

# Precision, Micropower, Low-Dropout Voltage References

## ABSOLUTE MAXIMUM RATINGS

Voltages Referenced to GND

|                                                              |                              |
|--------------------------------------------------------------|------------------------------|
| IN .....                                                     | -0.3V to +13.5V              |
| OUT .....                                                    | -0.3V to ( $V_{IN} + 0.3V$ ) |
| Output Short Circuit to GND or IN ( $V_{IN} < 6V$ ) .....    | Continuous                   |
| Output Short Circuit to GND or IN ( $V_{IN} \geq 6V$ ) ..... | 60s                          |

Continuous Power Dissipation ( $T_A = +70^\circ\text{C}$ )

|                                                                            |                                             |
|----------------------------------------------------------------------------|---------------------------------------------|
| 8-Pin SO (derate 5.88mW/ $^\circ\text{C}$ above $+70^\circ\text{C}$ )..... | 471mW                                       |
| Operating Temperature Range .....                                          | $-40^\circ\text{C}$ to $+85^\circ\text{C}$  |
| Storage Temperature Range .....                                            | $-65^\circ\text{C}$ to $+150^\circ\text{C}$ |
| Lead Temperature (soldering, 10s) .....                                    | $+300^\circ\text{C}$                        |

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—MAX6190

( $V_{IN} = 5V$ ,  $I_{OUT} = 0$ ,  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ\text{C}$ .)

| PARAMETER                                       | SYMBOL                               | CONDITIONS                             |          | MIN   | TYP   | MAX   | UNITS             |
|-------------------------------------------------|--------------------------------------|----------------------------------------|----------|-------|-------|-------|-------------------|
| OUTPUT                                          |                                      |                                        |          |       |       |       |                   |
| Output Voltage                                  | V <sub>OUT</sub>                     | T <sub>A</sub> = +25°C                 | MAX6190A | 1.248 | 1.250 | 1.252 | V                 |
|                                                 |                                      |                                        | MAX6190B | 1.246 | 1.250 | 1.254 |                   |
|                                                 |                                      |                                        | MAX6190C | 1.244 | 1.250 | 1.256 |                   |
| Output-Voltage Temperature Coefficient (Note 1) | TCV <sub>OUT</sub>                   | MAX6190A                               |          | 2     |       | 5     | ppm/°C            |
|                                                 |                                      | MAX6190B                               |          | 4     |       | 10    |                   |
|                                                 |                                      | MAX6190C                               |          | 8     |       | 25    |                   |
| Line Regulation                                 | ΔV <sub>OUT</sub> /ΔV <sub>IN</sub>  | 2.5V ≤ V <sub>IN</sub> ≤ 12.6V         |          | 8     |       | 80    | μV/V              |
| Load Regulation                                 | ΔV <sub>OUT</sub> /ΔI <sub>OUT</sub> | Sourcing: 0 ≤ I <sub>OUT</sub> ≤ 500μA |          | 0.12  |       | 0.5   | μV/μA             |
|                                                 |                                      | Sinking: -500μA ≤ I <sub>OUT</sub> ≤ 0 |          | 0.15  |       | 0.6   |                   |
| Short-Circuit Current                           | I <sub>SC</sub>                      | Short to GND                           |          | 4     |       |       | mA                |
|                                                 |                                      | Short to IN                            |          | 4     |       |       |                   |
| Temperature Hysteresis (Note 2)                 | ΔV <sub>OUT</sub> /cycle             |                                        |          | 75    |       |       | ppm               |
| Long-Term Stability                             | ΔV <sub>OUT</sub> /time              | 1000hrs at +25°C                       |          | 50    |       |       | ppm/1000hrs       |
| DYNAMIC                                         |                                      |                                        |          |       |       |       |                   |
| Noise Voltage                                   | e <sub>OUT</sub>                     | 0.1Hz to 10Hz                          |          | 25    |       |       | μV <sub>P-P</sub> |
|                                                 |                                      | 10Hz to 10kHz                          |          | 65    |       |       | μV <sub>RMS</sub> |
| Ripple Rejection                                | V <sub>OUT</sub> /V <sub>IN</sub>    | V <sub>IN</sub> = 5V ±100mV, f = 120Hz |          | 86    |       |       | dB                |
| Turn-On Settling Time                           | t <sub>R</sub>                       | To 0.1%, C <sub>OUT</sub> = 50pF       |          | 30    |       |       | μs                |
| Capacitive-Load Stability Range                 | C <sub>OUT</sub>                     | (Note 3)                               |          | 0     |       | 2.2   | nF                |
| INPUT                                           |                                      |                                        |          |       |       |       |                   |
| Supply Voltage Range                            | V <sub>IN</sub>                      | Guaranteed by line-regulation test     |          | 2.5   |       | 12.6  | V                 |
| Quiescent Supply Current                        | I <sub>IN</sub>                      |                                        |          |       | 27    | 35    | μA                |
| Change in Supply Current                        | I <sub>IN</sub> /V <sub>IN</sub>     | 2.5V ≤ V <sub>IN</sub> ≤ 12.6V         |          |       | 0.8   | 2     | μA/V              |

# Precision, Micropower, Low-Dropout Voltage References

## ELECTRICAL CHARACTERISTICS—MAX6191

( $V_{IN} = 5V$ ,  $I_{OUT} = 0$ ,  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ C$ .)

