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Risk Assessment Advice for High Reliability Amplifiers

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Introduction

In long life, high reliability systems, supplied power is provided only to essential circuitry. As a result many of the unpowered circuits may have voltages applied to inputs and outputs without proper supply biasing. As part of any diligent system safety risk assessment, a question often arises; will the unpowered components be damaged, degraded, or impair circuit performance under these abnormal operating conditions?

The purpose of this article is to provide advice for what lies within the pins of several common amplifiers used in these applications. Most of the amplifiers of interest are the radiation hard amplifiers so indicated with a device prefix of RH. Another amplifier, the LT6016, is particularly robust with over, under and reversed polarity voltage conditions and is included for reference.

With no power applied to the amplifier, forcing a voltage between two pins will cause a current to flow. The magnitude of this current differs from pin to pin and device to device. A curve tracer is used to show the current vs voltage characteristic when overdriving specific pin combinations.

Referencing these curve trace plots will provide an indication of the magnitude of current flow for a particular voltage applied and also any clamp voltage at the device pin. From these it is hoped that an educated assessment of the risk of damage can be made.

How to Interpret This Information?

For each amplifier a set of curve trace plots is provided. These plots indicate the expected current flow should the inputs and output be connected to voltages outside the supply rails.

Also shown is a plot of a normal supply connection voltage sweep which indicates the amplifier's start-up characteristic. A note added to this plot states at what point to expect a supply overvoltage condition where the supply current begins to increase rapidly.

Another plot shows what to expect under a reverse polarity supply connection.

A plot with voltage applied between the two inputs is also provided. For amplifiers which contain protection diodes between the inputs this plot is accurate. For amplifiers which do not contain such diodes this plot can be misleading since the supply voltage pins are open circuited. The internal transistor action with power supplied can be quite different. Devices having different characteristics with power supplied are noted.

The usefulness of these plots can be shown through an example. In Figure 1 an RH/LT1013 op amp is powered off with its supply pins at circuit ground while other circuitry is active and presents $\pm 10V$ potentials through resistors to the -IN pin and the OUTPUT pin.

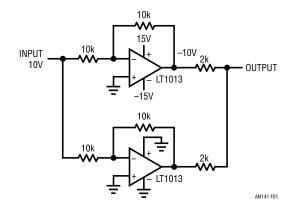


Figure 1. Example of Unpowered Redundant Circuitry

The input condition will try to pull the -IN pin positive. Pulling this input above the V^- supply rail is normal circuit operation for the RH/LT1013 so not a problem, but pulling it above the V^+ supply rail is abnormal and needs to

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be checked. Refer to the plot for the RH/LT1013 showing the –IN to V⁺ characteristic, as shown in Figure 2. With an input resistor of 10k the maximum current flow will be 1mA. At 1mA the –IN pin will pull up to near +1V. This plot shows that this input pin could be pulled to 50V above V⁺ with 30mA of input current without damage. The input biasing condition of this example is likely to be quite safe.

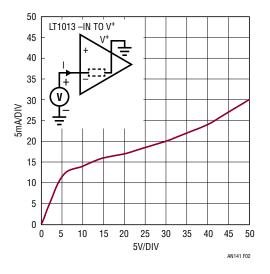


Figure 2. RH/LT1013 -IN Above V+ Plot

The output is being pulled negative through 4k of resistance. Checking the OUT to V^- plot for this amplifier, Figure 3, shows that the output will clamp at a diode drop below

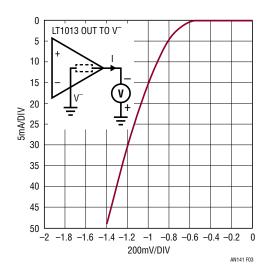


Figure 3. RH/LT1013 OUT Below V- Plot

the V^- rail, approximately -0.7V with 2.5mA of current flow. This internal diode is fairly large and as shown in the plot can safely conduct 10's of mAs. This condition will not likely cause any damage to the unpowered amplifier.

Another consequence of this condition however is loading of the powered amplifier caused by the output clamping of the unpowered amplifier. In this example the powered amplifier must be able to sink the 2.5mA of current to output the -10V level expected. If the powered amplifier is from another RH/LT1013 package, it is able to sink this much current so operation should be as expected. Other lower power amplifiers may not have the output current capability and the circuit output will be in error caused by the loading interaction from the unpowered amplifier.

