19-3786; Rev 2; 10/94

MAXIM

High-Speed, Low-Voltage, Micropower Op Amps

General Description

The MAX402/MAX403/MAX438/MAX439 micropower op amps combine high-speed performance with low-power operation. The MAX402/MAX403 are compensated for unity-gain stability, while the MAX438/MAX439 are compensated for stability in applications with a closed-loop gain (A_{VCL}) of 5V/V or greater.

The MAX402/MAX438 require less than 75µA of supply current while delivering 2MHz bandwidth with 6V/µs slew rate (MAX402), and 6MHz gain bandwidth with 10V/µs slew rate (MAX438).

For applications requiring increased speed, the MAX403/MAX439 consume less than 375µA of supply current while delivering 10MHz gain bandwidth with 40V/µs slew rate (MAX403), and 25MHz gain bandwidth with 48V/µs slew rate (MAX439).

Applications

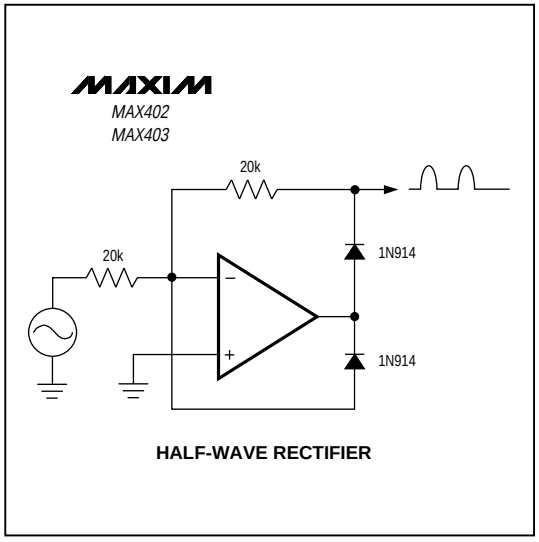
Low-Power Signal Processing

Filters

Portable Instruments

Remote Sensors

Typical Application Circuit



HALF-WAVE RECTIFIER

Features

MAX402

- **2MHz Unity-Gain Bandwidth**
- **6V/µs Slew Rate**
- **75µA Max Supply Current**

MAX403

- **10MHz Unity-Gain Bandwidth**
- **40V/µs Slew Rate**
- **375µA Max Supply Current**

MAX438

- **6MHz Gain Bandwidth (A_{VCL} ≥ 5V/V)**
- **10V/µs Slew Rate**
- **75µA Max Supply Current**

MAX439

- **25MHz Gain Bandwidth (A_{VCL} ≥ 5V/V)**
- **48V/µs Slew Rate**
- **375µA Max Supply Current**

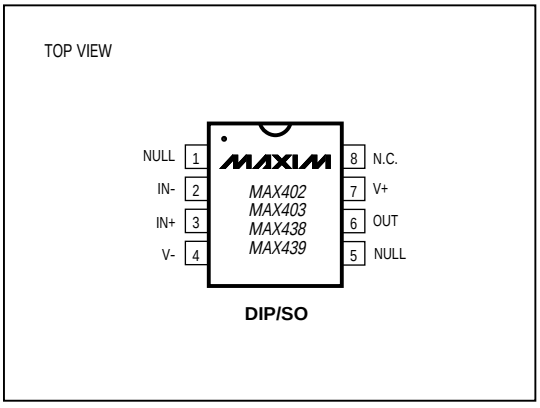
Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE
MAX402CPA	0°C to +70°C	8 Plastic DIP
MAX402CSA	0°C to +70°C	8 SO
MAX402C/D	0°C to +70°C	Dice*
MAX402EPA	-40°C to +85°C	8 Plastic DIP
MAX402ESA	-40°C to +85°C	8 SO

Ordering Information continued at end of data sheet.

** Dice are specified at T_A = +25°C, DC parameters only.*

Pin Configuration



DIP/SO

ABSOLUTE MAXIMUM RATINGS (Note 1)

Supply Voltage (V+ to V-).....12V
Input Voltage Range.....(V+ + 0.3V) to (V- - 0.3V)
Differential Input Voltage.....V+ to V-
Short-Circuit Current Duration.....Indefinite
Maximum Current into Any Pin.....50mA
Continuous Power Dissipation (T_A = +25°C)
Plastic DIP.....375mW
SO.....471mW

Operating Temperature Ranges
MAX40_ _ C_ _.....0°C to +70°C
MAX40_ _ E_ _.....-40°C to +85°C
Storage Temperature Range.....-65°C to +150°C
Lead Temperature (soldering, 10sec).....+300°C

Note 1: Absolute maximum ratings apply to packaged parts only, unless otherwise noted.