| PARAMETER                                       | SYMBOL                               | CONDITIONS                             |          | MIN   | TYP   | MAX               | UNITS |
|-------------------------------------------------|--------------------------------------|----------------------------------------|----------|-------|-------|-------------------|-------|
| OUTPUT                                          |                                      |                                        |          |       |       |                   |       |
| Output Voltage                                  | V <sub>OUT</sub>                     | T <sub>A</sub> = +25°C                 | MAX6191A | 2.046 | 2.048 | 2.050             | V     |
|                                                 |                                      |                                        | MAX6191B | 2.043 | 2.048 | 2.053             |       |
|                                                 |                                      |                                        | MAX6191C | 2.038 | 2.048 | 2.058             |       |
| Output-Voltage Temperature Coefficient (Note 1) | TCV <sub>OUT</sub>                   | MAX6191A                               | 2        |       | 5     | ppm/°C            |       |
|                                                 |                                      | MAX6191B                               | 4        |       | 10    |                   |       |
|                                                 |                                      | MAX6191C                               | 8        |       | 25    |                   |       |
| Line Regulation                                 | ΔV <sub>OUT</sub> /ΔV <sub>IN</sub>  | 2.5V ≤ V <sub>IN</sub> ≤ 12.6V         |          | 10    |       | 100               | μV/V  |
| Load Regulation                                 | ΔV <sub>OUT</sub> /ΔI <sub>OUT</sub> | Sourcing: 0 ≤ I <sub>OUT</sub> ≤ 500μA |          | 0.12  |       | 0.55              | μV/μA |
|                                                 |                                      | Sinking: -500μA ≤ I <sub>OUT</sub> ≤ 0 |          | 0.18  |       | 0.70              |       |
| Short-Circuit Current                           | I <sub>SC</sub>                      | Short to GND                           |          | 4     |       | mA                |       |
|                                                 |                                      | Short to IN                            |          | 4     |       |                   |       |
| Temperature Hysteresis (Note 2)                 | ΔV <sub>OUT</sub> /cycle             |                                        |          | 75    |       | ppm               |       |
| Long-Term Stability                             | ΔV <sub>OUT</sub> /time              | 1000hrs at +25°C                       |          | 50    |       | ppm/1000hrs       |       |
| DYNAMIC                                         |                                      |                                        |          |       |       |                   |       |
| Noise Voltage                                   | e <sub>OUT</sub>                     | 0.1Hz to 10Hz                          |          | 40    |       | μV <sub>P-P</sub> |       |
|                                                 |                                      | 10Hz to 10kHz                          |          | 105   |       | μV <sub>RMS</sub> |       |
| Ripple Rejection                                | V <sub>OUT</sub> /V <sub>IN</sub>    | V <sub>IN</sub> = 5V ±100mV, f = 120Hz |          | 84    |       | dB                |       |
| Turn-On Settling Time                           | t <sub>R</sub>                       | To 0.1%, C <sub>OUT</sub> = 50pF       |          | 30    |       | μs                |       |
| Capacitive-Load Stability Range                 | C <sub>OUT</sub>                     | (Note 3)                               |          | 0     |       | 2.2               | nF    |
| INPUT                                           |                                      |                                        |          |       |       |                   |       |
| Supply Voltage Range                            | V <sub>IN</sub>                      | Guaranteed by line-regulation test     |          | 2.5   |       | 12.6              | V     |
| Quiescent Supply Current                        | I <sub>IN</sub>                      |                                        |          | 27    |       | 35                | μA    |
| Change in Supply Current                        | I <sub>IN</sub> /V <sub>IN</sub>     | 2.5V ≤ V <sub>IN</sub> ≤ 12.6V         |          | 0.8   |       | 2                 | μA/V  |

MAX6190-MAX6195/MAX6198

# Precision, Micropower, Low-Dropout Voltage References

## ELECTRICAL CHARACTERISTICS—MAX6192

( $V_{IN} = 5V$ ,  $I_{OUT} = 0$ ,  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ C$ .)

