# Dual Precision Operational Amplifier

## DESCRIPTION

The RH1013M is the first precision dual operational amplifier which directly upgrades designs in the industry standard 8-pin DIP LM158/MC1558/OP-221 pin configuration. Low offset voltage (300µV max), low drift (≤2.5µV/°C), low offset current (≤1.5nA), and high gain (1.2 million min) combine to make the RH1013M two truly precision amplifers in one package.

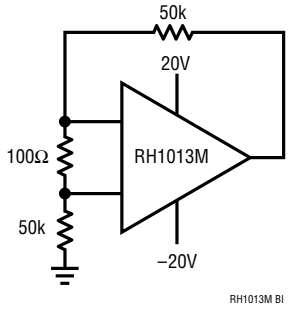
The wafer lots are processed to Linear Technology's in-house Class S flow to yield circuits usable in stringent military applications.

## ABSOLUTE MAXIMUM RATINGS

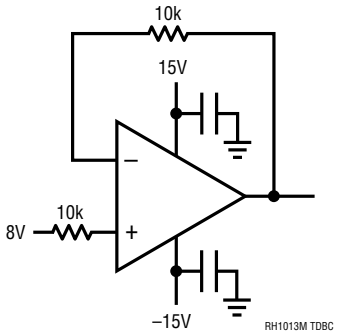
Supply Voltage ..... ±22V
Differential Input Voltage ..... ±30V
Input Voltage ..... Equal to Positive Supply Voltage
..... 5V Below Negative Supply Voltage
Output Short-Circuit Duration ..... Indefinite
Operating Temperature Range ..... –55°C to 125°C
Storage Temperature Range ..... –65°C to 150°C
Lead Temperature (Soldering, 10 sec) ..... 300°C

, LTC and LT are registered trademarks of Linear Technology Corporation.

