

MAXIM

+5V, +10V Precision Voltage References

REF01/REF02

General Description

The REF01/REF02 are industry-standard precision voltage references. The stable 10V output of the REF01 can be adjusted over a $\pm 3\%$ range with minimal effect on temperature stability, while the 5V output REF02 can be adjusted over a $\pm 6\%$ range. The 10V REF01 has a single-supply operation over an input voltage range of 13V to 33V, while the 5V REF02 has a single-supply operation over an input voltage range of 7V to 33V. Both devices offer a low-current drain of 1mA. The REF02 also provides a TEMP pin whose output voltage varies linearly with temperature, making this device suitable for a wide variety of temperature-sensing and control applications. For new designs, refer to the MAX6035 or MAX6143 data sheets.

Features

- ◆ Pretrimmed to +5V, +10V $\pm 0.3\%$
- ◆ Excellent Temperature Stability: 3ppm/ $^{\circ}\text{C}$
- ◆ Low Noise: 10 μV P-P (REF02)
- ◆ Low Supply Current: 1.4mA (max)
- ◆ Short-Circuit Protected
- ◆ Linear Temperature Transducer Output (REF02)

Ordering Information

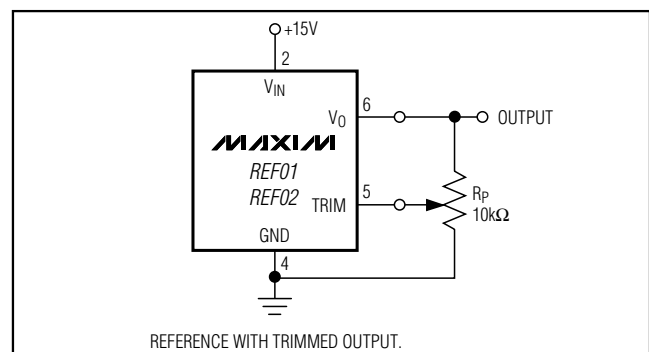
PART	TEMP RANGE	MAX TEMPCO (ppm/ $^{\circ}\text{C}$)	INITIAL ERROR (mV)	PIN-PACKAGE
REF01EP	0 $^{\circ}\text{C}$ to +70 $^{\circ}\text{C}$	8.5	± 30	8 Plastic DIP
REF01HP	0 $^{\circ}\text{C}$ to +70 $^{\circ}\text{C}$	25	± 50	8 Plastic DIP
REF01HSA	0 $^{\circ}\text{C}$ to +70 $^{\circ}\text{C}$	25	± 50	8 SO
REF01CP	0 $^{\circ}\text{C}$ to +70 $^{\circ}\text{C}$	65	± 100	8 Plastic DIP
REF01CSA	0 $^{\circ}\text{C}$ to +70 $^{\circ}\text{C}$	65	± 100	8 SO
REF01CESA	-40 $^{\circ}\text{C}$ to +85 $^{\circ}\text{C}$	65	± 100	8 SO
REF02EP	0 $^{\circ}\text{C}$ to +70 $^{\circ}\text{C}$	8.5	± 15	8 Plastic DIP
REF02HP	0 $^{\circ}\text{C}$ to +70 $^{\circ}\text{C}$	25	± 25	8 Plastic DIP
REF02HSA	0 $^{\circ}\text{C}$ to +70 $^{\circ}\text{C}$	25	± 25	8 SO
REF02CP	0 $^{\circ}\text{C}$ to +70 $^{\circ}\text{C}$	65	± 50	8 Plastic DIP
REF02CSA	0 $^{\circ}\text{C}$ to +70 $^{\circ}\text{C}$	65	± 50	8 SO
REF02CESA	-40 $^{\circ}\text{C}$ to +85 $^{\circ}\text{C}$	65	± 50	8 SO

Ordering Information continued at end of data sheet.