| PARAMETER                                       | SYMBOL                               | CONDITIONS                                          |                        | MIN   | TYP   | MAX               | UNITS |
|-------------------------------------------------|--------------------------------------|-----------------------------------------------------|------------------------|-------|-------|-------------------|-------|
| OUTPUT                                          |                                      |                                                     |                        |       |       |                   |       |
| Output Voltage                                  | V <sub>OUT</sub>                     | T <sub>A</sub> = +25°C                              | MAX6192A               | 2.498 | 2.500 | 2.502             | V     |
|                                                 |                                      |                                                     | MAX6192B               | 2.495 | 2.500 | 2.505             |       |
|                                                 |                                      |                                                     | MAX6192C               | 2.490 | 2.500 | 2.510             |       |
| Output-Voltage Temperature Coefficient (Note 1) | TCV <sub>OUT</sub>                   | MAX6192A                                            | 2                      |       | 5     | ppm/°C            |       |
|                                                 |                                      | MAX6192B                                            | 4                      |       | 10    |                   |       |
|                                                 |                                      | MAX6192C                                            | 8                      |       | 25    |                   |       |
| Line Regulation                                 | ΔV <sub>OUT</sub> /ΔV <sub>IN</sub>  | (V <sub>OUT</sub> + 0.2V) ≤ V <sub>IN</sub> ≤ 12.6V | 15                     |       | 140   | μV/V              |       |
| Load Regulation                                 | ΔV <sub>OUT</sub> /ΔI <sub>OUT</sub> | Sourcing: 0 ≤ I <sub>OUT</sub> ≤ 500μA              | 0.14                   |       | 0.60  | μV/μA             |       |
|                                                 |                                      | Sinking: -500μA ≤ I <sub>OUT</sub> ≤ 0              | 0.18                   |       | 0.80  |                   |       |
| Dropout Voltage (Note 4)                        | V <sub>IN</sub> - V <sub>OUT</sub>   | ΔV <sub>OUT</sub> ≤ 0.2%, I <sub>OUT</sub> = 500μA  | 100                    |       | 200   | mV                |       |
| Short-Circuit Current                           | I <sub>SC</sub>                      | Short to GND                                        | 4                      |       |       | mA                |       |
|                                                 |                                      | Short to I <sub>N</sub>                             | 4                      |       |       |                   |       |
| Temperature Hysteresis (Note 2)                 | ΔV <sub>OUT</sub> /cycle             |                                                     | 75                     |       |       | ppm               |       |
| Long-Term Stability                             | ΔV <sub>OUT</sub> /time              | 1000hrs at +25°C                                    | 50                     |       |       | ppm/1000hrs       |       |
| DYNAMIC                                         |                                      |                                                     |                        |       |       |                   |       |
| Noise Voltage                                   | e <sub>OUT</sub>                     | 0.1Hz to 10Hz                                       | 60                     |       |       | μV <sub>P-P</sub> |       |
|                                                 |                                      | 10Hz to 10kHz                                       | 125                    |       |       | μV <sub>RMS</sub> |       |
| Ripple Rejection                                | V <sub>OUT</sub> /V <sub>IN</sub>    | V <sub>IN</sub> = 5V ±100mV, f = 120Hz              | 82                     |       |       | dB                |       |
| Turn-On Settling Time                           | t <sub>R</sub>                       | To 0.1%, C <sub>OUT</sub> = 50pF                    | 85                     |       |       | μs                |       |
| Capacitive-Load Stability Range                 | C <sub>OUT</sub>                     | (Note 3)                                            | 0                      |       | 2.2   | nF                |       |
| INPUT                                           |                                      |                                                     |                        |       |       |                   |       |
| Supply Voltage Range                            | V <sub>IN</sub>                      | Guaranteed by line-regulation test                  | V <sub>OUT</sub> + 0.2 |       | 12.6  | V                 |       |
| Quiescent Supply Current                        | I <sub>IN</sub>                      |                                                     | 27                     |       | 35    | μA                |       |
| Change in Supply Current                        | I <sub>IN</sub> /V <sub>IN</sub>     | (V <sub>OUT</sub> + 0.2V) ≤ V <sub>IN</sub> ≤ 12.6V | 0.8                    |       | 2     | μA/V              |       |

# Precision, Micropower, Low-Dropout Voltage References

## ELECTRICAL CHARACTERISTICS—MAX6193

( $V_{IN} = 5V$ ,  $I_{OUT} = 0$ ,  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ C$ .)

| PARAMETER                                       | SYMBOL                              | CONDITIONS                                          |          | MIN                    | TYP   | MAX   | UNITS             |
|-------------------------------------------------|-------------------------------------|-----------------------------------------------------|----------|------------------------|-------|-------|-------------------|
| OUTPUT                                          |                                     |                                                     |          |                        |       |       |                   |
| Output Voltage                                  | V <sub>OUT</sub>                    | T <sub>A</sub> = +25°C                              | MAX6193A | 2.998                  | 3.000 | 3.002 | V                 |
|                                                 |                                     |                                                     | MAX6193B | 2.995                  | 3.000 | 3.005 |                   |
|                                                 |                                     |                                                     | MAX6193C | 2.990                  | 3.000 | 3.010 |                   |
| Output-Voltage Temperature Coefficient (Note 1) | TCV <sub>OUT</sub>                  | MAX6193A                                            |          | 2                      |       | 5     | ppm/°C            |
|                                                 |                                     | MAX6193B                                            |          | 4                      |       | 10    |                   |
|                                                 |                                     | MAX6193C                                            |          | 8                      |       | 25    |                   |
| Line Regulation                                 | ΔV <sub>OUT</sub> /ΔV <sub>IN</sub> | 2.5V ≤ V <sub>IN</sub> ≤ 12.6V                      |          | 20                     |       | 150   | μV/V              |
| Load Regulation                                 | ΔV <sub>OUT</sub> /ΔV <sub>IN</sub> | 2.5V ≤ V <sub>IN</sub> ≤ 12.6V                      |          | 0.14                   |       | 0.60  | μV/V              |
|                                                 |                                     |                                                     |          | 0.18                   |       | 0.80  |                   |
| Dropout Voltage (Note 4)                        | V <sub>IN</sub> - V <sub>OUT</sub>  | I <sub>OUT</sub> = 500μA                            |          | 100                    |       | 200   | mV                |
| Short-Circuit Current                           | I <sub>SC</sub>                     | Short to GND                                        |          | 4                      |       |       | mA                |
|                                                 |                                     | Short to I <sub>N</sub>                             |          | 4                      |       |       |                   |
| Temperature Hysteresis (Note 2)                 | ΔV <sub>OUT</sub> /cycle            |                                                     |          | 75                     |       |       | ppm               |
| Long-Term Stability                             | ΔV <sub>OUT</sub> /time             | 1000hrs at +25°C                                    |          | 50                     |       |       | ppm/1000hrs       |
| DYNAMIC                                         |                                     |                                                     |          |                        |       |       |                   |
| Noise Voltage                                   | e <sub>OUT</sub>                    | 0.1Hz to 10Hz                                       |          | 75                     |       |       | μV <sub>P-P</sub> |
|                                                 |                                     | 10Hz to 10kHz                                       |          | 150                    |       |       | μV <sub>RMS</sub> |
| Ripple Rejection                                | V <sub>OUT</sub> /V <sub>IN</sub>   | V <sub>IN</sub> = 5V ±100mV, f = 120Hz              |          | 80                     |       |       | dB                |
| Turn-On Settling Time                           | t <sub>R</sub>                      | To 0.1%, C <sub>OUT</sub> = 50pF                    |          | 100                    |       |       | μs                |
| Capacitive-Load Stability Range                 | C <sub>OUT</sub>                    | (Note 3)                                            |          | 0                      |       | 2.2   | nF                |
| INPUT                                           |                                     |                                                     |          |                        |       |       |                   |
| Supply Voltage Range                            | V <sub>IN</sub>                     | Guaranteed by line-regulation test                  |          | V <sub>OUT</sub> + 0.2 |       | 12.6  | V                 |
| Quiescent Supply Current                        | I <sub>IN</sub>                     |                                                     |          | 27                     |       | 35    | μA                |
| Change in Supply Current                        | I <sub>IN</sub> /V <sub>IN</sub>    | (V <sub>OUT</sub> + 0.2V) ≤ V <sub>IN</sub> ≤ 12.6V |          | 0.8                    |       | 2     | μA/V              |