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—MAX402/MAX403

(V+ = 5V, V- = -5V, T_A = +25°C, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MAX402			MAX403			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	V_{OS}			0.5	2.0		0.5	2.0	mV
Offset Voltage Tempco $\Delta V_{OS}/\Delta T$	TCV_{OS}	$T_A = T_{MIN}$ to T_{MAX}		25			25		µV/°C
Input Bias Current	I_B			±2	±5		±10	±25	nA
Input Voltage Range	IVR		±3.5	±3.8		±3.5	±3.8		V
Differential Input Resistance	R_{IN} (DIFF)			90			18		MΩ
Common-Mode Input Resistance	R_{IN} (CM)			1			1		GΩ
Input Noise-Voltage Density	e_n	f_o = 10Hz		43			33		$nV\sqrt{Hz}$
		f_o = 1000Hz		26			14		
Input Noise-Current Density	i_n	f_o = 10Hz		0.06			0.25		$pA\sqrt{Hz}$
		f_o = 1000Hz		0.03			0.07		
Common-Mode Rejection Ratio	CMRR	V_{CM} = ±3.5V	75	95		66	80		dB
Power-Supply Rejection Ratio	PSRR	V_S = ±4.5V to ±5.5V	56	65		60	70		dB
Large-Signal Gain	A_{VOL}	R_L = 20kΩ	68	75			80		dB
		R_L = 4kΩ				68	75		
Output Voltage Swing	V_{OUT}	R_L = 20kΩ	±3.6	±3.9		±3.6	±3.9		V
		R_L = 4kΩ				±3.3	±3.6		
Short-Circuit Output Current	I_{SC}			3			5		mA
Slew Rate (Note 2)	SR	20kΩ | | 20pF load	4.5	6		25	40		V/µs
Gain Bandwidth	GBW	20kΩ | | 20pF load	1.4	2		7	10		MHz
Quiescent Current	I_Q		40	60	75	200	250	375	µA

ELECTRICAL CHARACTERISTICS – MAX402C/MAX403C

(V+ = 5V, V- = -5V, T_A = 0°C to +70°C, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MAX402C_A			MAX403C_A			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	V_{OS}				4			4	mV
Input Bias Current	I_B				±10			±50	nA
Input Voltage Range	IVR		±3.5			±3.5			V
Common-Mode Rejection Ratio	CMRR	V_{CM} = ±3.5V	70			66			dB
Power-Supply Rejection Ratio	PSRR	V_S = ±4.5V to ±5.5V	54			60			dB
Large-Signal Gain	A_{VOL}	R_L = 20kΩ	60						dB
		R_L = 4kΩ				60			
Output Voltage Swing	V_{OUT}	R_L = 20kΩ	±3.5			±3.5			V
		R_L = 4kΩ				±3.2			
Slew Rate (Note 2)	SR	20kΩ | | 20pF load	4.0			22.5			V/µs
Gain Bandwidth	GBW	20kΩ | | 20pF load	1.3			7			MHz
Quiescent Current	I_Q		35		90	175		450	µA

ELECTRICAL CHARACTERISTICS – MAX402E/MAX403E

(V+ = 5V, V- = -5V, T_A = -40°C to +85°C, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MAX402E_A			MAX403E_A			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	V_{OS}				5			5	mW
Input Bias Current	I_B				±20			±100	nA
Input Voltage Range	IVR		±3.5			±3.5			V
Common-Mode Rejection Ratio	CMRR	V_{CM} = ±3.5V	68			66			dB
Power-Supply Rejection Ratio	PSRR	V_S = ±4.5V to ±5.5V	52			58			dB
Large-Signal Gain	A_{VOL}	R_L = 20kΩ	56						dB
		R_L = 4kΩ				56			
Output Voltage Swing	V_{OUT}	R_L = 20kΩ	±3.4			±3.4			V
		R_L = 4kΩ				±3.0			
Slew Rate (Note 2)	SR	20kΩ | | 20pF load	4.0			20			V/µs
Gain Bandwidth	GBW	20kΩ | | 20pF load	1.2			6			MHz
Quiescent Current	I_Q		30		95	150		475	µA

Note 2: ± Δ V_{IN} = 2Vp-p.

