19-2647; Rev 5; 12/10

# Ultra-High-Precision, Ultra-Low-Noise, Series Voltage Reference



## General Description

The MAX6126 is an ultra-low-noise, high-precision, low-dropout voltage reference. This family of voltage references feature curvature-correction circuitry and high-stability, laser-trimmed, thin-film resistors that result in 3ppm/°C (max) temperature coefficients and an excellent ±0.02% (max) initial accuracy. The proprietary low-noise reference architecture produces a low flicker noise of 1.3µVP-P and wideband noise as low as 60nV/√Hz (2.048V output) without the increased supply current usually found in low-noise references. Improve wideband noise to 35nV/√Hz and AC power-supply rejection by adding a 0.1µF capacitor at the noise reduction pin. The MAX6126 series mode reference operates from a wide 2.7V to 12.6V supply voltage range and load-regulation specifications are guaranteed to be less than 0.025Ω for sink and source currents up to 10mA. These devices are available over the automotive temperature range of -40°C to +125°C.

The MAX6126 typically draws 380µA of supply current and is available in 2.048V, 2.500V, 2.800V, 3.000V, 4.096V, and 5.000V output voltages. These devices also feature dropout voltages as low as 200mV. Unlike conventional shunt-mode (two-terminal) references that waste supply current and require an external resistor, the MAX6126 offers supply current that is virtually independent of supply voltage and does not require an external resistor. The MAX6126 is stable with 0.1µF to 10µF of load capacitance.

The MAX6126 is available in the tiny 8-pin µMAX®, as well as 8-pin SO packages.

## Applications

High-Resolution A/D and D/A Converters

ATE Equipment

High-Accuracy Reference Standard

Precision Current Sources

Digital Voltmeters

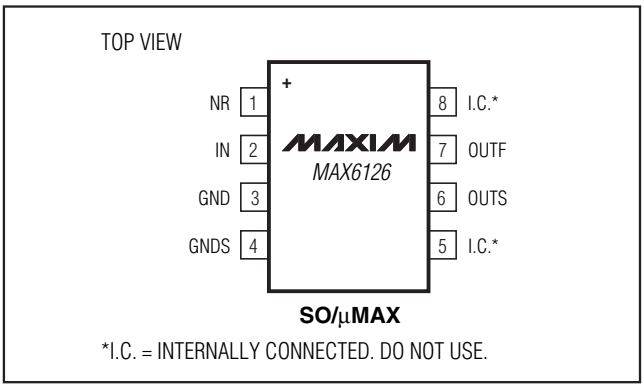
High-Accuracy Industrial and Process Control

*µMAX is a registered trademark of Maxim Integrated Products, Inc.*

## Features

- **Ultra-Low 1.3µVP-P Noise (0.1Hz to 10Hz, 2.048V Output)**
- **Ultra-Low 3ppm/°C (max) Temperature Coefficient**
- **±0.02% (max) Initial Accuracy**
- **Wide (VOUT + 200mV) to 12.6V Supply Voltage Range**
- **Low 200mV (max) Dropout Voltage**
- **380µA Quiescent Supply Current**
- **10mA Sink/Source-Current Capability**
- **Stable with CLOAD = 0.1µF to 10µF**
- **Low 20ppm/1000hr Long-Term Stability**
- **0.025Ω (max) Load Regulation**
- **20µV/V (max) Line Regulation**
- **Force and Sense Outputs for Remote Sensing**

## Pin Configuration




**SO/µMAX**

*I.C. = INTERNALLY CONNECTED. DO NOT USE.

## Ordering Information

| PART | TEMP RANGE | PIN-PACKAGE | OUTPUT VOLTAGE (V) | MAXIMUM INITIAL ACCURACY (%) | MAXIMUM TEMPCO (-40°C to +85°C) (ppm/°C) | TOP MARK |
|---|---|---|---|---|---|---|
| MAX6126AASA21+ | -40°C to +125°C | 8 SO | 2.048 | 0.02 | 3 | — |
| MAX6126BASA21+ | -40°C to +125°C | 8 SO | 2.048 | 0.06 | 5 | — |
| MAX6126A21+ | -40°C to +125°C | 8 µMAX | 2.048 | 0.06 | 3 | 6126A21 |

***Ordering Information continued at end of data sheet.***

*+Denotes a lead(Pb)-free/RoHS-compliant package.*

# Ultra-High-Precision, Ultra-Low-Noise, Series Voltage Reference

## ABSOLUTE MAXIMUM RATINGS

(All voltages referenced to GND)
GNDS .....-0.3V to +0.3V
IN ..... -0.3V to +13V
OUTF, OUTS, NR..... -0.3V to the lesser of ($V_{IN}$ + 0.3V) or +6V
Output Short Circuit to GND or IN .....60s
Continuous Power Dissipation ($T_A$ = +70°C)
8-Pin µMAX (derate 4.5mW/°C above +70°C) .....362mW
8-Pin SO (derate 5.88mW/°C above +70°C) .....471mW

Operating Temperature Range .....-40°C to +125°C
Junction Temperature .....+150°C
Storage Temperature Range .....-65°C to +150°C
Lead Temperature (soldering, 10s) .....+300°C
Soldering Temperature (reflow) .....+260°C

*Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.*

## ELECTRICAL CHARACTERISTICS—MAX6126_21 ($V_{OUT}$ = 2.048V)

($V_{IN}$ = 5V, $C_{LOAD}$ = 0.1µF, $I_{OUT}$ = 0, $T_A$ = $T_{MIN}$ to $T_{MAX}$, unless otherwise noted. Typical values are at $T_A$ = +25°C.)

| PARAMETER | SYMBOL | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| **OUTPUT** | | | | | | | |
| Output Voltage | $V_{OUT}$ | $T_A$ = +25°C | | | 2.048 | | V |
| Output Voltage Accuracy | | Referred to $V_{OUT}$, $T_A$ = +25°C | A grade SO | -0.02 | | +0.02 | % |
| | | | B grade SO | -0.06 | | +0.06 | |
| | | | A grade µMAX | -0.06 | | +0.06 | |
| | | | B grade µMAX | -0.1 | | +0.1 | |
| Output Voltage Temperature Coefficient (Note 1) | $TCV_{OUT}$ | $T_A$ = -40°C to +85°C | A grade SO | | 0.5 | 3 | ppm/°C |
| | | | B grade SO | | 1 | 5 | |
| | | | A grade µMAX | | 1 | 3 | |
| | | | B grade µMAX | | 2 | 7 | |
| | | $T_A$ = -40°C to +125°C | A grade SO | | 1 | 5 | |
| | | | B grade SO | | 2 | 10 | |
| | | | A grade µMAX | | 2 | 5 | |
| | | | B grade µMAX | | 3 | 12 | |
| Line Regulation | $\Delta V_{OUT}/\Delta V_{IN}$ | 2.7V ≤ $V_{IN}$ ≤ 12.6V | $T_A$ = +25°C | | 2 | 20 | µV/V |
| | | | $T_A$ = -40°C to +125°C | | | 40 | |
| Load Regulation | $\Delta V_{OUT}/\Delta I_{OUT}$ | Sourcing: 0 ≤ $I_{OUT}$ ≤ 10mA | | | 0.7 | 25 | µV/mA |
| | | Sinking: -10mA ≤ $I_{OUT}$ ≤ 0 | | | 1.3 | 25 | |
| OUT Short-Circuit Current | $I_{SC}$ | Short to GND | | | 160 | | mA |
| | | Short to IN | | | 20 | | |
| Thermal Hysteresis (Note 2) | $\Delta V_{OUT}$/cycle | SO | | | 25 | | ppm |
| | | µMAX | | | 80 | | |
| Long-Term Stability | $\Delta V_{OUT}$/time | 1000hr at $T_A$ = +25°C | SO | | 20 | | ppm/1000hr |
| | | | µMAX | | 100 | | |

## ELECTRICAL CHARACTERISTICS—MAX6126_21 ($V_{OUT}$ = 2.048V) (continued)

($V_{IN}$ = 5V, $C_{LOAD}$ = 0.1µF, $I_{OUT}$ = 0, $T_A$ = $T_{MIN}$ to $T_{MAX}$, unless otherwise noted. Typical values are at $T_A$ = +25°C.)

| PARAMETER | SYMBOL | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| **DYNAMIC CHARACTERISTICS** | | | | | | | |
| Noise Voltage | $e_{OUT}$ | f = 0.1Hz to 10Hz | | | 1.3 | | $\mu V_{P-P}$ |
| | | f = 1kHz, $C_{NR}$ = 0 | | | 60 | | $nV/\sqrt{Hz}$ |
| | | f = 1kHz, $C_{NR}$ = 0.1µF | | | 35 | | |
| Turn-On Settling Time | $t_R$ | To $V_{OUT}$ = 0.01% of final value | $C_{NR}$ = 0 | | 0.8 | | ms |
| | | | $C_{NR}$ = 0.1µF | | 20 | | |
| Capacitive-Load Stability Range | $C_{LOAD}$ | No sustained oscillations | | | 0.1 to 10 | | µF |
| **INPUT** | | | | | | | |
| Supply Voltage Range | $V_{IN}$ | Guaranteed by line-regulation test | | 2.7 | | 12.6 | V |
| Quiescent Supply Current | $I_{IN}$ | $T_A$ = +25°C | | | 380 | 550 | µA |
| | | $T_A$ = -40°C to +125°C | | | | 725 | |