Use of these plots can provide a good starting point for the evaluation of the risk of circuit damage and/or potential erroneous operation of systems subjected to abnormal supply connections. To help locate the plots for a particular amplifier this index is provided:

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Tips and Disclaimers

- 1. These measurements were taken on typical production devices.
- The majority of RH devices are electrically equivalent to the commercial LT version of the same device. Most of these measurements were taken on LT devices. The effects of radiation dosing is not addressed in this study.
- 3. This information is to be considered as typical room temperature performance. For characterization temperature behavior or radiation effects, the specific LT or RH die is highly recommended to obtain optimal data. No guarantee of device compliance to these measurements is to be assumed. Absolute Maximum Ratings apply. Check data sheet for more information.
- The intent of these measurements is solely to provide advice for what to expect under abnormal biasing conditions.
- Most amplifiers contain built-in protection circuitry at input and output pins, primarily for ESD protection. This circuitry is designed to redirect potentially destructive current from sensitive transistor structures.

- 6. A current of 10mA or less into or out of any pin of these amplifiers is generally considered safe and nondestructive short term or long term. Applied voltages less than the maximum rated supply voltage of the amplifier will be less likely to cause adverse transistor voltage breakdown effects.
- 7. A curve tracer sweeps the applied voltage for some measure of repetitive application. Long term effects or degradation from long term continuous or repetitive overvoltage conditions is not part of this study. If the current is flowing primarily through a simple protection diode it can generally be considered safe for the long term.
- 8. These tests were performed with voltage applied only to the indicated pins. Unless otherwise indicated the power supply pins of the amplifiers are open circuited.
- 9. After the curve trace testing, these units were verified to still have normal functionality in a typical application circuit on a lab bench setup at room temperature. They were not fully retested for all data sheet specifications on an automated production test system.



Amplifier Type: LT6016 Similar Devices: LT6015, LT6016, LT6017 Tested Device: LT6016 200 LT6016 +IN TO V+ LT6016 -IN TO V+ LT6016 OUT TO V+ 180 180 180 160 160 160 140 140 140 20µA/DIV 100 20µADIV 100 120 20µA/DIV 100 150 80 80 80 60 60 60 40 40 40 20 20 20 10 20 30 50 70 10 20 30 50 10 20 30 40 60 80 90 100 40 60 70 80 90 100 40 50 60 70 80 90 100 10V/DIV 10V/DIV 10V/DIV +IN to V+ -IN to V+ OUT to V+ 0 LT6016 -IN TO V LT6016 +IN TO V 0.5 0.5 1.0 1.0 6 1.5 0.5mA/DIV 2.0 2.0 2.5 2.5 3.0 2mA/DIV LT6016 OUT TO V 2.5 10 12 3.0 3.5 3.5 14 16 4.0 4.0 4.5 18 -5 -4.5 -4 -3.5 3 -2.5 2 -1.5 -1 -0.5 0 -5 -4.5 -4 -3.5 3 -2.5 2 -1.5 -1 -0.5 0 -1 -0.9 -0.8 -0.7 -0.6 -0.5 -0.4 -0.3 -0.2 -0.1 0 0.5V/DIV 0.5mV/DIV 100mV/DIV AN141 G04 AN141 G05 AN141 G06 +IN to V--IN to V-OUT to V-1000 2000 LT6016 +IN TO -IN LT6016 V- TO V+ LT6016 V+ TO V-DIFFERENTIAL INPUT 800 1800 REVERSE POWER APPLIED NORMAL POWER SUPPLY 1600 4.0 600 400 1400 3.5 200 1200 3.0 200µA/DIV 200µA/DIV 0.5mA/DIV 0 2.5 1000 -200 800 2.0 -400 600 -600 400 SUPPLY VOLTAGE BREAKDOWN BEGINS AT 72V. AT BREAKDOWN -800 DIFFERENT CHARACTERISTIC WITH POWER SUPPLIED ISUPPLY INCREASES TO 1200µA. -1000 60 -50 -40 -30 -20 -10 0 10 20 30 40 50 10 15 20 25 30 35 40 45 50 0 20 30 40 50 70 80 90 100 0 10V/DIV 10V/DIV V+ to V- (Normal Supply) V- to V+ (Reverse Supply) +IN to -IN (Differential Input)

