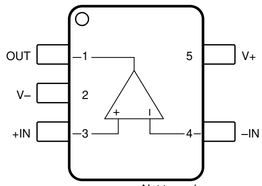
5 Pin Configuration and Functions

D and DGK Packages
8-Pin SOIC and 8-Pin VSSOP
Top View



Not to scale

DBV Package
5-Pin SOT-23
Top View



Not to scale

Pin Functions

PIN			I/O	DESCRIPTION
NAME	NO.			
	D (SOIC), DGK(VSSOP)	DBV (SOT-23)		
–IN	2	4	I	Inverting input
+IN	3	3	I	Non-inverting input
NC	1, 5, 8	—	—	No internal connection (can be left floating or connected to ground)
OUT	6	1	O	Output
V–	4	2	—	Negative (lowest) power supply
V+	7	5	—	Positive (highest) power supply

6 Specifications

6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted) (1)

	MIN	MAX	UNIT
Supply voltage, Vs = (V+) – (V–)		36	V
Input voltage - Common-mode (2)	(V–) -0.7	(V+) +0.7	V
Input voltage - Differential	–1	1	V
Output short-circuit (3)	Continuous		
Operating temperature	–55	125	°C
Junction temperature		150	°C
Storage temperature, T_{stg}	–65	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) Input current must be limited to 10 mA.
(3) Short circuit to ground, one amplifier per package.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 (1)	2000	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101 (2)	1000	

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

6.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

		MIN	NOM	MAX	UNIT
Supply voltage, Vs = (V+) – (V–)	Single Supply	4.5	30	36	V
	Dual Supply	±2.25	±15	±18	V
Specified temperature		–40		125	°C

6.4 Thermal Information

THERMAL METRIC (1)		OPA207			UNIT
		DGK (VSSOP)	D (SOIC)	DBV (SOT-23)	
		8 PINS	8 PINS	8 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	176.7	121.5	166.3	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	63.9	64.3	116.9	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	99.4	65.0	63.2	°C/W
ψ_{JT}	Junction-to-top characterization parameter	8.8	18.2	45	°C/W
ψ_{JB}	Junction-to-board characterization parameter	97.6	64.3	62.9	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package ThermalMetrics* application report.

6.5 Electrical Characteristics

at V_S = ±15 V, T_A = 25°C, R_L = 2 kΩ connected to V_S / 2, V_{CM} = V_S / 2, and V_{OUT} = V_S/2 (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
OFFSET VOLTAGE						
V_{OS}	Input offset voltage OPA207D			15	±100	μV
		T_A = –40°C to 85°C			±150	
		T_A = –40°C to 125°C			±200	
	Input offset voltage OPA207DGK			15	±125	
		T_A = 0°C to 85°C			±170	
		T_A = –40°C to 125°C			±225	
	Input offset voltage OPA207DBV			15	±130	
		T_A = 0°C to 85°C			±170	
		T_A = –40°C to 125°C			±225	
dV_{OS}/dT	Input offset voltage drift OPA207D	T_A = –40°C to 85°C		±0.2	±.8	μV/°C
		T_A = –40°C to 125°C		±0.2	±.8	
	Input offset voltage drift OPA207DGK and OPA207DBV	T_A = 0°C to 85°C		±0.2	±1.1	
		T_A = –40°C to 125°C		±0.2	±1.1	
PSRR	Input offset voltage versus power supply	V_S = ±2.25 V to ±18 V		±0.5	±3	μV/V
		V_S = ±2.25 V to ±18 V, T_A = –40°C to 85°C			±4.2	
		V_S = ±2.25 V to ±18 V, T_A = –40°C to 125°C			±5	
INPUT BIAS CURRENT						
I_B	Input bias current			±0.2	±1.5	nA
		T_A = –40°C to 85°C			±2	
		T_A = –40°C to 125°C			±7	
I_{OS}	Input offset current			±0.13	±1.5	nA
		T_A = –40°C to 85°C			±2	
		T_A = –40°C to 125°C			±7	
NOISE						
	Input voltage noise	f = 0.1 Hz to 10 Hz		0.16		μV_{PP}
				0.024		μV_{RMS}
e_N	Input voltage noise density	f = 1 Hz		9.5		nV/√Hz
		f = 10 Hz		7.5		
		f = 100 Hz		7.5		
		f = 1 kHz		7.5		
i_N	Input current noise	f = 1 kHz		0.18		pA/√Hz
INPUT VOLTAGE RANGE						
V_{CM}	Common-mode voltage range		(V–) + 1.25		(V+) – 1.25	V
CMRR	Common-mode rejection ratio	(V–) + 1.25 V < V_{CM} < (V+) – 1.25 V	120	140		dB
		(V–) + 1.25 V < V_{CM} < (V+) – 1.25 V, T_A = –40°C to 125°C	115	140		
INPUT CAPACITANCE						
Z_{ID}	Differential			3 || 14		MΩ || pF
Z_{ICM}	Common-mode			1 || 1		GΩ || pF
OPEN-LOOP GAIN						
A_{OL}	Open-loop voltage gain	(V–) + 200 mV < V_O < (V+) – 200 mV, R_L = 10 kΩ	130	140		dB
		(V–) + 200 mV < V_O < (V+) – 200 mV, R_L = 10 kΩ; T_A = –40°C to 125°C	126			
		(V–) + 200 mV < V_O < (V+) – 200 mV, R_L = 2 kΩ; OPA207D, OPA207DGK	120	140		
		(V–) + 300 mV < V_O < (V+) – 300 mV, R_L = 2 kΩ; OPA207DBV	130	140		
		(V–) + 200 mV < V_O < (V+) – 200 mV, R_L = 2 kΩ; T_A = –40°C to 125°C, OPA207D, OPA207DGK	114			
		(V–) + 300 mV < V_O < (V+) – 300 mV, R_L = 2 kΩ; T_A = –40°C to 125°C, OPA207DBV	120			

Electrical Characteristics (continued)

at V_S = ±15 V, T_A = 25°C, R_L = 2 kΩ connected to V_S / 2, V_{CM} = V_S / 2, and V_{OUT} = V_S/2 (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
FREQUENCY RESPONSE						
GBW	Gain-bandwidth product			1.3		MHz
SR	Slew rate	10-V step, G = 1		2.7		V/µs
t_S	Settling time	To 0.1%, 10-V step , G = 1		4.8		µs
		To 0.01%, 10-V step , G = 1		5.4		
		To 0.001%, 10-V step , G = 1		8.1		
	Overload recovery time	V_{IN} × gain > V_S		1.1		µs
	Total harmonic distortion + noise (THD+N)	V_O = 3 V_{RMS}, G = 1, f = 1 kHz, R_L = 10 kΩ		–114		dB
OUTPUT						
	Voltage output swing from rail	T_A = 25°C, no load, OPA207DBV		15	40	mV
		T_A = 25°C, R_L = 10 kΩ, OPA207DBV		40	60	
		T_A = 25°C, R_L = 2 kΩ, OPA207DBV		80	140	
		T_A = 25°C, no load, OPA207D, OPA207DGK		15	30	
		T_A = 25°C, R_L = 10 kΩ, OPA207D, OPA207DGK		40	50	
		T_A = 25°C, R_L = 2 kΩ, OPA207D, OPA207DGK		80	125	
		T_A = –40°C to 125°C, R_L = 10 kΩ		75	200	
I_{SC}	Short-circuit current	Sinking		–40		mA
		Sourcing		40		
C_{LOAD}	Capacitive load drive			200		pf
R_O	Open-loop output impedance	f = 1 MHz		45		Ω
POWER SUPPLY						
I_Q	Quiescent current per amplifier	I_O = 0 A		350	375	µA
		I_O = 0 A, T_A = –40°C to 125°C			450	
	Turnon time	At T_A = 25°C, V_S = 36 V, V_S ramp rate > 0.3 V/µs		27		µs

6.6 Typical Characteristics

at T_A = 25°C, V_S = ±15 V, and R_L = 2 kΩ (unless otherwise noted)

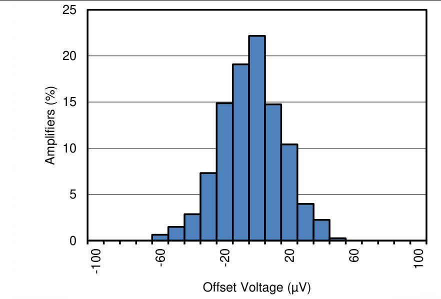


Figure 1. Input Referred Offset Voltage Distribution

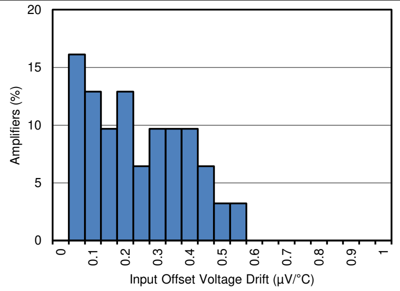


Figure 2. Input Referred Offset Voltage Drift Distribution

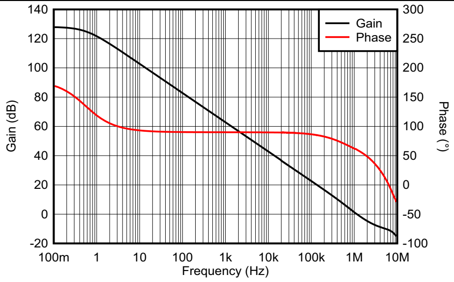


Figure 3. Open-Loop Gain and Phase vs Frequency

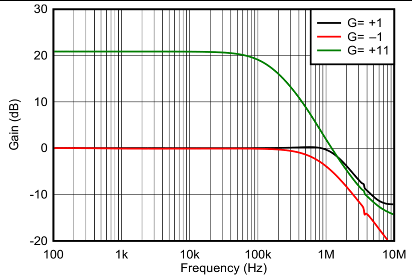


Figure 4. Closed Loop Gain vs Frequency

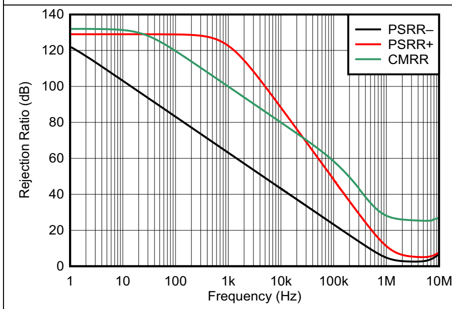


Figure 5. Power Supply Rejection Ratio and Common-Mode Rejection Ratio vs Frequency