ELECTRICAL CHARACTERISTICS – MAX438/MAX439

(V+ = 5V, V- = -5V, T_A = +25°C, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MAX438			MAX439			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	V_{OS}			0.5	2.0		0.5	2.0	mV
Offset Voltage Tempco $\Delta V_{OS}/\Delta T$	TCV_{OS}	$T_A = T_{MIN}$ to T_{MAX}		25			25		µV/°C
Input Bias Current	I_B			±2	±5		±5	±25	nA
Input Voltage Range	IVR		±3.5	±3.8		±3.5	±3.8		V
Differential Input Resistance	R_{IN} (DIFF)			90			18		MΩ
Common-Mode Input Resistance	R_{IN} (CM)			1			1		GΩ
Input Noise-Voltage Density	e_n	f_o = 10Hz		43			33		$nV\sqrt{Hz}$
		f_o = 1000Hz		26			14		
Input Noise-Current Density	i_n	f_o = 10Hz		0.06			0.25		$pA\sqrt{Hz}$
		f_o = 1000Hz		0.03			0.07		
Common-Mode Rejection Ratio	CMRR	V_{CM} = ±3.5V	75	95		66	80		dB
Power-Supply Rejection Ratio	PSRR	V_S = ±4.5V to ±5.5V	56	65		60	70		dB
Large-Signal Gain	A_{VOL}	R_L = 20kΩ	68	75			80		dB
		R_L = 4kΩ				68	75		
Output Voltage Swing	V_{OUT}	R_L = 20kΩ	±3.6	±3.9		±3.6	±3.9		V
		R_L = 4kΩ				±3.3	±3.6		
Short-Circuit Output Current	I_{SC}			3			5		mA
Slew Rate (Note 3)	SR	20kΩ | | 20pF load		10			48		V/µs
Gain Bandwidth	GBW	20kΩ | | 20pF load	4	6		18	25		MHz
Quiescent Current	I_Q		40	60	75	200	250	375	µA
Minimum Closed-Loop Gain	A_{VCL}		±5			±5			V/V

ELECTRICAL CHARACTERISTICS – MAX438C/MAX439C

(V+ = 5V, V- = -5V, T_A = 0°C to +70°C, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MAX438C_A			MAX439C_A			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	V_{OS}				4			4	mV
Input Bias Current	I_B				±10			±50	nA
Input Voltage Range	IVR		±3.5			±3.5			V
Common-Mode Rejection Ratio	CMRR	V_{CM} = ±3.5V	70			66			dB
Power-Supply Rejection Ratio	PSRR	V_S = ±4.5V to ±5.5V	54			60			dB
Large-Signal Gain	A_{VOL}	R_L = 20kΩ	60						dB
		R_L = 4kΩ				60			
Output Voltage Swing	V_{OUT}	R_L = 20kΩ	±3.5			±3.5			V
		R_L = 4kΩ				±3.2			
Slew Rate (Note 3)	SR	20kΩ | | 20pF load		7			40		V/µs
Gain Bandwidth	GBW	20kΩ | | 20pF load	3.7			16.5			MHz
Quiescent Current	I_Q		35		90	175		450	µA
Minimum Closed-Loop Gain	A_{VCL}		±5			±5			V/V

ELECTRICAL CHARACTERISTICS – MAX438E/MAX439E

(V+ = 5V, V- = -5V, T_A = -40°C to +85°C, unless otherwise noted.)

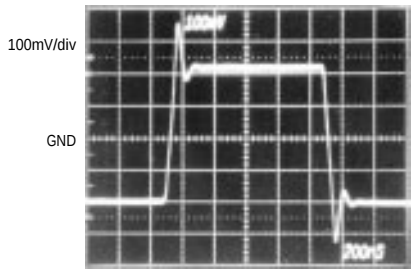
PARAMETER	SYMBOL	CONDITIONS	MAX438E_A MIN	MAX438E_A TYP	MAX438E_A MAX	MAX439E_A MIN	MAX439E_A TYP	MAX439E_A MAX	UNITS
Input Offset Voltage	V_{OS}				5			5	mV
Input Bias Current	I_B				±20			±100	nA
Input Voltage Range	IVR		±3.5			±3.5			V
Common-Mode Rejection Ratio	CMRR	V_{CM} = ±3.5V	68			66			dB
Power-Supply Rejection Ratio	PSRR	V_S = ±4.5V to ±5.5V	52			58			dB
Large-Signal Gain	A_{VOL}	R_L = 20kΩ	56						dB
		R_L = 4kΩ				56			
Output Voltage Swing	V_{OUT}	R_L = 20kΩ	±3.4			±3.4			V
		R_L = 4kΩ				±3.0			
Slew Rate (Note 3)	SR	20kΩ | | 20pF load		7			40		V/µs
Gain Bandwidth	GBW	20kΩ | | 20pF load	3.4			15			MHz
Quiescent Current	I_Q		30		95	150		475	µA
Minimum Closed-Loop Gain	A_{VCL}		±5			±5			V/V

