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 ±10V potentials through resistors to the –IN pin and the OUTPUT pin.

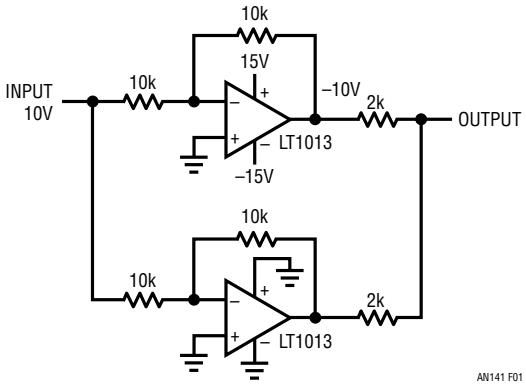


Figure 1. Example of Unpowered Redundant Circuitry

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

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.

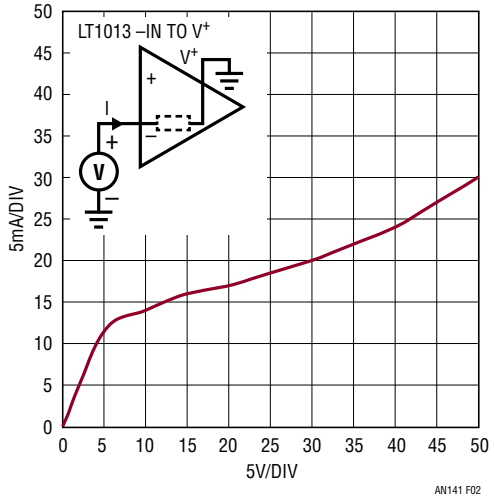


Figure 2. RH/LT1013 –IN Above V+ Plot

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

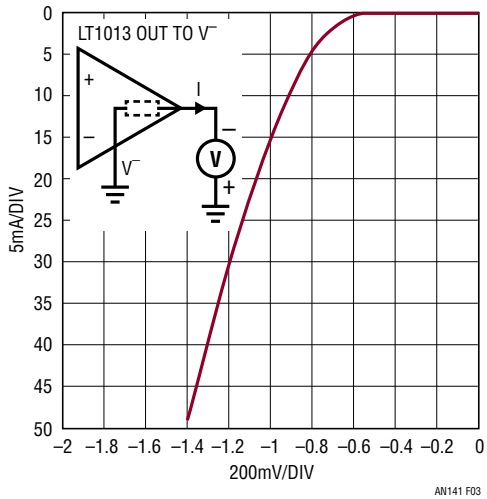


Figure 3. RH/LT1013 OUT Below V– Plot

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.

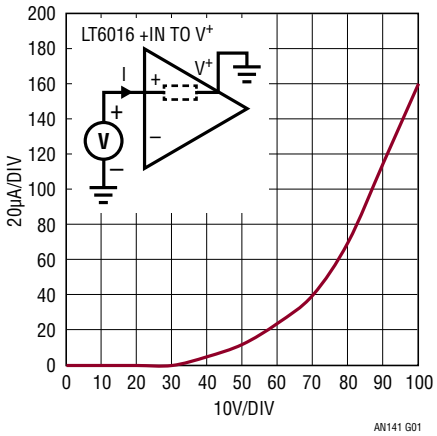
Use of these plots can provide a good starting point for the evaluation of the risk of circuit damage and/or potential erroneous operation of systems subjected to abnormal supply connections. To help locate the plots for a particular amplifier this index is provided:

INDEX

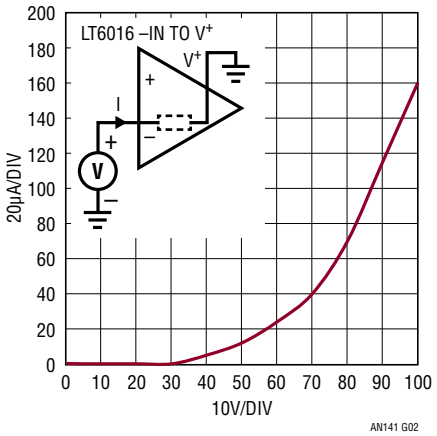
Tips and Disclaimers

1. These measurements were taken on typical production devices.
2. 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.**
4. The intent of these measurements is solely to provide advice for what to expect under abnormal biasing conditions.
5. 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 non-destructive 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.

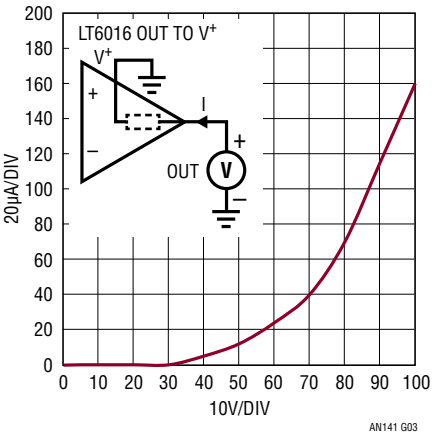
Amplifier Type: **LT6016** Similar Devices: **LT6015, LT6016, LT6017** Tested Device: **LT6016**



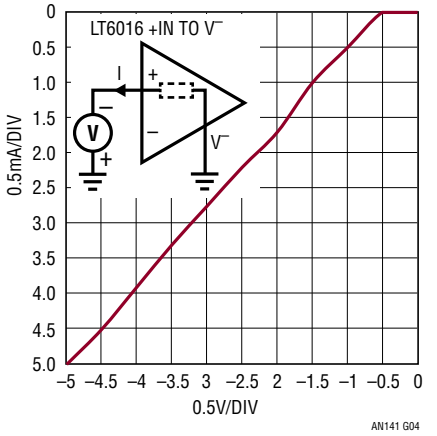
+IN to V+



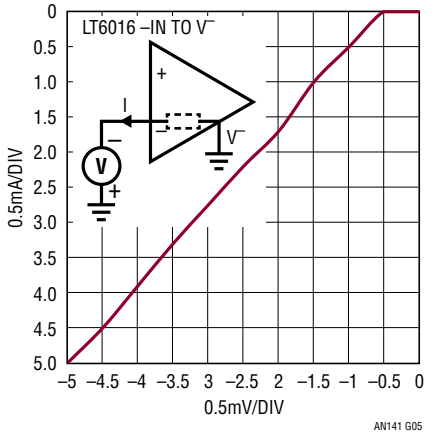
–IN to V+



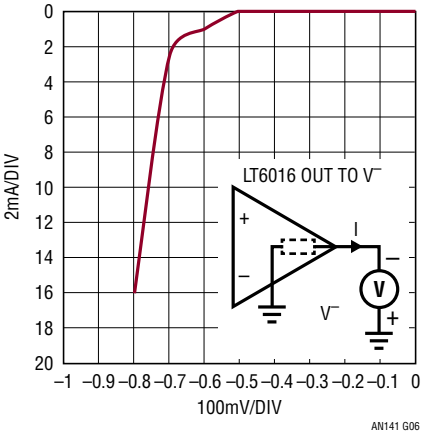
OUT to V+



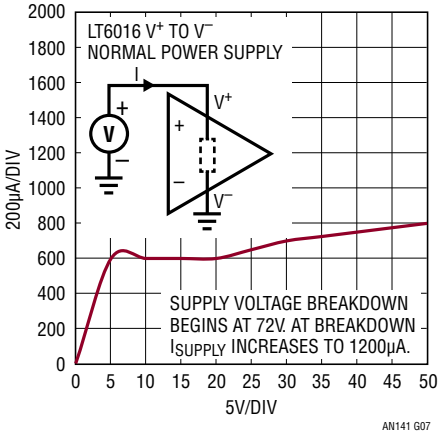
+IN to V–



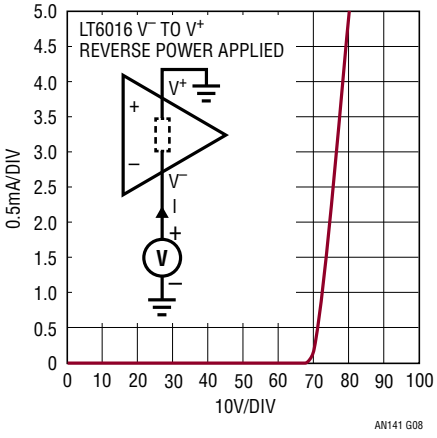
–IN to V–



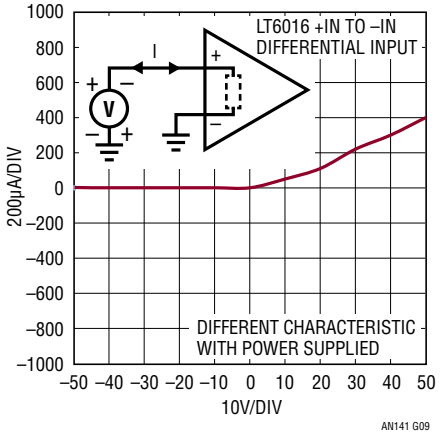
OUT to V–



V+ to V– (Normal Supply)

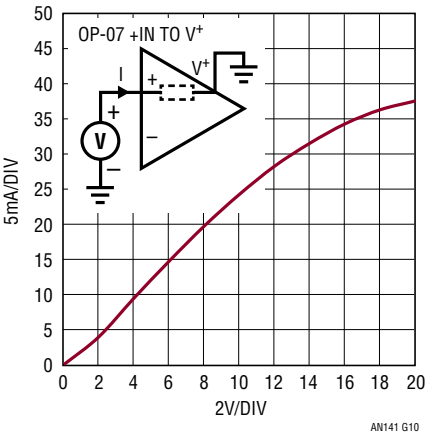


V– to V+ (Reverse Supply)

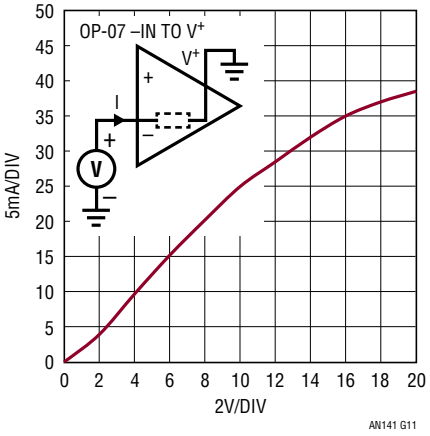


+IN to –IN (Differential Input)