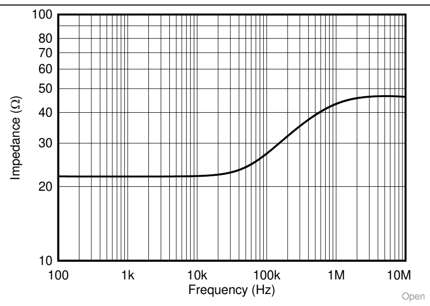


Figure 6. Open-Loop Output Impedance vs Frequency

Typical Characteristics (continued)

at T_A = 25°C, V_S = ±15 V, and R_L = 2 kΩ (unless otherwise noted)

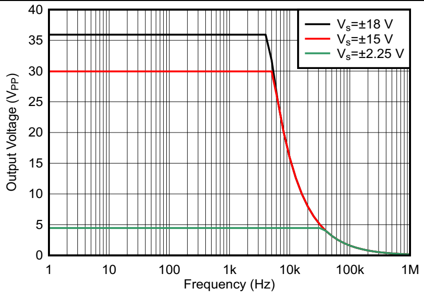


Figure 7. Full Power Bandwidth

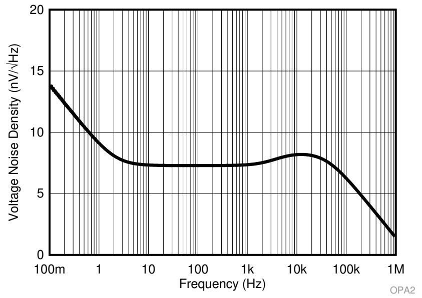


Figure 8. Input Voltage Noise Spectral Density vs Frequency

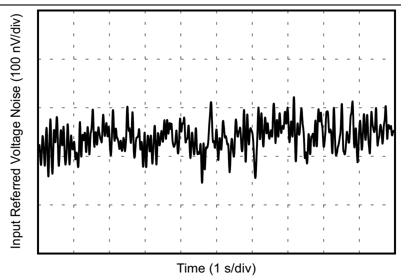


Figure 9. 0.1-Hz to 10-Hz Noise Voltage

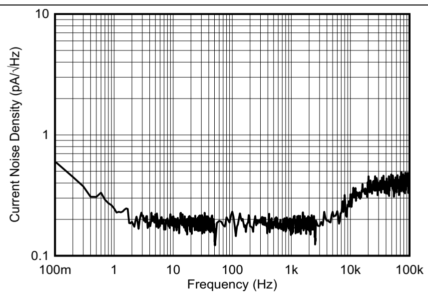


Figure 10. Input Current Noise vs Frequency

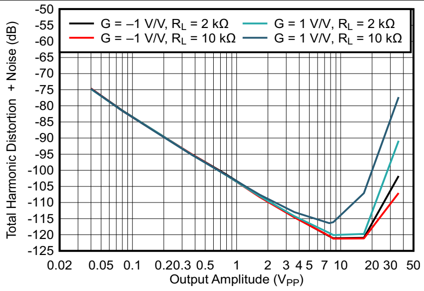


Figure 11. Total Harmonic Distortion + Noise vs Output Amplitude

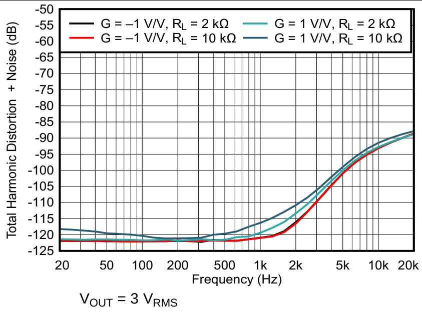
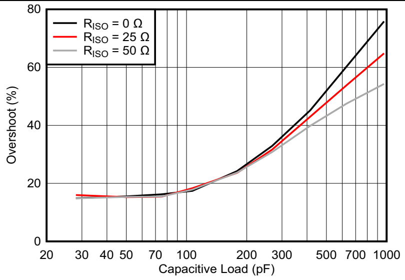


Figure 12. Total Harmonic Distortion + Noise vs Frequency

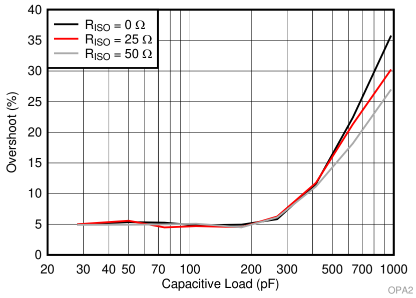
Typical Characteristics (continued)

at T_A = 25°C, V_S = ±15 V, and R_L = 2 kΩ (unless otherwise noted)



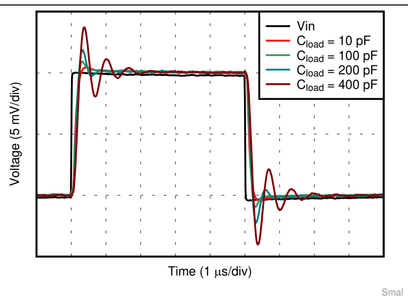
G = +1 V/V

Figure 13. Overshoot vs Capacitive Load



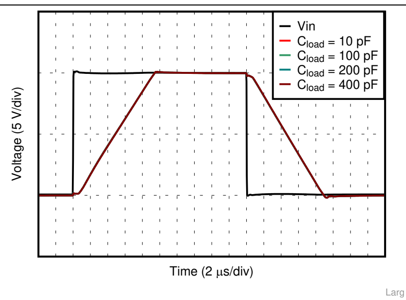
G = –1 V/V

Figure 14. Overshoot vs Capacitive Load



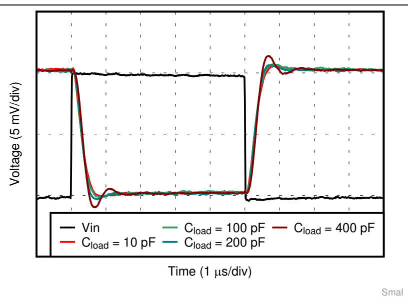
G = +1 V/V

Figure 15. Small-Signal Step Response



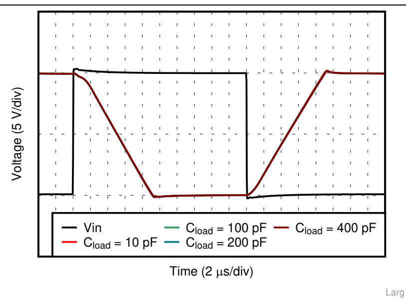
G = +1 V/V

Figure 16. Large-Signal Step Response



G = –1 V/V

Figure 17. Small-Signal Step Response



G = –1 V/V

Figure 18. Large-Signal Step Response

Typical Characteristics (continued)

at T_A = 25°C, V_S = ±15 V, and R_L = 2 kΩ (unless otherwise noted)

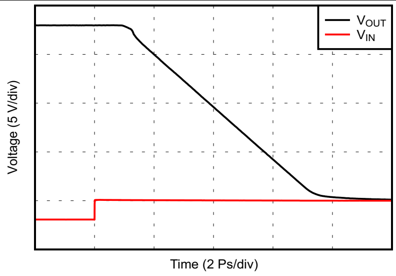


Figure 19. Overload Recovery From Positive Overload

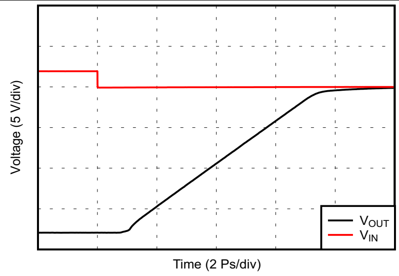
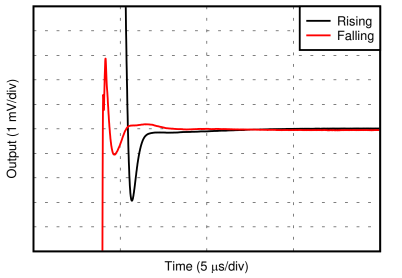
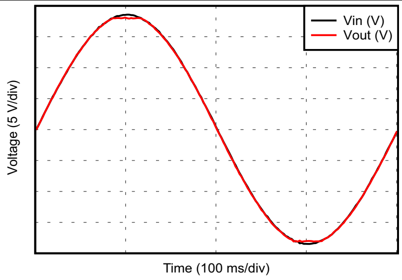


Figure 20. Overload Recovery from Negative Overload



V_{OUT} = 3 V_{RMS}

Figure 21. Settling Time



V_{OUT} = 3 V_{RMS}

Figure 22. No Phase Reversal

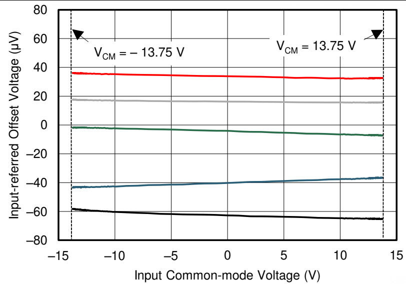


Figure 23. Input Offset Voltage vs Input Common-mode Voltage

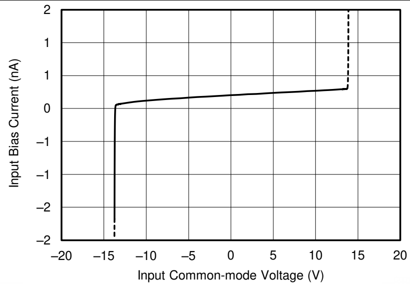


Figure 24. Input Bias Current vs Input Common-mode Voltage

Typical Characteristics (continued)

at T_A = 25°C, V_S = ±15 V, and R_L = 2 kΩ (unless otherwise noted)