## ELECTRICAL CHARACTERISTICS—MAX6126_25 ($V_{OUT}$ = 2.500V)

($V_{IN}$ = 5V, $C_{LOAD}$ = 0.1µF, $I_{OUT}$ = 0, $T_A$ = $T_{MIN}$ to $T_{MAX}$, unless otherwise noted. Typical values are at $T_A$ = +25°C.)

| PARAMETER | SYMBOL | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| **OUTPUT** | | | | | | | |
| Output Voltage | $V_{OUT}$ | $T_A$ = +25°C | | | 2.500 | | V |
| Output Voltage Accuracy | | Referred to $V_{OUT}$, $T_A$ = +25°C | A grade SO | -0.02 | | +0.02 | % |
| | | | B grade SO | -0.06 | | +0.06 | |
| | | | A grade µMAX | -0.06 | | +0.06 | |
| | | | B grade µMAX | -0.1 | | +0.1 | |
| Output Voltage Temperature Coefficient (Note 1) | $TCV_{OUT}$ | $T_A$ = -40°C to +85°C | A grade SO | | 0.5 | 3 | ppm/°C |
| | | | B grade SO | | 1 | 5 | |
| | | | A grade µMAX | | 1 | 3 | |
| | | | B grade µMAX | | 2 | 7 | |
| | | $T_A$ = -40°C to +125°C | A grade SO | | 1 | 5 | |
| | | | B grade SO | | 2 | 10 | |
| | | | A grade µMAX | | 2 | 5 | |
| | | | B grade µMAX | | 3 | 12 | |
| Line Regulation | $\Delta V_{OUT}/\Delta V_{IN}$ | 2.7V ≤ $V_{IN}$ ≤ 12.6V | $T_A$ = +25°C | | 3 | 20 | µV/V |
| | | | $T_A$ = -40°C to +125°C | | | 40 | |
| Load Regulation | $\Delta V_{OUT}/\Delta I_{OUT}$ | Sourcing: 0 ≤ $I_{OUT}$ ≤ 10mA | | | 1 | 25 | µV/mA |
| | | Sinking: -10mA ≤ $I_{OUT}$ ≤ 0 | | | 1.8 | 25 | |

# Ultra-High-Precision, Ultra-Low-Noise, Series Voltage Reference

## ELECTRICAL CHARACTERISTICS—MAX6126_25 ($V_{OUT}$ = 2.500V) (continued)

($V_{IN}$ = 5V, $C_{LOAD}$ = 0.1µF, $I_{OUT}$ = 0, $T_A$ = $T_{MIN}$ to $T_{MAX}$, unless otherwise noted. Typical values are at $T_A$ = +25°C.)

| PARAMETER | SYMBOL | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| Dropout Voltage (Note 3) | $V_{IN}$ - $V_{OUT}$ | $\Delta V_{OUT}$ = 0.1% | $I_{OUT}$ = 5mA | | 0.06 | 0.2 | V |
| | | | $I_{OUT}$ = 10mA | | 0.12 | 0.4 | |
| OUT Short-Circuit Current | $I_{SC}$ | Short to GND | | | 160 | | mA |
| | | Short to IN | | | 20 | | |
| Thermal Hysteresis (Note 2) | $\Delta V_{OUT}$/ cycle | SO | | | 35 | | ppm |
| | | µMAX | | | 80 | | |
| Long-Term Stability | $\Delta V_{OUT}$/ time | 1000hr at $T_A$ = +25°C | SO | | 20 | | ppm/ 1000hr |
| | | | µMAX | | 100 | | |
| **DYNAMIC CHARACTERISTICS** | | | | | | | |
| Noise Voltage | $e_{OUT}$ | f = 0.1Hz to 10Hz | | | 1.45 | | $\mu V_{P-P}$ |
| | | f = 1kHz, $C_{NR}$ = 0 | | | 75 | | $nV/\sqrt{Hz}$ |
| | | f = 1kHz, $C_{NR}$ = 0.1µF | | | 45 | | |
| Turn-On Settling Time | $t_R$ | To $V_{OUT}$ = 0.01% of final value | $C_{NR}$ = 0 | | 1 | | ms |
| | | | $C_{NR}$ = 0.1µF | | 20 | | |
| Capacitive-Load Stability Range | $C_{LOAD}$ | No sustained oscillations | | | 0.1 to 10 | | µF |
| **INPUT** | | | | | | | |
| Supply Voltage Range | $V_{IN}$ | Guaranteed by line-regulation test | | 2.7 | | 12.6 | V |
| Quiescent Supply Current | $I_{IN}$ | $T_A$ = +25°C | | | 380 | 550 | µA |
| | | $T_A$ = -40°C to +125°C | | | | 725 | |

## ELECTRICAL CHARACTERISTICS—MAX6126_28 ($V_{OUT}$ = 2.800V)

($V_{IN}$ = 5V, $C_{LOAD}$ = 0.1µF, $I_{OUT}$ = 0, $T_A$ = $T_{MIN}$ to $T_{MAX}$, unless otherwise noted. Typical values are at $T_A$ = +25°C.)

| PARAMETER | SYMBOL | CONDTIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| **OUTPUT** | | | | | | | |
| Output Voltage | $V_{OUT}$ | $T_A$ = +25°C | | | 2.800 | | V |
| Output Voltage Accuracy | | Referred to VOUT, $T_A$ = +25°C | A grade µMAX | -0.06 | | +0.06 | % |
| | | | B grade µMAX | -0.10 | | +0.10 | |
| Output Voltage Temperature Coefficient (Note 1) | $TCV_{OUT}$ | $T_A$ = -40°C to +85°C | A grade µMAX | | 1 | 3 | ppm/°C |
| | | | B grade µMAX | | 2 | 7 | |
| | | $T_A$ = -40°C to +125°C | A grade µMAX | | 2 | 5 | |
| | | | B grade µMAX | | 3 | 12 | |
| Line Regulation | $\Delta V_{OUT}/\Delta V_{IN}$ | 3.0V ≤ $V_{IN}$ ≤ 12.6V | $T_A$ = +25°C | | 3.5 | 23 | µV/V |
| | | | $T_A$ = -40°C to +125°C | | | 45 | |
| Load Regulation | $\Delta V_{OUT}/\Delta V_{IN}$ | Sourcing: 0 ≤ $I_{OUT}$ ≤ 10mA | | | 1.3 | 28 | µV/mA |
| | | Sinking: -10mA ≤ $I_{OUT}$ ≤ 0 | | | 2.4 | 28 | |
| Dropout Voltage (Note 3) | $V_{IN}$ - $V_{OUT}$ | $\Delta V_{OUT}$ = 0.1% | $I_{OUT}$ = 5mA | | 0.06 | 0.2 | V |
| | | | $I_{OUT}$ = 10mA | | 0.12 | 0.4 | |

## ELECTRICAL CHARACTERISTICS—MAX6126_28 ($V_{OUT}$ = 2.800V) (continued)

($V_{IN}$ = 5V, $C_{LOAD}$ = 0.1µF, $I_{OUT}$ = 0, $T_A$ = $T_{MIN}$ to $T_{MAX}$, unless otherwise noted. Typical values are at $T_A$ = +25°C.)

| PARAMETER | SYMBOL | CONDTIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| OUT Short-Circuit Current | $I_{SC}$ | Short to GND | | | 160 | | mA |
| | | Short to IN | | | 20 | | |
| Thermal Hysteresis (Note 2) | $\Delta V_{OUT}$/cycle | µMAX | | | 80 | | ppm |
| Long-Term Stability | $\Delta V_{OUT}$/time | 1000hr at $T_A$ = +25°C | µMAX | | 100 | | ppm/ 1000hr |
| **DYNAMIC CHARACTERISTICS** | | | | | | | |
| Noise Voltage | $e_{OUT}$ | f = 0.1Hz to 10Hz | | | 1.45 | | $\mu V_{P-P}$ |
| | | f = 1kHz, $C_{NR}$ = 0 | | | 75 | | nV/√Hz |
| | | f = 1kHz, $C_{NR}$ = 0.1µF | | | 45 | | |
| Turn-On Settling Time | $t_R$ | To $V_{OUT}$ = 0.01% of final value | $C_{NR}$ = 0 | | 1 | | ms |
| | | | $C_{NR}$ = 0.1µF | | 20 | | |
| Capacitive-Load Stability Range | $C_{LOAD}$ | No sustained oscillations | | | 0.1 to 10 | | µF |
| **INPUT** | | | | | | | |
| Supply Voltage Range | $V_{IN}$ | Guaranteed by line-regulation test | | 3.0 | | 12.6 | V |
| Quiescent Supply Current | $I_{IN}$ | $T_A$ = +25°C | | | 380 | 550 | µA |
| | | $T_A$ = -40°C to +125°C | | | | 725 | |