Applications

Analog-to-Digital Converters
 Digital-to-Analog Converters
 Digital Voltmeters
 Voltage Regulators
 Threshold Detectors

Typical Operating Circuit



+5V, +10V Precision Voltage References

ABSOLUTE MAXIMUM RATINGS—REF01

Input Voltage	
REF01, A, E, H.....	40V
REF01C	30V
Continuous Power Dissipation	
T099 (J) (derate at 7.1mW/°C above +80°C).....	500mW
CERDIP (2) (derate at 6.7mW/°C above +75°C)	500mW
Plastic Dip (P) (derate at 5.6mW/°C above +36°C)	500mW
Small Outline (S) (derate at 5.0mW/°C above +55°C) ..	300mW

Output Short-Circuit Duration (to ground or V_{IN})	Indefinite
Storage Temperature Range	-65°C to +150°C
Operating Temperature Range	
REF01A, REF01	-55°C to +125°C
REF01E, REF01H, REF01C (except REF01CESA).....	0°C to +70°C
REF01CESA	-40°C to +85°C
Lead Temperature (soldering, 60s)	+300°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—REF01/REF01A/REF01E/REF01H

($V_{IN} = +15V$, $T_A = +25^\circ C$, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	REF01A/REF01E			REF01/REF01H			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
Output Voltage	V_O	$I_L = 0$	9.97	10.00	10.03	9.95	10.00	10.05	V
Output Adjustment Range	ΔV_{trim}	$R_P = 10k\Omega$	± 3.0	± 3.3		± 3.0	± 3.3		%
Output Voltage Noise	e_{nP-P}	0.1Hz to 10Hz (Note 1)		20	30		20	30	μV_{P-P}
Line Regulation		$V_{IN} = 13V$ to 33V (Note 2)		0.006	0.010		0.006	0.010	%/V
Load Regulation		$I_L = 0$ to 10mA (Note 2)		0.005	0.008		0.006	0.010	%/mA
Turn-On Settling Time	t_{ON}	To $\pm 0.1\%$ of final value		400			400		μs
Quiescent Supply Current	I_{SY}	No load		1.0	1.4		1.0	1.4	mA
Load Current	I_L	To specified output voltage tolerance	10	21		10	21		mA
Sink Current	I_S	To specified output voltage tolerance	0.3	0.5		0.3	0.5		mA
Short-Circuit Current	I_{SC}	$V_O = 0V$		30			30		mA

ELECTRICAL CHARACTERISTICS—REF01/REF01A/REF01E/REF01H

($V_{IN} = +15V$, $-55^\circ C \leq T_A \leq +125^\circ C$ for REF01A and REF01, $0^\circ C \leq T_A \leq +70^\circ C$ for REF01E and REF01H, $I_L = 0mA$, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	REF01A/REF01E			REF01/REF01H			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
Output Voltage Change with Temperature (Note 3)	ΔV_{OT}	$0^\circ C \leq T_A \leq +70^\circ C$		0.02	0.06		0.07	0.17	%
		$-55^\circ C \leq T_A \leq +125^\circ C$		0.06	0.15		0.18	0.45	
Output Voltage Temperature Coefficient	TCV_O	(Note 4)		3	8.5		10.0	25.0	ppm/°C
Change in V_O Temperature Coefficient with Output Adjustment		$R_P = 10k\Omega$		0.7			0.7		ppm/%
Line Regulation ($V_{IN} = 13V$ to 33V) (Note 2)		$0^\circ C \leq T_A \leq +70^\circ C$		0.007	0.012		0.007	0.012	%/V
		$-55^\circ C \leq T_A \leq +125^\circ C$		0.009	0.015		0.009	0.015	
Load Regulation ($I_L = 0$ to 8mA) (Note 2)		$0^\circ C \leq T_A \leq +70^\circ C$		0.006	0.010		0.007	0.012	%/mA
		$-55^\circ C \leq T_A \leq +125^\circ C$		0.007	0.012		0.009	0.015	

+5V, +10V Precision Voltage References

REF01/REF02

ELECTRICAL CHARACTERISTICS—REF01C

($V_{IN} = +15V$, $T_A = +25^\circ C$, $I_L = 0mA$, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	REF01C			UNITS
			MIN	TYP	MAX	
Output Voltage	V_O	$I_L = 0mA$	9.90	10.00	10.10	V
Output Adjustment Range	ΔV_{trim}	$R_P = 10k\Omega$	± 2.7	± 3.3		%
Output Voltage Noise	$e_{n\text{P-P}}$	0.1Hz to 10Hz (Note 1)		25	35	$\mu\text{VP-P}$
Line Regulation		$V_{IN} = 13V$ to $30V$ (Note 2)		0.009	0.015	%/V
Load Regulation (Note 2)		$I_L = 0$ to $8mA$		0.006	0.015	%/mA
		$I_L = 0$ to $4mA$		0.006	0.015	
Turn-On Settling Time	t_{ON}	To $\pm 0.1\%$ of final value		400		μs
Quiescent Supply Current	I_{SY}	No load		1.0	1.6	mA
Load Current	I_L	To specified output voltage tolerance	8	21		mA
Sink Current	I_S	To specified output voltage tolerance	0.2	0.5		mA
Short-Circuit Current	I_{SC}	$V_O = 0V$		30		mA