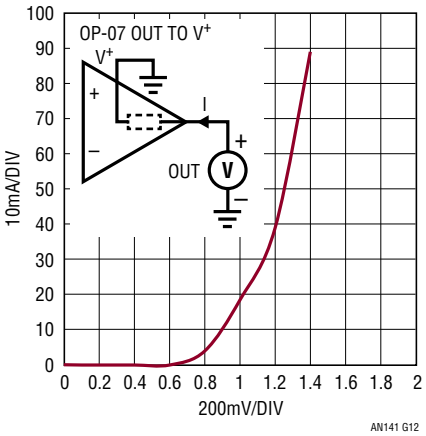
Amplifier Type: **RH07** Similar Devices: **OP07** Tested Device: **OP07**



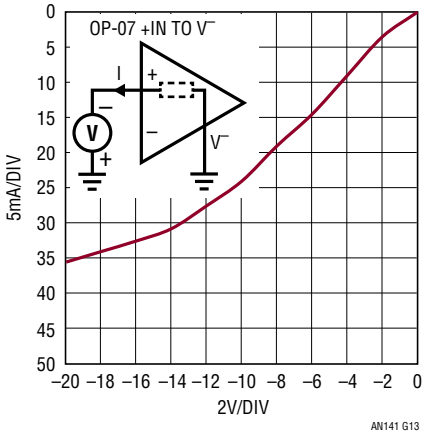
+IN to V+



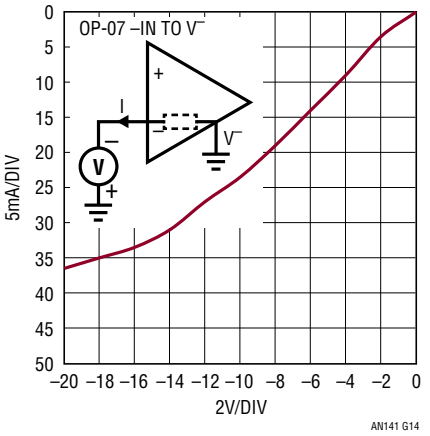
–IN to V+



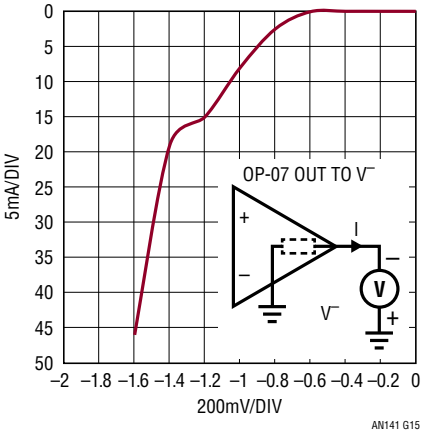
OUT to V+



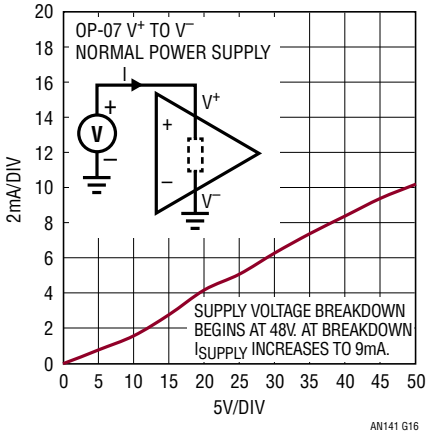
+IN to V–



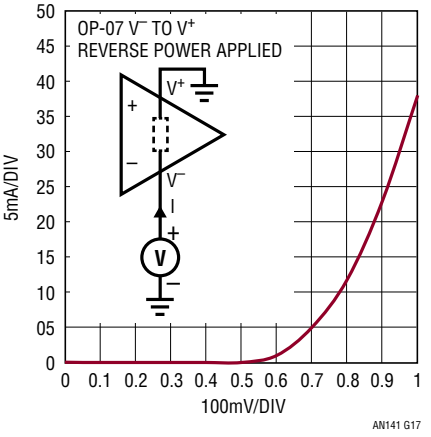
–IN to V–



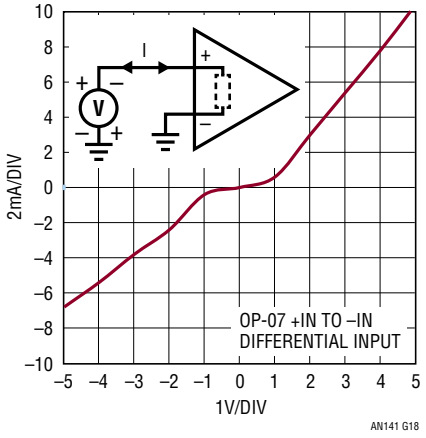
OUT to V–



V+ to V– (Normal Supply)

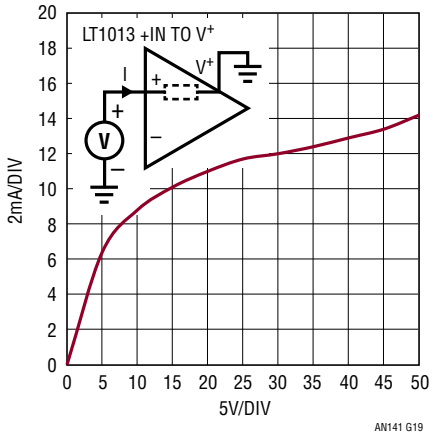


V– to V+ (Reverse Supply)

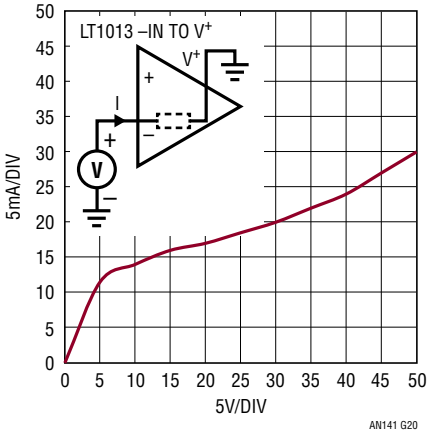


+IN to –IN (Differential Input)

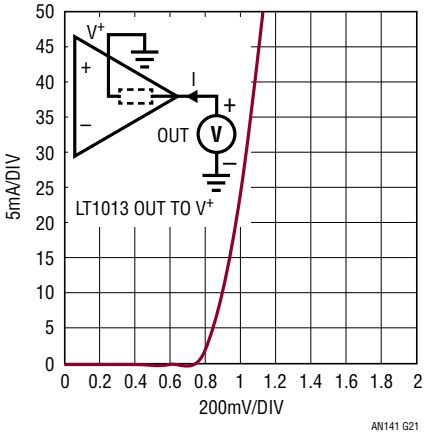
Amplifier Type: **RH1013** Similar Devices: **LT1013** Tested Device: **LT1013**



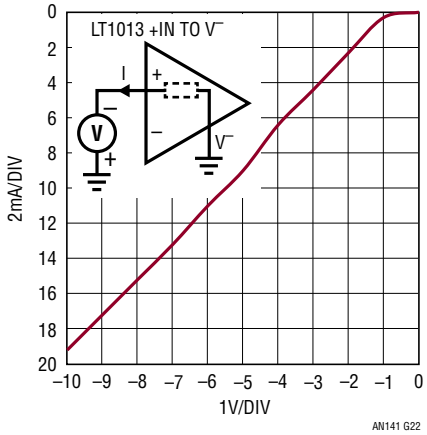
+IN to V⁺



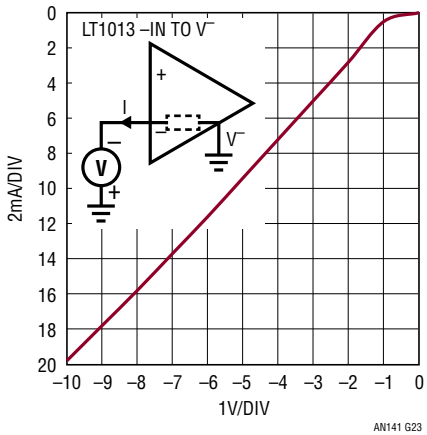
–IN to V⁺



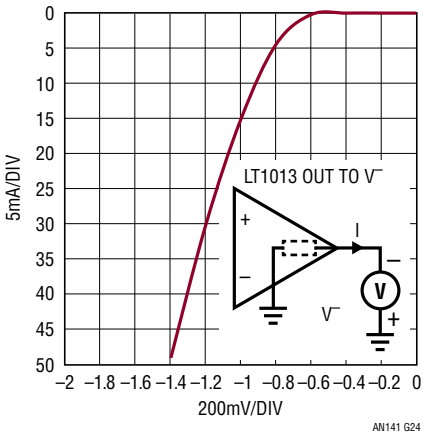
OUT to V⁺



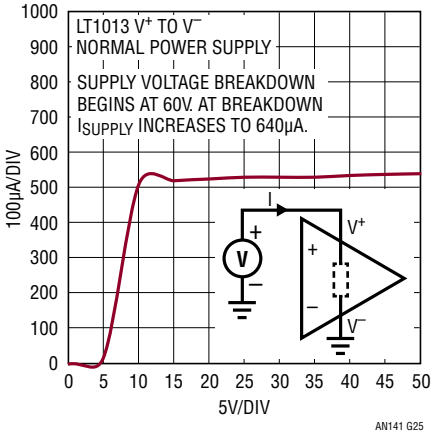
+IN to V⁻



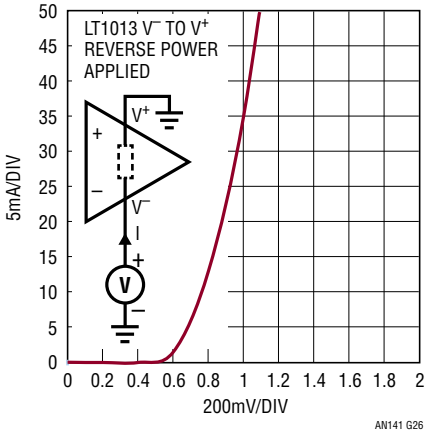
–IN to V⁻



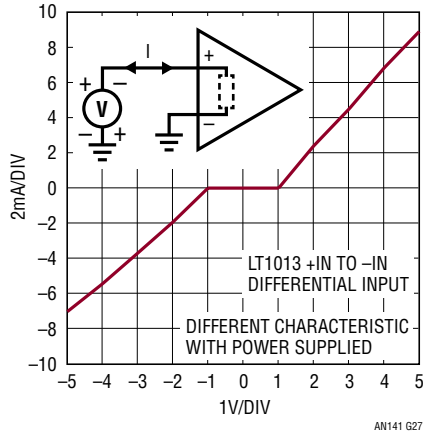
OUT to V⁻



V⁺ to V⁻ (Normal Supply)