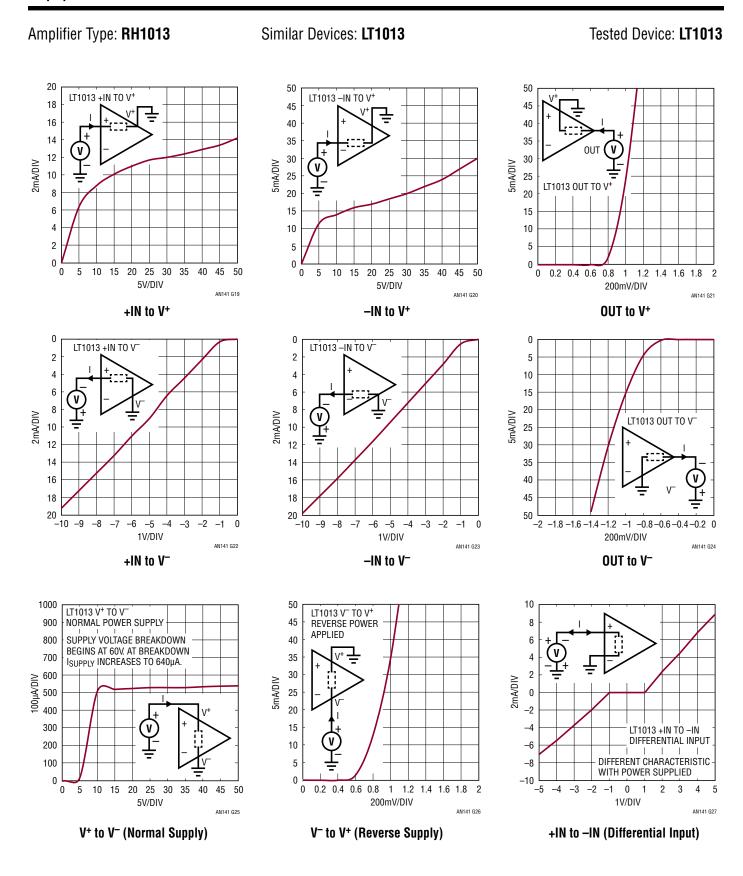


Tested Device: **OP07**

Amplifier Type: RH07 OP-07 -IN TO V+ OP-07 +IN TO V+ OP-07 OUT TO V+ 45 45 90 40 40 80 35 70 35 30 30 60 5mA/DIV 10mA/DIV 5mA/DIV 25 25 50 20 20 40 15 15 30 10 10 20 5 5 10 2 0.2 0.4 0.6 0.8 2 12 0 4 6 10 12 14 16 18 4 6 8 10 14 16 18 1 1.2 1.4 1.6 1.8 2V/DIV 2V/DIV 200mV/DIV AN141 G11 +IN to V+ -IN to V+ OUT to V+ 0 0P-07 +IN TO V 0P-07 -IN TO V 5 5 5 10 10 10 15 15 15 20 20 20 5mA/DIV 5mA/DIV 5mA/DIV OP-07 OUT TO V 25 25 25 30 30 30 35 35 35 40 40 40 45 45 45 50 -20 -18 -16 -14 -12 -10 -8 -6 , -20 -18 -16 -14 -12 -10 -8 -2 -1.8 -1.6 -1.4 -1.2 -1 -0.8 -0.6 -0.4 -0.2 0 200mV/DIV 2V/DIV 2V/DIV AN141 G15 AN141 G13 AN141 G14 +IN to V--IN to V-OUT to V 20 50 OP-07 V- TO V+ OP-07 V+ TO V REVERSE POWER APPLIED 18 NORMAL POWER SUPPLY 40 16 35 14 30 2mA/DIV 10 0 25 20 8 -2 6 15 10 SUPPLY VOLTAGE BREAKDOWN OP-07 +IN TO -IN BEGINS AT 48V. AT BREAKDOWN DIFFERENTIAL INPUT I_{SUPPLY} INCREASES TO 9mA. 10 15 20 30 35 40 45 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 -5 -3 -2 -1 0 2 3 25 100mV/DIV 1V/DIV 5V/DIV V+ to V- (Normal Supply) V- to V+ (Reverse Supply) +IN to -IN (Differential Input)