Note 3: ± Δ V_{IN} = 1Vp-p.

Typical Operating Characteristics

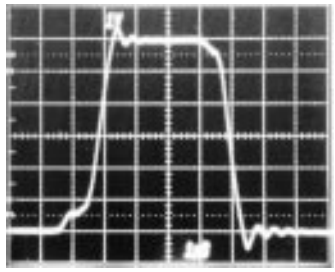
(T_A = +25°C, unless otherwise noted.)

MAX402
SMALL-SIGNAL TRANSIENT RESPONSE



NONINVERTING, A_{VCL} = +1
V_{SUPPLY} = ±5V, R_L = 10kΩ || 10pF

MAX402
LARGE-SIGNAL TRANSIENT RESPONSE

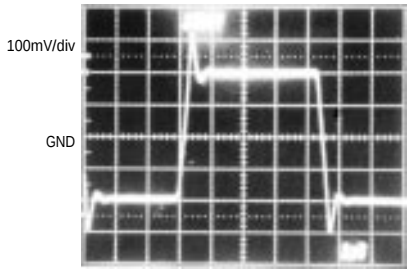


NONINVERTING, A_{VCL} = +1
V_{SUPPLY} = ±5V, R_L = 10kΩ || 100pF

Typical Operating Characteristics (continued)

(T_A = +25°C, unless otherwise noted.)

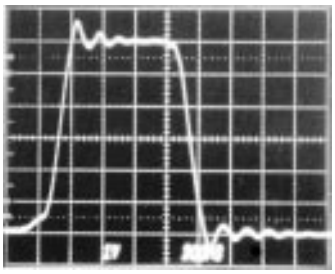
MAX403
SMALL-SIGNAL TRANSIENT RESPONSE



200ns/div

NONINVERTING, A_{VCL} = +1
V_{SUPPLY} = ±5V, R_L = 2kΩ || 10pF

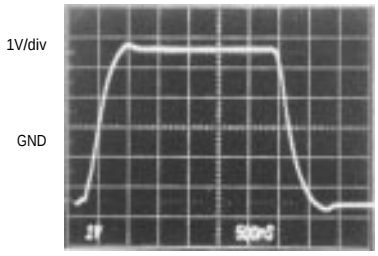
MAX403
LARGE-SIGNAL TRANSIENT RESPONSE



200ns/div

NONINVERTING, A_{VCL} = +1
V_{SUPPLY} = ±5V, R_L = 2kΩ || 100pF

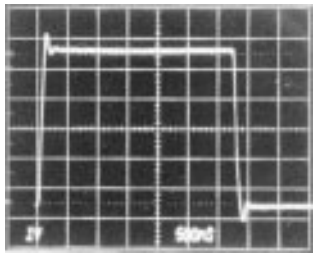
MAX438
PULSE RESPONSE



500ns/div

NONINVERTING,
A_{VCL} = +5V/V, R_L = 10kΩ || 20pF

MAX439
PULSE RESPONSE



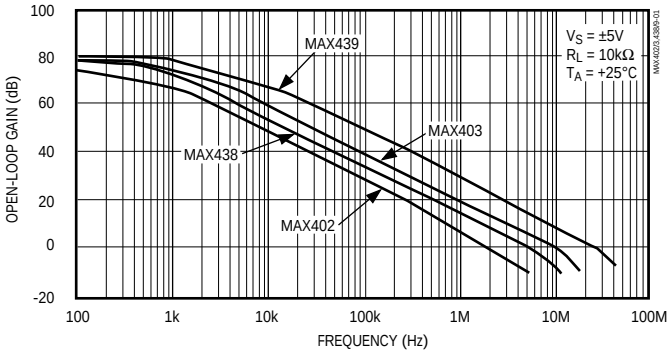
500ns/div

NONINVERTING,
A_V = +5V/V, R_L = 10kΩ || 20pF

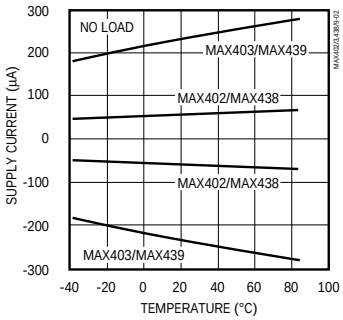
Typical Operating Characteristics (continued)

(T_A = +25°C, unless otherwise noted.)