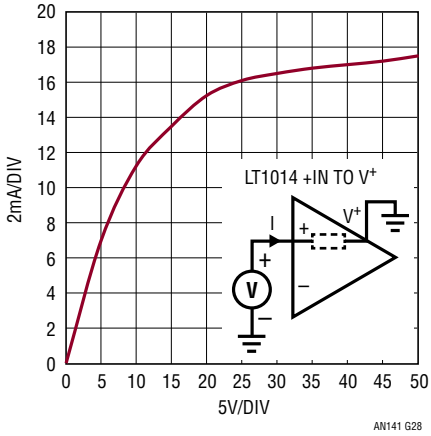


V⁻ to V⁺ (Reverse Supply)

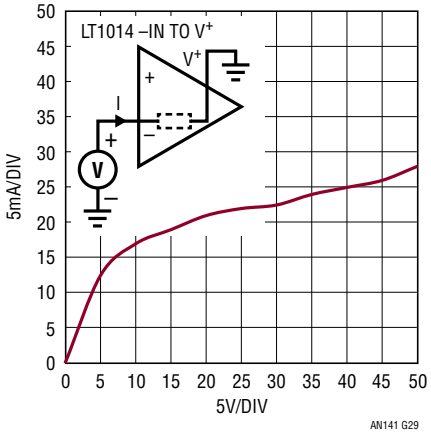


+IN to –IN (Differential Input)

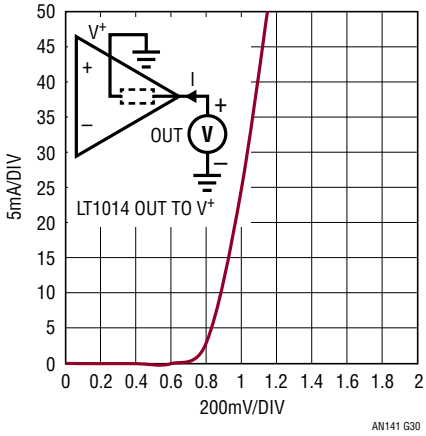
Amplifier Type: **RH1014** Similar Devices: **LT1014** Tested Device: **LT1014**



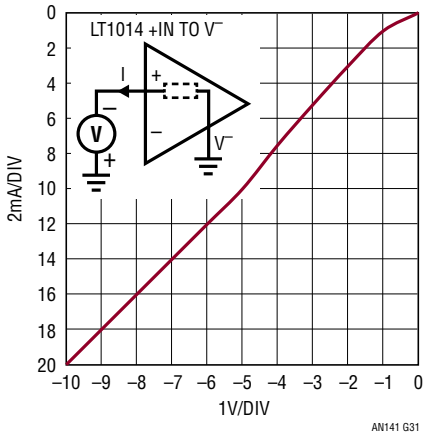
+IN to V⁺



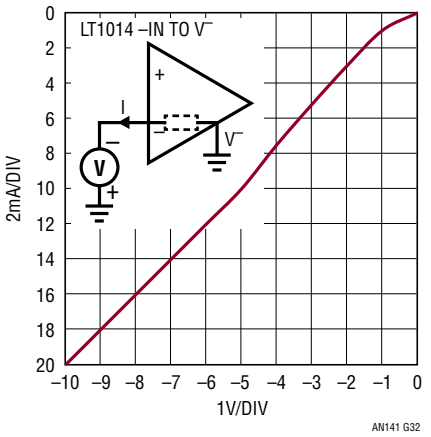
–IN to V⁺



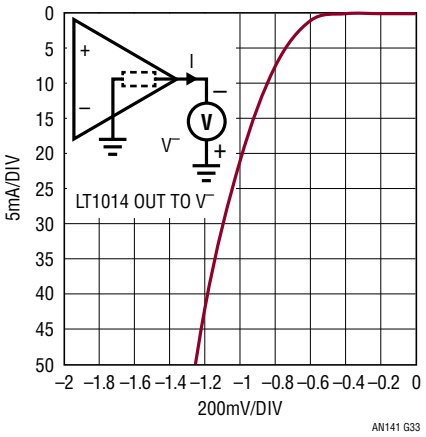
OUT to V⁺



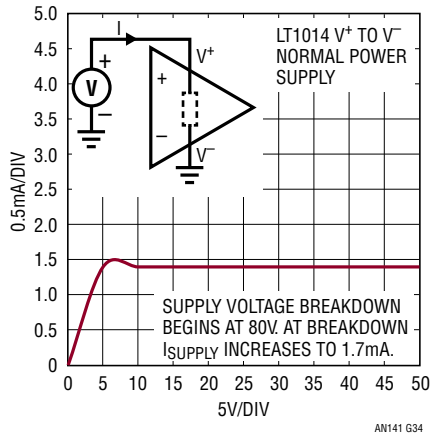
+IN to V⁻



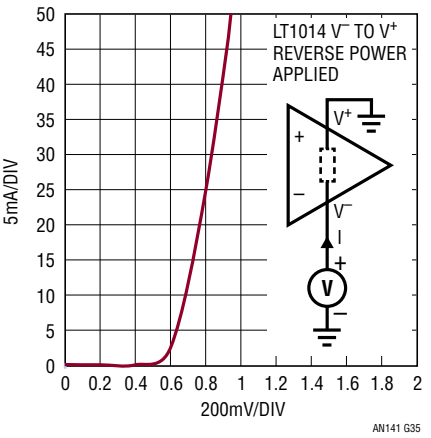
–IN to V⁻



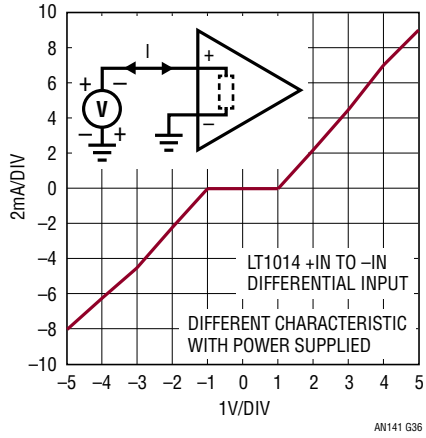
OUT to V⁻



V⁺ to V⁻ (Normal Supply)

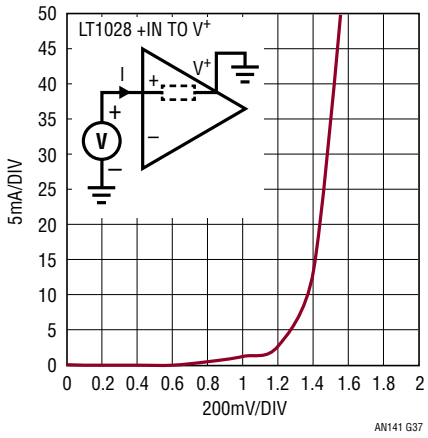


V⁻ to V⁺ (Reverse Supply)

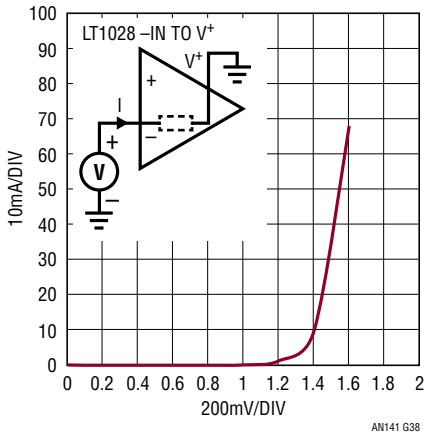


+IN to –IN (Differential Input)

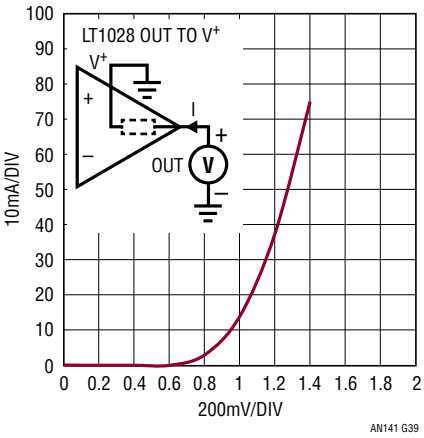
Amplifier Type: **RH1028, RH1128** Similar Devices: **LT1028, LT1128** Tested Device: **LT1028**