ELECTRICAL CHARACTERISTICS—REF01C

($V_{IN} = +15V$, $T_A = T_{MIN}$ to T_{MAX} , unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	REF01C			UNITS
			MIN	TYP	MAX	
Output Voltage Change with Temperature	ΔV_{OT}	(Note 3)		0.14	0.45	%
Output Voltage Temperature Coefficient	TCV_O	(Note 4)		20	65	ppm/ $^\circ C$
Change in V_O Temperature Coefficient with Output Adjustment		$R_P = 10k\Omega$		0.7		ppm/%
Line Regulation		$V_{IN} = 13V$ to $30V$ (Note 2)		0.011	0.018	%/V
Load Regulation		$I_L = 0$ to $5mA$ (Note 2)		0.008	0.018	%/mA

Note 1: Guaranteed by design for REF01EP, REF01HP, REF01HSA, REF01CP, REF01CSA, REF01CESA. Sample tested for all other grades and packages.

Note 2: Line and load regulation specifications include the effect of self heating. REF01EP, REF01HP, REF01HSA, REF01CP, REF01CSA, REF01CESA are 100% production tested at $T_A = +25^\circ C$ and guaranteed by design for $T_A = T_{MIN}$ to T_{MAX} , as specified.

Note 3: ΔV_{OT} is defined as the absolute difference between the maximum output voltage and the minimum output voltage over the specified temperature range expressed as a percentage of 10V. REF01CP, REF01CSA, REF01CESA, REF01HSA guaranteed by design.

$$\Delta V_{OT} = \left[\frac{V_{MAX} - V_{MIN}}{10V} \right] \times 100$$

Note 4: TCV_O is defined as ΔV_{OT} divided by the temperature range. REF01CP, REF01CSA, REF01CESA, REF01HSA guaranteed by design.

Output Adjustment

The REF01 trim terminal can be used to adjust the voltage over a $10V \pm 300mV$ range. This feature allows the system designer to trim system errors by setting the reference to a voltage other than 10V, including 10.240V for

binary applications (see the *Typical Operating Circuit*).

Adjustment of the output does not significantly affect the temperature performance of the device. The temperature coefficient change is approximately 0.7ppm/ $^\circ C$ for 100mV of output adjustment.

+5V, +10V Precision Voltage References

ABSOLUTE MAXIMUM RATINGS—REF02

Input Voltage	
REF02, A, E, H.....	40V
REF02C, D.....	30V
Continuous Power Dissipation	
T099 (J) (derate at 7.1mW/°C above +80°C).....	500mW
CERDIP (2) (derate at 6.7mW/°C above +75°C)	500mW
Plastic Dip (P) (derate at 5.6mW/°C above +36°C)	500mW
Small Outline (S) (derate at 5.0mW/°C above +55°C) ..	300mW
Storage Temperature Range	-65°C to +150°C

Operating Temperature Range	
REF02A, REF02	-55°C to +125°C
REF02E, REF02H	0°C to +70°C
REF02C (except REF02CESA), REF02D	0°C to +70°C
REF02CESA	-40°C to +85°C
Output Short-Circuit Duration	
(to ground or V_{IN})	Indefinite
Lead Temperature (soldering, 60s)	+300°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—REF02/REF02A/REF02E/REF02H

($V_{IN} = +15V$, $T_A = +25^\circ C$, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	REF02A/REF02E			REF02/REF02H			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
Output Voltage	V_O	$I_L = 0$	4.985	5.000	5.015	4.975	5.000	5.025	V
Output Adjustment Range	ΔV_{trim}	$R_P = 10k\Omega$	± 3	± 6		± 3	± 6		%
Output Voltage Noise	e_{nP-P}	0.1Hz to 10Hz (Note 5)		10	15		10	15	μV_{P-P}
Line Regulation		$V_{IN} = 8V$ to 33V (Note 6)		0.006	0.010		0.006	0.010	%/V
Load Regulation		$I_L = 0$ to 10mA (Note 6)		0.005	0.010		0.006	0.010	%/mA
Turn-On Settling Time	t_{ON}	To $\pm 0.1\%$ of final value		230			230		μs
Quiescent Supply Current	I_{SY}	No load		1.0	1.4		1.0	1.4	mA
Load Current	I_L	To specified output voltage tolerance	10	21		10	21		mA
Sink Current	I_S	To specified output voltage tolerance	0.3	0.5		0.3	0.5		mA
Short-Circuit Current	I_{SC}	$V_O = 0V$		30			30		mA
Temperature Voltage Output	V_T	(Note 7)		630			630		mV