Similar Devices: **OP07**





Amplifier Type: RH1014 Similar Devices: LT1014 Tested Device: LT1014 20 50 LT1014 -IN TO V+ 18 45 45 16 40 40 14 35 12 30 30 5mA/DIV LT1014 +IN TO V+ 25 25 10 LT1014 OUT TO V 20 20 15 6 15 10 4 10 2 5 10 15 5 10 15 5 30 35 40 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 25 30 35 40 45 0 20 25 45 5V/DIV 5V/DIV 200mV/DIV AN141 G28 AN141 G29 AN141 G30 +IN to V+ -IN to V+ OUT to V+ 0 LT1014 +IN TO V LT1014 -IN TO V 2 2 5 4 10 6 6 15 8 20 10 10 25 LT1014 OUT TO V 12 30 35 14 14 40 16 16 45 18 18 _10 _9 -9 -8 -8 -2 -1.8 -1.6 -1.4 -1.2 -1 -0.8 -0.6 -0.4 -0.2 0 -5 -10 -6 -5 1V/DIV 1V/DIV 200mV/DIV +IN to V--IN to V-OUT to V-10 5.0 50 LT1014 V TO V+ LT1014 V⁺ TO V⁻ NORMAL POWER SUPPLY 8 4.5 45 REVERSE POWER 6 4.0 40 3.5 35 3.0 2.5 2.0 2.0 30 2mA/DIV 0 25 -2 20 1.5 15 LT1014 +IN TO -IN DIFFERENTIAL INPUT 1.0 -6 10 SUPPLY VOLTAGE BREAKDOWN DIFFERENT CHARACTERISTIC BEGINS AT 80V. AT BREAKDOWN 0.5 _8 I_{SUPPLY} INCREASES TO 1.7mA. WITH POWER SUPPLIED 0 5 10 15 20 25 30 35 40 45 50 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 -3 0 2 3 200mV/DIV 1V/DIV 5V/DIV AN141 G35 V+ to V- (Normal Supply) V⁻ to V⁺ (Reverse Supply) +IN to -IN (Differential Input)



Amplifier Type: RH1028, RH1128 Similar Devices: LT1028, LT1128 Tested Device: LT1028 LT1028 +IN TO V+ LT1028 -IN TO V+ LT1028 OUT TO V+ 45 90 90 40 80 80 35 70 30 60 10mA/DIV 10mA/DIV 5mA/DIV 25 50 50 20 40 40 30 15 30 20 20 10 10 10 1.4 1.6 1.8 1.4 1.6 1.8 1.4 1.6 1.8 0.2 0.4 0.6 0.8 1 1.2 0.2 0.4 0.6 0.8 0.2 0.4 0.6 1 1.2 0.8 1 1.2 200mV/DIV 200mV/DIV 200mV/DIV AN141 G37 AN141 G38 AN141 G39 +IN to V+ -IN to V+ OUT to V+ 10 10 10 20 20 20 30 30 LT1028 -IN TO V 10mA/DIV 10mA/DIV LT1028 +IN TO V 50 LT1028 OUT TO V 60 70 70 70 80 90 90 90 -2 -1.8 -1.6 -1.4 -1.2 -1 -0.8 -0.6 -0.4 -0.2 0 -2 -1.8 -1.6 -1.4 -0.8 -0.6 -0.4 -0.2 0 _10 <u>_</u>9 -8 -6 -5 200mV/DIV 200mV/DIV 1V/DIV AN141 G40 AN141 G41 AN141 G42 OUT to V-+IN to V -IN to V-100 10 LT1028 V- T0 V+ LT1028 V+ TO V-90 REVERSE POWER NORMAL POWER SUPPLY 80 70 60 10mA/DIV 2mA/DIV 1mA/DIV 50 0 -2 40 30 3 20 SUPPLY VOLTAGE BREAKDOWN BEGINS AT 52V. AT BREAKDOWN LT1028 +IN TO -IN 10 I_{SUPPLY} INCREASES TO 7mA. DIFFERENTIAL INPUT 10 12 14 16 18 20 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 -1 -0.8-0.6-0.4-0.2 0 0.2 0.4 0.6 0.8 2 2V/DIV 200mV/DIV 500mV/DIV

V- to V+ (Reverse Supply)

AN141 G44



+IN to -IN (Differential Input)

AN141 G45

AN141 G43

V+ to V- (Normal Supply)