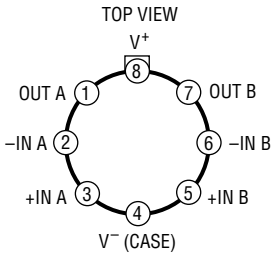
## BURN-IN CIRCUIT



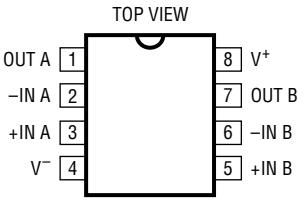

## TOTAL DOSE BIAS CIRCUIT



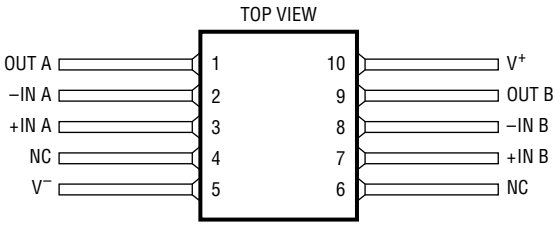

## PACKAGE/ORDER INFORMATION




H PACKAGE
8-LEAD TO-5 METAL CAN




J8 PACKAGE
8-LEAD CERAMIC DIP




W PACKAGE
10-LEAD CERPAC

## TABLE 1: ELECTRICAL CHARACTERISTICS (Pre-Irradiation)

**$V_S$ = ±15V, $V_{CM}$ = 0V, unless otherwise noted.**

| SYMBOL | PARAMETER | CONDITIONS | NOTES | $T_A$ = 25°C MIN | TYP | MAX | SUB-GROUP | −55°C ≤ $T_A$ ≤ 125°C MIN | TYP | MAX | SUB-GROUP | UNITS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $V_{OS}$ | Input Offset Voltage | | | | | 300 | 1 | | | 550 | 2,3 | µV |
| | | | 2 | | | 450 | 1 | | | 750 | 3 | µV |
| | | $V_{CM}$ = 0.1V | | | | | | | | 750 | 2 | µV |
| $\frac{\Delta V_{OS}}{\Delta Temp}$ | Average Tempco of Offset Voltage | | 1 | | | | | | | 2.5 | | µV/°C |
| $\frac{\Delta V_{OS}}{\Delta Time}$ | Long Term $V_{OS}$ Stability | | | | 0.5 | | | | | | | µV/Mo |
| $I_{OS}$ | Input Offset Current | | | | | 10 | 1 | | | 20 | 2,3 | nA |
| | | | 2 | | | 10 | 1 | | | 20 | 2,3 | nA |
| $I_B$ | Input Bias Current | | | | | 30 | 1 | | | 45 | 2,3 | nA |
| | | | 2 | | | 50 | 1 | | | 120 | 2,3 | nA |
| $e_n$ | Input Noise Voltage | 0.1Hz to 10Hz | | | 0.55 | | | | | | | $µV_{P-P}$ |
| | Input Noise Voltage | $f_O$ = 10Hz | | | 24 | | | | | | | nV/√Hz |
| | Density | $f_O$ = 1000Hz | | | 22 | | | | | | | nV/√Hz |
| $i_n$ | Input Noise Current Density | $f_O$ = 10Hz | | | 0.07 | | | | | | | pA/√Hz |
| $R_{IN}$ | Input Resistance | Differential | 1 | 70 | | | | | | | | MΩ |
| | | Common Mode | | | 4 | | | | | | | GΩ |
| $A_{VOL}$ | Large-Signal Voltage Gain | $V_O$ = ±10V, $R_L$ ≥ 2k | | 1.2 | | | 4 | 0.25 | | | 5,6 | V/µV |
| | | $V_O$ = ±10V, $R_L$ ≥ 600Ω | | 0.5 | | | 4 | | | | | V/µV |
| | | $V_O$ = 5mV to 4V, $R_L$ = 500Ω | 2 | | 1 | | | | | | | V/µV |
| | Input Voltage Range | | 1 | 13.5 | | | | | | | | V |
| | | | 1 | –15.0 | | | | | | | | V |
| | | | 1,2 | 3.5 | | | | | | | | V |
| | | | 1,2 | 0 | | | | | | | | V |
| CMRR | Common-Mode Rejection | $V_{CM}$ = 13.5V, –15V | | 97 | | | 1 | | | | | dB |
| | Ratio | $V_{CM}$ = 13V, –14.9V | | | | | | 94 | | | 2,3 | dB |
| PSRR | Power Supply Rejection Ratio | $V_S$ = ±2V to ±18V | | 100 | | | 1 | 97 | | | 2,3 | dB |
| | Channel Separation | $V_O$ = ±10V, $R_L$ = 2k | | 120 | | | 1 | | | | | dB |
| $V_{OUT}$ | Output Voltage Swing | $R_L$ ≥ 2k | | ±12.5 | | | 4 | ±11.5 | | | 5,6 | V |
| | | Output Low, No Load | 2 | | | 25 | 4 | | | | | mV |
| | | Output Low, 600Ω to GND | 2 | | | 10 | 4 | | | 18 | 5,6 | mV |
| | | Output Low, $I_{SINK}$ = 1mA | 2 | | | 350 | 4 | | | | | mV |
| | | Output High, No Load | 2 | 4.0 | | | 4 | | | | | V |
| | | Output High, 600Ω to GND | 2 | 3.4 | | | 4 | 3.1 | | | 5,6 | V |
| SR | Slew Rate | | | 0.2 | | | 4 | | | | | V/µs |
| $I_S$ | Supply Current | Per Amplifier | | | | 0.55 | 1 | | | 0.70 | 2,3 | mA |
| | | | 2 | | | 0.50 | 1 | | | 0.65 | 2,3 | mA |