ELECTRICAL CHARACTERISTICS—REF02/REF02A/REF02E/REF02H

($V_{IN} = +15V$, $-55^\circ C \leq T_A \leq +125^\circ C$ for REF02A and REF02, $0^\circ C \leq T_A \leq +70^\circ C$ for REF02E and REF02H, $I_L = 0mA$, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	REF02A/REF02E			REF02/REF02H			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
Output Voltage Change with Temperature (Note 8)	ΔV_{OT}	$0^\circ C \leq T_A \leq +70^\circ C$		0.02	0.06		0.07	0.17	%
		$-55^\circ C \leq T_A \leq +125^\circ C$		0.06	0.15		0.18	0.45	
Output Voltage Temperature Coefficient	TCV_O	(Note 9)		3	8.5		10	25	ppm/°C
Change in V_O Temperature Coefficient with Output Adjustment		$R_P = 10k\Omega$		0.7			0.7		ppm/%
Line Regulation ($V_{IN} = 8V$ to 33V) (Note 6)		$0^\circ C \leq T_A \leq +70^\circ C$		0.007	0.012		0.007	0.012	%/V
		$-55^\circ C \leq T_A \leq +125^\circ C$		0.009	0.015		0.009	0.015	
Load Regulation ($I_L = 0$ to 8mA) (Note 6)		$0^\circ C \leq T_A \leq +70^\circ C$		0.006	0.010		0.007	0.012	%/mA
		$-55^\circ C \leq T_A \leq +125^\circ C$		0.007	0.012		0.009	0.015	

+5V, +10V Precision Voltage References

REF01/REF02

ELECTRICAL CHARACTERISTICS—REF02/REF02A/REF02E/REF02H (continued)

($V_{IN} = +15V$, $-55^{\circ}C \leq T_A \leq +125^{\circ}C$ for REF02A and REF02, $0^{\circ}C \leq T_A \leq +70^{\circ}C$ for REF02E and REF02H, $I_L = 0mA$, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	REF02A/REF02E			REF02/REF02H			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
Temperature Voltage Output Temperature Coefficient	TCVT	(Note 7)	2.1			2.1			mV/°C

ELECTRICAL CHARACTERISTICS—REF02C/REF02D

($V_{IN} = +15V$, $T_A = +25^{\circ}C$, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	REF02C			REF02D			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
Output Voltage	V_O	$I_L = 0mA$	4.950	5.000	5.050	4.900	5.000	5.100	V
Output Adjustment Range	ΔV_{trim}	$R_P = 10k\Omega$	± 2.7	± 6.0		± 2.0	± 6.0		%
Output Voltage Noise	e_{nP-P}	0.1Hz to 10Hz (Note 5)		12	18		12		μV_{P-P}
Line Regulation		$V_{IN} = 8V$ to 30V (Note 6)		0.009	0.015		0.010	0.04	%/V
Load Regulation (Note 6)		$I_L = 0$ to 8mA		0.006	0.015				%/mA
		$I_L = 0$ to 4mA					0.015	0.04	
Turn-On Settling Time	t_{ON}	To $\pm 0.1\%$ of final value		230			230		μs
Quiescent Supply Current	I_{SY}	No load		1.0	1.6		1.0	2.0	mA
Load Current	I_L	To specified output voltage tolerance	8	21		8	21		mA
Sink Current	I_S	To specified output voltage tolerance	0.2	0.5		0.2	0.5		mA
Short-Circuit Current	I_{SC}	$V_O = 0V$		30			30		mA
Temperature Voltage Output	V_T	(Note 7)		630			630		mV