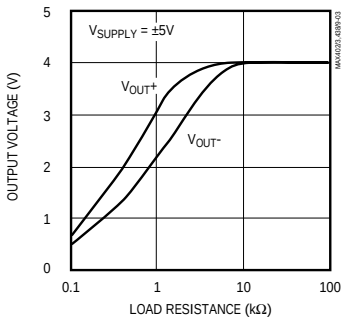
OPEN-LOOP GAIN vs. FREQUENCY



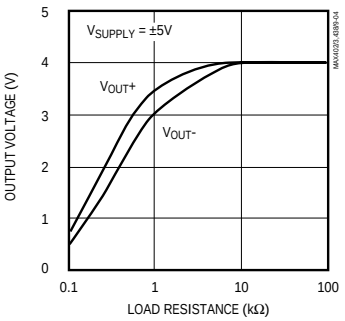
SUPPLY CURRENT vs. TEMPERATURE



MAX402/MAX438 OUTPUT VOLTAGE SWING vs. LOAD RESISTANCE



MAX403/MAX439 OUTPUT VOLTAGE SWING vs. LOAD RESISTANCE

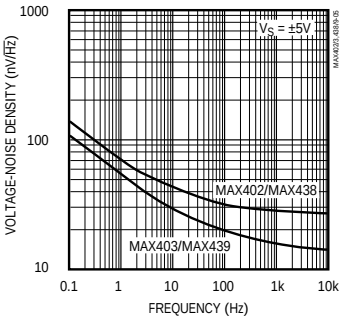


High-Speed, Low-Voltage, Micropower Op Amps

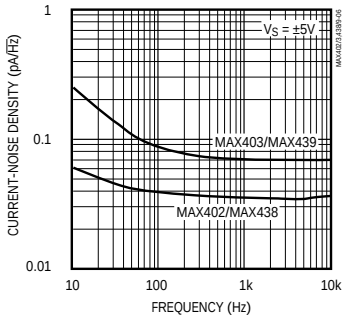
Typical Operating Characteristics (continued)

(T_A = +25°C, unless otherwise noted.)

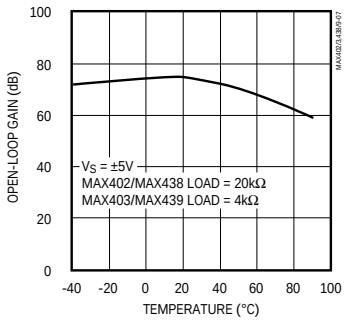
VOLTAGE-NOISE DENSITY vs. FREQUENCY



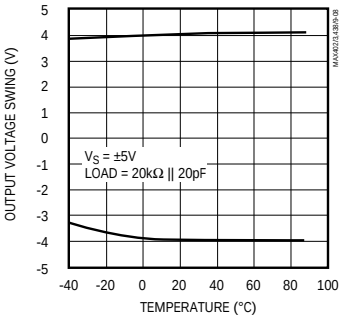
CURRENT-NOISE DENSITY vs. FREQUENCY



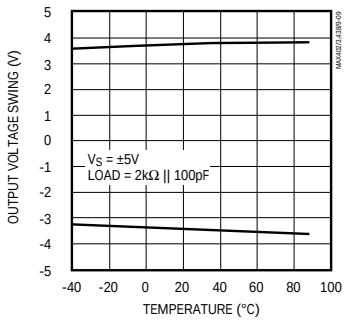
OPEN-LOOP GAIN vs. TEMPERATURE



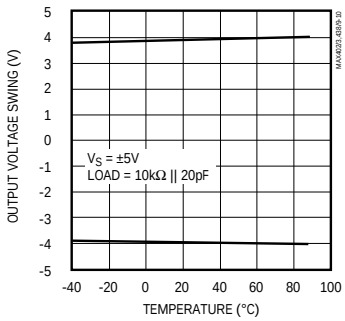
MAX402/MAX438 OUTPUT VOLTAGE SWING vs. TEMPERATURE