MAX6190-MAX6195/MAX6198

# Precision, Micropower, Low-Dropout Voltage References

## ELECTRICAL CHARACTERISTICS—MAX6194

( $V_{IN} = 5V$ ,  $I_{OUT} = 0$ ,  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ C$ .)

| PARAMETER                                       | SYMBOL                               | CONDITIONS                                          |          | MIN                    | TYP   | MAX    | UNITS             |
|-------------------------------------------------|--------------------------------------|-----------------------------------------------------|----------|------------------------|-------|--------|-------------------|
| INPUT                                           |                                      |                                                     |          |                        |       |        |                   |
| Output Voltage                                  | V <sub>OUT</sub>                     | T <sub>A</sub> = +25°C                              | MAX6194A | 4.498                  | 4.500 | 4.502  | V                 |
|                                                 |                                      |                                                     | MAX6194B | 4.495                  | 4.500 | 4.505  |                   |
|                                                 |                                      |                                                     | MAX6194C | 4.490                  | 4.500 | 4.510  |                   |
| Output-Voltage Temperature Coefficient (Note 1) | TCV <sub>OUT</sub>                   | MAX6194A                                            | 2        |                        | 5     | ppm/°C |                   |
|                                                 |                                      | MAX6194B                                            | 4        |                        | 10    |        |                   |
|                                                 |                                      | MAX6194C                                            | 8        |                        | 25    |        |                   |
| Line Regulation                                 | ΔV <sub>OUT</sub> /ΔV <sub>IN</sub>  | (V <sub>OUT</sub> + 0.2V) ≤ V <sub>IN</sub> ≤ 12.6V |          | 25                     |       | 160    | μV/V              |
| Load Regulation                                 | ΔV <sub>OUT</sub> /ΔI <sub>OUT</sub> | Sourcing: 0 ≤ I <sub>OUT</sub> ≤ 500μA              |          | 0.16                   |       | 0.80   | μV/μA             |
|                                                 |                                      | Sinking: -500μA ≤ I <sub>OUT</sub> ≤ 0              |          | 0.22                   |       | 1.00   |                   |
| Dropout Voltage (Note 4)                        | V <sub>IN</sub> - V <sub>OUT</sub>   | ΔV <sub>OUT</sub> ≤ 0.2%, I <sub>OUT</sub> = 500μA  |          | 100                    |       | 200    | mV                |
| Short-Circuit Current                           | I <sub>SC</sub>                      | Short to GND                                        |          | 4                      |       |        | mA                |
|                                                 |                                      | Short to IN                                         |          | 4                      |       |        |                   |
| Temperature Hysteresis (Note 2)                 | ΔV <sub>OUT</sub> /cycle             |                                                     |          | 75                     |       |        | ppm               |
| Long-Term Stability                             | ΔV <sub>OUT</sub> /time              | 1000hrs at +25°C                                    |          | 50                     |       |        | ppm/1000hrs       |
| DYNAMIC                                         |                                      |                                                     |          |                        |       |        |                   |
| Noise Voltage                                   | e <sub>OUT</sub>                     | 0.1Hz to 10Hz                                       |          | 110                    |       |        | μV <sub>P-P</sub> |
|                                                 |                                      | 10Hz to 10kHz                                       |          | 215                    |       |        | μV <sub>RMS</sub> |
| Ripple Rejection                                | V <sub>OUT</sub> /V <sub>IN</sub>    | V <sub>IN</sub> = 5V ±100mV, f = 120Hz              |          | 76                     |       |        | dB                |
| Turn-On Settling Time                           | t <sub>R</sub>                       | To 0.1%, C <sub>OUT</sub> = 50pF                    |          | 180                    |       |        | μs                |
| Capacitive-Load Stability Range                 | C <sub>OUT</sub>                     | (Note 3)                                            |          | 0                      |       | 2.2    | nF                |
| OUTPUT                                          |                                      |                                                     |          |                        |       |        |                   |
| Supply Voltage Range                            | V <sub>IN</sub>                      | Guaranteed by line-regulation test                  |          | V <sub>OUT</sub> + 0.2 |       | 12.6   | V                 |
| Quiescent Supply Current                        | I <sub>IN</sub>                      |                                                     |          | 27                     |       | 35     | μA                |
| Change in Supply Current                        | I <sub>IN</sub> /V <sub>IN</sub>     | (V <sub>OUT</sub> + 0.2V) ≤ V <sub>IN</sub> ≤ 12.6V |          | 0.8                    |       | 2      | μA/V              |

# Precision, Micropower, Low-Dropout Voltage References

## ELECTRICAL CHARACTERISTICS—MAX6195

( $V_{IN} = 5.5V$ ,  $I_{OUT} = 0$ ,  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ C$ .)