ELECTRICAL CHARACTERISTICS—REF02C/REF02D

($V_{IN} = +15V$, $T_A = T_{MIN}$ to T_{MAX} , $I_L = 0mA$, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	REF02C			REF02D			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
Output Voltage Change with Temperature	ΔV_{OT}	(Note 8)		0.14	0.45		0.49	1.7	%
Output Voltage Temperature Coefficient	TCVO	(Note 9)		20	65		70	250	ppm/°C
Change in V_O Temperature Coefficient with Output Adjustment		$R_P = 10k\Omega$		0.7			0.7		ppm/%
Line Regulation		$V_{IN} = 8V$ to 30V (Note 6)		0.011	0.018		0.012	0.05	%/V
Load Regulation		$I_L = 0$ to 5mA (Note 6)		0.008	0.018		0.016	0.05	%/mA
Temperature Voltage Output Temperature Coefficient	TCVT	(Note 7)		2.1			2.1		mV/°C

+5V, +10V Precision Voltage References

ELECTRICAL CHARACTERISTICS—REF02 (continued)

($V_{IN} = +15V$, $T_A = T_{MIN}$ to T_{MAX} , $I_L = 0mA$, unless otherwise noted.)

Note 5: Guaranteed by design for REF02EP, REF02HP, REF02HSA, REF02CP, REF02CSA, REF02CESA. Sample tested for all other grades and packages.

Note 6: Line and load regulation specifications include the effect of self heating. REF02EP, REF02HP, REF02HSA, REF02CP, REF02CSA, REF02CESA are 100% production tested at $T_A = +25^\circ C$ and guaranteed by design for $T_A = T_{MIN}$ to T_{MAX} , as specified.

Note 7: Limit current in or out of pin 3 to 50nA and capacitance on pin 3 to 30pF.

Note 8: ΔV_{OT} is defined as the absolute difference between the maximum output voltage and the minimum output voltage over the specified temperature range expressed as a percentage of 5V. REF02CP, REF02CSA, REF02CESA, REF02HSA guaranteed by design.

$$\Delta V_{OT} = \left[\frac{V_{MAX} - V_{MIN}}{5V} \right] \times 100$$

Note 9: TCV_O is defined as ΔV_{OT} divided by the temperature range. REF02CP, REF02CSA, REF02CESA, REF02HSA guaranteed by design.

Output Adjustment

The REF02 trim terminal can be used to adjust the output voltage over a $5V \pm 300mV$ range. This feature allows the system designer to trim system errors by setting the reference to a voltage other than 5V (refer to the *Typical Operating Circuit*).

Adjustment of the output does not significantly affect the temperature performance of the device. Typically, the temperature coefficient change is $0.7ppm/^\circ C$ for 100mV of output adjustment.

Temperature Voltage Output

The REF02 provides a temperature-dependent output voltage on the TEMP pin. This voltage is proportional to the absolute temperature, and has a scale factor of approximately $2.1mV/^\circ C$ (Figure 1).

$$\text{Output Voltage} = 2.1(T + 273)mV$$

where T = Temperature in $^\circ C$.

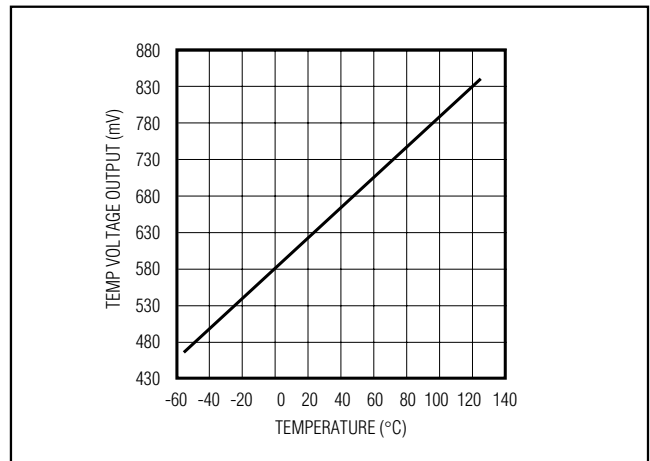


Figure 1. REF02 Temperature/Voltage Output vs. Temperature

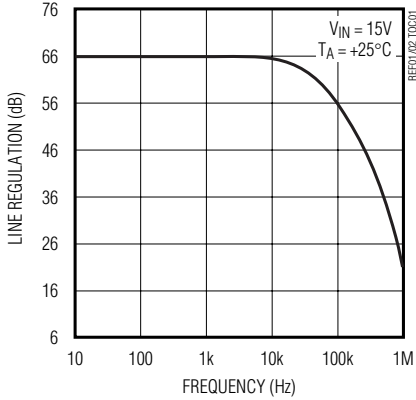
+5V, +10V Precision Voltage References

Typical Operating Characteristics

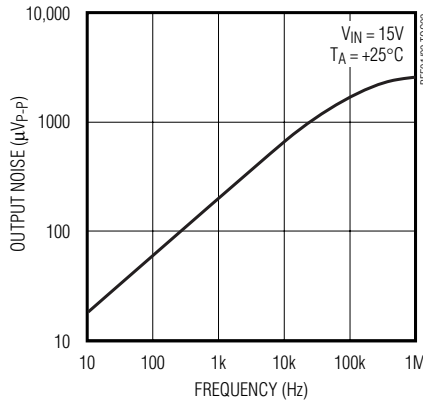
($T_A = +25^\circ\text{C}$, unless otherwise noted.)