## ELECTRICAL CHARACTERISTICS—MAX6126_30 ($V_{OUT}$ = 3.000V)

($V_{IN}$ = 5V, $C_{LOAD}$ = 0.1µF, $I_{OUT}$ = 0, $T_A$ = $T_{MIN}$ to $T_{MAX}$, unless otherwise noted. Typical values are at $T_A$ = +25°C.)

| PARAMETER | SYMBOL | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| **OUTPUT** | | | | | | | |
| Output Voltage | $V_{OUT}$ | $T_A$ = +25°C | | | 3.000 | | V |
| Output Voltage Accuracy | | Referred to $V_{OUT}$, $T_A$ = +25°C | A grade SO | -0.02 | | +0.02 | % |
| | | | B grade SO | -0.06 | | +0.06 | |
| | | | A grade µMAX | -0.06 | | +0.06 | |
| | | | B grade µMAX | -0.1 | | +0.1 | |
| Output Voltage Temperature Coefficient (Note 1) | $TCV_{OUT}$ | $T_A$ = -40°C to +85°C | A grade SO | | 0.5 | 3 | ppm/°C |
| | | | B grade SO | | 1 | 5 | |
| | | | A grade µMAX | | 1 | 3 | |
| | | | B grade µMAX | | 2 | 7 | |
| | | $T_A$ = -40°C to +125°C | A grade SO | | 1 | 5 | |
| | | | B grade SO | | 2 | 10 | |
| | | | A grade µMAX | | 2 | 5 | |
| | | | B grade µMAX | | 3 | 12 | |

# Ultra-High-Precision, Ultra-Low-Noise, Series Voltage Reference

## ELECTRICAL CHARACTERISTICS—MAX6126_30 ($V_{OUT}$ = 3.000V) (continued)

($V_{IN}$ = 5V, $C_{LOAD}$ = 0.1µF, $I_{OUT}$ = 0, $T_A$ = $T_{MIN}$ to $T_{MAX}$, unless otherwise noted. Typical values are at $T_A$ = +25°C.)

| PARAMETER | SYMBOL | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| Line Regulation | $\Delta V_{OUT}/\Delta V_{IN}$ | 3.2V ≤ $V_{IN}$ ≤ 12.6V | $T_A$ = +25°C | | 4 | 25 | µV/V |
| | | | $T_A$ = -40°C to +125°C | | | 50 | |
| Load Regulation | $\Delta V_{OUT}/\Delta I_{OUT}$ | Sourcing: 0 ≤ $I_{OUT}$ ≤ 10mA | | | 1.5 | 30 | µV/mA |
| | | Sinking: -10mA ≤ $I_{OUT}$ ≤ 0 | | | 2.8 | 30 | |
| Dropout Voltage (Note 3) | $V_{IN}$ - $V_{OUT}$ | $\Delta V_{OUT}$ = 0.1% | $I_{OUT}$ = 5mA | | 0.06 | 0.2 | V |
| | | | $I_{OUT}$ = 10mA | | 0.11 | 0.4 | |
| OUT Short-Circuit Current | $I_{SC}$ | Short to GND | | | 160 | | mA |
| | | Short to IN | | | 20 | | |
| Thermal Hysteresis (Note 2) | $\Delta V_{OUT}$/cycle | SO | | | 20 | | ppm |
| | | µMAX | | | 80 | | |
| Long-Term Stability | $\Delta V_{OUT}$/time | 1000hr at $T_A$ = +25°C | SO | | 20 | | ppm/1000hr |
| | | | µMAX | | 100 | | |
| **DYNAMIC CHARACTERISTICS** | | | | | | | |
| Noise Voltage | $e_{OUT}$ | f = 0.1Hz to 10Hz | | | 1.75 | | $\mu V_{P-P}$ |
| | | f = 1kHz, $C_{NR}$ = 0 | | | 90 | | $nV/\sqrt{Hz}$ |
| | | f = 1kHz, $C_{NR}$ = 0.1µF | | | 55 | | |
| Capacitive-Load Stability Range | $C_{LOAD}$ | No sustained oscillations | | | 0.1 to 10 | | µF |
| Turn-On Settling Time | $t_R$ | To $V_{OUT}$ = 0.01% of final value | $C_{NR}$ = 0 | | 1.2 | | ms |
| | | | $C_{NR}$ = 0.1µF | | 20 | | |
| **INPUT** | | | | | | | |
| Supply Voltage Range | $V_{IN}$ | Guaranteed by line-regulation test | | 3.2 | | 12.6 | V |
| Quiescent Supply Current | $I_{IN}$ | $T_A$ = +25°C | | | 380 | 550 | µA |
| | | $T_A$ = -40°C to +125°C | | | | 725 | |

## ELECTRICAL CHARACTERISTICS—MAX6126_41 ($V_{OUT}$ = 4.096V)

($V_{IN}$ = 5V, $C_{LOAD}$ = 0.1µF, $I_{OUT}$ = 0, $T_A$ = $T_{MIN}$ to $T_{MAX}$, unless otherwise noted. Typical values are at $T_A$ = +25°C.)

| PARAMETER | SYMBOL | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| **OUTPUT** | | | | | | | |
| Output Voltage | $V_{OUT}$ | $T_A$ = +25°C | | | 4.096 | | V |
| Output Voltage Accuracy | | Referred to $V_{OUT}$, $T_A$ = +25°C | A grade SO | -0.02 | | +0.02 | % |
| | | | B grade SO | -0.06 | | +0.06 | |
| | | | A grade µMAX | -0.06 | | +0.06 | |
| | | | B grade µMAX | -0.1 | | +0.1 | |

## ELECTRICAL CHARACTERISTICS—MAX6126_41 ($V_{OUT}$ = 4.096V) (continued)

($V_{IN}$ = 5V, $C_{LOAD}$ = 0.1µF, $I_{OUT}$ = 0, $T_A$ = $T_{MIN}$ to $T_{MAX}$, unless otherwise noted. Typical values are at $T_A$ = +25°C.)

| PARAMETER | SYMBOL | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| Output Voltage Temperature Coefficient (Note 1) | $TCV_{OUT}$ | $T_A$ = -40°C to +85°C | A grade SO | | 0.5 | 3 | ppm/°C |
| | | | B grade SO | | 1 | 5 | |
| | | | A grade µMAX | | 1 | 3 | |
| | | | B grade µMAX | | 2 | 7 | |
| | | $T_A$ = -40°C to +125°C | A grade SO | | 1 | 5 | |
| | | | B grade SO | | 2 | 10 | |
| | | | A grade µMAX | | 2 | 5 | |
| | | | B grade µMAX | | 3 | 12 | |
| Line Regulation | $\Delta V_{OUT}/\Delta V_{IN}$ | 4.3V ≤ $V_{IN}$ ≤ 12.6V | $T_A$ = +25°C | | 4.5 | 30 | µV/V |
| | | | $T_A$ = -40°C to +125°C | | | 60 | |
| Load Regulation | $\Delta V_{OUT}/\Delta I_{OUT}$ | Sourcing: 0 ≤ $I_{OUT}$ ≤ 10mA | | | 2 | 40 | µV/mA |
| | | Sinking: -10mA ≤ $I_{OUT}$ ≤ 0 | | | 5 | 40 | |
| Dropout Voltage (Note 3) | $V_{IN}$ - $V_{OUT}$ | $\Delta V_{OUT}$ = 0.1% | $I_{OUT}$ = 5mA | | 0.05 | 0.2 | V |
| | | | $I_{OUT}$ = 10mA | | 0.1 | 0.4 | |
| OUT Short-Circuit Current | $I_{SC}$ | Short to GND | | | 160 | | mA |
| | | Short to IN | | | 20 | | |
| Thermal Hysteresis (Note 2) | $\Delta V_{OUT}$/cycle | SO | | | 20 | | ppm |
| | | µMAX | | | 80 | | |
| Long-Term Stability | $\Delta V_{OUT}$/time | 1000hr at $T_A$ = +25°C | SO | | 20 | | ppm/1000hr |
| | | | µMAX | | 100 | | |
| **DYNAMIC CHARACTERISTICS** | | | | | | | |
| Noise Voltage | $e_{OUT}$ | f = 0.1Hz to 10Hz | | | 2.4 | | $\mu V_{P-P}$ |
| | | f = 1kHz, $C_{NR}$ = 0 | | | 120 | | $nV/\sqrt{Hz}$ |
| | | f = 1kHz, $C_{NR}$ = 0.1µF | | | 80 | | |
| Capacitive-Load Stability Range | $C_{LOAD}$ | No sustained oscillations | | | 0.1 to 10 | | µF |
| Turn-On Settling Time | $t_R$ | To $V_{OUT}$ = 0.01% of final value | $C_{NR}$ = 0 | | 1.6 | | ms |
| | | | $C_{NR}$ = 0.1µF | | 20 | | |
| **INPUT** | | | | | | | |
| Supply Voltage Range | $V_{IN}$ | Guaranteed by line-regulation test | | 4.3 | | 12.6 | V |
| Quiescent Supply Current | $I_{IN}$ | $T_A$ = +25°C | | | 380 | 550 | µA |
| | | $T_A$ = -40°C to +125°C | | | | 725 | |