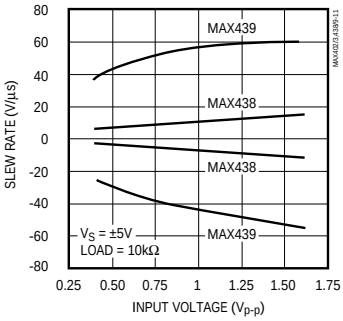
MAX403/MAX439 OUTPUT VOLTAGE SWING vs. TEMPERATURE (2kΩ LOAD)



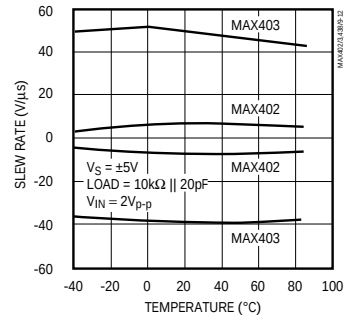
MAX403/MAX439 OUTPUT VOLTAGE SWING vs. TEMPERATURE (10kΩ LOAD)



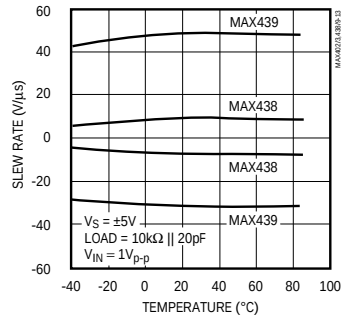
MAX438/MAX439 SLEW RATE vs. INPUT VOLTAGE



MAX402/MAX403 SLEW RATE vs. TEMPERATURE



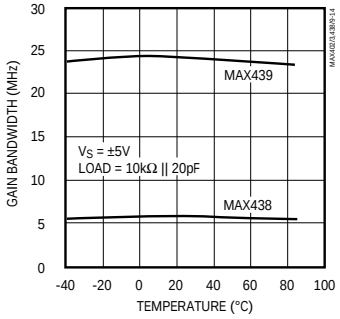
MAX438/MAX439 SLEW RATE vs. TEMPERATURE



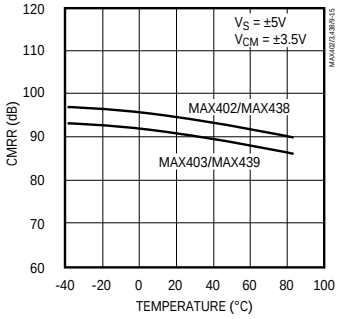
Typical Operating Characteristics (continued)

(T_A = +25°C, unless otherwise noted.)

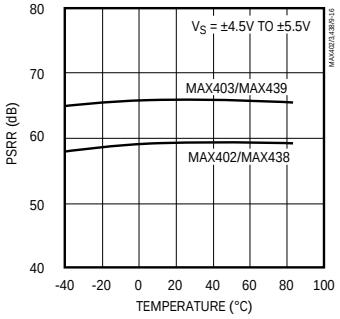
MAX438/MAX439
GAIN BANDWIDTH vs. TEMPERATURE



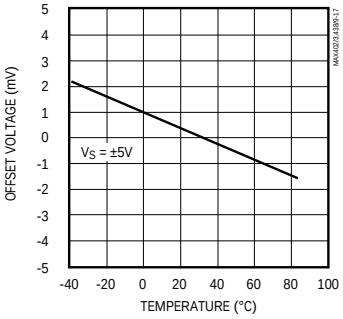
COMMON-MODE REJECTION RATIO vs. TEMPERATURE



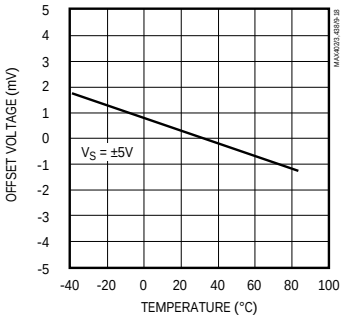
POWER-SUPPLY REJECTION RATIO vs. TEMPERATURE