REF01/REF02

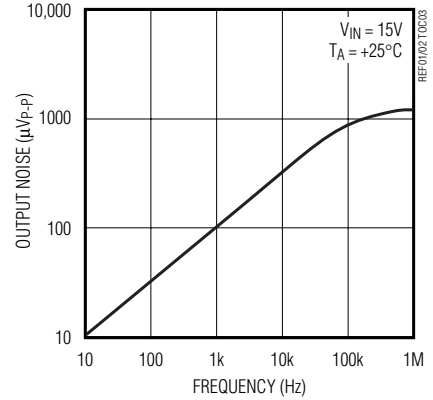
LINE REGULATION vs. FREQUENCY



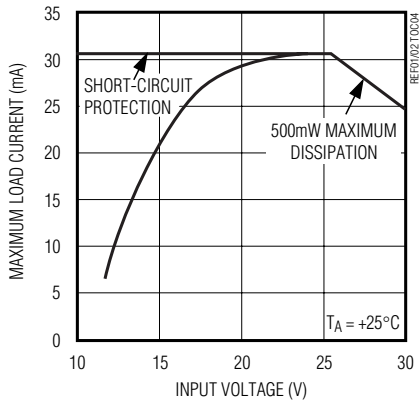
REF01 OUTPUT WIDEBAND NOISE vs. BANDWIDTH (0.1Hz TO FREQUENCY INDICATED)



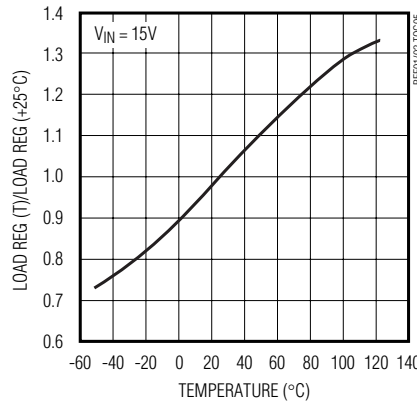
REF02 OUTPUT WIDEBAND NOISE vs. BANDWIDTH (0.1Hz TO FREQUENCY INDICATED)



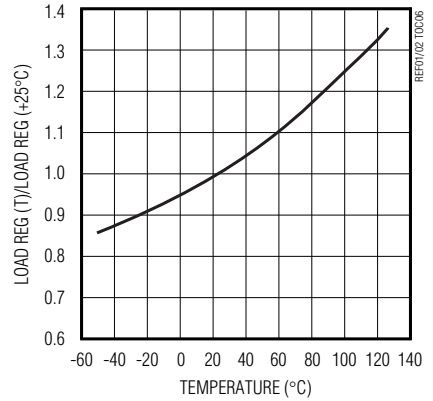
MAXIMUM LOAD CURRENT vs. INPUT VOLTAGE



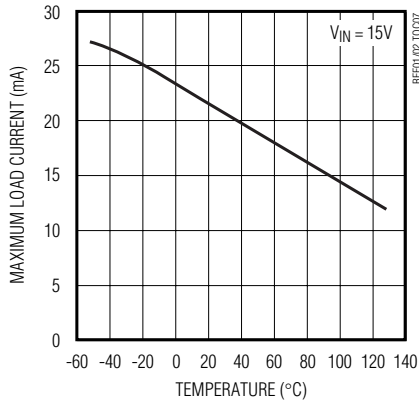
NORMALIZED LOAD REGULATION ($\Delta I_L = 10\text{mA}$) vs. TEMPERATURE