## TABLE 1A: ELECTRICAL CHARACTERISTICS (Post-Irradiation)

**$V_S$ = ±15V, $V_{CM}$ = 0V, $T_A$ = 25°C, unless otherwise noted.**

| SYMBOL | PARAMETER | CONDITIONS | NOTES | 10KRAD(Si) MIN | 10KRAD(Si) MAX | 20KRAD(Si) MIN | 20KRAD(Si) MAX | 50KRAD(Si) MIN | 50KRAD(Si) MAX | 100KRAD(Si) MIN | 100KRAD(Si) MAX | 200KRAD(Si) MIN | 200KRAD(Si) MAX | UNITS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $V_{OS}$ | Input Ofset Voltage | | | | 450 | | 450 | | 600 | | 750 | | 900 | µV |
| | | | 2 | | 600 | | 600 | | 750 | | 900 | | | µV |
| $I_{OS}$ | Input Offset Current | | | | 10 | | 10 | | 15 | | 20 | | 25 | nA |
| | | | 2 | | 10 | | 10 | | 15 | | 20 | | | nA |
| $I_B$ | Input Bias Current | | | | 60 | | 75 | | 100 | | 175 | | 250 | nA |
| | | | 2 | | 80 | | 100 | | 125 | | 200 | | | nA |
| | Input Voltage Range | | 1 | 13.5 | | 13.5 | | 13.5 | | 13.5 | | 13.5 | | V |
| | | | 1 | –15.0 | | –15.0 | | –15.0 | | –15.0 | | –15.0 | | V |
| | | | 2 | 3.5 | | 3.5 | | 3.5 | | 3.5 | | | | V |
| | | | 2 | 0 | | 0 | | 0 | | 0 | | | | V |
| CMRR | Common-Mode Rejection Ratio | $V_{CM}$ = 13V, – 15V | | 97 | | 97 | | 94 | | 90 | | 86 | | dB |
| PSRR | Power Supply Rejection Ratio | $V_S$ = ±10V to ±18V | | 100 | | 98 | | 94 | | 86 | | 80 | | dB |
| $A_{VOL}$ | Large-Signal Voltage Gain | $R_L$ ≥ 10k, $V_O$ = ±10V | | 500 | | 200 | | 100 | | 50 | | 25 | | V/mV |
| $V_{OUT}$ | Maximum Output Voltage Swing | $R_L$ ≥ 10k | | ±12.5 | | ±12.5 | | ±12.5 | | ±12.5 | | ±12.5 | | V |
| | | Output Low, No Load | 2 | | 25 | | 30 | | 40 | | 50 | | | mV |
| | | Output Low, 600Ω to GND | 2 | | 10 | | 10 | | 10 | | 10 | | | mV |
| | | Output Low, $I_{SINK}$ = 1mA | 2 | | 0.6 | | 0.8 | | 1.0 | | 1.6 | | | V |
| | | Output High, No Load | 2 | 4.0 | | 4.0 | | 4.0 | | 4.0 | | | | V |
| | | Output High, 600Ω to GND | 2 | 3.4 | | 3.2 | | 3.0 | | 2.8 | | | | V |
| SR | Slew Rate | $R_L$ ≥ 10k | | 0.13 | | 0.12 | | 0.11 | | 0.07 | | 0.01 | | V/µs |
| $I_S$ | Supply Current | Per Amplifier | | | 0.55 | | 0.55 | | 0.55 | | 0.55 | | 0.55 | mA |
| | | | 2 | | 0.50 | | 0.50 | | 0.50 | | 0.50 | | | mA |

**Note 1:** Guaranteed by design, characterization, or correlation to other tested parameters..

**Note 2:** Specification applies for $V_S^+$ = 5V, $V_S^-$ = 0V, $V_{CM}$ = 0V, $V_{OUT}$ = 1.4V.

## TABLE 2: ELECTRICAL TEST REQUIREMENTS

| MIL-STD-883 TEST REQUIREMENTS | SUBGROUP |
|---|---|
| Final Electrical Test Requirements (Method 5004) | 1*,2,3,4,5,6 |
| Group A Test Requirements (Method 5005) | 1,2,3,4,5,6 |
| Group B and D for Class S, and<br>Group C and D for Class B<br>End Point Electrical Parameters (Method 5005) | 1,2,3 |

* PDA applies to subgroup 1. See PDA Test Notes.