# Ultra-High-Precision, Ultra-Low-Noise, Series Voltage Reference

## ELECTRICAL CHARACTERISTICS—MAX6126_50 ($V_{OUT}$ = 5.000V)

($V_{IN}$ = 5.5V, $C_{LOAD}$ = 0.1µF, $I_{OUT}$ = 0, $T_A$ = $T_{MIN}$ to $T_{MAX}$, unless otherwise noted. Typical values are at $T_A$ = +25°C.)

| PARAMETER | SYMBOL | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| **OUTPUT** | | | | | | | |
| Output Voltage | $V_{OUT}$ | $T_A$ = +25°C | | | 5.000 | | V |
| Output Voltage Accuracy | | $T_A$ = +25°C | A grade SO | -0.02 | | +0.02 | % |
| | | | B grade SO | -0.06 | | +0.06 | |
| | | | A grade µMAX | -0.06 | | +0.06 | |
| | | | B grade µMAX | -0.1 | | +0.1 | |
| Output Voltage Temperature Coefficient (Note 1) | $TCV_{OUT}$ | $T_A$ = -40°C to +85°C | A grade SO | | 0.5 | 3 | ppm/°C |
| | | | B grade SO | | 1 | 5 | |
| | | | A grade µMAX | | 1 | 3 | |
| | | | B grade µMAX | | 2 | 7 | |
| | | $T_A$ = -40°C to +125°C | A grade SO | | 1 | 5 | |
| | | | B grade SO | | 2 | 10 | |
| | | | A grade µMAX | | 2 | 5 | |
| | | | B grade µMAX | | 3 | 12 | |
| Line Regulation | $\Delta V_{OUT}/\Delta V_{IN}$ | 5.2V ≤ $V_{IN}$ ≤ 12.6V | $T_A$ = +25°C | | 3 | 40 | µV/V |
| | | | $T_A$ = -40°C to +125°C | | | 80 | |
| Load Regulation | $\Delta V_{OUT}/\Delta I_{OUT}$ | Sourcing: 0 ≤ $I_{OUT}$ ≤ 10mA | | | 2.5 | 50 | µV/mA |
| | | Sinking: -10mA ≤ $I_{OUT}$ ≤ 0 | | | 6.5 | 50 | |
| Dropout Voltage (Note 3) | $V_{IN}$ - $V_{OUT}$ | $\Delta V_{OUT}$ = 0.1% | $I_{OUT}$ = 5mA | | 0.05 | 0.2 | V |
| | | | $I_{OUT}$ = 10mA | | 0.1 | 0.4 | |
| OUT Short-Circuit Current | $I_{SC}$ | Short to GND | | | 160 | | mA |
| | | Short to IN | | | 20 | | |
| Thermal Hysteresis (Note 2) | $\Delta V_{OUT}$/cycle | SO | | | 15 | | ppm |
| | | µMAX | | | 80 | | |
| Long-Term Stability | $\Delta V_{OUT}$/time | 1000hr at $T_A$ = +25°C | SO | | 20 | | ppm/1000hr |
| | | | µMAX | | 100 | | |
| **DYNAMIC CHARACTERISTICS** | | | | | | | |
| Noise Voltage | $e_{OUT}$ | f = 0.1Hz to 10Hz | | | 2.85 | | $\mu V_{P-P}$ |
| | | f = 1kHz, $C_{NR}$ = 0 | | | 145 | | $nV/\sqrt{Hz}$ |
| | | f = 1kHz, $C_{NR}$ = 0.1µF | | | 95 | | |
| Capacitive-Load Stability Range | $C_{LOAD}$ | No sustained oscillations | | | 0.1 to 10 | | µF |

## ELECTRICAL CHARACTERISTICS—MAX6126_50 ($V_{OUT}$ = 5.000V) (continued)

($V_{IN}$ = 5.5V, $C_{LOAD}$ = 0.1µF, $I_{OUT}$ = 0, $T_A$ = $T_{MIN}$ to $T_{MAX}$, unless otherwise noted. Typical values are at $T_A$ = +25°C.)

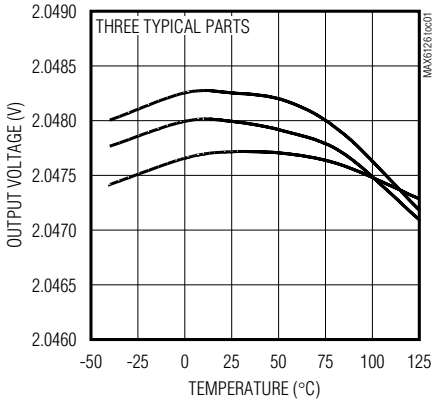
| PARAMETER | SYMBOL | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| Turn-On Settling Time | $t_R$ | To $V_{OUT}$ = 0.01% of final value | $C_{NR}$ = 0 | | 2 | | ms |
| | | | $C_{NR}$ = 0.1µF | | 20 | | |
| **INPUT** | | | | | | | |
| Supply Voltage Range | $V_{IN}$ | Guaranteed by line-regulation test | | 5.2 | | 12.6 | V |
| Quiescent Supply Current | $I_{IN}$ | $T_A$ = +25°C | | | 380 | 550 | µA |
| | | $T_A$ = -40°C to +125°C | | | | 725 | |

**Note 1:** Temperature coefficient is measured by the "box" method, i.e., the maximum $\Delta V_{OUT}$ / $V_{OUT}$ is divided by the maximum $\Delta T$.
**Note 2:** Thermal hysteresis is defined as the change in +25°C output voltage before and after cycling the device from $T_{MAX}$ to $T_{MIN}$.
**Note 3:** Dropout voltage is defined as the minimum differential voltage ($V_{IN}$ - $V_{OUT}$) at which $V_{OUT}$ decreases by 0.1% from its original value at $V_{IN}$ = 5.0V ($V_{IN}$ = 5.5V for $V_{OUT}$ = 5.0V).

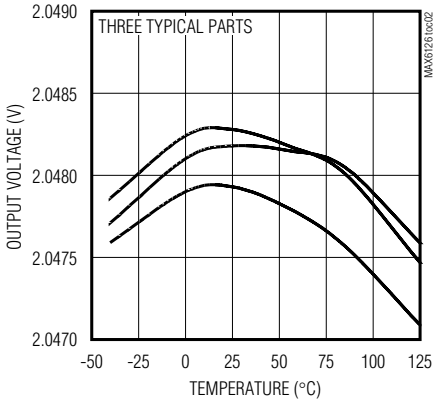
## Typical Operating Characteristics

($V_{IN}$ = 5V for MAX6126_21/25/30/41, $V_{IN}$ = 5.5V for MAX6126_50, $C_{LOAD}$ = 0.1µF, $I_{OUT}$ = 0, $T_A$ = +25°C, unless otherwise specified.) (Note 5)

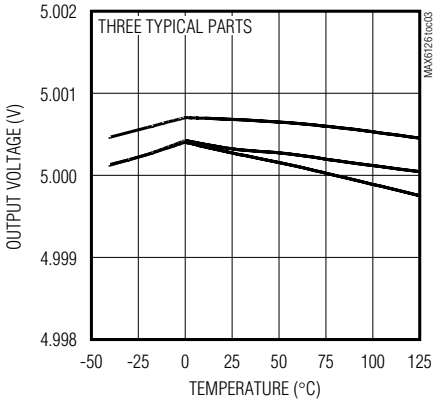
**MAX6126A_21**
**OUTPUT VOLTAGE TEMPERATURE DRIFT**
**($V_{OUT}$ = 2.048V) (SO)**




**MAX6126A_21**
**OUTPUT VOLTAGE TEMPERATURE DRIFT**
**($V_{OUT}$ = 2.048V) (µMAX)**




**MAX6126A_50**
**OUTPUT VOLTAGE TEMPERATURE DRIFT**
**($V_{OUT}$ = 5.000V) (SO)**

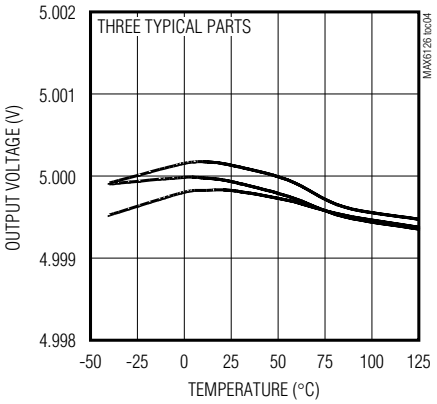


# Ultra-High-Precision, Ultra-Low-Noise, Series Voltage Reference

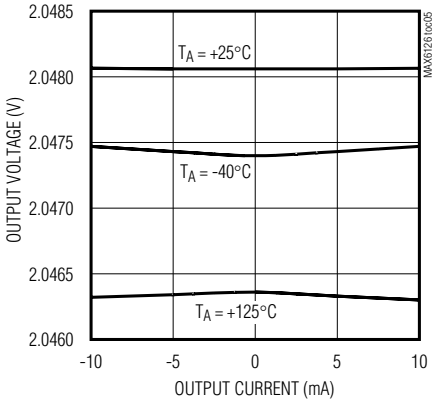
## Typical Operating Characteristics (continued)