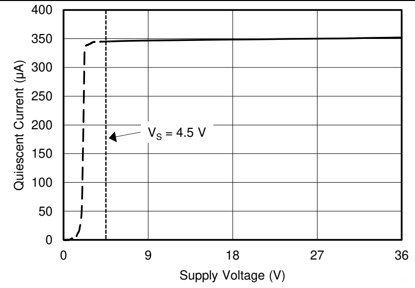


Figure 25. Quiescent Current vs Power Supply Voltage

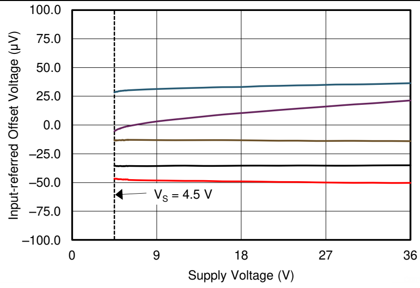


Figure 26. Input Offset Voltage vs Power Supply Voltage

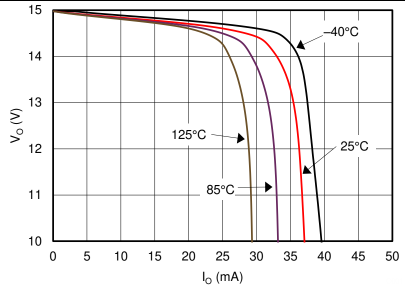


Figure 27. Output Voltage vs Output Current (Sourcing)

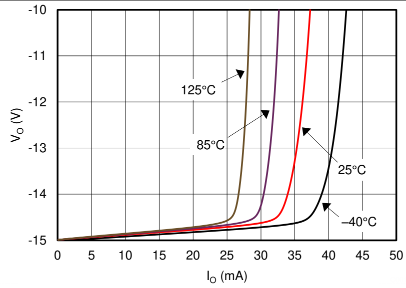


Figure 28. Output Voltage vs Output Current (Sinking)

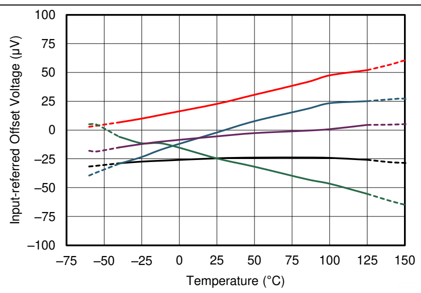


Figure 29. Input Offset Voltage vs Temperature

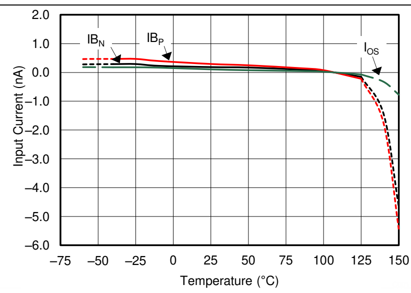


Figure 30. Input Bias Current vs Temperature

Typical Characteristics (continued)

at T_A = 25°C, V_S = ±15 V, and R_L = 2 kΩ (unless otherwise noted)

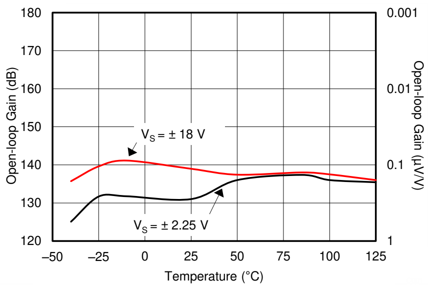


Figure 31. Open Loop Gain vs Temperature

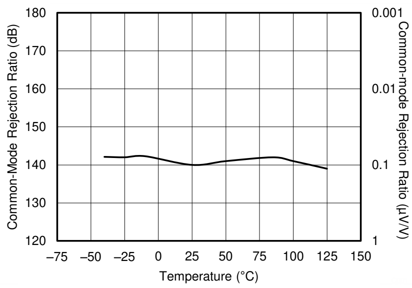


Figure 32. Common-Mode Rejection Ratio vs Temperature

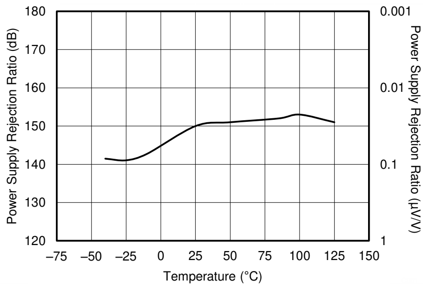


Figure 33. Power Supply Rejection Ratio vs Temperature

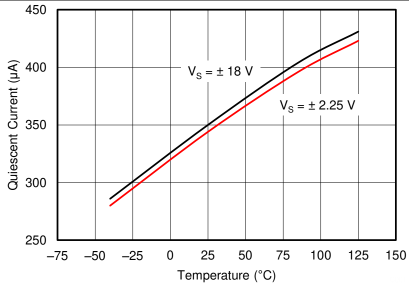


Figure 34. Quiescent Current vs Temperature

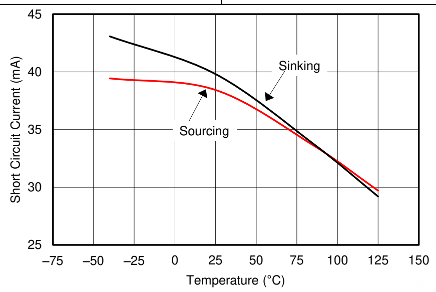


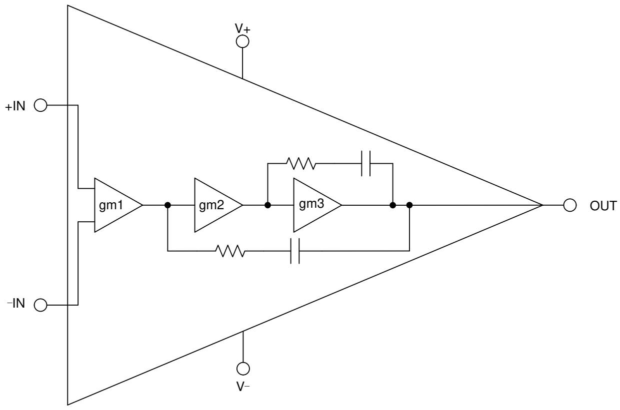
Figure 35. Output Short Circuit Current vs Temperature

7 Detailed Description

7.1 Overview

The OPA207 precision operational amplifier replaces the industry standard OP-177. The OPA207 offers improved noise, wider output voltage swing, has twice the bandwidth, ten times the slew rate and consumes only half the quiescent current as the OP-177. Additional features include ultralow offset voltage and drift, low bias current, high common-mode rejection, and high power supply rejection.

7.2 Functional Block Diagram



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7.3 Feature Description

The OPA207 is unity-gain stable and free from unexpected output phase reversal, making it easy to use in a wide range of applications. Applications with noisy or high-impedance power supplies may require decoupling capacitors close to the device pins. In most cases 0.1-µF capacitors are adequate.

7.3.1 Operating Voltage

The OPA207 operates from ±2.25 V to ±18 V supplies with excellent performance. Key parameters are assured over the specified temperature range, –40°C to 125°C. Most behavior remains unchanged through the full operating voltage range (±2.25 V to ±18 V). Parameters which vary significantly with operating voltage or temperature are shown in *Typical Characteristics*.

Feature Description (continued)

7.3.2 Input Protection

The input stage of the OPA207 is internally protected with resistors in series with diode clamps as shown in Figure 36. The inputs can withstand ±10 V differential inputs without damage and the maximum input current should be limited to 10 mA or less.. The protection diodes conduct current when the inputs are over-driven such as when the opamp output is slewing. This may disturb the slewing behavior of unity-gain follower applications, but will not damage the operational amplifier.

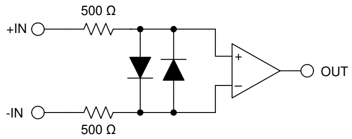

Figure 36. Simplified OPA207 Input Protection Circuit

7.3.3 ESD Protection

The OPA207 is internally protected against ESD events that can occur during manufacturing, handling, or printed-circuit-board assembly. The internal ESD protection diodes are not intended to protect the OPA207 during normal operation when the device is operating under power. In cases where the inputs or output can be driven above the positive power supply or below the negative power supply care must be taken to limit the current through the internal diodes to 10 mA or less. In harsh electrical environments external protection circuitry may be required and is dependant upon the application requirements and environmental conditions.

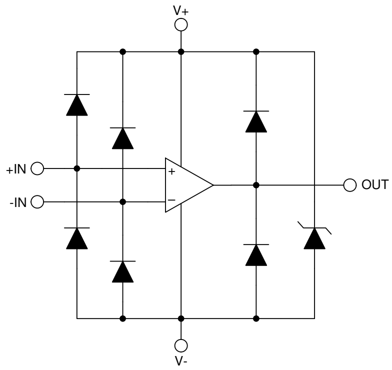

Figure 37. Simplified OPA207 ESD Protection Circuit

Feature Description (continued)

7.3.4 Input Stage Linearization

The OPA207 uses linearization techniques to reduce the total harmonic distortion. Figure 38 illustrates the linearization concept, and Figure 38 illustrates the total harmonic distortion performance of the OPA207.