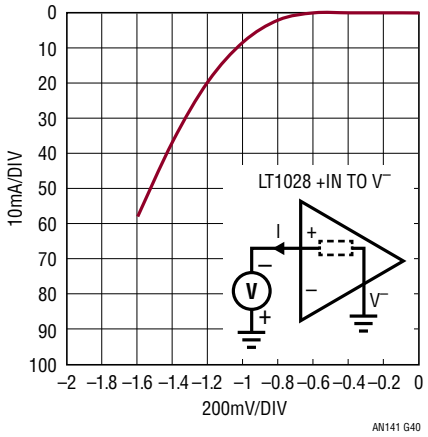
+IN to V⁺



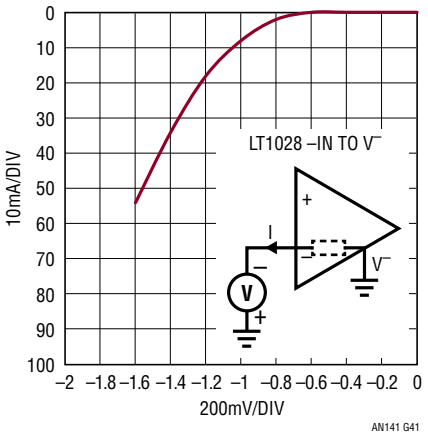
–IN to V⁺



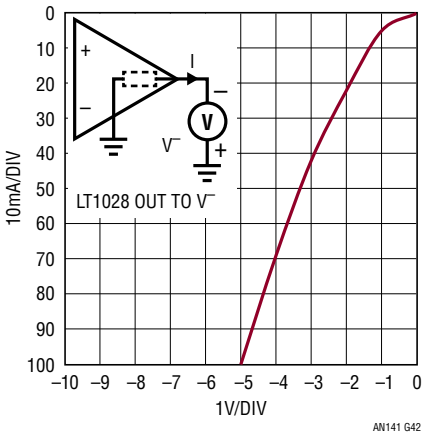
OUT to V⁺



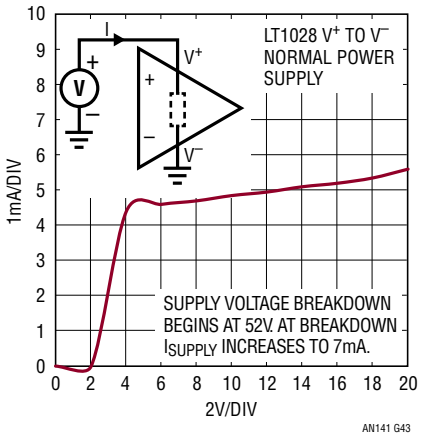
+IN to V⁻



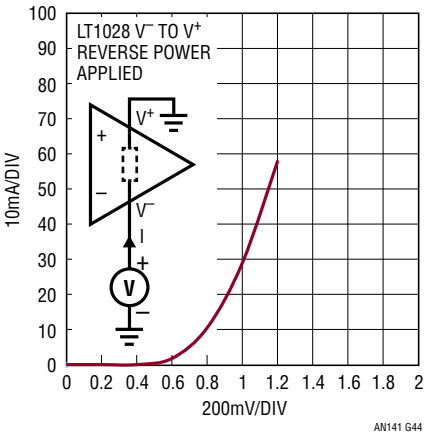
–IN to V⁻



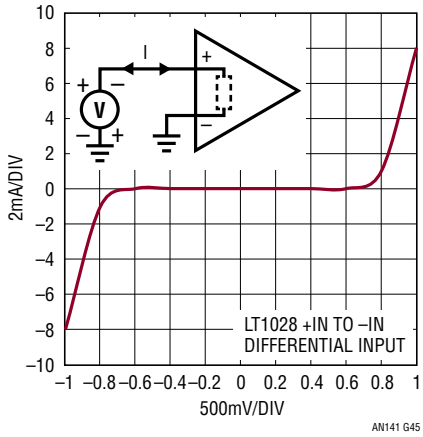
OUT to V⁻



V⁺ to V⁻ (Normal Supply)

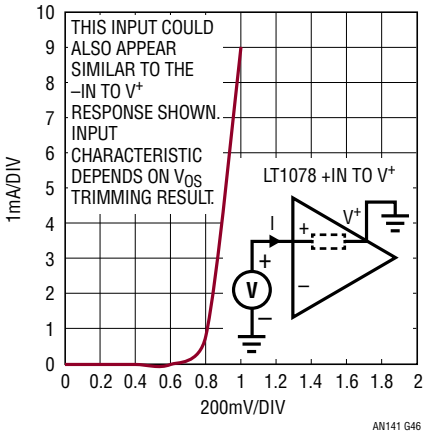


V⁻ to V⁺ (Reverse Supply)

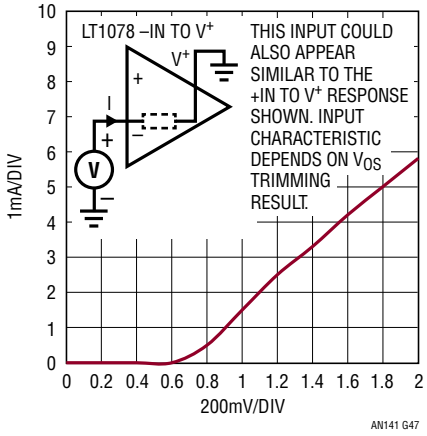


+IN to –IN (Differential Input)

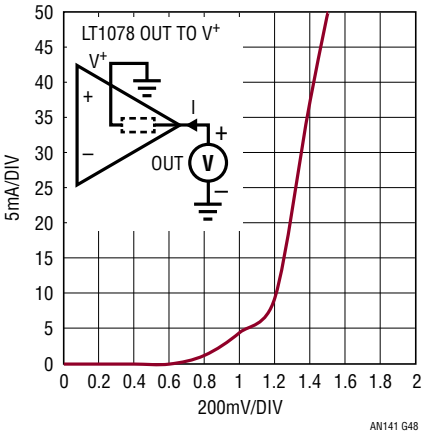
Amplifier Type: **RH1078** Similar Devices: **LT1078, LT1079** Tested Device: **LT1078**



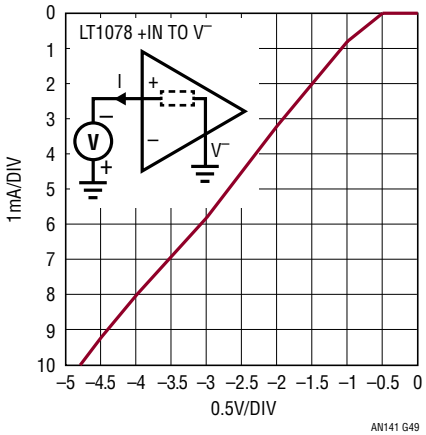
+IN to V⁺



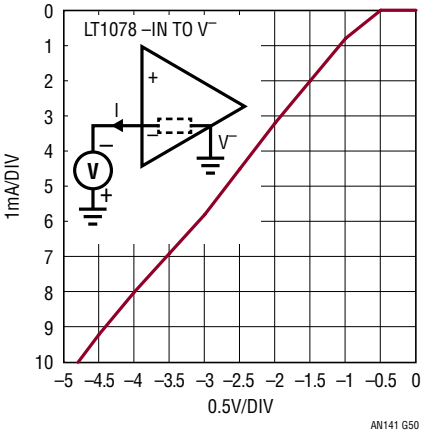
–IN to V⁺



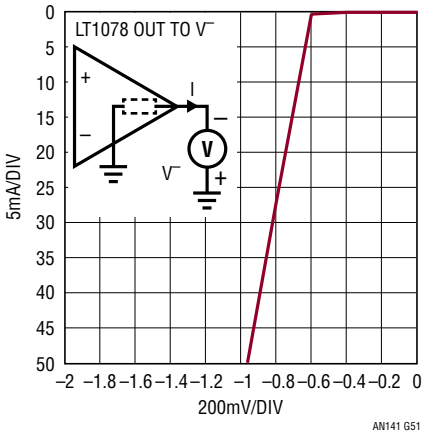
OUT to V⁺



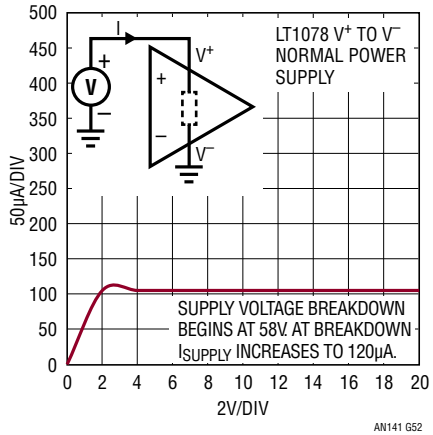
+IN to V⁻



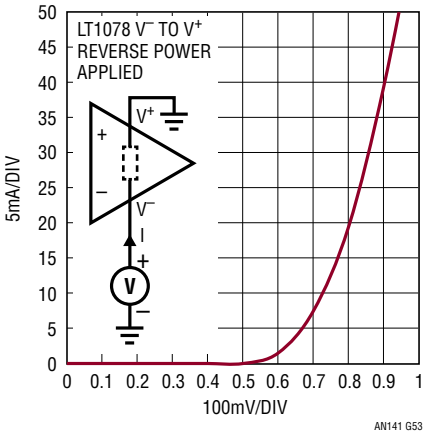
–IN to V⁻



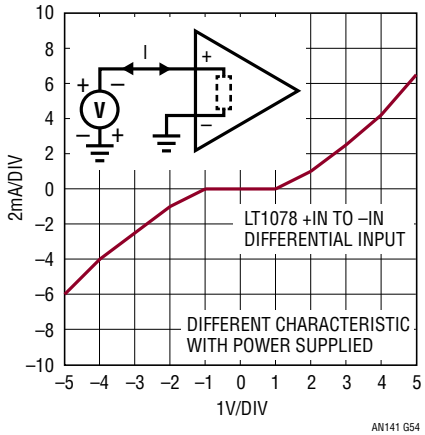
OUT to V⁻



V⁺ to V⁻ (Normal Supply)

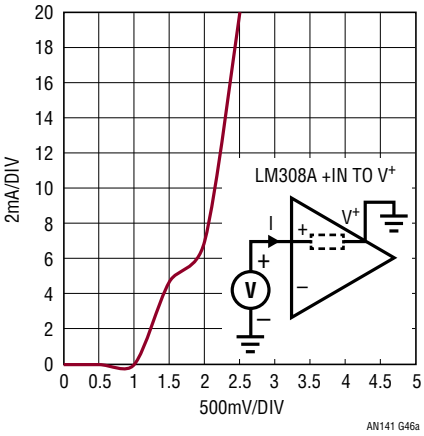


V⁻ to V⁺ (Reverse Supply)

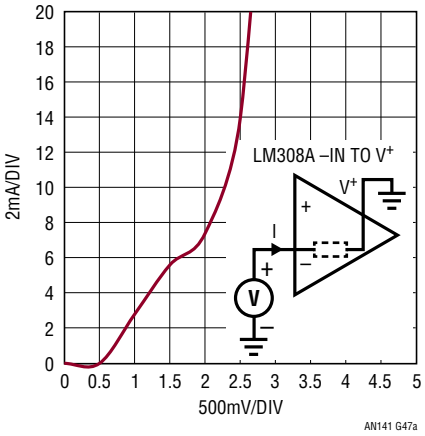


+IN to –IN (Differential Input)