($V_{IN}$ = 5V for MAX6126_21/25/30/41, $V_{IN}$ = 5.5V for MAX6126_50, $C_{LOAD}$ = 0.1µF, $I_{OUT}$ = 0, $T_A$ = +25°C, unless otherwise specified.) (Note 5)

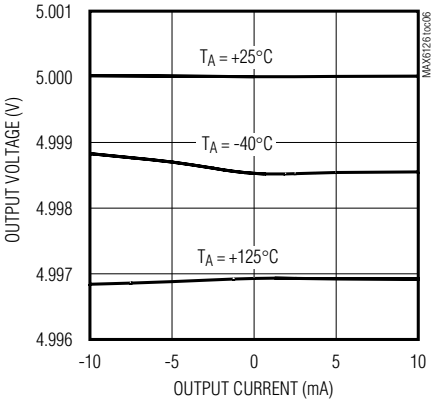
**MAX6126A_50**
**OUTPUT VOLTAGE TEMPERATURE DRIFT**
**($V_{OUT}$ = 5.000V) (µMAX)**



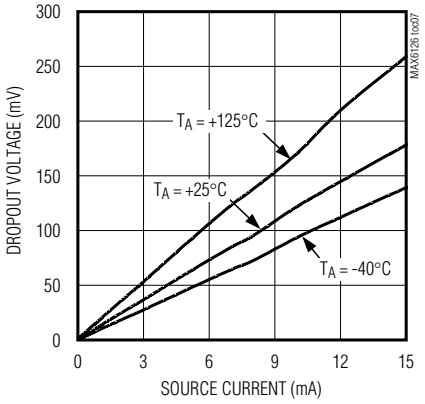

**MAX6126_21**
**LOAD REGULATION**



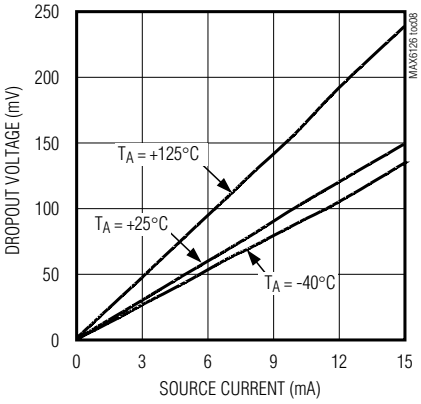

**MAX6126_50**
**LOAD REGULATION**



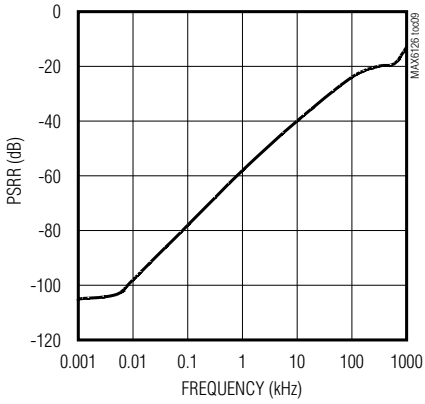

**MAX6126_25**
**DROPOUT VOLTAGE**
**vs. SOURCE CURRENT**



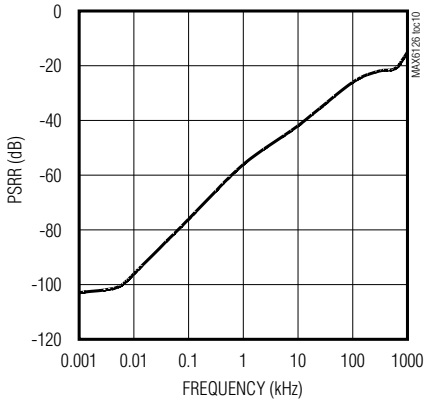

**MAX6126_50**
**DROPOUT VOLTAGE**
**vs. SOURCE CURRENT**



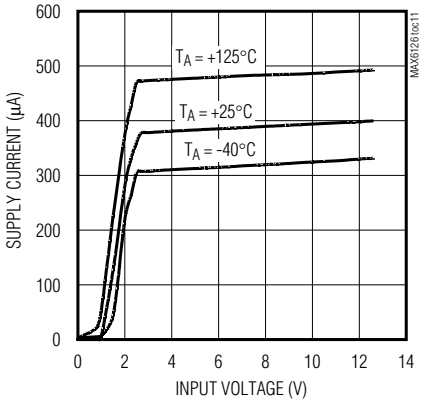

**MAX6126_21**
**POWER-SUPPLY REJECTION RATIO**
**vs. FREQUENCY**



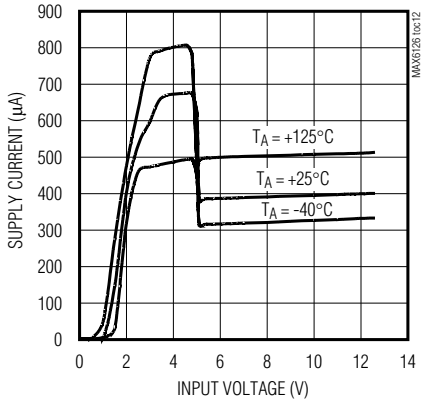

**MAX6126_50**
**POWER-SUPPLY REJECTION RATIO**
**vs. FREQUENCY**




**MAX6126_21**
**SUPPLY CURRENT vs. INPUT VOLTAGE**



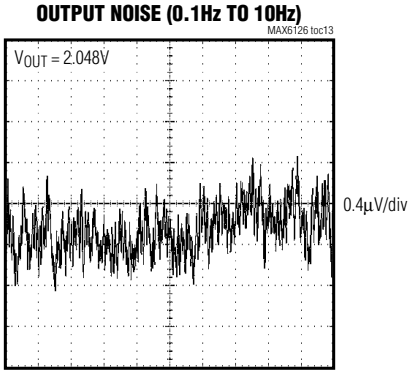

**MAX6126_50**
**SUPPLY CURRENT vs. INPUT VOLTAGE**



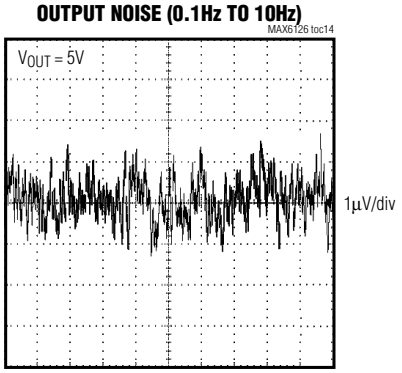
## Typical Operating Characteristics (continued)

($V_{IN}$ = 5V for MAX6126_21/25/30/41, $V_{IN}$ = 5.5V for MAX6126_50, $C_{LOAD}$ = 0.1µF, $I_{OUT}$ = 0, $T_A$ = +25°C, unless otherwise specified.) (Note 5)

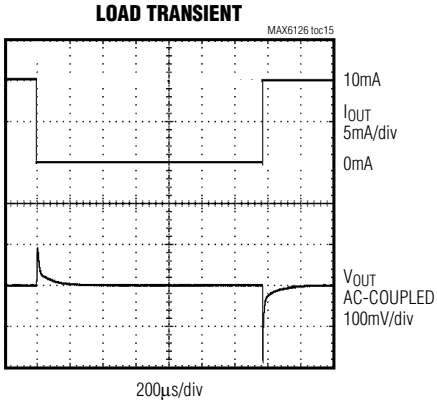
**MAX6126_21**
**OUTPUT NOISE (0.1Hz TO 10Hz)**