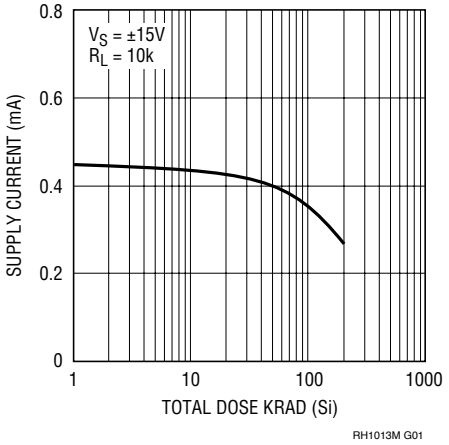
**PDA Test Notes**

The PDA is specified as 5% based on failures from group A, subgroup 1, tests after cooldown as the final electrical test in accordance with method 5004 of MIL-STD-883. The verified failures of group A, subgroup 1, after burn-in divided by the total number of devices submitted for burn-in in that lot shall be used to determine the percent for the lot.

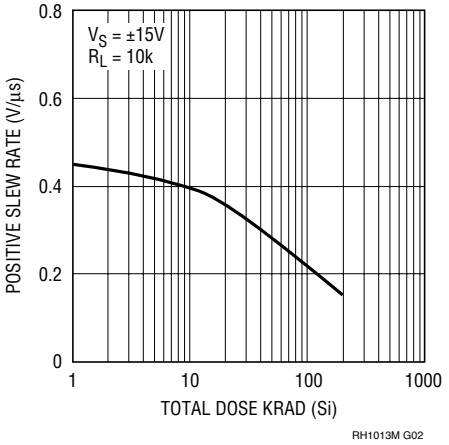
Linear Technology Corporation reserves the right to test to tighter limits than those given.