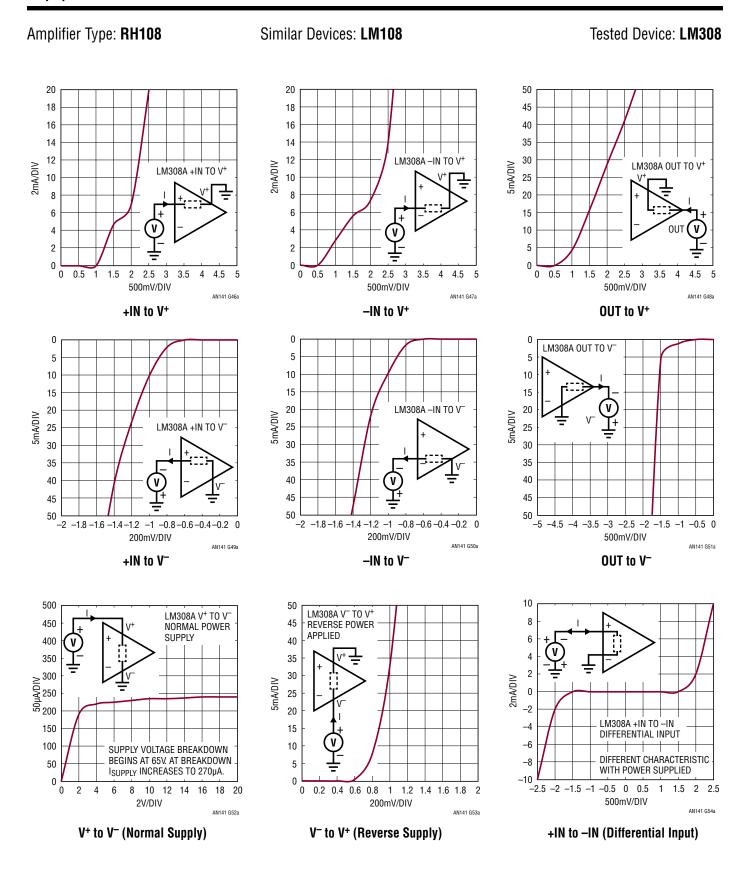
Tested Device: LT1078

THIS INPUT COULD THIS INPUT COULD ALSO APPEAR LT1078 -IN TO V+ LT1078 OUT TO V+ ALSO APPEAR 9 45 SIMILAR TO THE SIMILAR TO THE 40 -IN TO V⁺ +IN TO V+ RESPONSE RESPONSE SHOWN. SHOWN. INPUT 35 CHARACTERISTIC CHARACTERISTIC 30 DEPENDS ON VOS 5mA/DIV DEPENDS ON VOS LT1078 +IN TO V+ TRIMMING 25 TRIMMING RESULT. RESULT. 20 3 3 15 2 2 10 0.2 0.4 0.6 0.8 0.2 0.4 0.6 0.8 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 1 1.2 1.4 1.6 1.8 1 1.2 1.4 1.6 1.8 200mV/DIV 200mV/DIV 200mV/DIV AN141 G46 AN141 G47 AN141 G48 +IN to V+ -IN to V+ OUT to V+ LT1078 -IN TO V LT1078 OUT TO V LT1078 +IN TO V 5 2 2 10 3 3 15 20 5mA/DIV 25 6 30 6 35 7 40 8 -5 -4.5 -4 -3.5 -3 -2.5 -2 -1.5 -1 -0.5 0 -5 -4.5 -4 -3.5 -3 -2.5 -2 -2 -1.8-1.6-1.4-1.2 -1 -0.8-0.6-0.4-0.2 0 -1.5 -1 -0.5 0 0.5V/DIV 0.5V/DIV 200mV/DIV AN141 G50 AN141 G51 +IN to V--IN to V-OUT to V-500 50 LT1078 V- TO V+ LT1078 V+ T0 V 45 450 REVERSE POWER NORMAL POWER SUPPLY 6 40 400 35 350 300 250 30 5mA/DIV 0 25 <u>ā</u> 200 LT1078 +IN TO -IN 20 DIFFERENTIAL INPUT 150 15 100 10 SUPPLY VOLTAGE BREAKDOWN DIFFERENT CHARACTERISTIC -8 BEGINS AT 58V. AT BREAKDOWN 50 WITH POWER SUPPLIED I_{SUPPLY} INCREASES TO 120μA. -3 -2 2 4 6 10 12 14 16 18 20 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 0 8 1V/DIV 2V/DIV 100mV/DIV AN141 G54 V+ to V- (Normal Supply) V- to V+ (Reverse Supply) +IN to -IN (Differential Input)