**MAX6126_50**
**OUTPUT NOISE (0.1Hz TO 10Hz)**

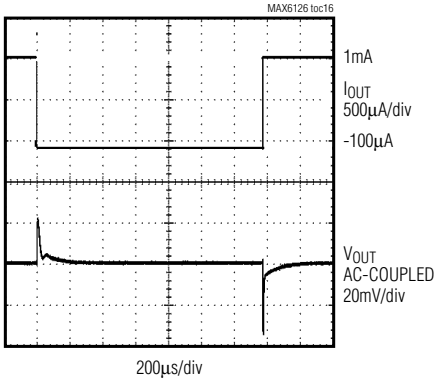



**MAX6126_21**
**LOAD TRANSIENT**



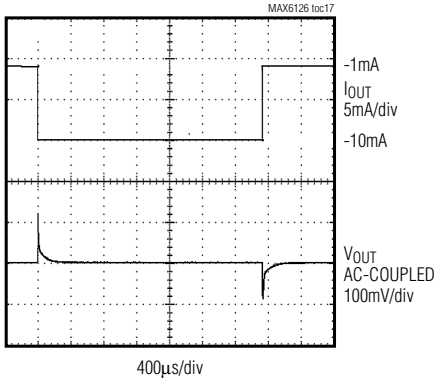

$C_{LOAD}$ = 0.1µF $I_{OUT}$ = 0 TO 10mA
$V_{IN}$ = 5V $V_{OUT}$ = 2.048V

**MAX6126_21**
**LOAD TRANSIENT**



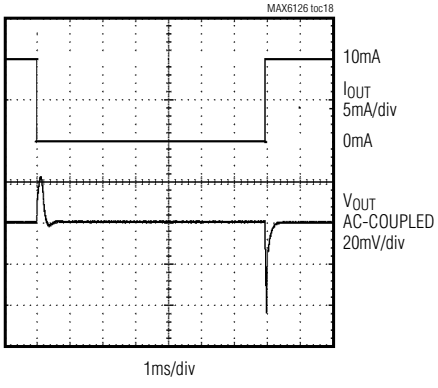

$C_{LOAD}$ = 0.1µF $I_{OUT}$ = -100µA TO 1mA
$V_{IN}$ = 5V $V_{OUT}$ = 2.048V

**MAX6126_21**
**LOAD TRANSIENT**




$C_{LOAD}$ = 0.1µF $I_{OUT}$ = -1mA TO -10mA
$V_{IN}$ = 5V $V_{OUT}$ = 2.048V

**MAX6126_21**
**LOAD TRANSIENT**



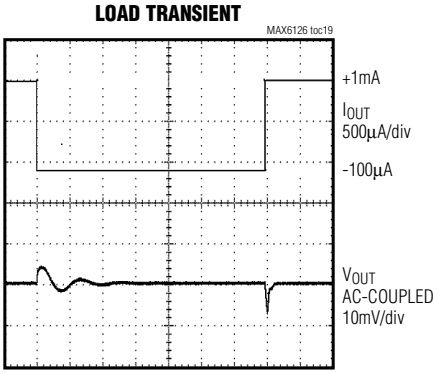

$C_{LOAD}$ = 10µF $I_{OUT}$ = 0 TO 10mA
$V_{IN}$ = 5V $V_{OUT}$ = 2.048V

# Ultra-High-Precision, Ultra-Low-Noise, Series Voltage Reference

## Typical Operating Characteristics (continued)

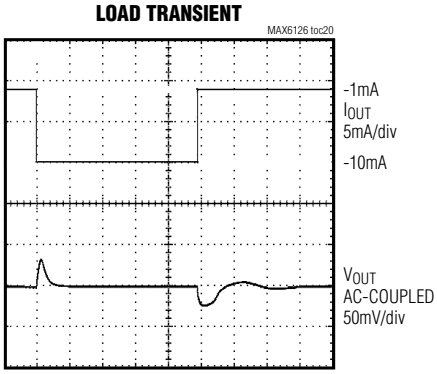
($V_{IN}$ = 5V for MAX6126_21/25/30/41, $V_{IN}$ = 5.5V for MAX6126_50, $C_{LOAD}$ = 0.1µF, $I_{OUT}$ = 0, $T_A$ = +25°C, unless otherwise specified.) (Note 5)

**MAX6126_21**
**LOAD TRANSIENT**



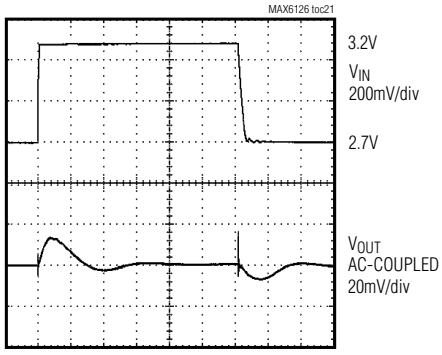

$C_{LOAD}$ = 10µF $I_{OUT}$ = -100µA TO 1mA
$V_{IN}$ = 5V $V_{OUT}$ = 2.048V

**MAX6126_21**
**LOAD TRANSIENT**



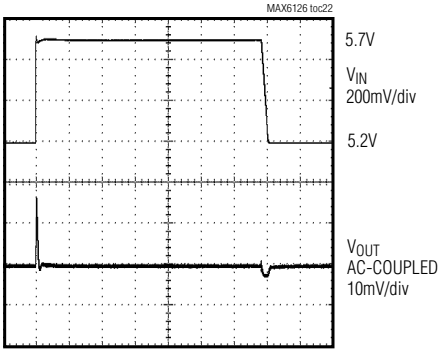

$C_{LOAD}$ = 10µF $I_{OUT}$ = -1mA TO -10mA
$V_{IN}$ = 5V $V_{OUT}$ = 2.048V

**MAX6126_21**
**LINE TRANSIENT**



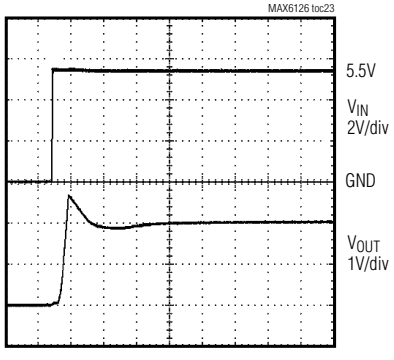

$V_{OUT}$ = 2.048V $C_{LOAD}$ = 0.1µF

**MAX6126_50**
**LINE TRANSIENT**



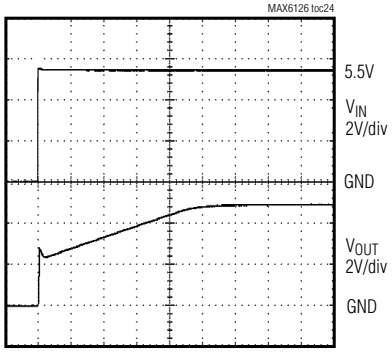

$V_{IN}$ = 5.2V TO 5.7V $C_{LOAD}$ = 0.1µF
$V_{OUT}$ = 5V

**MAX6126_21**
**TURN-ON TRANSIENT**




$C_{LOAD}$ = 0.1µF
$V_{OUT}$ = 2.048V

**MAX6126_50**
**TURN-ON TRANSIENT**

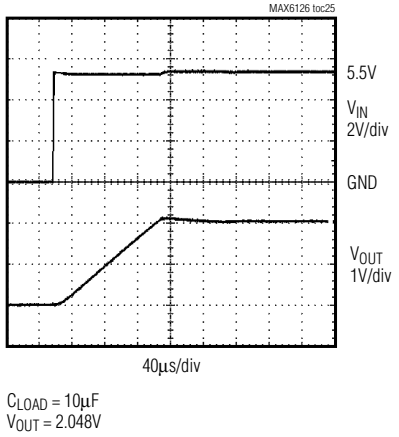



$C_{LOAD}$ = 0.1µF
$V_{OUT}$ = 5V

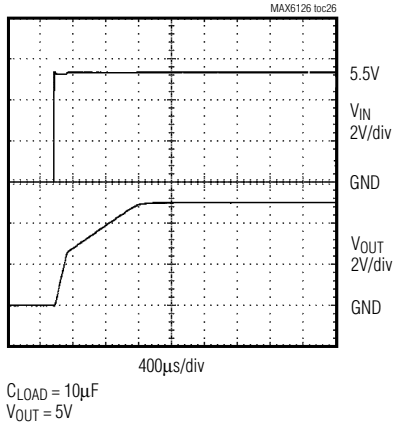
## Typical Operating Characteristics (continued)

($V_{IN}$ = 5V for MAX6126_21/25/30/41, $V_{IN}$ = 5.5V for MAX6126_50, $C_{LOAD}$ = 0.1µF, $I_{OUT}$ = 0, $T_A$ = +25°C, unless otherwise specified.) (Note 5)