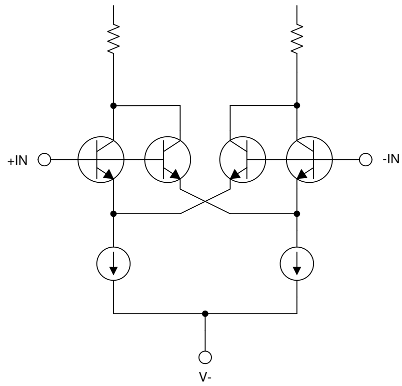

Figure 38. Simplified Input Stage Linearization Circuit

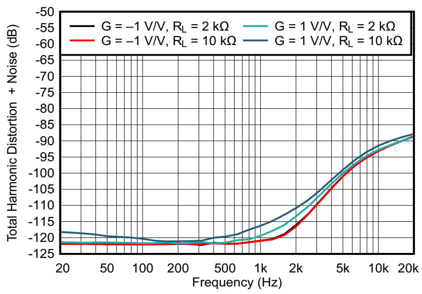

Figure 39. Total Harmonic Distortion

Feature Description (continued)

7.3.5 Rail-to-Rail Output

The OPA207 uses a rail-to-rail output stage capable of swinging within a few millivolts from either power supply rail while maintaining high open-loop gain. Figure 40 shows a simplified drawing of the output stage circuit. Resistors connected in series with each output transistor ensure a consistent output current limit. Limiting the output current in this way ensures reliable operation of the OPA207 under short circuited conditions and protects sensitive loads from being damaged by excessive current. Figure 41 and Figure 42 illustrate the maximum output current available from the OPA207 at various temperatures.

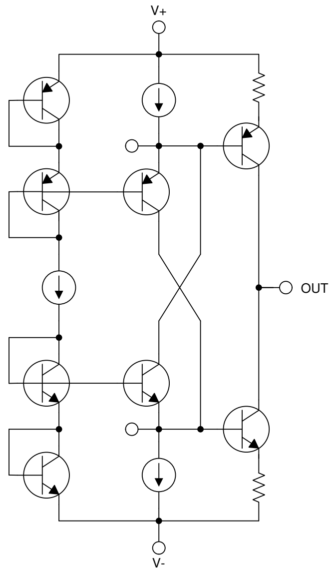

Figure 40. Simplified Rail-to-Rail Output Stage Circuit

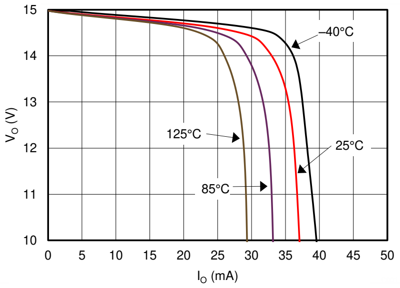

Figure 41. Output Swing to Rail While Sourcing Current

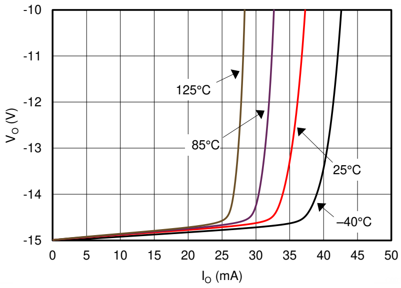

Figure 42. Output Swing to Rail While Sinking Current

Feature Description (continued)

7.3.6 Low Input Bias Current

The OPA207 uses super-beta bipolar transistors and employs an input bias current cancellation technique. This combination results in very low input bias currents that remain low over the full specified temperature range from –40°C to + 125°C unlike CMOS or JFET amplifiers whose input bias currents typically double every 10°C and can be extremely high at 125°C. Figure 43 illustrates the comparison between the OPA207 and typical CMOS or JFET amplifiers.

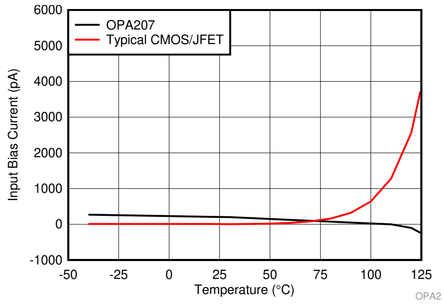

Figure 43. Input Bias Current vs Temperature

It is common practice to place a bias current cancellation resistor as illustrated in Figure 42. This approach works well with amplifiers that do not employ an internal input bias current cancellation technique. Because the OPA207 uses an internal bias current cancellation technique, TI does not recommend the bias cancellation resistor.

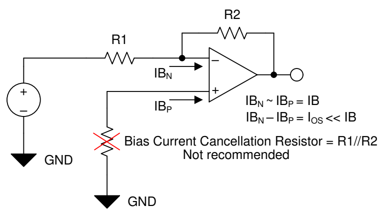

Figure 44. Bias Current Cancellation Resistor — Not Recommended

Feature Description (continued)

7.3.7 Slew Boost

The OPA207 uses a novel internal slew-boost technique. This method allows the OPA207 to consume very low power yet still achieve a high slew rate of 3.6 V/µs. This makes the OPA207 ideal for applications that require low noise and high out voltage swings where the high slew rate is necessary to achieve fast settling times.

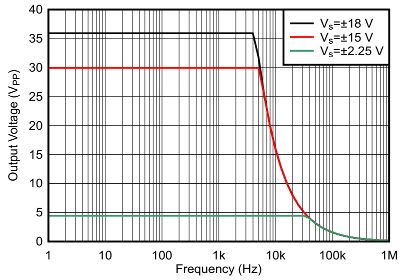

Figure 45. Full Power Bandwidth

7.3.8 EMI Rejection Ratio (EMIRR)

The electromagnetic interference (EMI) rejection ratio, or EMIRR, describes the EMI immunity of operational amplifiers. An adverse effect that is common to many operational amplifiers is a change in the offset voltage as a result of RF signal rectification. An operational amplifier that is more efficient at rejecting this change in offset as a result of EMI has a higher EMIRR and is quantified by a decibel value. Measuring EMIRR can be performed in many ways, but this report provides the EMIRR IN+, which specifically describes the EMIRR performance when the RF signal is applied to the noninverting input pin of the operational amplifier. In general, only the noninverting input is tested for EMIRR for the following three reasons:

1. Operational amplifier input pins are known to be the most sensitive to EMI, and typically rectify RF signals better than the supply or output pins.
2. The noninverting and inverting operational amplifier inputs have symmetrical physical layouts and exhibit nearly matching EMIRR performance.
3. EMIRR is easier to measure on noninverting pins than on other pins because the noninverting input terminal can be isolated on a printed circuit board (PCB). This isolation allows the RF signal to be applied directly to the noninverting input terminal with no complex interactions from other components or connecting PCB traces.

A more formal discussion of the EMIRR IN+ definition and test method is provided in TI Application Report *EMI Rejection Ratio of Operational Amplifiers*, available for download at www.ti.com. The EMIRR IN+ of the OPA207 is plotted versus frequency as shown in Figure 46.

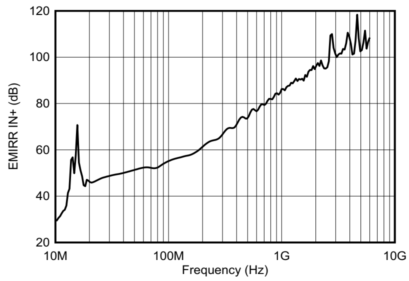

Figure 46. OPA207 EMIRR IN+ vs Frequency

Feature Description (continued)

If available, any dual and quad operational amplifier device versions have nearly similar EMIRR IN+ performance. The OPA207 unity-gain bandwidth is 1 MHz. EMIRR performance below this frequency denotes interfering signals that fall within the operational amplifier bandwidth.

Table 1 shows the EMIRR IN+ values for the OPA207 at particular frequencies commonly encountered in real-world applications. Applications listed in Table 1 may be centered on or operated near the particular frequency shown. This information may be of special interest to designers working with these types of applications, or working in other fields likely to encounter RF interference from broad sources, such as the industrial, scientific, and medical (ISM) radio band.

Table 1. OPA207 EMIRR IN+ for Frequencies of Interest

FREQUENCY	APPLICATION/ALLOCATION	EMIRR IN+
400 MHz	Mobile radio, mobile satellite/space operation, weather, radar, UHF	72 dB
900 MHz	GSM, radio com/nav./GPS (to 1.6 GHz), ISM, aeronautical mobile, UHF	83 dB
1.8 GHz	GSM, mobile personal comm. broadband, satellite, L-band	95 dB
2.4 GHz	802.11b/g/n, Bluetooth®, mobile personal comm., ISM, amateur radio/satellite, S-band	94 dB
3.6 GHz	Radiolocation, aero comm./nav., satellite, mobile, S-band	103 dB
5 GHz	802.11a/n, aero comm./nav., mobile comm., space/satellite operation, C-band	102 dB

7.4 Device Functional Modes

The OPA207 has a single functional mode and is operational when the power-supply voltage is greater than 4.5 V (± 2.25 V). The maximum power supply voltage for the OPA207 is 36 V (±18 V).

8 Application and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

8.1 Application Information

Low-pass filters are commonly employed in signal processing applications to reduce noise and prevent aliasing. The OPA207 is designed to construct high-precision active filters. Figure 47 shows a second-order, low-pass filter commonly encountered in signal processing applications.

8.2 Typical Applications

8.2.1 Typical OPA207 Application

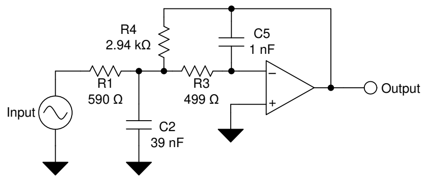

Figure 47. Typical OPA207 Application Schematic

8.2.1.1 Design Requirements

Use the following parameters for this design example:

- Gain = 5 V/V (inverting gain)
- Low-pass cutoff frequency = 25 kHz
- Second-order Chebyshev filter response with 3-dB gain peaking in the passband

8.2.1.2 Detailed Design Procedure

The infinite-gain multiple-feedback circuit for a low-pass network function is shown in Figure 47. Use Equation 1 to calculate the voltage transfer function.

$$\frac{\text{Output}}{\text{Input}}(s) = \frac{-1/R_1R_3C_2C_5}{s^2 + (s/C_2)(1/R_1 + 1/R_3 + 1/R_4) + 1/R_3R_4C_2C_5} \quad (1)$$

This circuit produces a signal inversion. For this circuit, the gain at dc and the low-pass cutoff frequency are calculated by Equation 2:

$$\text{Gain} = \frac{R_4}{R_1}$$

$$f_c = \frac{1}{2\pi}\sqrt{(1/R_3R_4C_2C_5)} \quad (2)$$

Software tools are readily available to simplify filter design. WEBENCH® Filter Designer is a simple, powerful, and easy-to-use active filter design program. The WEBENCH Filter Designer lets designers create optimized filter designs using a selection of TI operational amplifiers and passive components from TI's vendor partners.