Similar Devices: LT1078, LT1079



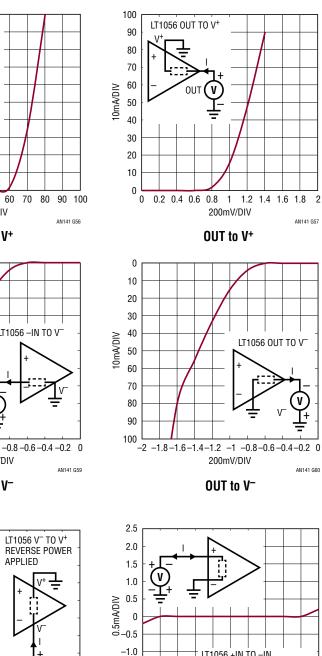
Amplifier Type: RH1078

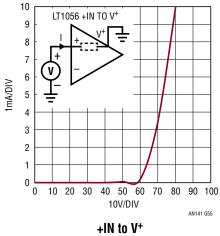


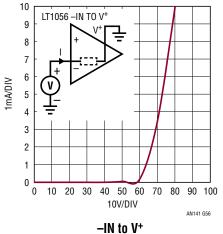
Tested Device: LT1056

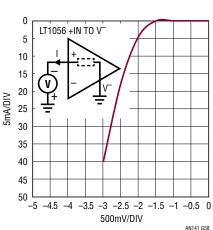
Amplifier Type: RH1056

Similar Devices: **LT1055**, **LT1056**, **LT1057**

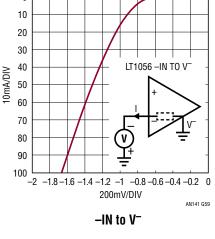


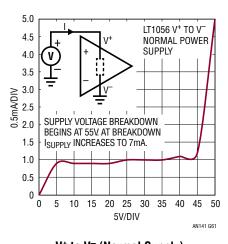






+IN to V-





50 45 40 35 30 25 20 15 10 5 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 200mV/DIV

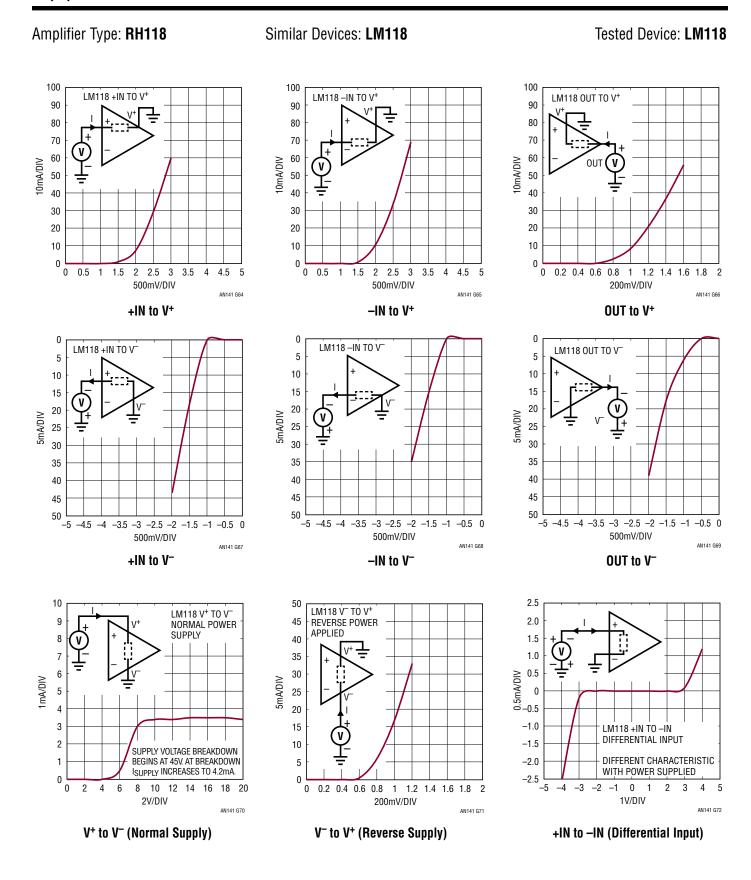
LT1056 +IN TO -IN DIFFERENTIAL INPUT -1.5 DIFFERENT CHARACTERISTIC -2.0 WITH POWER SUPPLIED -50 -40 -30 -20 -10 0 10 30 40 50 10V/DIV

V+ to V- (Normal Supply)

V- to V+ (Reverse Supply)

+IN to -IN (Differential Input)