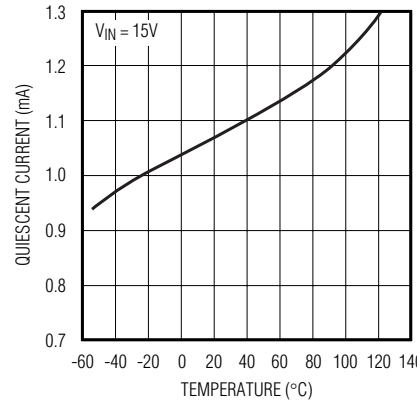
NORMALIZED LINE REGULATION vs. TEMPERATURE



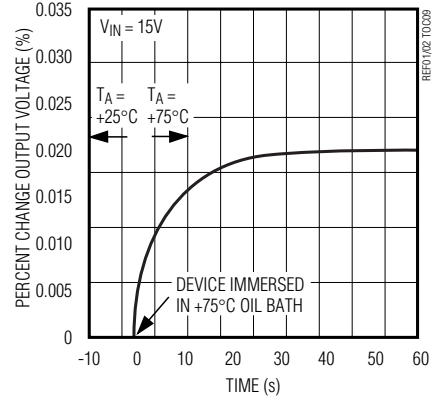
MAXIMUM LOAD CURRENT vs. TEMPERATURE



QUIESCENT CURRENT vs. TEMPERATURE



OUTPUT CHANGE DUE TO THERMAL SHOCK



+5V, +10V Precision Voltage References

Typical Applications

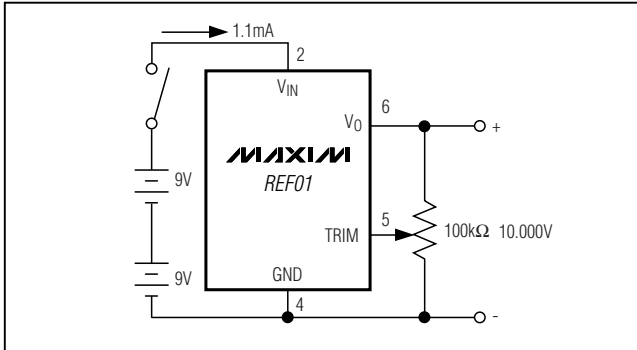


Figure 2. Precision Calibration Standard

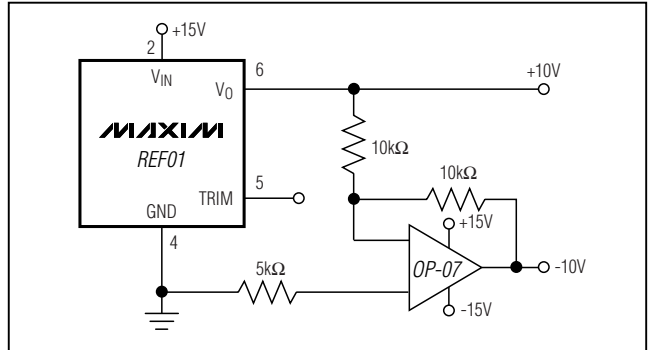


Figure 3. ±10V Reference

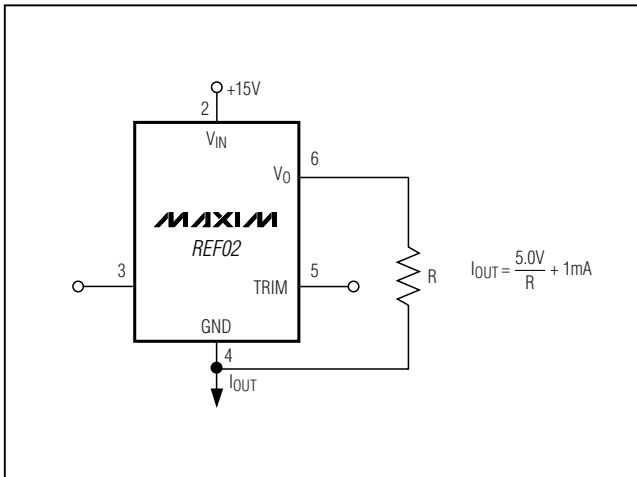


Figure 4. Current Source

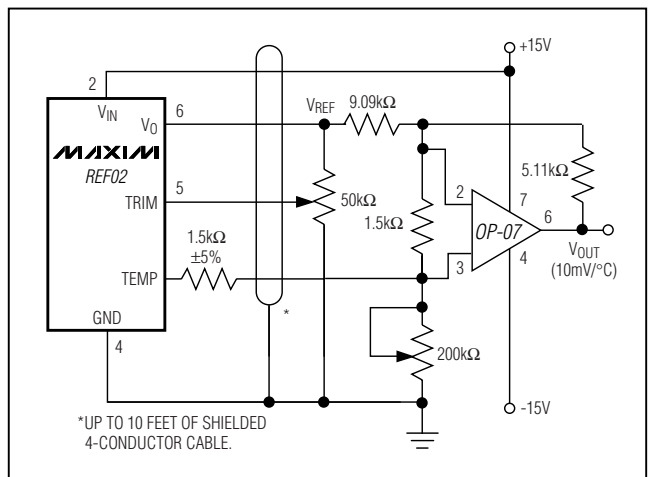


Figure 5. Precision Temperature Transducer with Remote Sensor

+5V, +10V Precision Voltage References

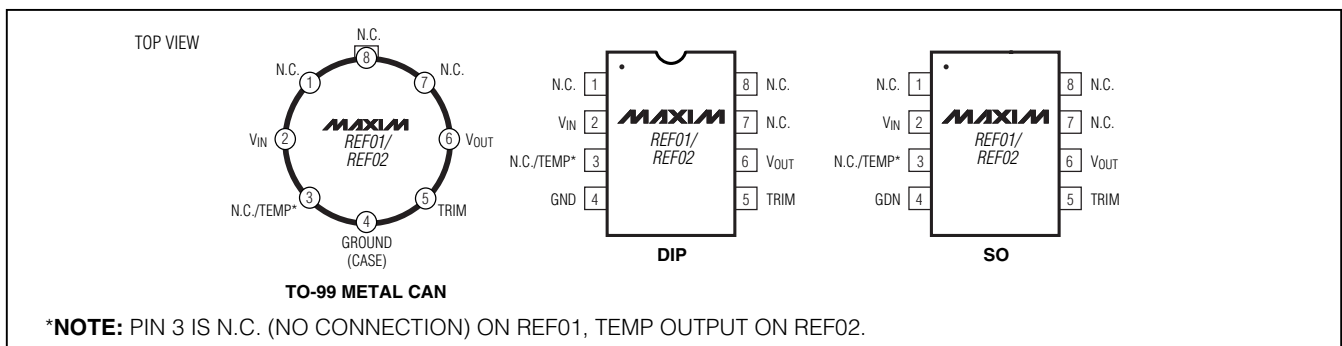
Ordering Information (continued)

REF01/REF02

PART	TEMP RANGE	MAX TEMPCO	INITIAL ERROR	PIN-PACKAGE
REF01AJ*	-55°C to +125°C	8.5	±30	8 TO-99
REF01AZ*	-55°C to +125°C	8.5	±15	8 Hermetic DIP
REF01CJ*	0°C to +70°C	65	±100	8 TO-99
REF01CP-2*	0°C to +70°C	65	±100	8 Plastic DIP
REF01CZ*	0°C to +70°C	65	±100	8 CERDIP