Available as a web-based tool from the WEBENCH® Design Center, WEBENCH® Filter Designer allows to design, optimize, and simulate complete multi-stage active filter solutions within minutes.

Typical Applications (continued)

8.2.1.3 Application Curve

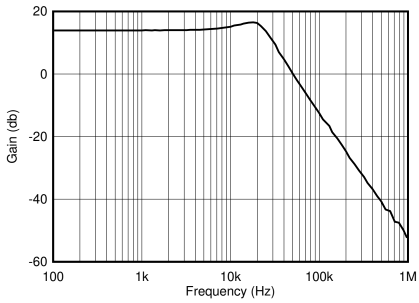

Figure 48. Low-Pass Filter Transfer Function

8.2.2 Precision Low-Side Current Sensing

With low offset voltage and low offset voltage drift over time and temperature the OPA207 works well for precision low-side current sensing applications as shown in Figure 49

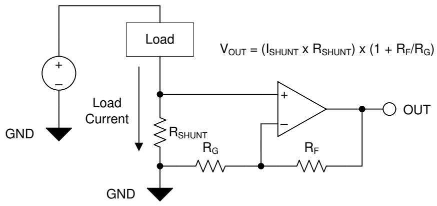

Figure 49. Precision Low-Side Current Sensing

Typical Applications (continued)

8.2.3 Precision Buffer With Increased Output Current

The OPA207 can be configured as illustrated in Figure 50 to drive low impedance loads. In Figure 50, the OPA207 is configured in a gain of +10 V/V, and the output current is boosted by the NPN (2N2904) and PNP (2N2906) bipolar transistors. For low output voltages the OPA207 supplies the load current directly through the 100-Ω resistor. The bipolar transistors begin to supply current when the voltage drop across the 100-Ω resistor exceeds approximately 500 mV. Figure 50 illustrates the results for a 50-Ω load resistor driven with a 10-V step at the output. This results in a 200-mA current supplied by the circuit.

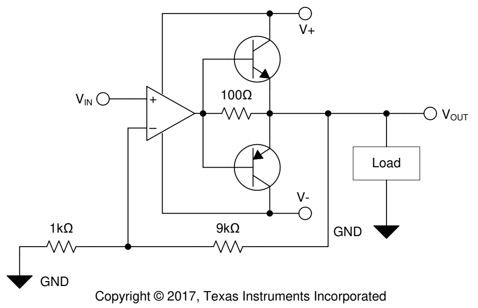

Figure 50. Precision Buffer (G = 10 V/V) With High Output Drive Capability

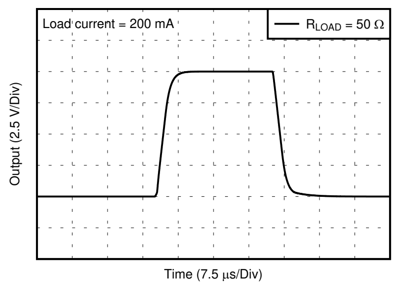

Figure 51. 50-Ω Load Driven With a 10-V Step

9 Power Supply Recommendations

The OPA207 is specified for operation from 4.5 V to 36 V (±2.25 V to ±18 V); many specifications apply from –40°C to +125°C. Parameters that can exhibit significant variance with regard to operating voltage or temperature are presented in the *Typical Characteristics*.

> **CAUTION**
>
> Supply voltages larger than 36 V can permanently damage the device; see the *Absolute Maximum Ratings*.

Place 0.1-µF bypass capacitors close to the power-supply pins to reduce errors coupling in from noisy or high-impedance power supplies. For more detailed information on bypass capacitor placement, refer to the *Layout Guidelines*.

10 Layout

10.1 Layout Guidelines

The OPA207 series has low offset voltage and drift. To achieve highest performance, optimize the circuit layout and mechanical conditions. Offset voltage and drift can be degraded by small thermoelectric potentials at the op amp inputs. Connections of dissimilar metals generate thermal potential, which can degrade the ultimate performance of the OPA207. These thermal potentials can be made to cancel by assuring that they are equal in both input terminals.

- Keep the thermal mass of the connections to the two input terminals similar.
- Locate heat sources as far as possible from the critical input circuitry.
- Shield operational amplifier and input circuitry from air currents, such as cooling fans.

For best operational performance of the device, use good PCB layout practices, including:

- Noise can propagate into analog circuitry through the power pins of the circuit as a whole and op amp itself. Bypass capacitors are used to reduce the coupled noise by providing low-impedance power sources local to the analog circuitry.
  – Connect low-ESR, 0.1–µF ceramic bypass capacitors between each supply pin and ground, placed as close as possible to the device. A single bypass capacitor from V+ to ground is applicable for single-supply applications.
- Separate grounding for analog and digital portions of circuitry is one of the simplest and most-effective methods of noise suppression. One or more layers on multilayer PCBs are usually devoted to ground planes. A ground plane helps distribute heat and reduces EMI noise pickup. Make sure to physically separate digital and analog grounds paying attention to the flow of the ground current.
- In order to reduce parasitic coupling, run the input traces as far away from the supply or output traces as possible. If these traces cannot be kept separate, crossing the sensitive trace perpendicular is much better as opposed to in parallel with the noisy trace.
- Place the external components as close as possible to the device. As shown in *Layout Example*, keeping RF and RG close to the inverting input minimizes parasitic capacitance.
- Keep the length of input traces as short as possible. Always remember that the input traces are the most sensitive part of the circuit.
- Consider a driven, low-impedance guard ring around the critical traces. A guard ring can significantly reduce leakage currents from nearby traces that are at different potentials.
- For best performance, TI recommends cleaning the PCB following board assembly.
- Any precision integrated circuit may experience performance shifts due to moisture ingress into the plastic package. Following any aqueous PCB cleaning process, TI recommends baking the PCB assembly to remove moisture introduced into the device packaging during the cleaning process. A low temperature, post-cleaning bake at 85°C for 30 minutes is sufficient for most circumstances.

10.2 Layout Example

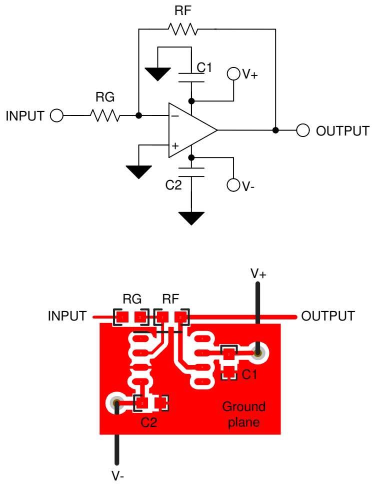

Figure 52. OPA207 Layout Example for the Inverting Configuration

11 Device and Documentation Support

11.1 Device Support

11.1.1 Development Support

11.1.1.1 Webench Filter Designer Tool

WEBENCH® Filter Designer is a simple, powerful, and easy-to-use active filter design program. The WEBENCH Filter Designer lets you create optimized filter designs using a selection of TI operational amplifiers and passive components from TI's vendor partners.

11.1.1.2 TINA-TI™ (Free Software Download)

TINA™ is a simple, powerful, and easy-to-use circuit simulation program based on a SPICE engine. TINA-TI is a free, fully-functional version of the TINA software, preloaded with a library of macro models in addition to a range of both passive and active models. TINA-TI provides all the conventional dc, transient, and frequency domain analysis of SPICE, as well as additional design capabilities.

Available as a free download from the Analog eLab Design Center, TINA-TI offers extensive post-processing capability that allows users to format results in a variety of ways. Virtual instruments offer the ability to select input waveforms and probe circuit nodes, voltages, and waveforms, creating a dynamic quick-start tool.

NOTE

These files require that either the TINA software (from DesignSoft™) or TINA-TI software be installed. Download the free TINA-TI software from the TINA-TI folder.

11.1.1.3 TI Precision Designs

The OPA207 is featured in several TI Precision Designs, available online at http://www.ti.com/ww/en/analog/precision-designs/. TI Precision Designs are analog solutions created by TI's precision analog applications experts and offer the theory of operation, component selection, simulation, complete PCB schematic and layout, bill of materials, and measured performance of many useful circuits.

11.2 Documentation Support

11.2.1 Related Documentation

For related documentation, see the following:

- Texas Instruments, *EMI Rejection Ratio of Operational Amplifiers*
- Texas Instruments, *Circuit Board Layout Techniques*

11.3 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on *Alert me* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

11.4 Support Resources

TI E2E™ support forums are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

Linked content is provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

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TINA, DesignSoft are trademarks of DesignSoft, Inc.
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11.6 Electrostatic Discharge Caution

These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
OPA207ID	ACTIVE	SOIC	D	8	75	RoHS & Green	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	OPA207	Samples
OPA207IDBVR	ACTIVE	SOT-23	DBV	5	3000	RoHS & Green	NIPDAUAG	Level-2-260C-1 YEAR	-40 to 125	1NBW	Samples
OPA207IDBVT	ACTIVE	SOT-23	DBV	5	250	RoHS & Green	NIPDAUAG	Level-2-260C-1 YEAR	-40 to 125	1NBW	Samples
OPA207IDGKR	ACTIVE	VSSOP	DGK	8	2500	RoHS & Green	NIPDAUAG	Level-2-260C-1 YEAR	-40 to 125	1I7Q	Samples
OPA207IDGKT	ACTIVE	VSSOP	DGK	8	250	RoHS & Green	NIPDAUAG	Level-2-260C-1 YEAR	-40 to 125	1I7Q	Samples
OPA207IDR	ACTIVE	SOIC	D	8	2500	RoHS & Green	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	OPA207	Samples

(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) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