# TYPICAL PERFORMANCE CHARACTERISTICS

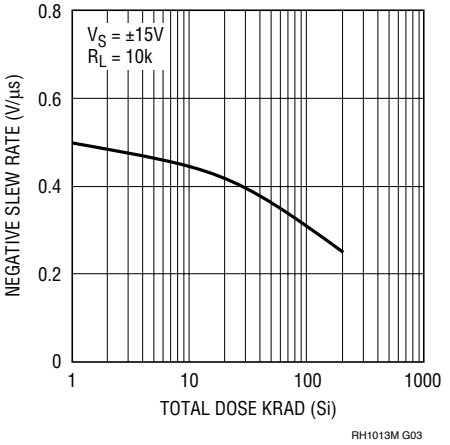
**Supply Current (Per Amplifier)**



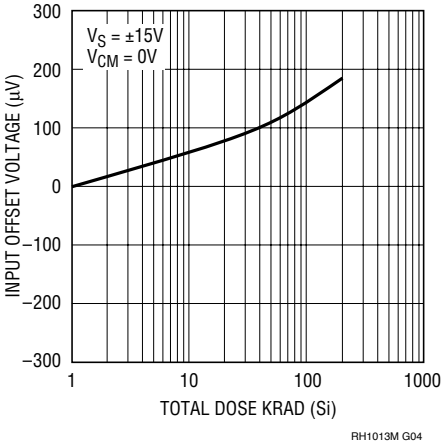

**Positive Slew Rate**



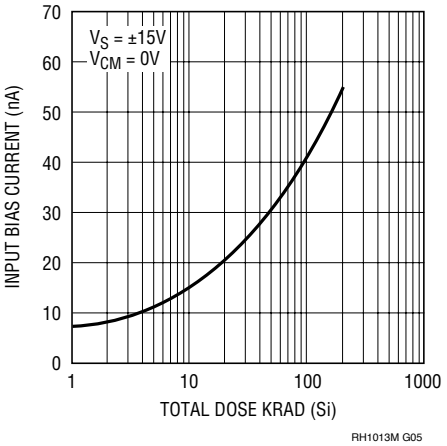

**Negative Slew Rate**



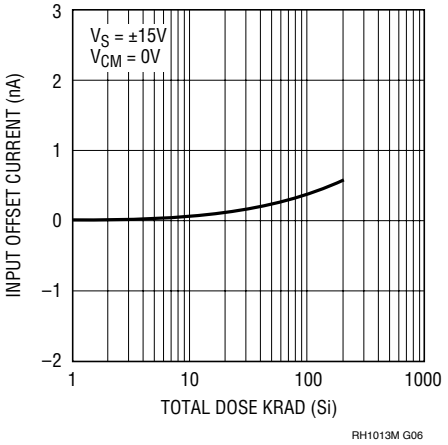

**Input Offset Voltage**



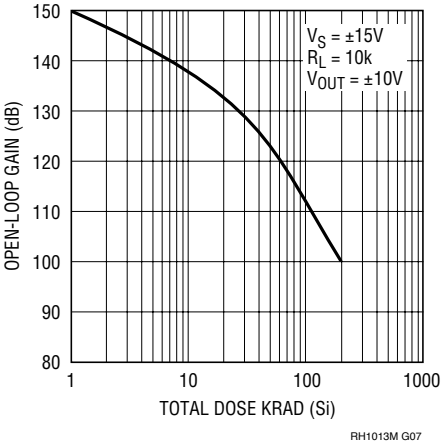

**Input Bias Current**




**Input Offset Current**

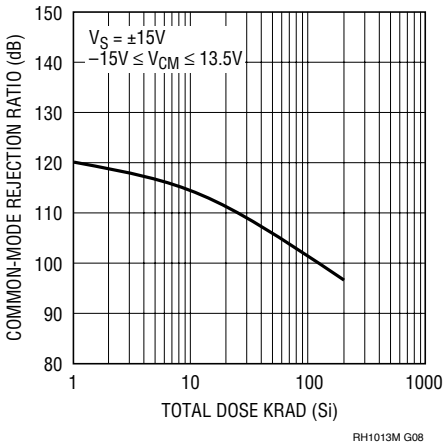



**Open-Loop Gain**

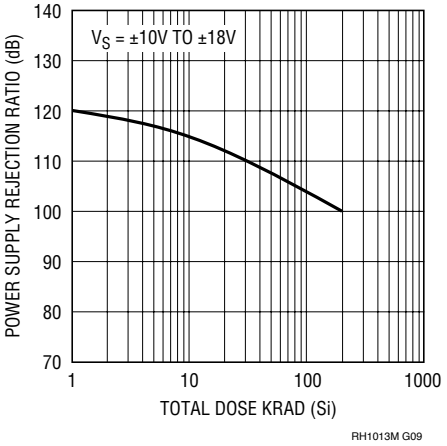


# TYPICAL PERFORMANCE CHARACTERISTICS

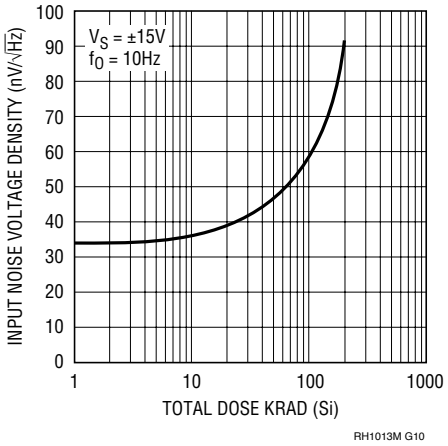
**Common-Mode Rejection Ratio**



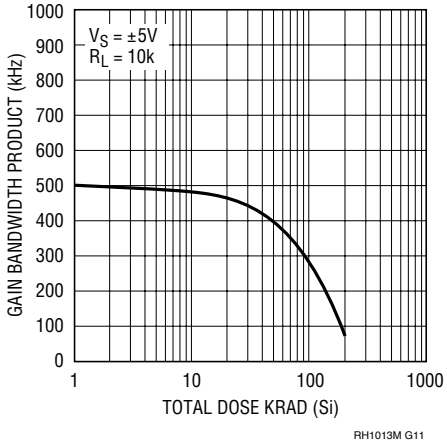

**Power Supply Rejection Ratio**




**Input Noise Voltage Density**




**Gain Bandwidth Product**




Information furnished by Linear Technology Corporation is believed to be accurate and reliable. However, no responsibility is assumed for its use. Linear Technology Corporation makes no representation that the interconnection of its circuits as described herein will not infringe on existing patent rights.