REF01EJ*	0°C to +70°C	8.5	±30	8 TO-99
REF01EZ*	0°C to +70°C	8.5	±30	8 CERDIP
REF01HF*	0°C to +70°C	25	±50	8 TO-99
REF01HZ*	0°C to +70°C	25	±50	8 Hermetic DIP
REF01J*	-55°C to +125°C	25	±50	8 TO-99
REF01Z*	-55°C to +125°C	25	±50	8 CERDIP
REF02AJ*	-55°C to +125°C	8.5	±15	8 TO-99
REF02AZ*	-55°C to +125°C	8.5	±15	8 Hermetic DIP
REF02CJ*	0°C to +70°C	65	±50	8 TO-99
REF02CZ*	0°C to +70°C	65	±50	8 CERDIP
REF02DJ*	0°C to +70°C	25	±100	8 TO-99
REF02DP*	0°C to +70°C	25	±100	8 Plastic DIP
REF02DSA*	0°C to +70°C	25	±100	8 SO
REF02EJ*	0°C to +70°C	8.5	±15	8 TO-99
REF02EZ*	0°C to +70°C	8.5	±15	8 CERDIP
REF02HJ*	0°C to +70°C	25	±25	8 TO-99
REF02HZ*	0°C to +70°C	25	±25	8 Hermetic DIP
REF02J*	-55°C to +125°C	25	±25	8 TO-99
REF02Z*	-55°C to +125°C	25	±25	8 CERDIP

*Not recommended for new designs. Contact factory for availability.

Pin Configurations



Package Information

For the latest package outline information, go to www.maxim-ic.com/packages.

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