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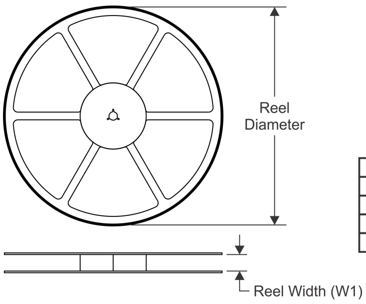
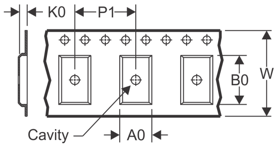
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

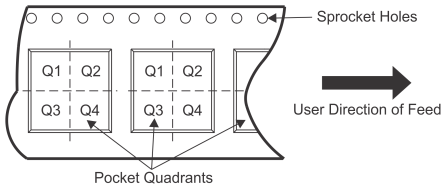


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

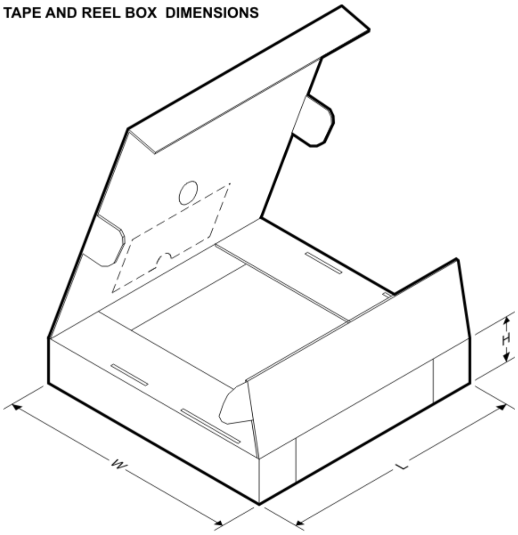
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
OPA207IDBVR	SOT-23	DBV	5	3000	180.0	8.4	3.23	3.17	1.37	4.0	8.0	Q3
OPA207IDBVT	SOT-23	DBV	5	250	180.0	8.4	3.23	3.17	1.37	4.0	8.0	Q3
OPA207IDGKR	VSSOP	DGK	8	2500	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
OPA207IDGKT	VSSOP	DGK	8	250	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
OPA207IDR	SOIC	D	8	2500	330.0	12.5	6.4	5.2	2.1	8.0	12.0	Q1

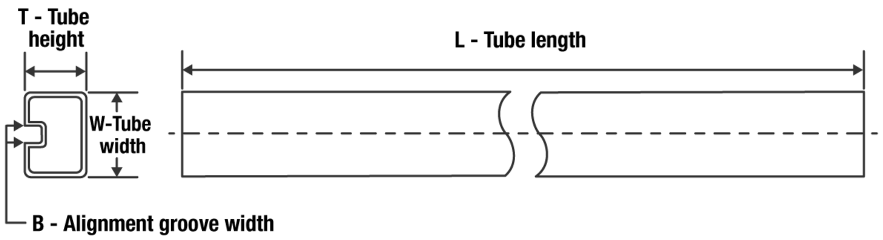
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
OPA207IDBVR	SOT-23	DBV	5	3000	213.0	191.0	35.0
OPA207IDBVT	SOT-23	DBV	5	250	213.0	191.0	35.0
OPA207IDGKR	VSSOP	DGK	8	2500	366.0	364.0	50.0
OPA207IDGKT	VSSOP	DGK	8	250	366.0	364.0	50.0
OPA207IDR	SOIC	D	8	2500	340.5	336.1	25.0

TUBE



*All dimensions are nominal

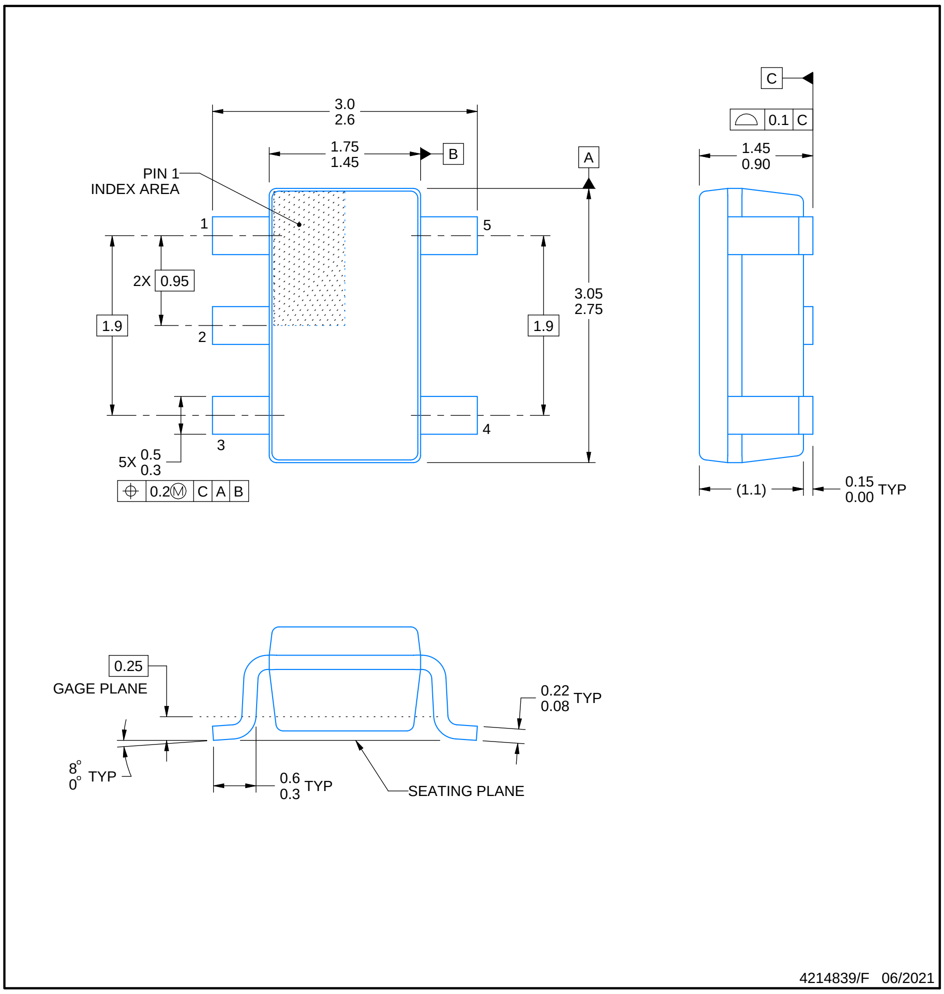
Device	Package Name	Package Type	Pins	SPQ	L (mm)	W (mm)	T (µm)	B (mm)
OPA207ID	D	SOIC	8	75	507	8	3940	4.32

DBV0005A

PACKAGE OUTLINE

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Refernce JEDEC MO-178.
4. Body dimensions do not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.25 mm per side.

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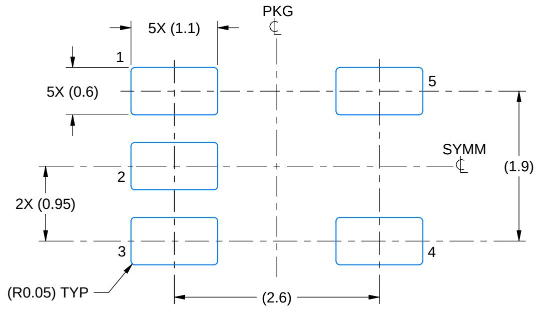
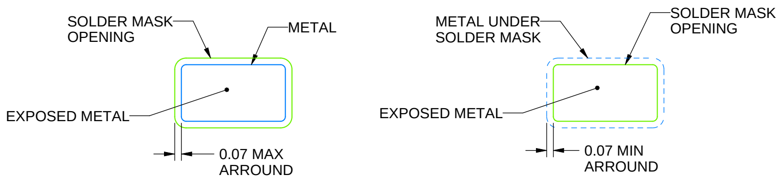


LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:15X



NON SOLDER MASK DEFINED (PREFERRED)

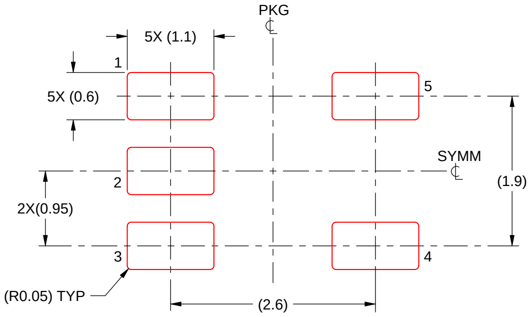
SOLDER MASK DEFINED

SOLDER MASK DETAILS

4214839/F 06/2021

NOTES: (continued)

5. Publication IPC-7351 may have alternate designs.
6. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

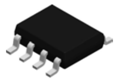


SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE:15X

4214839/F 06/2021

NOTES: (continued)

7. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
8. Board assembly site may have different recommendations for stencil design.