## *Rad Hard*

This table provides example specifications for our Rad Hard products. For complete Rad Hard data sheets, contact 1-800-4-LINEAR.

| DEVICE | SYMBOL | CONDITIONS | 10Krad (Si) MIN | 10Krad (Si) MAX | 20Krad (Si) MIN | 20Krad (Si) MAX | 50Krad (Si) MIN | 50Krad (Si) MAX | 80Krad (Si) MIN | 80Krad (Si) MAX | 100Krad (Si) MIN | 100Krad (Si) MAX | 200Krad (Si) MIN | 200Krad (Si) MAX | UNITS | PACKAGE OPTIONS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RH07 | $V_{OS}$ | | | 90 | | 150 | | 200 | | | | 250 | | 300 | µV | J8, H |
| | $I_{OS}$ | | | 2.8 | | 4 | | 8 | | | | 12 | | 20 | nA | |
| RH27C | $V_{OS}$ | | | 100 | | 130 | | 180 | | | | 280 | | 400 | µV | H, W |
| | $I_{OS}$ | | | 75 | | 75 | | 90 | | | | 120 | | 180 | nA | |
| RH37C | $V_{OS}$ | | | 100 | | 130 | | 180 | | | | 280 | | 400 | µV | H, W |
| | $I_{OS}$ | | | 75 | | 75 | | 90 | | | | 120 | | 180 | nA | |
| RH101A | $V_{OS}$ | | | 2 | | 2 | | 2 | | | | 2 | | 3 | mV | H, W |
| | $I_{OS}$ | | | 10 | | 10 | | 10 | | | | 10 | | 20 | nA | |
| RH108A | $V_{OS}$ | | | 0.5 | | 0.5 | | 0.5 | | 1.0 | | | | | mV | H, W |
| | $I_{OS}$ | | | 0.2 | | 0.2 | | 0.2 | | 0.2 | | | | | nA | |
| RH117 | $V_{REF}$ | $3V \le (V_{IN} - V_{OUT}) \le 40V$<br>$10mA \le I_{OUT} \le I_{MAX}$, $P \le P_{MAX}$ | 1.20 | 1.30 | 1.20 | 1.30 | 1.20 | 1.30 | | | 1.20 | 1.30 | | | V | H, K |
| RH118 | $V_{OS}$ | | | 4 | | 4 | | 4 | | | | 4 | | 10 | mV | H, W |
| | SR | $V_S = \pm15V$, $A_V = 1$ | 50 | | 50 | | 50 | | | | 50 | | 50 | | V/µs | |
| RH119 | $V_{OS}$ | | | 4 | | 4 | | 4 | | | | 4 | | 8 | mV | H, J, W |
| | $I_{OS}$ | | | 75 | | 100 | | 150 | | | | 300 | | 500 | nA | |
| RH129 | $V_Z$ | | 6.7 | 7.2 | 6.7 | 7.2 | 6.7 | 7.2 | | | 6.7 | 7.2 | 6.7 | 7.2 | V | H |
| | $\Delta V_Z/\Delta TEMP$ | RH129A | | 10 | | 10 | | 10 | | | | 15 | | 20 | ppm/°C | |
| | | RH129B | | 20 | | 20 | | 20 | | | | 25 | | 30 | ppm/°C | |
| | | RH129C | | 50 | | 50 | | 50 | | | | 55 | | 60 | ppm/°C | |
| RH137 | $V_{REF}$ | $\lvert V_{IN} - V_{OUT} \rvert \le 5V$, $I_{OUT} = 10mA$<br>$3V \le \lvert V_{IN} - V_{OUT} \rvert \le 40$ V<br>$10mA \le I_{OUT} \le I_{MAX}$, $P \le P_{MAX}$ | –1.225<br>–1.2 | –1.275<br>–1.3 | –1.225<br>–1.2 | –1.275<br>–1.3 | –1.225<br>–1.2 | –1.275<br>–1.3 | | | –1.225<br>–1.2 | –1.275<br>–1.3 | –1.22<br>–1.2 | –1.23<br>–1.3 | V<br>V | K, H |
| RH1009 | $V_Z$ | | 2.495 | 2.505 | 2.495 | 2.505 | 2.495 | 2.505 | | | 2.495 | 2.505 | 2.495 | 2.505 | V | H |