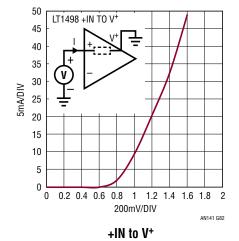




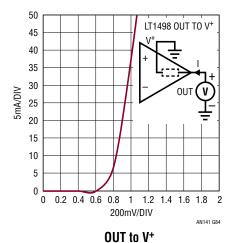
Amplifier Type: RH1498, RH1499

Similar Devices: LT1498, LT1499

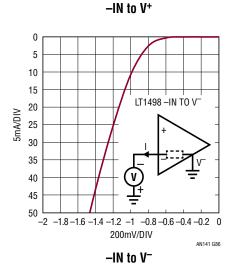
Tested Device: LT1498

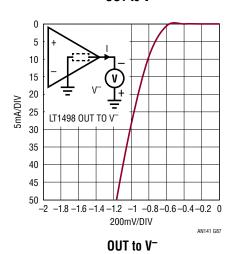


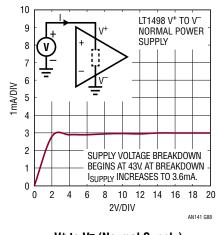
LT1498 -IN TO V+ 45 40 35 30 25 20 15 10 5 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 200mV/DIV AN141 G83

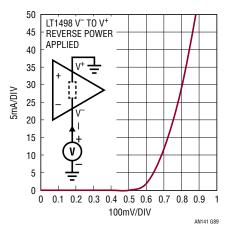


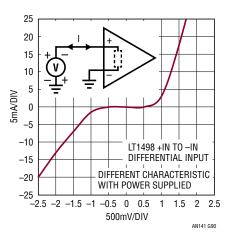
0 5 10 15 20 25 30 35 40 45 50 -2 -1.8 -1.6 -1.4 -1.2 -1 -0.8 -0.6 -0.4 -0.2 0 500mV/DIV AN141 GBS











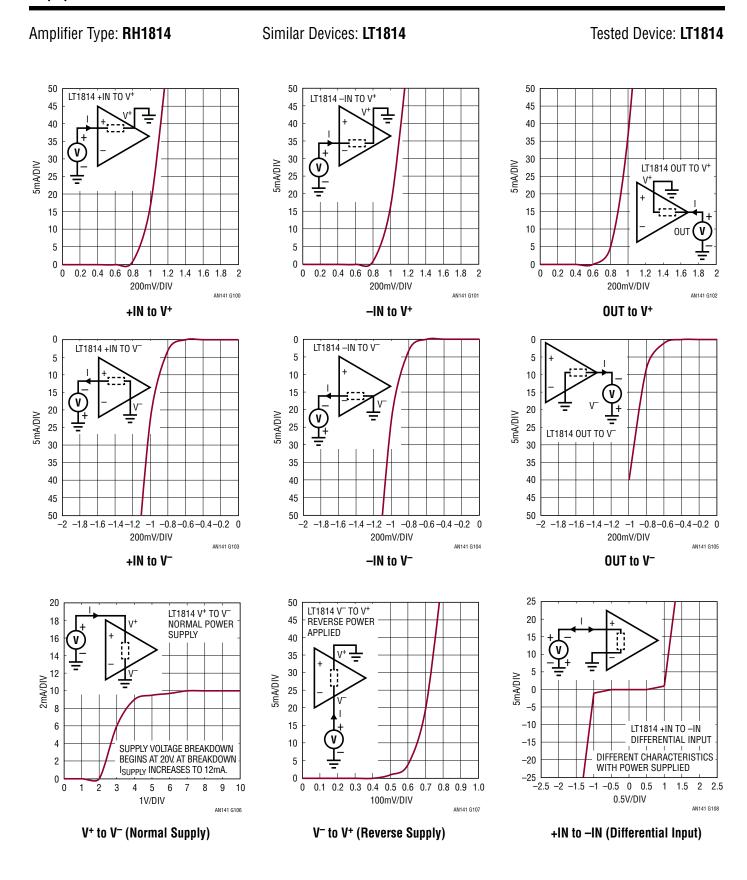
V⁺ to V⁻ (Normal Supply)

V- to V+ (Reverse Supply)

+IN to -IN (Differential Input)