MAX402/MAX438
OFFSET VOLTAGE vs. TEMPERATURE



MAX403/MAX439
OFFSET VOLTAGE vs. TEMPERATURE



High-Speed, Low-Voltage, Micropower Op Amps

Pin Description

PIN	NAME	FUNCTION
1, 5	NULL	Offset-Voltage Adjustment
2	IN-	Inverting Input
3	IN+	Noninverting Input
4	V-	Negative Power Supply (V_{EE})
6	OUT	Amplifier Signal Output
7	V+	Positive Power Supply (V_{CC})
8	N.C.	No Connect—no internal connection

Applications Information

Input Offset-Voltage Adjustment

The NULL pins (1 and 5) can be used to null the input offset voltage. To adjust the amplifier's offset voltage, connect a potentiometer between the two NULL pins with the wiper connected to V-, as shown in Figure 1. Use a 10kΩ potentiometer with the MAX402/MAX438, and a 2kΩ potentiometer with the MAX403/MAX439. Offset voltage can be adjusted over a range of approximately 12mV with these trim potentiometers.

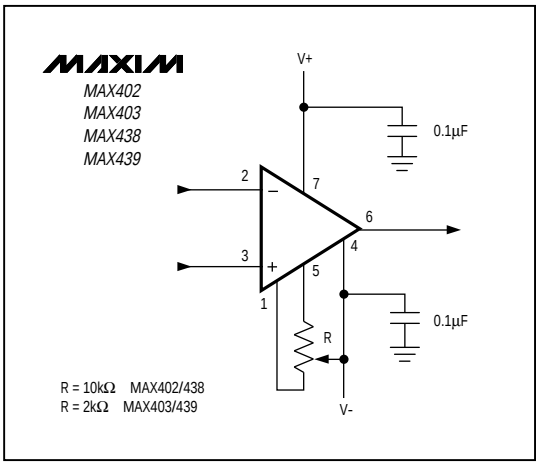


Figure 1. Offset-Voltage Adjustment

Operating Supply Voltage

The MAX402/MAX403/MAX438/MAX439 are specified with ±5V power supplies, but also operate with dual supplies down to ±3V or single supplies ranging from +6V to +10V if the common-mode input voltage is kept between (V- + 1.5V) and (V+ - 1.5V). With a single +6V supply, the common-mode input voltage ranges between +1.5V and +4.5V.

Layout and Bypassing

Bypass the power-supply inputs with 0.1µF ceramic capacitors positioned as close to the power-supply pins as possible. To maximize performance in high-speed applications, use a ground plane. Connections to the amplifier's input terminals should be as short and direct as possible with a minimum of inductance and capacitance. Stray capacitance at the input terminals adds to the amplifier's approximate 3pF input capacitance, and can limit overall bandwidth. Also, minimize lead lengths in connections from the power-supply bypass capacitors to ground to further reduce inductance. Surface-mount (chip) capacitors are ideal for this application.

Slew Rate vs. Input Voltage

Like most high-speed op amps, the slew rate of the MAX402/MAX403/MAX438/MAX439 depends on the signal level driving the amplifier inputs. Slew-rate limiting in high-speed circuits becomes more significant as the amplifier's closed-loop gain increases (inadequate gain bandwidth is more likely to limit performance in low-gain circuits). For this reason, the MAX438/MAX439 have been characterized for slew rate vs. input voltage, as shown in the MAX438/MAX439 Slew Rate vs. Input Voltage graph in the *Typical Operating Characteristics.*

Overload Conditions

The amplifier inputs withstand differential voltages equal to the power-supply rails without requiring external clamp diodes or input current-limiting resistors. Schottky diodes, used internally throughout the devices, prevent saturation of the internal transistors and allow the amplifiers to recover quickly from overload conditions.

Many op amps exhibit phase reversal at the output when the input common-mode voltage range is exceeded—a potentially serious problem in servo-control systems. Phase reversal protection circuitry in the MAX402/MAX403/MAX438/MAX439 eliminates this problem for any input voltage level.

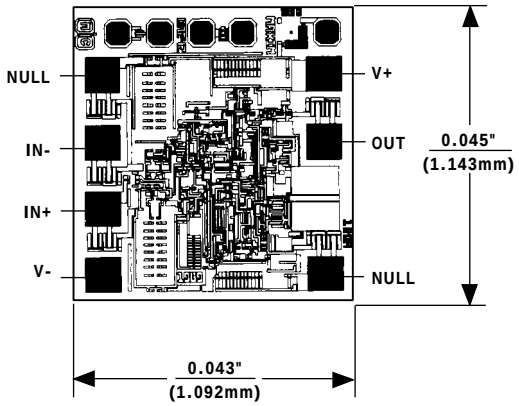
Each amplifier's output stage employs a current-limit circuit that prevents amplifier damage in the event of a fault condition. The output may be shorted to either power supply or ground continuously without damage.