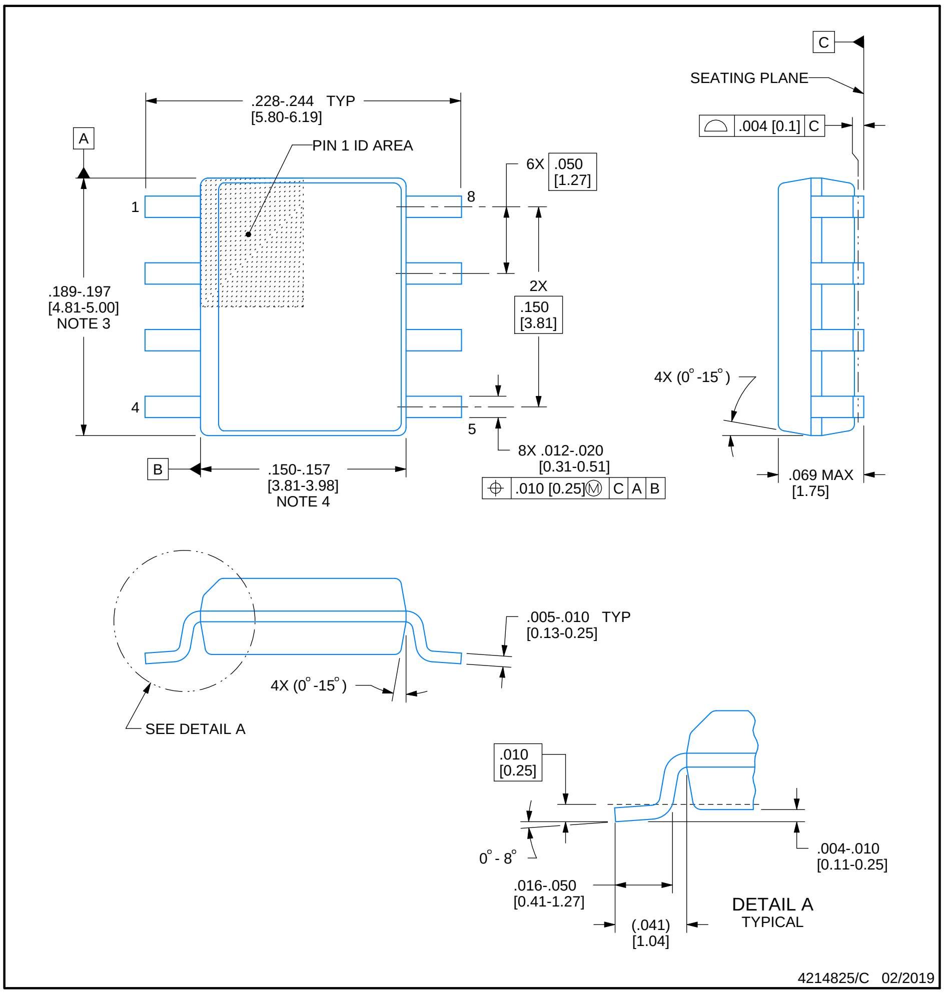


D0008A

PACKAGE OUTLINE

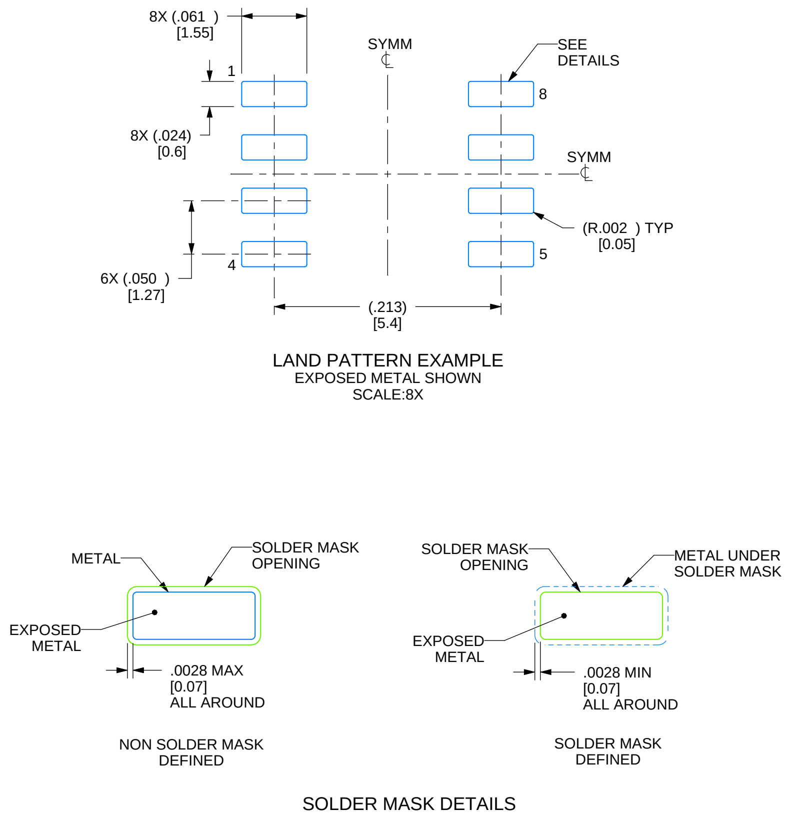
SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



NOTES:

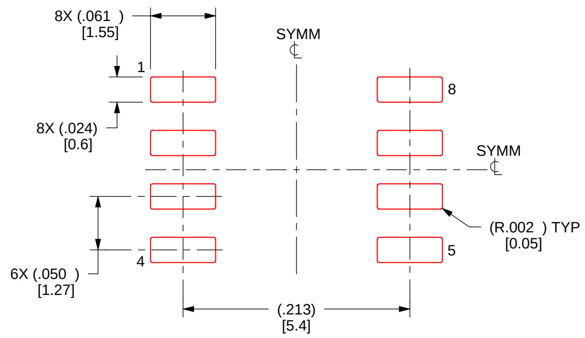
1. Linear dimensions are in inches [millimeters]. Dimensions in parenthesis are for reference only. Controlling dimensions are in inches. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed .006 [0.15] per side.
4. This dimension does not include interlead flash.
5. Reference JEDEC registration MS-012, variation AA.



4214825/C 02/2019

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.



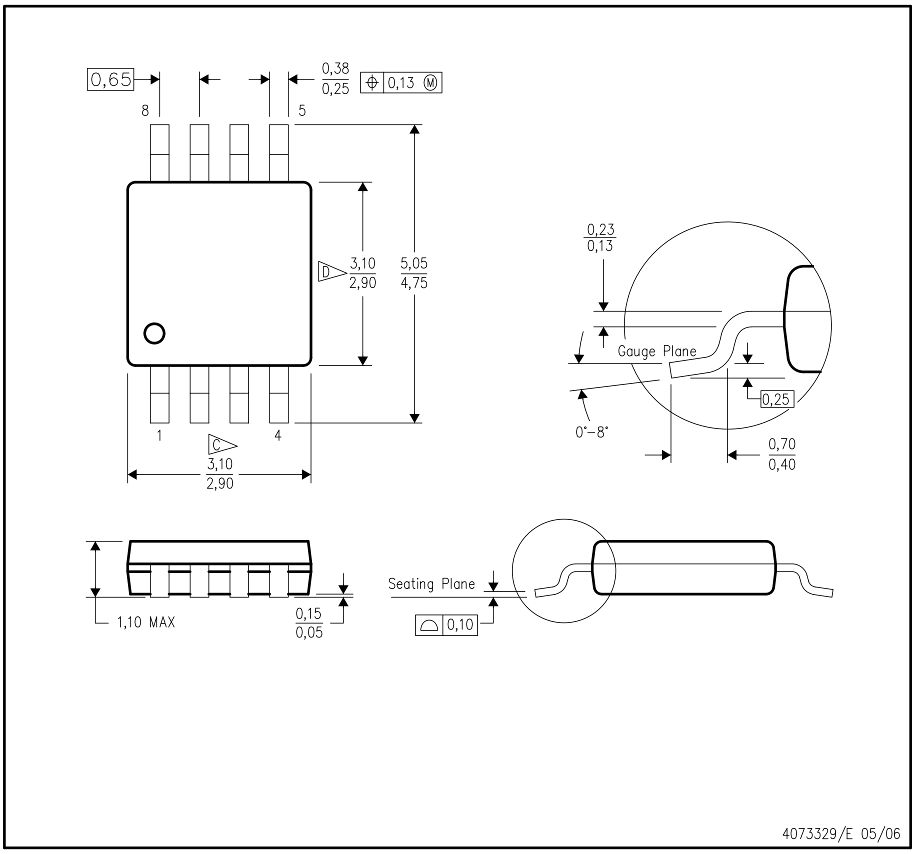
SOLDER PASTE EXAMPLE
BASED ON .005 INCH [0.125 MM] THICK STENCIL
SCALE:8X

4214825/C 02/2019

NOTES: (continued)

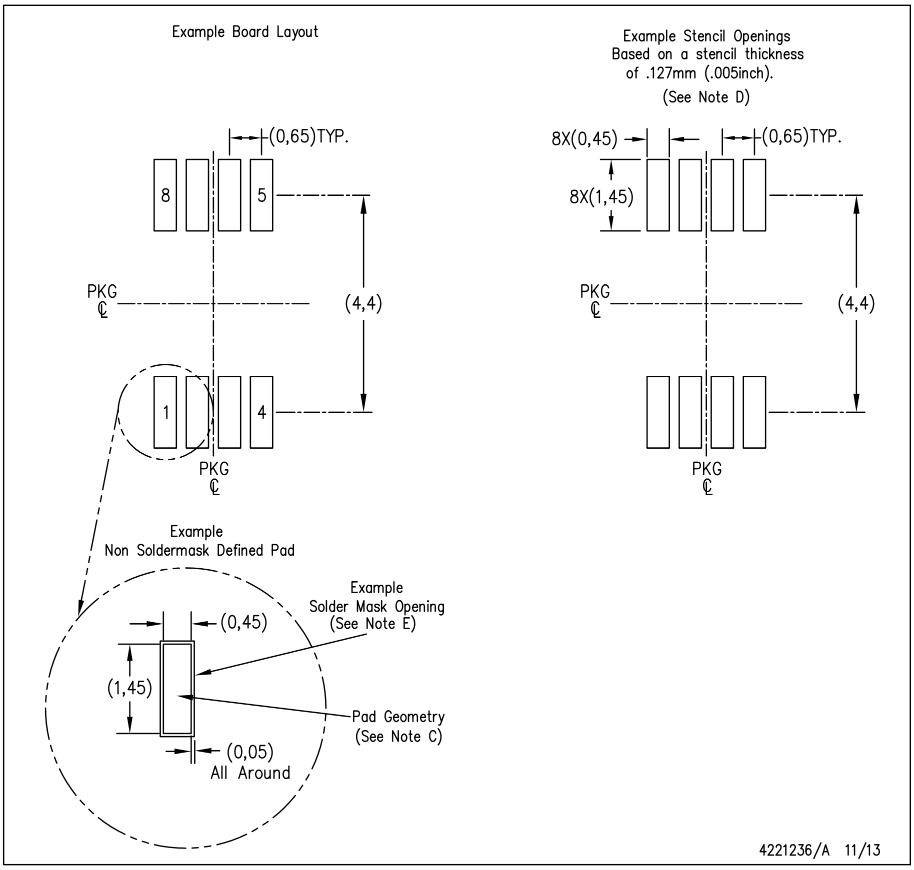
8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

DGK (S-PDSO-G8) PLASTIC SMALL-OUTLINE PACKAGE



NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 per end.
D. Body width does not include interlead flash. Interlead flash shall not exceed 0.50 per side.
E. Falls within JEDEC MO-187 variation AA, except interlead flash.