| PARAMETER                                       | SYMBOL                               | CONDITIONS                                          |          | MIN                    | TYP   | MAX   | UNITS             |
|-------------------------------------------------|--------------------------------------|-----------------------------------------------------|----------|------------------------|-------|-------|-------------------|
| INPUT                                           |                                      |                                                     |          |                        |       |       |                   |
| Output Voltage                                  | V <sub>OUT</sub>                     | T <sub>A</sub> = +25°C                              | MAX6195A | 4.998                  | 5.000 | 5.002 | V                 |
|                                                 |                                      |                                                     | MAX6195B | 4.995                  | 5.000 | 5.005 |                   |
|                                                 |                                      |                                                     | MAX6195C | 4.990                  | 5.000 | 5.010 |                   |
| Output-Voltage Temperature Coefficient (Note 1) | TCV <sub>OUT</sub>                   | MAX6195A                                            |          | 2                      |       | 5     | ppm/°C            |
|                                                 |                                      | MAX6195B                                            |          | 4                      |       | 10    |                   |
|                                                 |                                      | MAX6195C                                            |          | 8                      |       | 25    |                   |
| Line Regulation                                 | ΔV <sub>OUT</sub> /ΔV <sub>IN</sub>  | (V <sub>OUT</sub> + 0.2V) ≤ V <sub>IN</sub> ≤ 12.6V |          | 25                     |       | 160   | μV/V              |
| Load Regulation                                 | ΔV <sub>OUT</sub> /ΔI <sub>OUT</sub> | Sourcing: 0 ≤ I <sub>OUT</sub> ≤ 500μA              |          | 0.17                   |       | 0.85  | μV/μA             |
|                                                 |                                      | Sinking: -500μA ≤ I <sub>OUT</sub> ≤ 0              |          | 0.24                   |       | 1.10  |                   |
| Dropout Voltage (Note 4)                        | V <sub>IN</sub> - V <sub>OUT</sub>   | ΔV <sub>OUT</sub> ≤ 0.2%, I <sub>OUT</sub> = 500μA  |          | 100                    |       | 200   | mA                |
| Short-Circuit Current                           | I <sub>SC</sub>                      | Short to GND                                        |          | 4                      |       |       | mA                |
|                                                 |                                      | Short to I <sub>N</sub>                             |          | 4                      |       |       |                   |
| Temperature Hysteresis (Note 2)                 | ΔV <sub>OUT</sub> /cycle             |                                                     |          | 75                     |       |       | ppm               |
| Long-Term Stability                             | ΔV <sub>OUT</sub> /time              | 1000hrs at +25°C                                    |          | 50                     |       |       | ppm/1000hrs       |
| DYNAMIC                                         |                                      |                                                     |          |                        |       |       |                   |
| Noise Voltage                                   | e <sub>OUT</sub>                     | 0.1Hz to 10Hz                                       |          | 120                    |       |       | μV <sub>P-P</sub> |
|                                                 |                                      | 10Hz to 10kHz                                       |          | 240                    |       |       | μV <sub>RMS</sub> |
| Ripple Rejection                                | V <sub>OUT</sub> /V <sub>IN</sub>    | V <sub>IN</sub> = 5.5V ±100mV, f = 120Hz            |          | 72                     |       |       | dB                |
| Turn-On Settling Time                           | t <sub>R</sub>                       | To 0.1%, C <sub>OUT</sub> = 50pF                    |          | 220                    |       |       | μs                |
| Capacitive-Load Stability Range                 | C <sub>OUT</sub>                     | (Note 3)                                            |          | 0                      |       | 2.2   | nF                |
| OUTPUT                                          |                                      |                                                     |          |                        |       |       |                   |
| Supply Voltage Range                            | V <sub>IN</sub>                      | Guaranteed by line-regulation test                  |          | V <sub>OUT</sub> + 0.2 |       | 12.6  | V                 |
| Quiescent Supply Current                        | I <sub>IN</sub>                      |                                                     |          | 27                     |       | 35    | μA                |
| Change in Supply Current                        | I <sub>IN</sub> /V <sub>IN</sub>     | (V <sub>OUT</sub> + 0.2V) ≤ V <sub>IN</sub> ≤ 12.6V |          | 0.8                    |       | 2     | μA/V              |

MAX6190-MAX6195/MAX6198

# Precision, Micropower, Low-Dropout Voltage References

## ELECTRICAL CHARACTERISTICS—MAX6198

( $V_{IN} = 5V$ ,  $I_{OUT} = 0$ ,  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ C$ .)