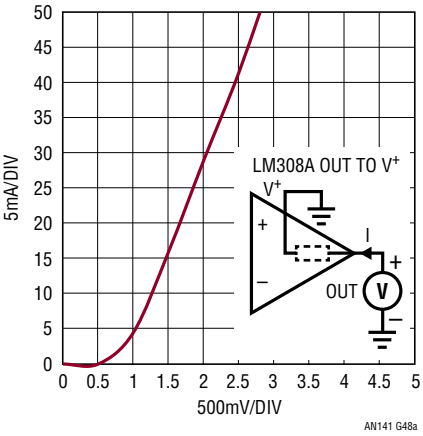
Amplifier Type: **RH108** Similar Devices: **LM108** Tested Device: **LM308**



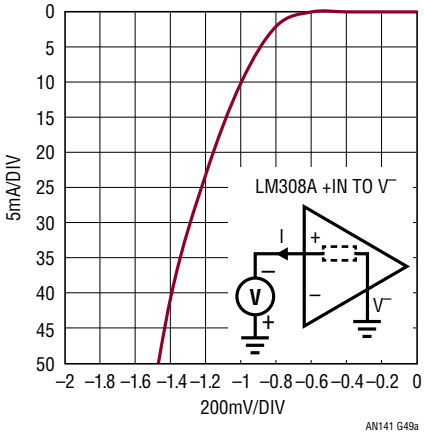
+IN to V⁺



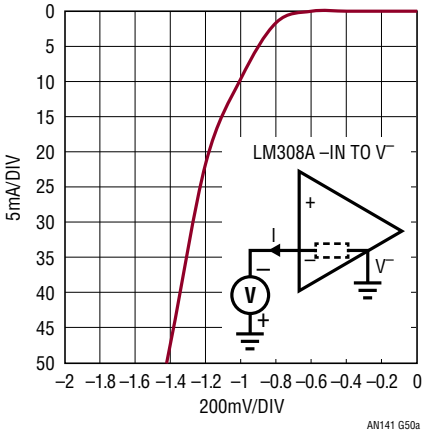
–IN to V⁺



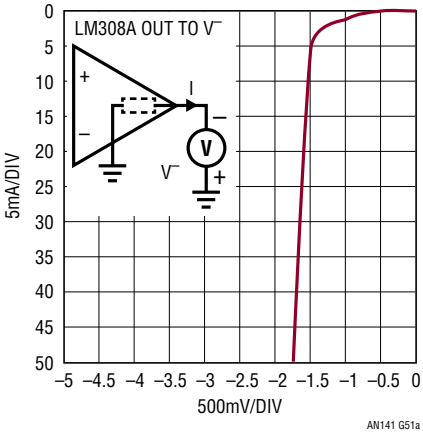
OUT to V⁺



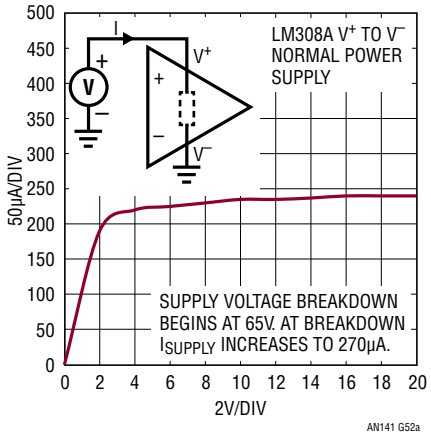
+IN to V⁻



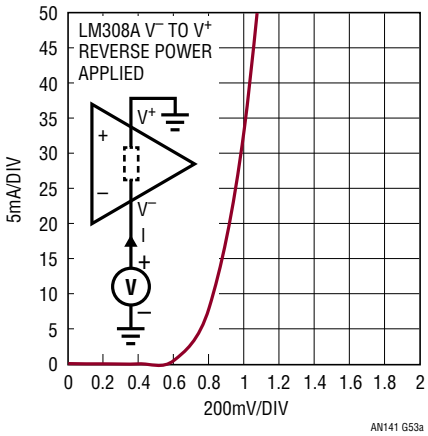
–IN to V⁻



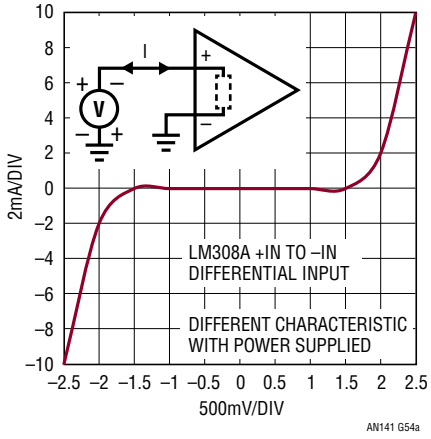
OUT to V⁻



V⁺ to V⁻ (Normal Supply)

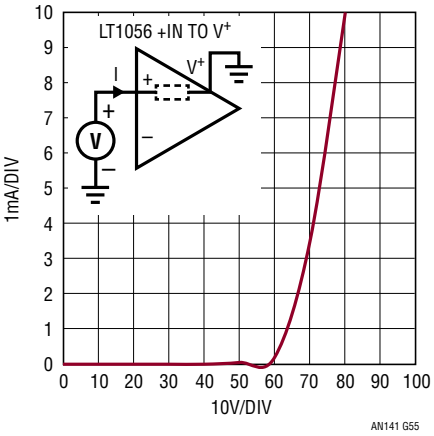


V⁻ to V⁺ (Reverse Supply)

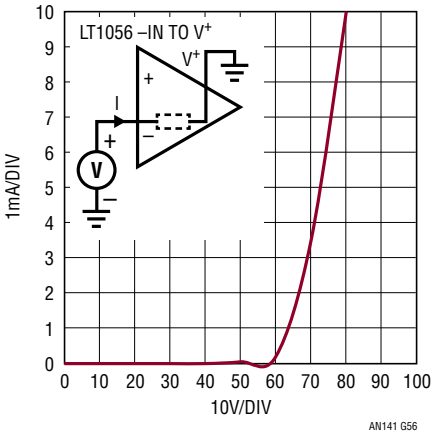


+IN to –IN (Differential Input)

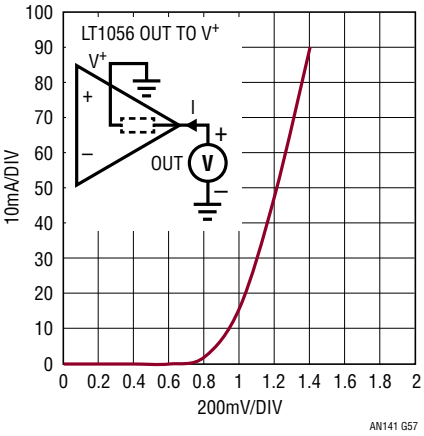
Amplifier Type: **RH1056** Similar Devices: **LT1055, LT1056, LT1057** Tested Device: **LT1056**



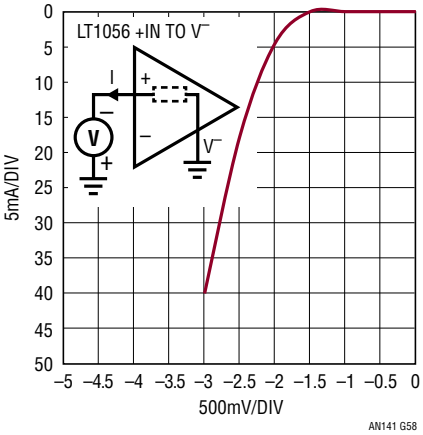
+IN to V+



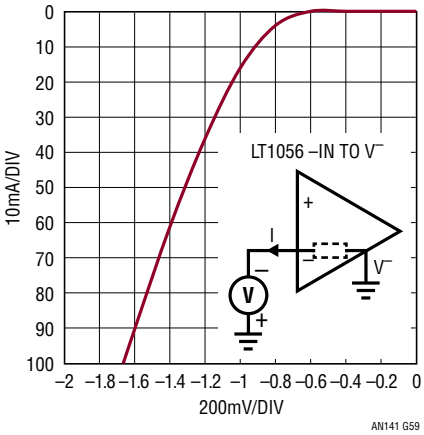
–IN to V+



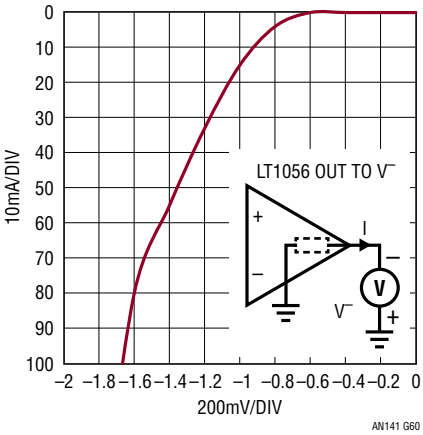
OUT to V+



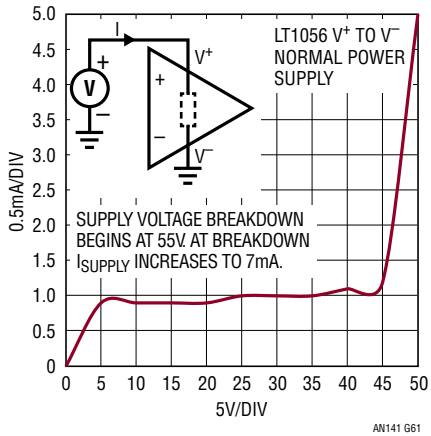
+IN to V–



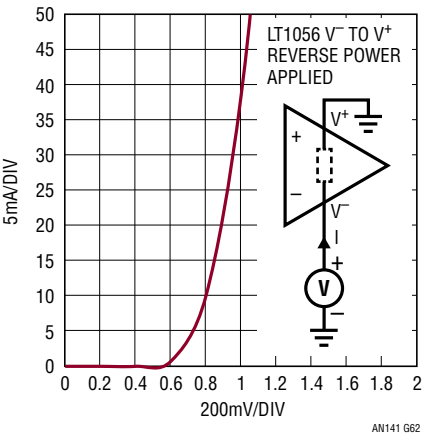
–IN to V–



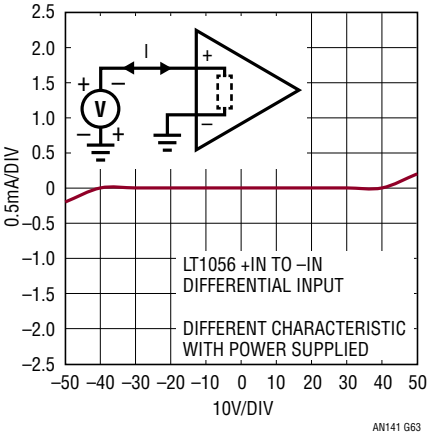
OUT to V–



V+ to V– (Normal Supply)