| | $\Delta V_Z/\Delta I_Z$ | | | 6 | | 6 | | 8 | | | | 10 | | 12 | mV | |
| RH1011 | $V_{OS}$ | | | 1.5 | | 1.5 | | 1.5 | | | | 1.5 | | 2 | mV | H, J8, W |
| | $I_{OS}$ | | | 4 | | 4 | | 4 | | | | 20 | | 50 | nA | |
| RH1013 | $V_{OS}$ | | | 450 | | 450 | | 600 | | | | 750 | | 900 | µV | H, J8, W |
| | $I_{OS}$ | | | 10 | | 10 | | 15 | | | | 20 | | 25 | nA | |
| RH1014 | $V_{OS}$ | | | 450 | | 450 | | 600 | | | | 750 | | 900 | µV | J, W |
| | $I_{OS}$ | | | 10 | | 10 | | 15 | | | | 20 | | 25 | nA | |
| RH1021-5 | $V_{OUT}$ | RH1021CM-5 | 4.9975 | 5.0025 | 4.995 | 5.005 | 4.993 | 5.007 | | | 4.9925 | 5.008 | 4.99 | 5.01 | V | H |
| | | RH1021BM-5, DM-5 | 4.95 | 5.05 | 4.945 | 5.055 | 4.942 | 5.058 | | | 4.94 | 5.06 | 4.935 | 5.065 | V | |
| | $TCV_{OUT}$ | RH1021BM-5 | | 5 | | 5 | | 5 | | | | 7 | | 10 | ppm/°C | |
| | | RH1021CM-5, DM-5 | | 20 | | 20 | | 20 | | | | 22 | | 25 | ppm/°C | |
| RH1021-7 | $V_{OUT}$ | | 6.95 | 7.05 | 6.95 | 7.05 | 6.95 | 7.05 | | | 6.94 | 7.06 | 6.93 | 7.07 | V | H |
| | $TCV_{OUT}$ | RH1021BM-7 | | 5 | | 5 | | 5 | | | | 7 | | 10 | ppm/°C | |
| | | RH1021DM-7 | | 20 | | 20 | | 20 | | | | 22 | | 25 | ppm/°C | |
| RH1021-10 | $V_{OUT}$ | RH1021CM-10 | 9.995 | 10.005 | 9.99 | 10.01 | 9.987 | 10.013 | | | 9.985 | 10.015 | 9.98 | 10.02 | V | H |
| | | RH1021BM-10, DM-10 | 9.95 | 10.05 | 9.945 | 10.055 | 9.942 | 10.06 | | | 9.98 | 10.06 | 9.935 | 10.065 | V | |
| | $TCV_{OUT}$ | RH1021BM-10 | | 5 | | 5 | | 5 | | | | 7 | | 10 | ppm/°C | |
| | | RH1021CM-10, DM-10 | | 20 | | 20 | | 20 | | | | 22 | | 25 | ppm/°C | |
| RH1056A | $V_{OS}$ | | | 180 | | 180 | | 250 | | | | 450 | | 450 | µV | H, W |
| | $I_{OS}$ | | | ±10 | | ±50 | | ±150 | | | | ±250 | | ±350 | pA | |
| RH1078 | $V_{OS}$ | | | 350 | | 500 | | 650 | 75k | 800 | | 1000 | | | µV | H, J8, W |
| | $I_{OS}$ | | | 2 | | 18 | | 13 | 75k | 18 | | 23 | | | nA | J, W |
| RH1086 | $V_{REF}$ | $I_{OUT} = 10mA$<br>$10mA \le I_{OUT} \le I_{FULL\ LOAD}$ | | 1.258 | | 1.257 | | 1.253 | | | | 1.247 | | 1.241 | V | H, K |
| | | $1.5V \le (V_{IN} - V_{OUT}) \le 15V$ | | 1.271 | | 1.269 | | 1.265 | | | | 1.260 | | 1.253 | V | |
| | Dropout V | $\Delta V_{REF} = 1\%$, $I_{OUT} = 1.5A$ (K)<br>$\Delta V_{REF} = 1\%$, $I_{OUT} = 0.5A$ (H) | | 1.5 | | 1.51 | | 1.52 | | | | 1.55 | | 1.575 | V | |

I.D. No. 66-11-1013 Rev. E 0103



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