| PARAMETER                                       | SYMBOL                               | CONDITIONS                                          |          | MIN                    | TYP   | MAX   | UNITS             |
|-------------------------------------------------|--------------------------------------|-----------------------------------------------------|----------|------------------------|-------|-------|-------------------|
| OUTPUT                                          |                                      |                                                     |          |                        |       |       |                   |
| Output Voltage                                  | V <sub>OUT</sub>                     | T <sub>A</sub> = +25°C                              | MAX6198A | 4.094                  | 4.096 | 4.098 | V                 |
|                                                 |                                      |                                                     | MAX6198B | 4.091                  | 4.096 | 4.101 |                   |
|                                                 |                                      |                                                     | MAX6198C | 4.086                  | 4.096 | 4.106 |                   |
| Output-Voltage Temperature Coefficient (Note 1) | TCV <sub>OUT</sub>                   | MAX6198A                                            |          | 2                      |       | 5     | ppm/°C            |
|                                                 |                                      | MAX6198B                                            |          | 4                      |       | 10    |                   |
|                                                 |                                      | MAX6198C                                            |          | 8                      |       | 25    |                   |
| Line Regulation                                 | ΔV <sub>OUT</sub> /ΔV <sub>IN</sub>  | (V <sub>OUT</sub> + 0.2V) ≤ V <sub>IN</sub> ≤ 12.6V |          | 25                     |       | 160   | μV/V              |
| Load Regulation                                 | ΔV <sub>OUT</sub> /ΔI <sub>OUT</sub> | Sourcing: 0 ≤ I <sub>OUT</sub> ≤ 500μA              |          | 0.15                   |       | 0.70  | μV/μA             |
|                                                 |                                      | Sinking: -500μA ≤ I <sub>OUT</sub> ≤ 0              |          | 0.20                   |       | 0.90  |                   |
| Dropout Voltage (Note 4)                        | V <sub>IN</sub> - V <sub>OUT</sub>   | ΔV <sub>OUT</sub> ≤ 0.2%, I <sub>OUT</sub> = 500μA  |          | 100                    |       | 200   | mV                |
| Short-Circuit Current                           | I <sub>SC</sub>                      | Short to GND                                        |          | 4                      |       |       | mA                |
|                                                 |                                      | Short to IN                                         |          | 4                      |       |       |                   |
| Temperature Hysteresis (Note 2)                 | ΔV <sub>OUT</sub> /cycle             |                                                     |          | 75                     |       |       | ppm               |
| Long-Term Stability                             | ΔV <sub>OUT</sub> /time              | 1000hrs at +25°C                                    |          | 50                     |       |       | ppm/1000hrs       |
| DYNAMIC                                         |                                      |                                                     |          |                        |       |       |                   |
| Noise Voltage                                   | e <sub>OUT</sub>                     | 0.1Hz to 10Hz                                       |          | 100                    |       |       | μV <sub>P-P</sub> |
|                                                 |                                      | 10Hz to 10kHz                                       |          | 200                    |       |       | μV <sub>RMS</sub> |
| Ripple Rejection                                | V <sub>OUT</sub> /V <sub>IN</sub>    | V <sub>IN</sub> = 5V ±100mV, f = 120Hz              |          | 77                     |       |       | dB                |
| Turn-On Settling Time                           | t <sub>R</sub>                       | To 0.1%, C <sub>OUT</sub> = 50pF                    |          | 160                    |       |       | μs                |
| Capacitive-Load Stability Range                 | C <sub>OUT</sub>                     | (Note 3)                                            |          | 0                      |       | 2.2   | nF                |
| INPUT                                           |                                      |                                                     |          |                        |       |       |                   |
| Supply Voltage Range                            | V <sub>IN</sub>                      | Guaranteed by line-regulation test                  |          | V <sub>OUT</sub> + 0.2 |       | 12.6  | V                 |
| Quiescent Supply Current                        | I <sub>IN</sub>                      |                                                     |          | 27                     |       | 35    | μA                |
| Change in Supply Current                        | I <sub>IN</sub> /V <sub>IN</sub>     | (V <sub>OUT</sub> + 0.2V) ≤ V <sub>IN</sub> ≤ 12.6V |          | 0.8                    |       | 2     | μA/V              |

**Note 1:** Temperature Coefficient is measured by the "box" method; i.e., the maximum  $\Delta V_{OUT}$  is divided by the maximum  $\Delta t$ .

**Note 2:** Thermal Hysteresis is defined as the change in  $+25^\circ C$  output voltage before and after cycling the device from  $T_{MIN}$  to  $T_{MAX}$ .