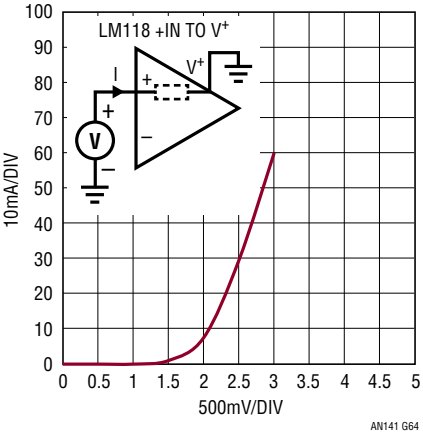


V– to V+ (Reverse Supply)

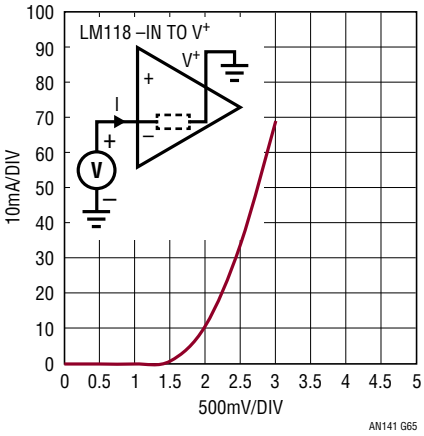


+IN to –IN (Differential Input)

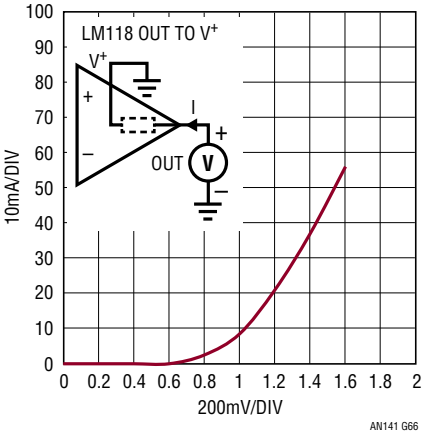
Amplifier Type: **RH118** Similar Devices: **LM118** Tested Device: **LM118**



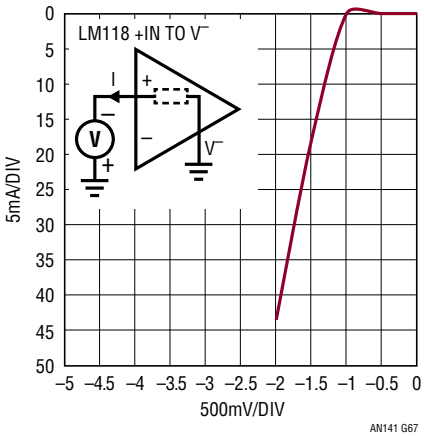
+IN to V+



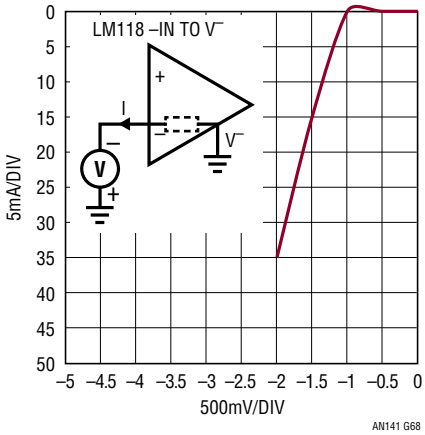
–IN to V+



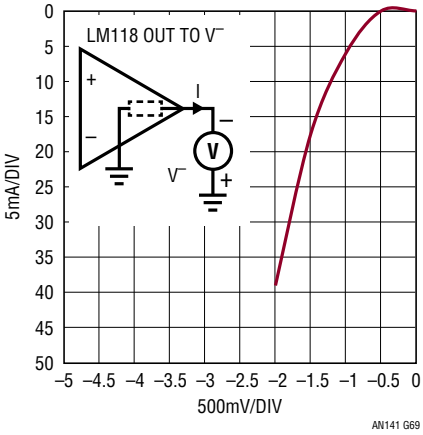
OUT to V+



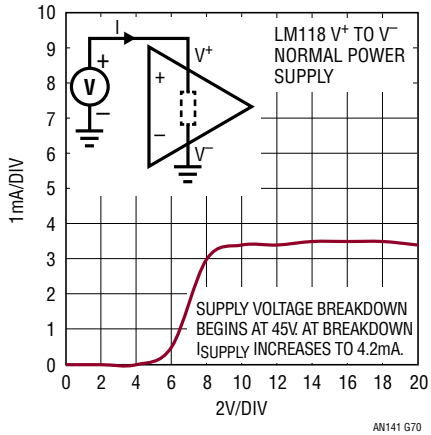
+IN to V–



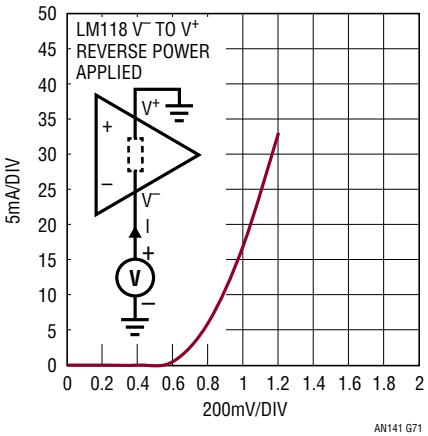
–IN to V–



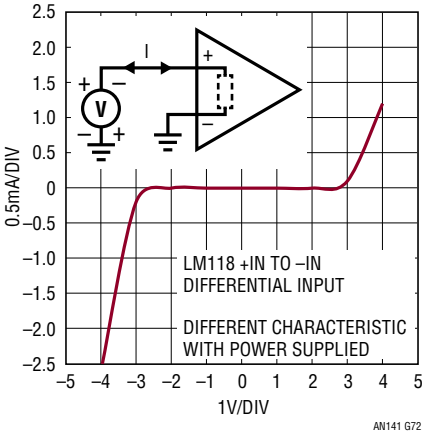
OUT to V–



V+ to V– (Normal Supply)

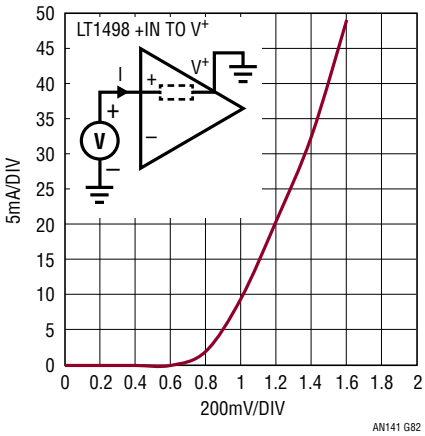


V– to V+ (Reverse Supply)

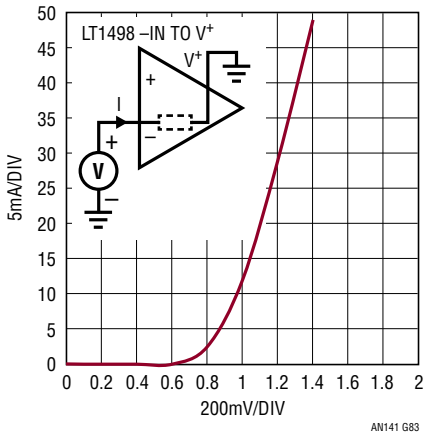


+IN to –IN (Differential Input)

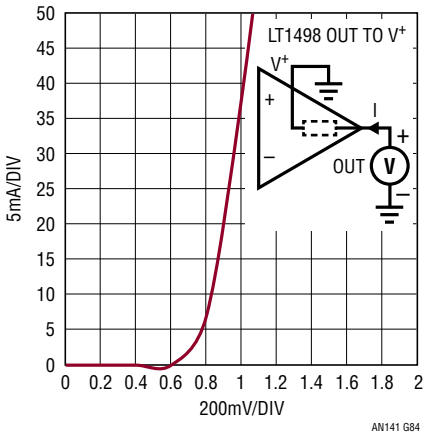
Amplifier Type: **RH1498, RH1499** Similar Devices: **LT1498, LT1499** Tested Device: **LT1498**