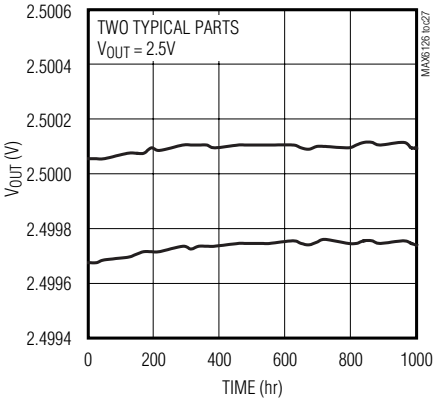
**MAX6126_21**
**TURN-ON TRANSIENT**



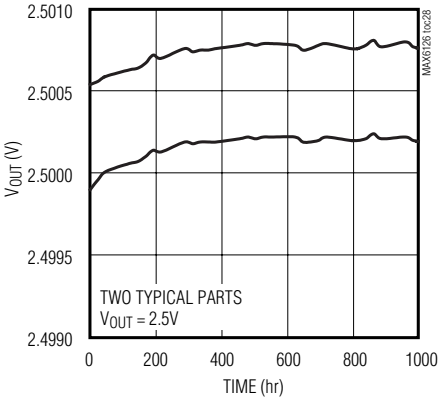

**MAX6126_50**
**TURN-ON TRANSIENT**



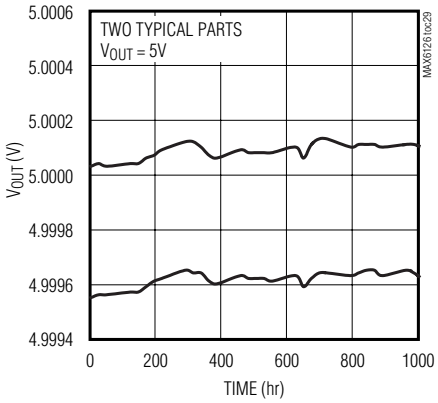

**MAX6126B_25**
**LONG-TERM STABILITY vs. TIME (SO)**



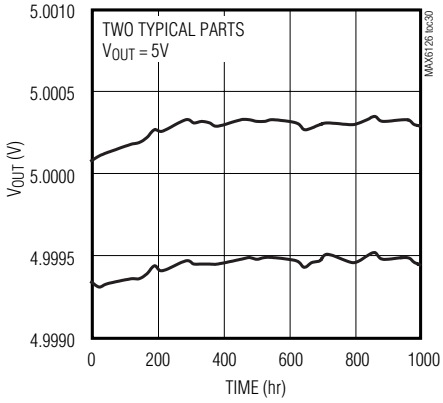

**MAX6126B_25**
**LONG-TERM STABILITY vs. TIME (µMAX)**




**MAX6126B_50**
**LONG-TERM STABILITY vs. TIME (SO)**




**MAX6126B_50**
**LONG-TERM STABILITY vs. TIME (µMAX)**




**Note 5:** Many of the MAX6126 *Typical Operating Characteristics* are extremely similar. The extremes of these characteristics are found in the MAX6126_21 (2.048V output) and the MAX6126_50 (5.000V output). The *Typical Operating Characteristics* of the remainder of the MAX6126 family typically lie between those two extremes and can be estimated based on their output voltages.

# Ultra-High-Precision, Ultra-Low-Noise, Series Voltage Reference

## Pin Description

| PIN | NAME | FUNCTION |
|---|---|---|
| 1 | NR | Noise Reduction. Connect a 0.1µF capacitor to improve wideband noise. Leave unconnected if not used (see Figure 1). |
| 2 | IN | Positive Power-Supply Input |
| 3 | GND | Ground |
| 4 | GNDS | Ground-Sense Connection. Connect to ground connection at load. |
| 5, 8 | I.C. | Internally Connected. **Do not connect anything to these pins.** |
| 6 | OUTS | Voltage Reference Sense Output |
| 7 | OUTF | Voltage Reference Force Output. Short OUTF to OUTS as close to the load as possible. Bypass OUTF with a capacitor (0.1µF to 10µF) to GND. |

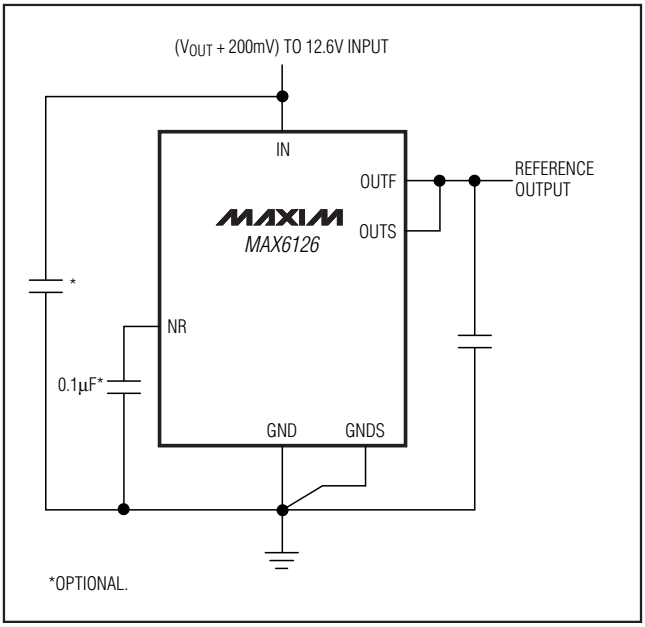



*Figure 1. Noise-Reduction Capacitor*

## Detailed Description

### Wideband Noise Reduction

To improve wideband noise and transient power-supply noise, add a 0.1µF capacitor to NR (Figure 1). Larger values do not improve noise appreciably. A 0.1µF NR capacitor reduces the noise from 60nV/√Hz to 35nV/√Hz for the 2.048V output. Noise in the power-supply input can affect output noise, but can be reduced by adding an optional bypass capacitor between IN and GND, as shown in the *Typical Operating Circuit*.

### Output Bypassing

The MAX6126 requires an output capacitor between 0.1µF and 10µF. Locate the output capacitor as close to OUTF as possible. For applications driving switching capacitive loads or rapidly changing load currents, it is advantageous to use a 10µF capacitor in parallel with a 0.1µF capacitor. Larger capacitor values reduce transients on the reference output.

### Supply Current

The quiescent supply current of the series-mode MAX6126 family is typically 380µA and is virtually independent of the supply voltage, with only a 2µA/V (max) variation with supply voltage.

When the supply voltage is below the minimum specified input voltage during turn-on, the device can draw up to 300µA beyond the nominal supply current. The input voltage source must be capable of providing this current to ensure reliable turn-on.

### Thermal Hysteresis

Thermal hysteresis is the change of output voltage at $T_A$ = +25°C before and after the device is cycled over its entire operating temperature range. The typical thermal hysteresis value is 20ppm (SO package).

### Turn-On Time

These devices typically turn on and settle to within 0.1% of their final value in 200µs to 2ms depending on the device. The turn-on time can increase up to 4ms with the device operating at the minimum dropout voltage and the maximum load. A noise reduction capacitor of 0.1µF increases the turn-on time to 20ms.

### Output Force and Sense

The MAX6126 provides independent connections for the power-circuit output (OUTF) supplying current into a load, and for the circuit input regulating the voltage applied to that load (OUTS). This configuration allows for the cancellation of the voltage drop on the lines connecting the MAX6126 and the load. When using the Kelvin connection made possible by the independent current and voltage connections, take the power connection to the load from OUTF, and bring a line from OUTS to join the line from OUTF, at the point where the voltage accu-

racy is needed. The MAX6126 has the same type of Kelvin connection to cancel drops in the ground return line. Connect the load to ground and bring a connection from GNDS to exactly the same point.

## Applications Information

### Precision Current Source

Figure 2 shows a typical circuit providing a precision current source. The OUTF output provides the bias current for the bipolar transistor. OUTS and GNDS sense the voltage across the resistor and adjust the current sourced by OUTF accordingly. For even higher precision, use a MOSFET to eliminate base current errors.

### High-Resolution DAC and Reference from a Single Supply

Figure 3 shows a typical circuit providing the reference for a high-resolution, 16-bit MAX541 D/A converter.

### Temperature Coefficient vs. Operating Temperature Range for a 1 LSB Maximum Error

In a data converter application, the reference voltage of the converter must stay within a certain limit to keep the error in the data converter smaller than the resolution limit through the operating temperature range. Figure 4 shows the maximum allowable reference voltage temperature coefficient to keep the conversion error to less than 1 LSB, as a function of the operating temperature range ($T_{MAX}$ - $T_{MIN}$) with the converter resolution as a parameter. The graph assumes the reference voltage temperature coefficient as the only parameter affecting accuracy.

In reality, the absolute static accuracy of a data converter is dependent on the combination of many parameters such as integral nonlinearity, differential nonlinearity, offset error, gain error, as well as voltage reference changes.

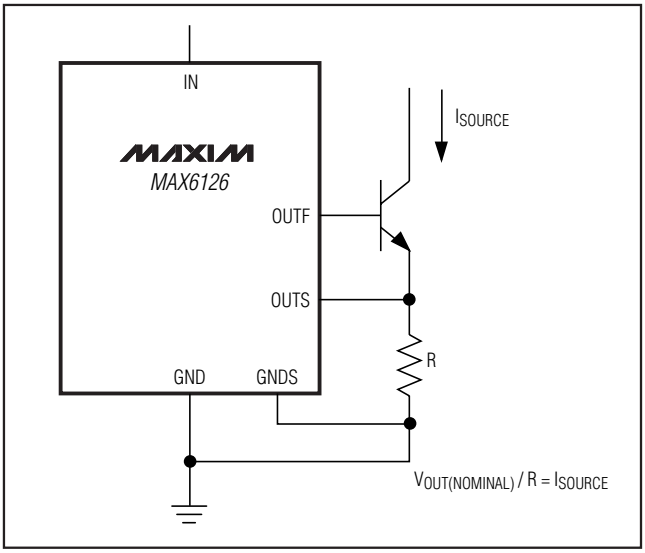



*Figure 2. Precision Current Source*

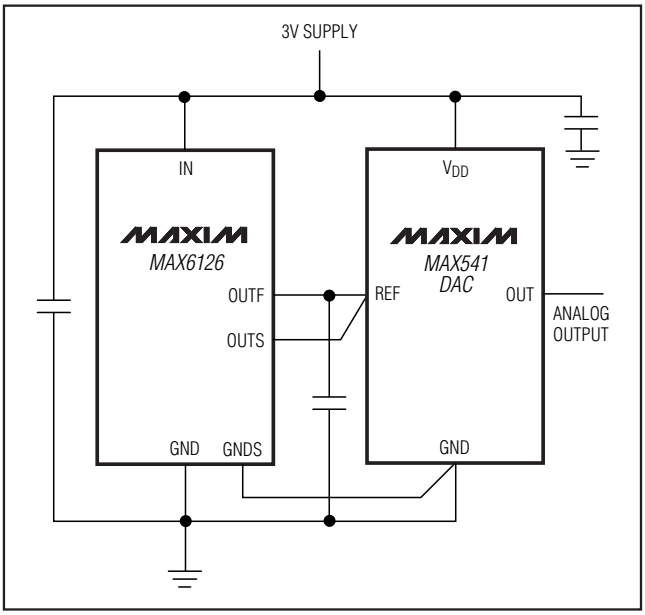



*Figure 3. 14-Bit High-Resolution DAC and Positive Reference from a Single 3V Supply*