**Note 3:** Not production tested. Guaranteed by design.

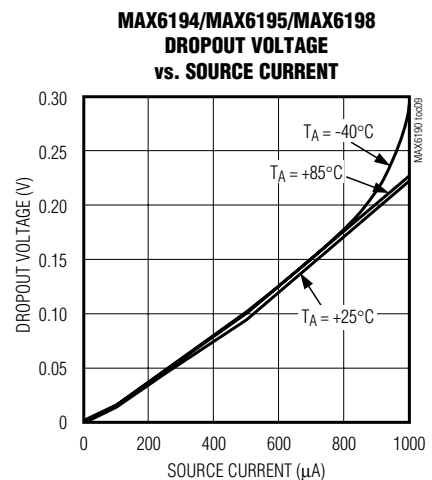
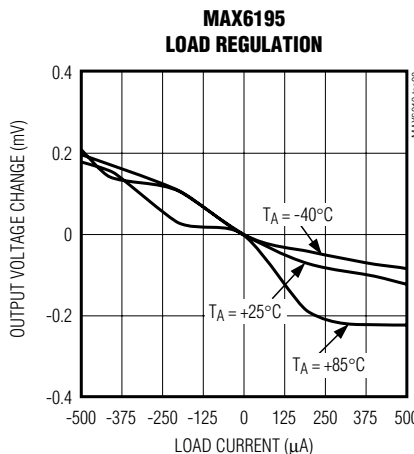
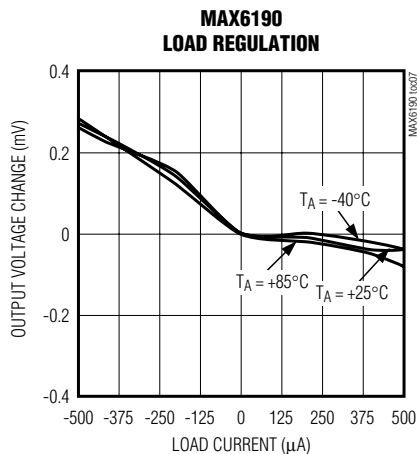
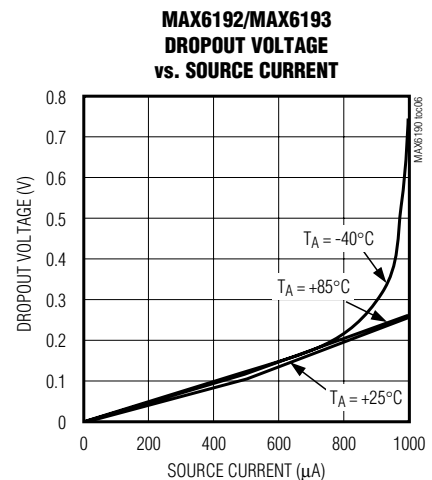
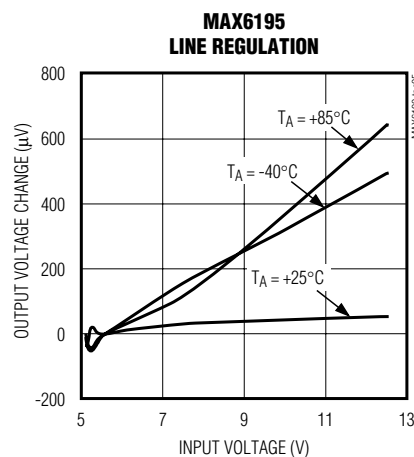
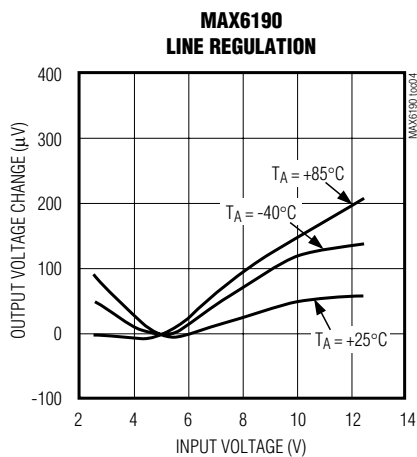
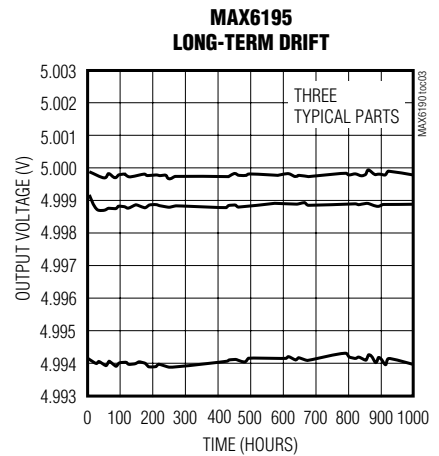
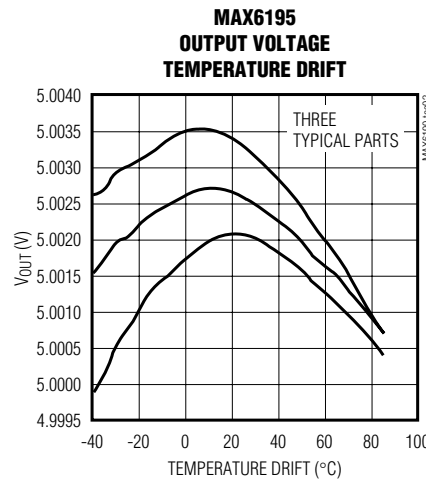
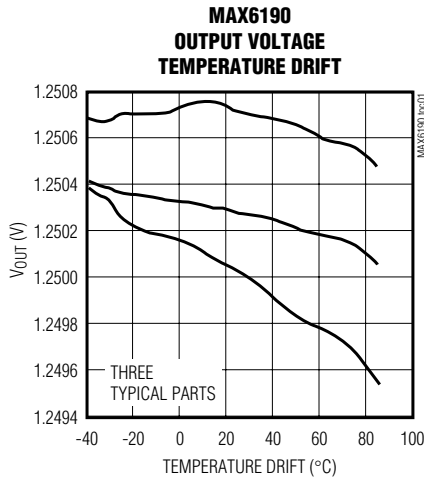
**Note 4:** Dropout voltage is the minimum input voltage at which  $V_{OUT}$  changes  $\leq 0.2\%$  from  $V_{OUT}$  at  $V_{IN} = 5.0V$  ( $V_{IN} = 5.5V$  for MAX6195).

# Precision, Micropower, Low-Dropout Voltage References

## Typical Operating Characteristics

( $V_{IN} = 5V$  for MAX6190/1/2/3/4/8,  $V_{IN} = 5.5V$  for MAX6195;  $I_{OUT} = 0$ ;  $T_A = +25^\circ C$ ; unless otherwise noted.) (Note 5)