DGK (S–PDSO–G8) PLASTIC SMALL OUTLINE PACKAGE



NOTES:
- A. All linear dimensions are in millimeters.
- B. This drawing is subject to change without notice.
- C. Publication IPC–7351 is recommended for alternate designs.
- D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC–7525 for other stencil recommendations.
- E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

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Mini-Circuits

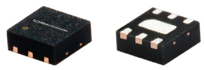
MICROWAVE PRECISION

Fixed Attenuator

YAT-30A+

50Ω 1W 30 dB DC to 18 GHz

THE BIG DEAL
- Wide bandwidth, DC-18 GHz
- Miniature package MCLP™ 2 x 2 mm
- Excellent attenuation accuracy & flatness



Generic photo used for illustration purposes only

CASE STYLE: MC1630

+RoHS Compliant
The +Suffix identifies RoHS Compliance.
See our website for methodologies and qualifications

APPLICATIONS
- Cellular
- PCS
- Communications
- Radar
- Defense

PRODUCT OVERVIEW
YAT-30A+ (RoHS compliant) is a fixed value, absorptive MMIC attenuator fabricated using highly repetitive IPD process technology with thin film resistors on GaAs substrates. This design incorporates through-wafer metallization vias to realize low thermal resistance and wideband operation with outstanding attenuation accuracy and flatness over its full operating bandwidth. YAT-A family attenuators are available with nominal attenuation values of 0 to 10 dB (in 1 dB steps), 12, 15, 20, and 30 dB. Packaged in a tiny 2 x 2 mm MCLPTM package, it's ideal for tight spaces in crowded board layouts. Also available in die form.

KEY FEATURES

Feature	Advantages
Wideband operation, DC to 18 GHz	Supports a wide array of applications including wireless cellular, microwave Communications, satellite, Defense and aerospace, medical broadband and optic applications.
Small Size and simple to use (2 mm x 2 mm)	As a single chip solution, the YAT-A series occupies less board space than a "T" or "Pi" pad configuration, and ensures repeatable performance over wide frequency ranges.
High Power, Up to 1W	High power handling in a small size package.
Wide range of nominal attenuation values 0 to 10 dB (in 1 dB steps), and 12, 15, 20, and 30 dB	Small increment offering enables circuit designer to change attenuation values without motherboard redesign making the YAT-A series ideal for select at test application.
MCLP™ Package	Low Inductance, repeatable transitions, excellent thermal path make the YAT-A series an ideal solution as an alternative to "do it yourself" resistor based attenuators.

MICROWAVE PRECISION

Fixed Attenuator

YAT-30A+

50Ω 1W 30 dB DC to 18 GHz

ELECTRICAL SPECIFICATIONS[1] AT 25°C, 50Ω (CPW)

Parameter	Frequency (GHz)	Min.	Typ.	Max.	Unit
Frequency Range		DC	—	18	GHz
Attenuation	0.01	—	30	—	dB
	DC - 5	29.5	29.97	30.5	
	5 - 15	29.6	30.41	31.7	
	15 - 18	30.2	30.95	31.8	
VSWR	DC - 5	—	1.16	1.37	:1
	5 - 15	—	1.12	2.10	
	15 - 18	—	1.20	2.10	

1. Tested on Mini-Circuits test board TB-YAT-30A+ using coplanar wave guide (CPW) input and output traces (see suggested PCB layout on page 4 of this data sheet)

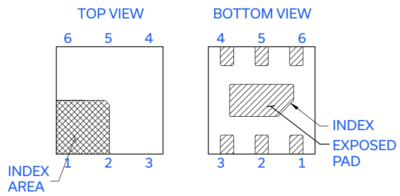
MAXIMUM RATINGS[4]

Parameter	Ratings
Operating Case Temperature[3]	-40°C to 85°C
Storage Temperature	-65°C to 150°C
RF Input Power[2]	1W

2. RF Power at 25°C case temperature: 1.0 Watt. Derate linearly to 0.8 W at 85°C
3. Case is defined as ground lead.
4. Permanent damage may occur if any of these limits are exceeded.

PAD DESCRIPTION

Function	Pad Number	Description
RF-IN	2	RF input pad
RF-OUT	5	RF output pad
GND	1,3,4,6 Bottom Exposed pad	Connected to ground externally



CHARACTERIZATION TEST CIRCUIT

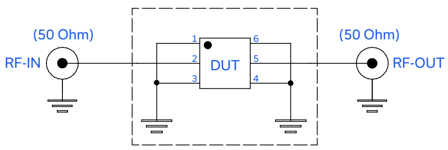
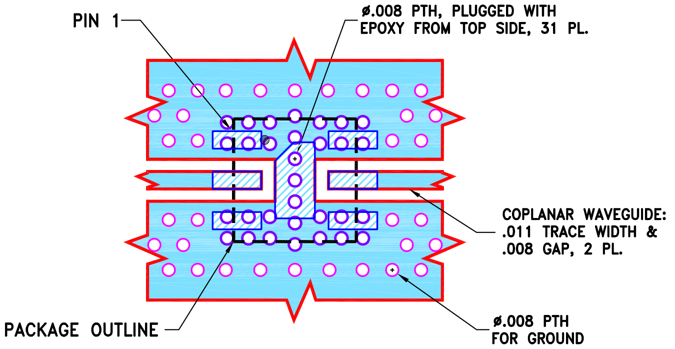


Fig 1. Block diagram of Test Circuit used for characterization, Test board TB-YAT-30A+
Conditions: Attenuation, VSWR: Pin=-10 dBm

SUGGESTED PCB LAYOUT (PL-586)

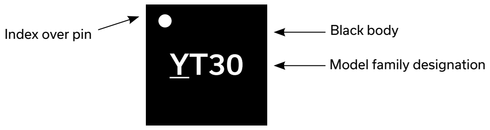


NOTES:
1. TRACE WIDTH & GAP PARAMETERS ARE SHOWN FOR ROGERS RO4350B WITH DIELECTRIC THICKNESS .0066±.0007. COPPER: 1/2 OZ. EACH SIDE. FOR OTHER MATERIALS TRACE WIDTH & GAP MAY NEED TO BE MODIFIED.
2. BOTTOM SIDE OF THE PCB IS CONTINUOUS GROUND PLANE.

DENOTES PCB COPPER LAYOUT WITH SMOBC (SOLDER MASK OVER BARE COPPER).

DENOTES COPPER LAND PATTERN FREE OF SOLDER MASK.

PRODUCT MARKING



Marking may contain other features or characters for internal lot control

MICROWAVE PRECISION

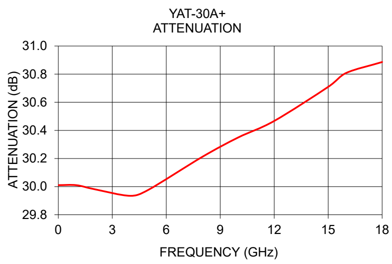
Fixed Attenuator

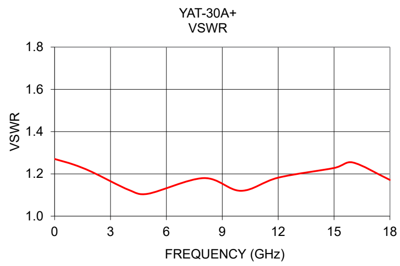
YAT-30A+

50Ω 1W 30 dB DC to 18 GHz

TYPICAL PERFORMANCE DATA AT 25°C

Frequency (GHz)	Attenuation (dB)	VSWR (:1)
0.01	30.01	1.27
1.0	30.01	1.24
2.0	29.98	1.21
4.0	29.93	1.12
5.0	29.98	1.11
8.0	30.21	1.18
10.0	30.35	1.12
12.0	30.47	1.18
15.0	30.71	1.23
16.0	30.81	1.25
18.0	30.89	1.17





MICROWAVE PRECISION

Fixed Attenuator

YAT-30A+

50Ω 1W 30 dB DC to 18 GHz

ADDITIONAL DETAILED TECHNICAL INFORMATION IS AVAILABLE ON OUR DASH BOARD. TO ACCESS CLICK HERE

Performance Data	Data Table Swept Graphs
Case Style	MC1630 Plastic package, Terminal finish: Matte Tin Plate
Tape & Reel **Standard quantities available on reel**	F108 7" reels with 20, 50, 100, 200, 500, 1K, or 2K devices
Suggested Layout for PCB Design	PL-586
Evaluation Board	TB-YAT-30A+
Environmental Ratings	ENV08T1

ESD RATING

Human Body Model (HBM): Class 2 (Pass 2000 V) per ANSI/ESD STM 5.1-2001

MSL RATING

Moisture Sensitivity: MSL1 in accordance with IPC/JEDEC J-STD-020D

NOTES

A. Performance and quality attributes and conditions not expressly stated in this specification document are intended to be excluded and do not form a part of this specification document.

B. Electrical specifications and performance data contained in this specification document are based on Mini-Circuit's applicable established test performance criteria and measurement instructions.

C. The parts covered by this specification document are subject to Mini-Circuits standard limited warranty and terms and conditions (collectively, "Standard Terms"); Purchasers of this part are entitled to the rights and benefits contained therein. For a full statement of the standard. Terms and the exclusive rights and remedies thereunder, please visit Mini-Circuits' website at www.minicircuits.com/MCLStore/terms.jsp