# Ultra-High-Precision, Ultra-Low-Noise, Series Voltage Reference

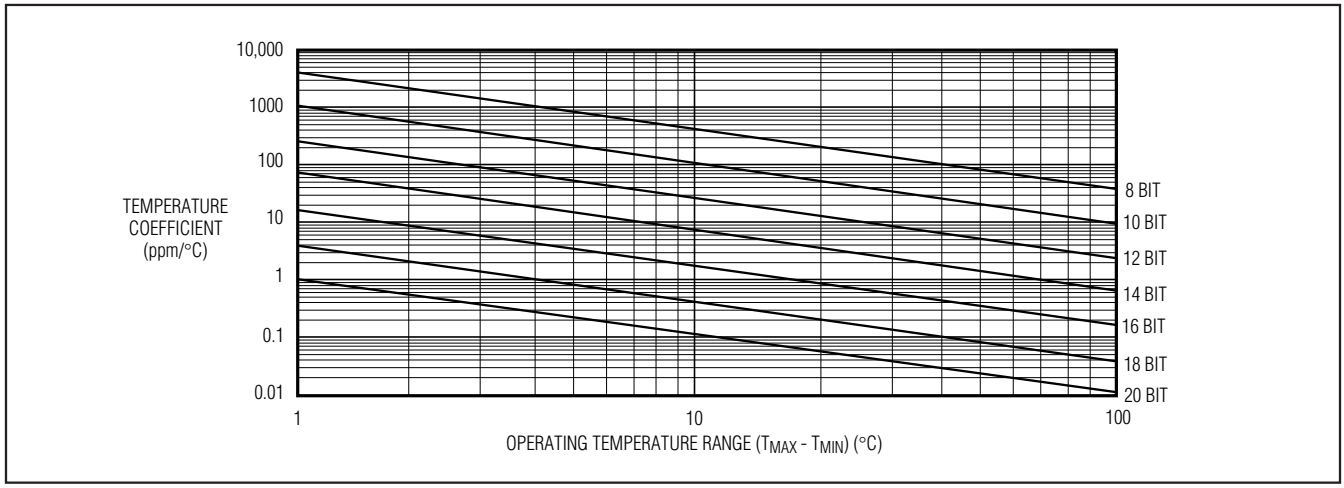
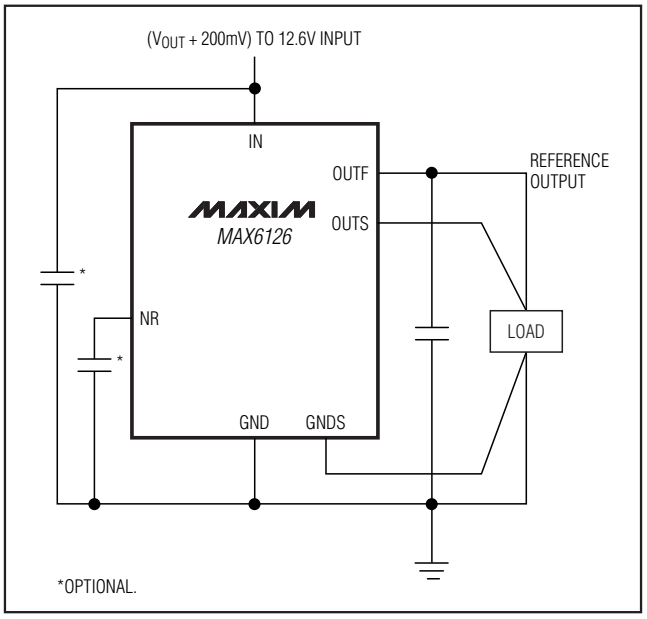



*Figure 4. Temperature Coefficient vs. Operating Temperature Range for a 1 LSB Maximum Error*

## Typical Operating Circuit




## Chip Information

PROCESS: BiCMOS

# Ultra-High-Precision, Ultra-Low-Noise, Series Voltage Reference

## Ordering Information (continued)

| PART | TEMP RANGE | PIN-PACKAGE | OUTPUT VOLTAGE (V) | MAXIMUM INITIAL ACCURACY (%) | MAXIMUM TEMPCO (-40°C to +85°C) (ppm/°C) | TOP MARK |
|---|---|---|---|---|---|---|
| MAX6126B21+ | -40°C to +125°C | 8 µMAX | 2.048 | 0.1 | 7 | 6126B21 |
| MAX6126AASA25+ | -40°C to +125°C | 8 SO | 2.500 | 0.02 | 3 | — |
| MAX6126BASA25+ | -40°C to +125°C | 8 SO | 2.500 | 0.06 | 5 | — |
| MAX6126A25+ | -40°C to +125°C | 8 µMAX | 2.500 | 0.06 | 3 | 6126A25 |
| MAX6126B25+ | -40°C to +125°C | 8 µMAX | 2.500 | 0.1 | 7 | 6126B25 |
| MAX6126A28+ | -40°C to +125°C | 8 µMAX | 2.800 | 0.06 | 3 | 6126A28 |
| MAX6126B28+ | -40°C to +125°C | 8 µMAX | 2.800 | 0.1 | 7 | 6126B28 |
| MAX6126AASA30+ | -40°C to +125°C | 8 SO | 3.000 | 0.02 | 3 | — |
| MAX6126BASA30+ | -40°C to +125°C | 8 SO | 3.000 | 0.06 | 5 | — |
| MAX6126A30+ | -40°C to +125°C | 8 µMAX | 3.000 | 0.06 | 3 | 6126A30 |
| MAX6126B30+ | -40°C to +125°C | 8 µMAX | 3.000 | 0.1 | 7 | 6126B30 |
| MAX6126AASA41+ | -40°C to +125°C | 8 SO | 4.096 | 0.02 | 3 | — |
| MAX6126BASA41+ | -40°C to +125°C | 8 SO | 4.096 | 0.06 | 5 | — |
| MAX6126A41+ | -40°C to +125°C | 8 µMAX | 4.096 | 0.06 | 3 | 6126A41 |
| MAX6126B41+ | -40°C to +125°C | 8 µMAX | 4.096 | 0.1 | 7 | 6126B41 |
| MAX6126AASA50+ | -40°C to +125°C | 8 SO | 5.000 | 0.02 | 3 | — |
| MAX6126BASA50+ | -40°C to +125°C | 8 SO | 5.000 | 0.06 | 5 | — |
| MAX6126A50+ | -40°C to +125°C | 8 µMAX | 5.000 | 0.06 | 3 | 6126A50 |
| MAX6126B50+ | -40°C to +125°C | 8 µMAX | 5.000 | 0.1 | 7 | 6126B50 |

*+Denotes a lead(Pb)-free/RoHS-compliant package.*

## Package Information

For the latest package outline information and land patterns, go to **www.maxim-ic.com/packages**. Note that a "+", "#", or "-" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.

| PACKAGE TYPE | PACKAGE CODE | OUTLINE NO. | LAND PATTERN NO. |
|---|---|---|---|
| 8 µMAX | U8+1 | 21-0036 | 90-0092 |
| 8 SO | S8+4 | 21-0041 | 90-0096 |

# Ultra-High-Precision, Ultra-Low-Noise, Series Voltage Reference

## Revision History

| REVISION NUMBER | REVISION DATE | DESCRIPTION | PAGES CHANGED |
|---|---|---|---|
| 0 | 10/02 | Initial release | — |
| 1 | 3/03 | Remove “future product” and “contact factory” notes | 1, 16 |
| 2 | 6/03 | Add “A” grade devices | 1, 16 |
| 3 | 12/03 | Change µMAX part number | 1, 16 |
| 4 | 7/04 | Add top mark to *Ordering Information* | 1, 16 |
| 5 | 12/10 | Add 2.8V option, add lead-free options, update *Package Information* | 1, 2, 4, 15, 16 |