_Ordering Information (continued)

PART	TEMP. RANGE	PIN-PACKAGE
MAX403CPA	0°C to +70°C	8 Plastic DIP
MAX403CSA	0°C to +70°C	8 SO
MAX403C/D	0°C to +70°C–	Dice*
MAX403EPA	-40°C to +85°C	8 Plastic DIP
MAX403ESA	-40°C to +85°C	8 SO
MAX438CPA	0°C to +70°C	8 Plastic DIP
MAX438CSA	0°C to +70°C	8 SO
MAX438C/D	0°C to +70°C–	Dice*
MAX438EPA	-40°C to +85°C	8 Plastic DIP
MAX438ESA	-40°C to +85°C	8 SO
MAX439CPA	0°C to +70°C	8 Plastic DIP
MAX439CSA	0°C to +70°C	8 SO
MAX439C/D	0°C to +70°C–	Dice*
MAX439EPA	-40°C to +85°C	8 Plastic DIP
MAX439ESA	-40°C to +85°C	8 SO

** Dice are specified at T_A = +25°C, DC parameters only.*

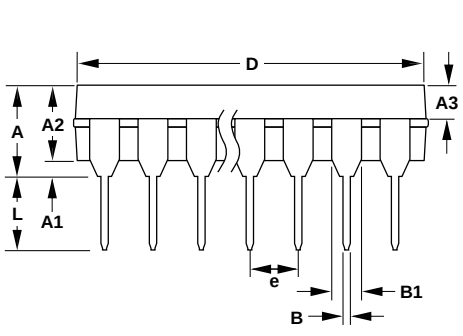
_____Chip Topography



SUBSTRATE CONNECTS TO V-.

TRANSISTOR COUNT: 82

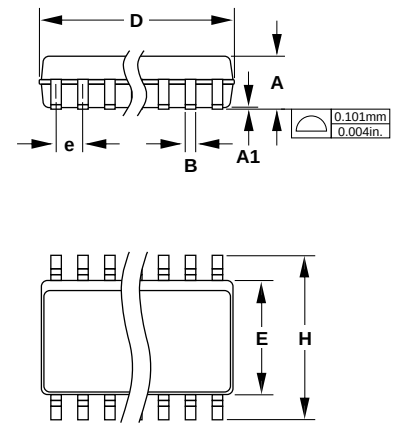
Package Information



Plastic DIP
PLASTIC
DUAL-IN-LINE
PACKAGE
(0.300 in.)

DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	–	0.200	–	5.08
A1	0.015	–	0.38	–
A2	0.125	0.175	3.18	4.45
A3	0.055	0.080	1.40	2.03
B	0.016	0.022	0.41	0.56
B1	0.045	0.065	1.14	1.65
C	0.008	0.012	0.20	0.30
D1	0.005	0.080	0.13	2.03
E	0.300	0.325	7.62	8.26
E1	0.240	0.310	6.10	7.87
e	0.100	–	2.54	–
eA	0.300	–	7.62	–
eB	–	0.400	–	10.16
L	0.115	0.150	2.92	3.81

DIM	PINS	INCHES		MILLIMETERS	
		MIN	MAX	MIN	MAX
D	8	0.348	0.390	8.84	9.91
D	14	0.735	0.765	18.67	19.43
D	16	0.745	0.765	18.92	19.43
D	18	0.885	0.915	22.48	23.24
D	20	1.015	1.045	25.78	26.54
D	24	1.14	1.265	28.96	32.13



SO
SMALL OUTLINE
PACKAGE
(0.150 in.)

DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.053	0.069	1.35	1.75
A1	0.004	0.010	0.10	0.25
B	0.014	0.019	0.35	0.49
C	0.007	0.010	0.19	0.25
E	0.150	0.157	3.80	4.00
e	0.050		1.27	
H	0.228	0.244	5.80	6.20
L	0.016	0.050	0.40	1.27

DIM	PINS	INCHES		MILLIMETERS	
		MIN	MAX	MIN	MAX
D	8	0.189	0.197	4.80	5.00
D	14	0.337	0.344	8.55	8.75
D	16	0.386	0.394	9.80	10.00

21-0041A