LINEAR

an141f



Amplifier Type: RH27, RH37 Similar Devices: 0P27, 0P37, LT1007, LT1037 Tested Device: LT1007 100 LT1007 +IN TO V+ LT1007 OUT TO V+ LT1007 -IN TO V+ 90 90 90 80 80 80 70 70 60 60 60 10mA/DIV 10mA/DIV 10mA/DIV 50 50 50 40 40 40 30 30 30 20 20 20 10 10 10 0.5 2.5 3.5 0.5 0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 1 1.5 2 2.5 3 3.5 4.5 500mV/DIV 500mV/DIV 200mV/DIV AN141 G109 AN141 G110 AN141 G111 +IN to V+ -IN to V+ OUT to V+ 0 0 0 10 5 10 20 20 10 30 30 15 40 40 20 LT1007 -IN TO V 10mA/DIV LT1007 OUT TO V LT1007 +IN TO V 50 50 25 30 60 60 70 35 70 80 80 40 90 45 90 -2 -1.8 -1.6 -1.4 -1.2 -1 -0.8 - 0.6-2 -1.8 -1.6 -1.4 -1 -0.8 -0.6 -0.4 -0.2 0 -2 -1.8 -1.6 -1.4 -1.2 -1 -0.8 -0.6 -0.4 -0.2 0 200mV/DIV 200mV/DIV 200mV/DIV AN141 G112 AN141 G114 +IN to V--IN to V-OUT to V 25 5.0 100 LT1007 V+ TO V LT1007 V- TO V+ NORMAL POWER 20 90 4.5 REVERSE POWER 15 80 SUPPLY VOLTAGE BREAKDOWN 10 70 BEGINS AT 56V. AT BREAKDOWN I_{SUPPLY} INCREASES TO 3.6mA. 3.0 2.5 2.0 2.0 60 5mA/DIV 10mA/DIV 0 50 -5 40 -10 1.5 30 -15 20 1.0 LT1007 +IN TO -IN -20



5 6 7

1V/DIV

V+ to V- (Normal Supply)

3 4 9

AN141 G115

10

8

0.5

0.2 0.4 0.6 0.8

1 1.2 1.4 1.6 1.8

AN141 G116

200mV/DIV

V⁻ to V⁺ (Reverse Supply)

10

DIFFERENTIAL INPUT

1.5

0 0.5

500mV/DIV

+IN to -IN (Differential Input)

2

2.5

-2.5 -2 -1.5 -1 -0.5

Amplifier Type: RH6200 Similar Devices: LT6200 Tested Device: LT6200 LT6200 +IN TO V+ LT6200 OUT TO V+ LT6200 -IN TO V+ 45 45 45 40 40 40 35 35 35 30 30 30 5mA/DIV 5mA/DIV 5mA/DIV 25 25 25 20 20 20 15 15 15 10 10 10 5 5 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 0.2 0.4 0.6 0.8 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 1 1.2 1.4 1.6 1.8 200mV/DIV 200mV/DIV 200mV/DIV +IN to V+ -IN to V+ OUT to V+ 0 LT6200 +IN TO V LT6200 -IN TO V 5 5 5 10 10 10 15 15 15 20 20 20 5mA/DIV 5mA/DIV LT6200 OUT TO V 25 25 25 30 30 30 35 35 35 40 40 40 45 45 45 -2 -1.8 -1.6 -1.4 -1.2 -1 -0.8 -0.6 -0.4 -0.2 0 -0.8 -0.6 -0.4 -0.2 0 -2 -1.8 -1.6 -1.4 -1.2 -1 -2 -1.8 -1.6 -1.4 -1.2 -1 -0.8 -0.6 -0.4 -0.2 0 200mV/DIV 200mV/DIV 200mV/DIV +IN to V--IN to V-OUT to V-25 50 LT6200 V⁺ TO V⁻ NORMAL POWER LT6200 V- TO V+ 45 20 SUPPLY 40 40 15 SUPPLY VOLTAGE BREAKDOWN 35 10 35 BEGINS AT 20V. AT BREAKDOWN I_{SUPPLY} INCREASES TO 15mA. 30 30 5mA/DIV 5mA/DIV 25 0 25 20 20 -5 15 15 -1010 -15 10 LT6200 +IN TO -IN -20 5 DIFFERENTIAL INPUT 7 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 -1 -0.8-0.6-0.4-0.2 0 0.2 0.4 0.6 0.8 1 2 3 4 5 6 8 9 10 100mV/DIV 200mV/DIV 1V/DIV V+ to V- (Normal Supply) V- to V+ (Reverse Supply) +IN to -IN (Differential Input)