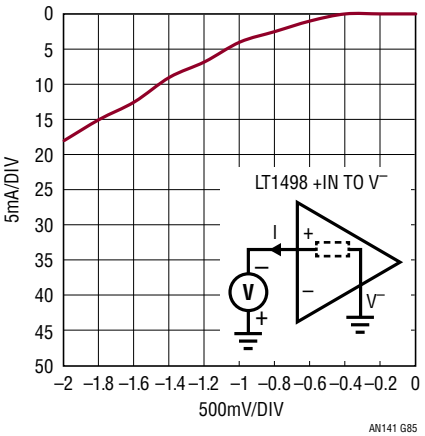
+IN to V+



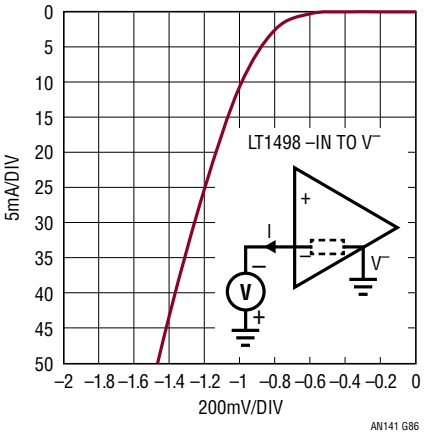
–IN to V+



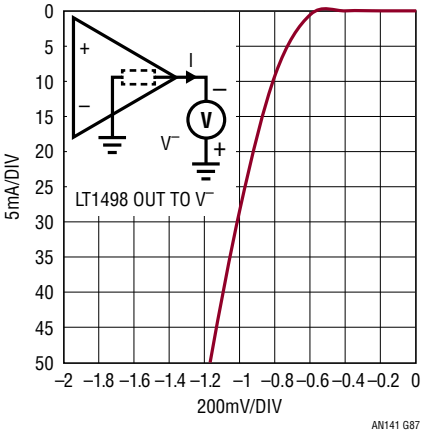
OUT to V+



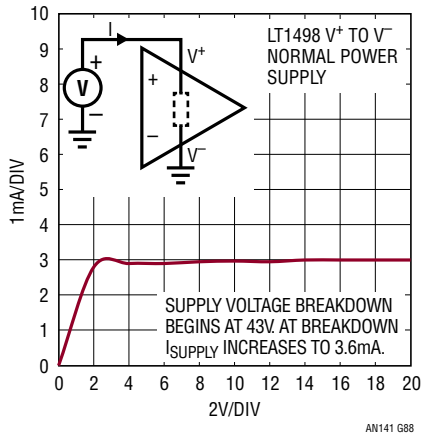
+IN to V–



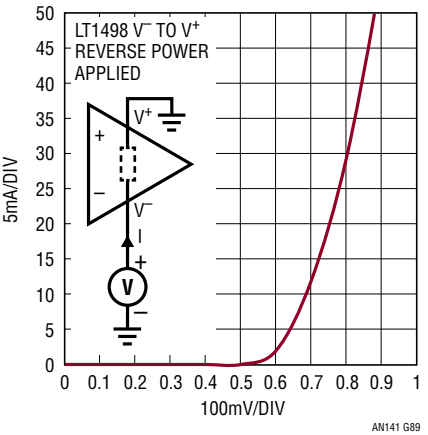
–IN to V–



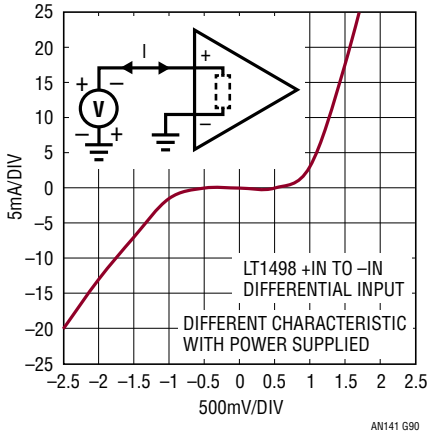
OUT to V–



V+ to V– (Normal Supply)

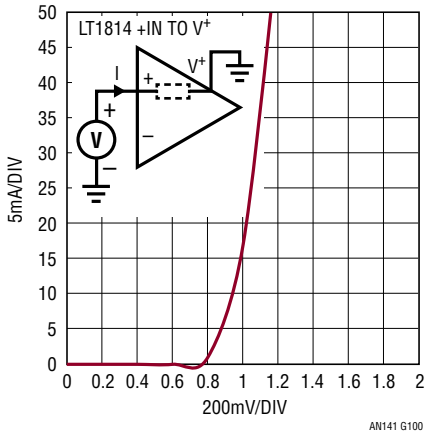


V– to V+ (Reverse Supply)

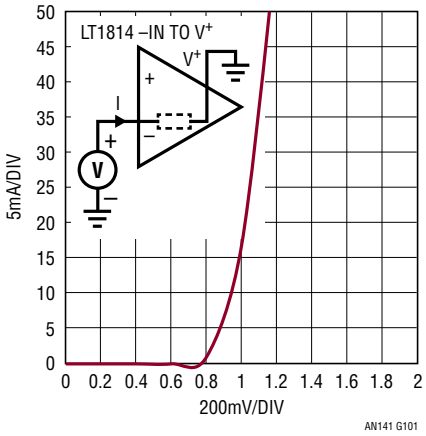


+IN to –IN (Differential Input)

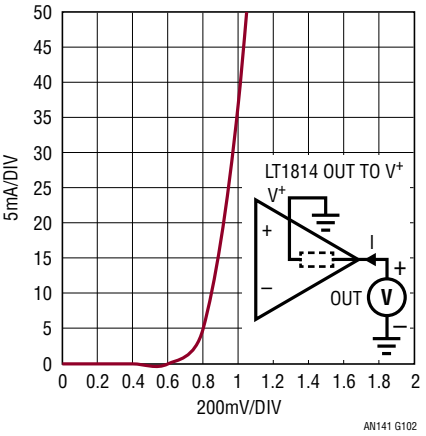
Amplifier Type: **RH1814** Similar Devices: **LT1814** Tested Device: **LT1814**



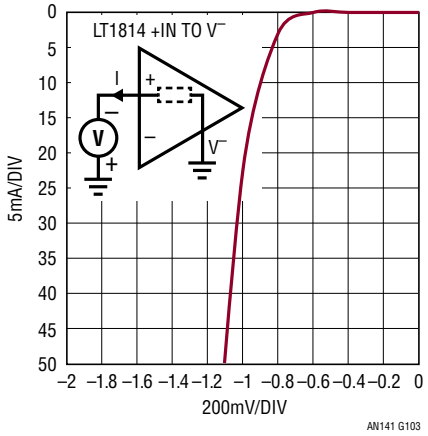
+IN to V⁺



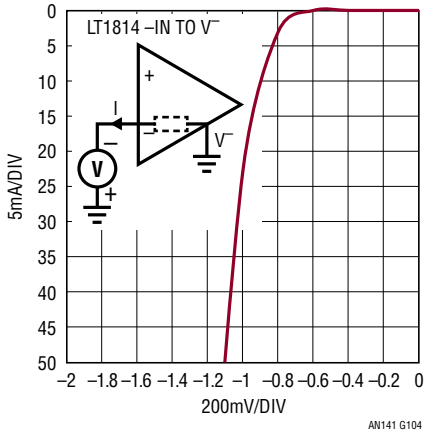
–IN to V⁺



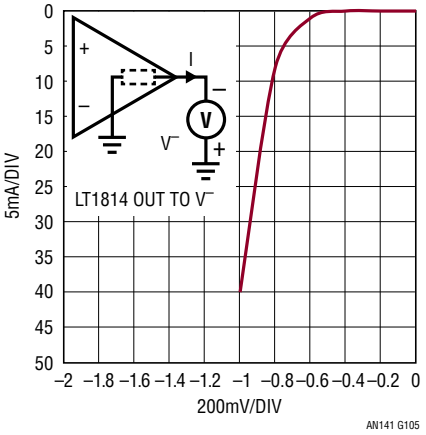
OUT to V⁺



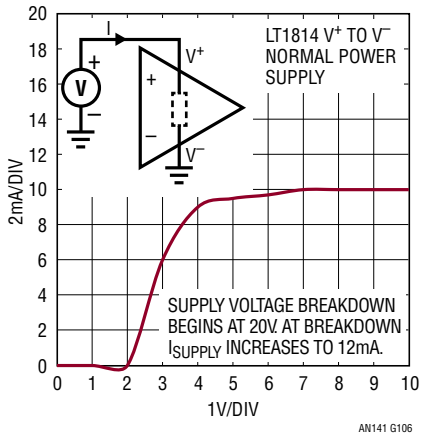
+IN to V⁻



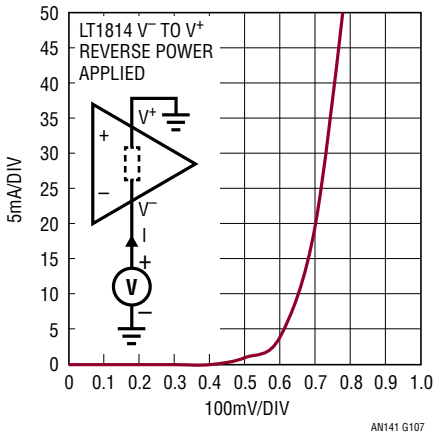
–IN to V⁻



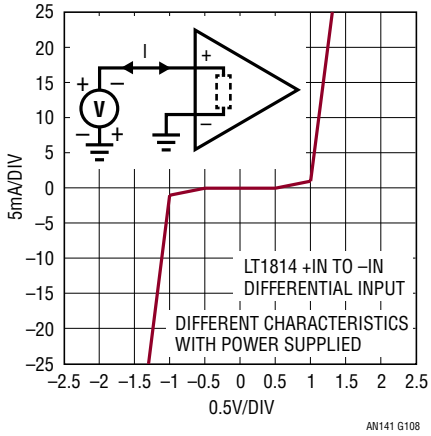
OUT to V⁻



V⁺ to V⁻ (Normal Supply)

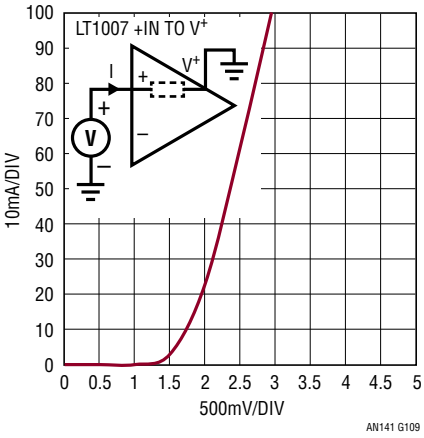


V⁻ to V⁺ (Reverse Supply)

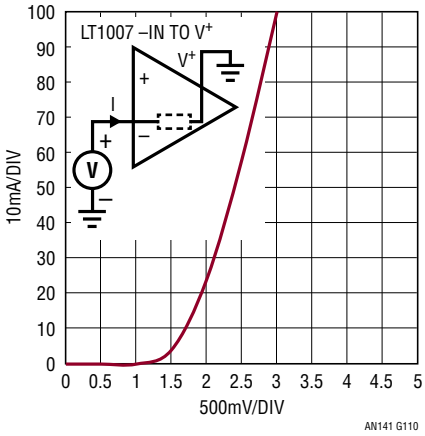


+IN to –IN (Differential Input)

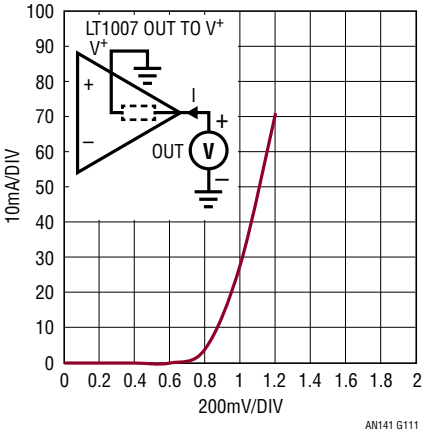
Amplifier Type: **RH27, RH37** Similar Devices: **OP27, OP37, LT1007, LT1037** Tested Device: **LT1007**



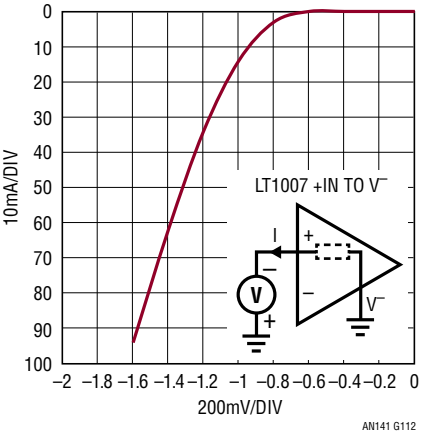
+IN to V⁺



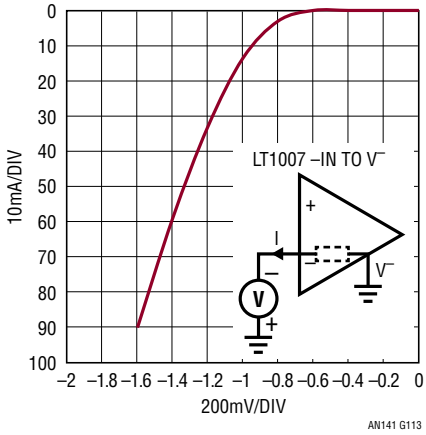
–IN to V⁺



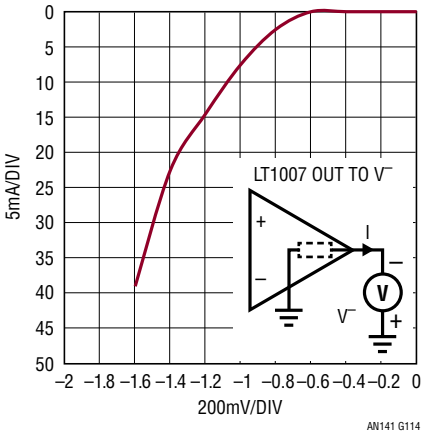
OUT to V⁺



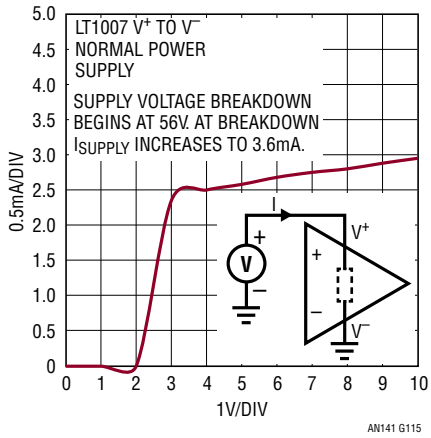
+IN to V⁻



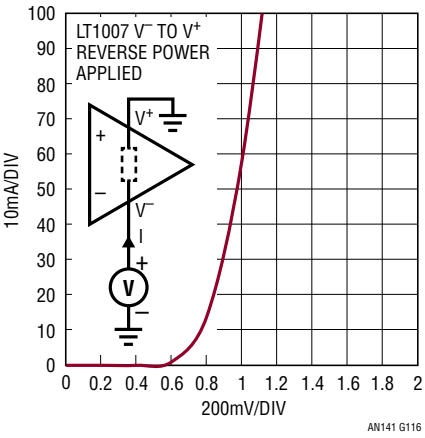
–IN to V⁻



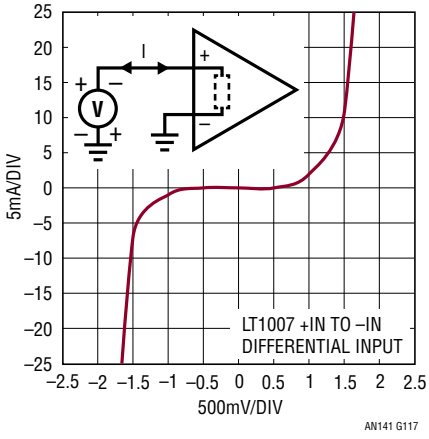
OUT to V⁻



V⁺ to V⁻ (Normal Supply)

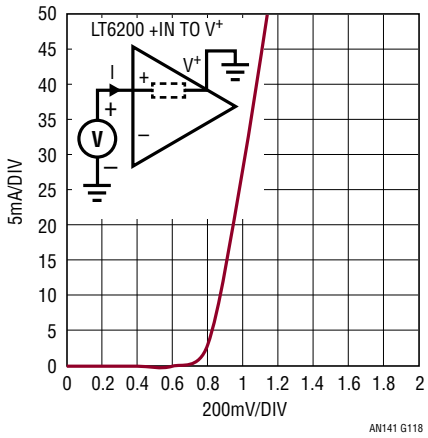


V⁻ to V⁺ (Reverse Supply)

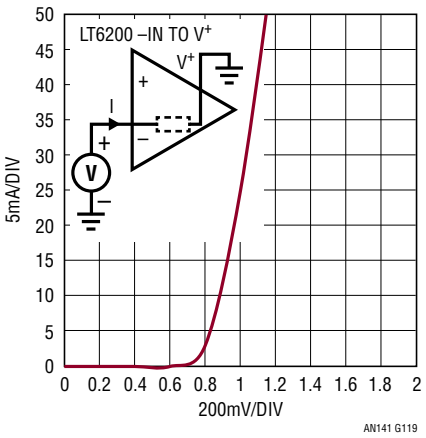


+IN to –IN (Differential Input)

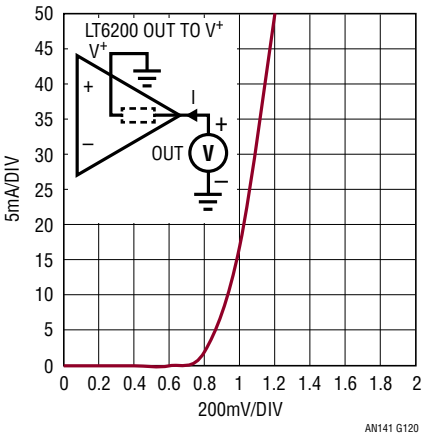
Amplifier Type: **RH6200** Similar Devices: **LT6200** Tested Device: **LT6200**



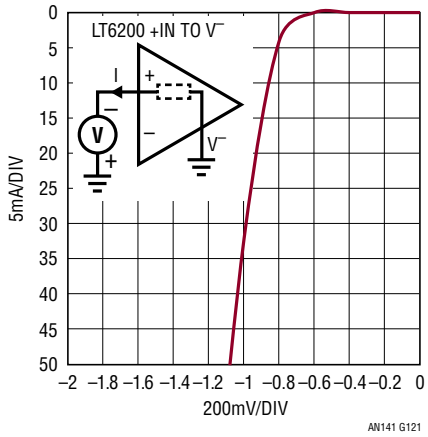
+IN to V⁺



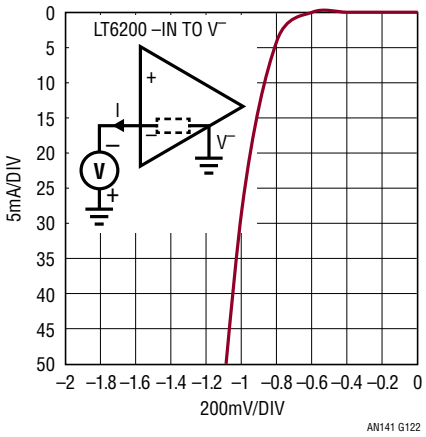
–IN to V⁺



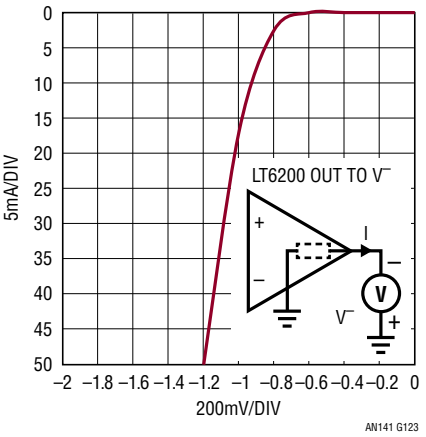
OUT to V⁺



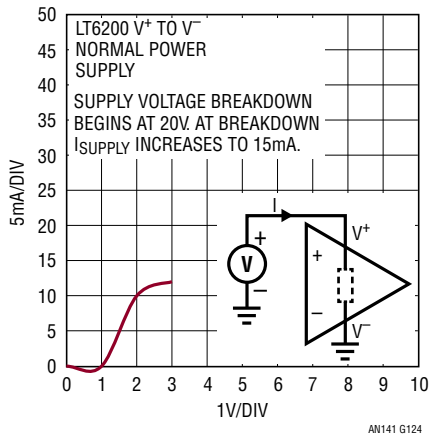
+IN to V⁻



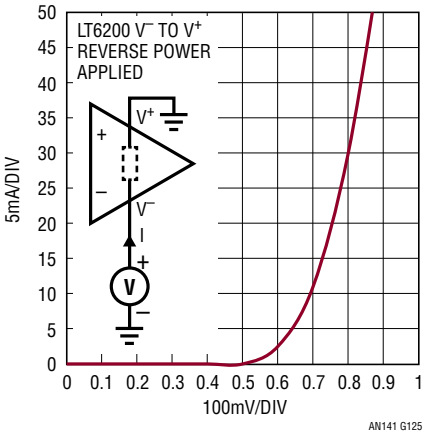
–IN to V⁻



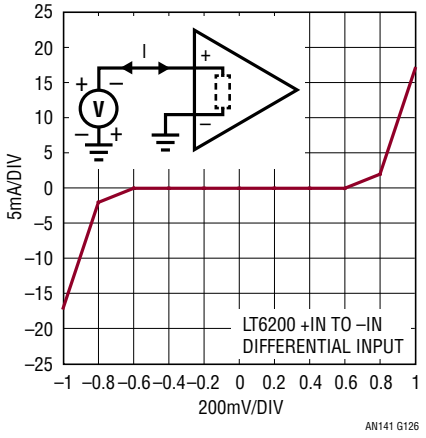
OUT to V⁻



V⁺ to V⁻ (Normal Supply)



V⁻ to V⁺ (Reverse Supply)



+IN to –IN (Differential Input)

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