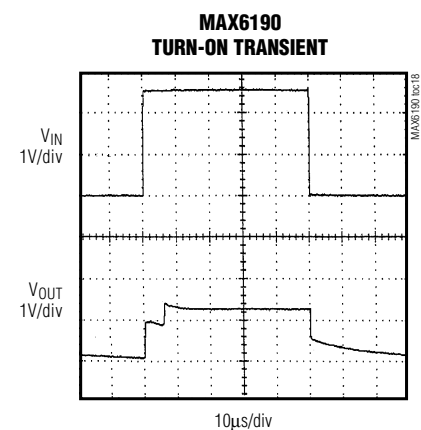
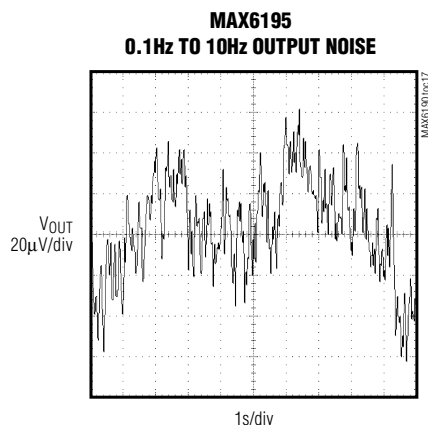
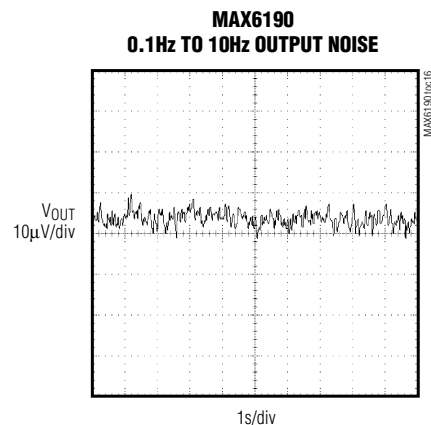
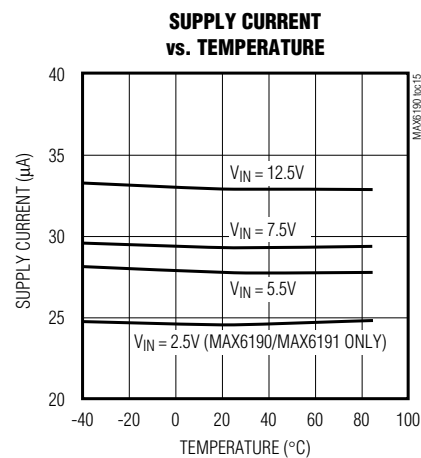
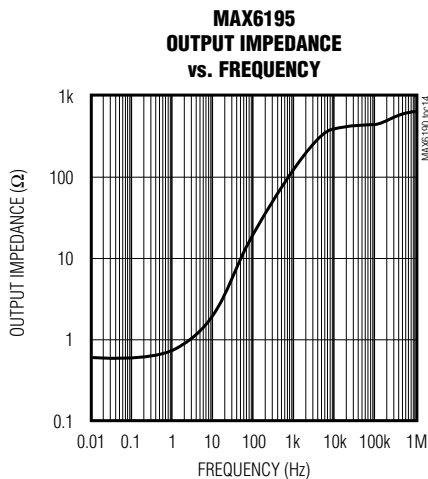
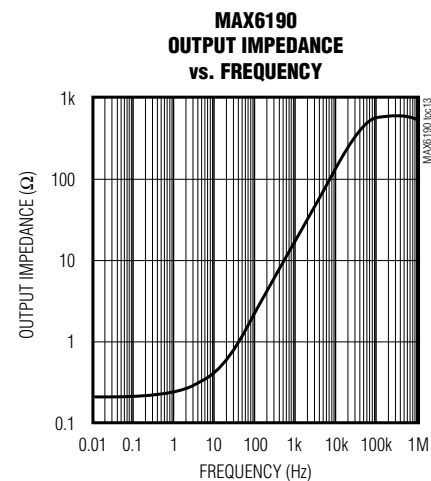
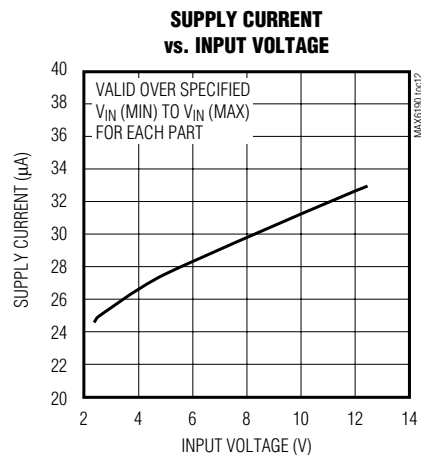
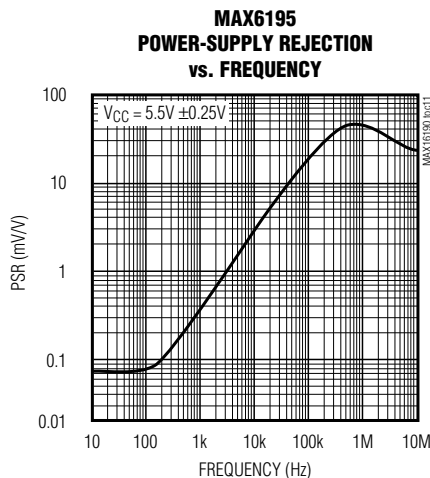
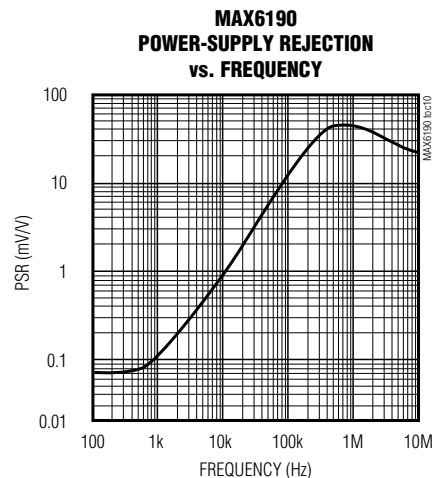
MAX6190-MAX6195/MAX6198



# Precision, Micropower, Low-Dropout Voltage References

## Typical Operating Characteristics (continued)

( $V_{IN} = 5V$  for MAX6190/1/2/3/4/8,  $V_{IN} = 5.5V$  for MAX6195;  $I_{OUT} = 0$ ;  $T_A = +25^\circ C$ ; unless otherwise noted.) (Note 5)



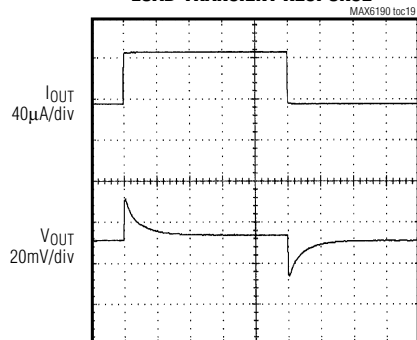
# Precision, Micropower, Low-Dropout Voltage References

## Typical Operating Characteristics (continued)

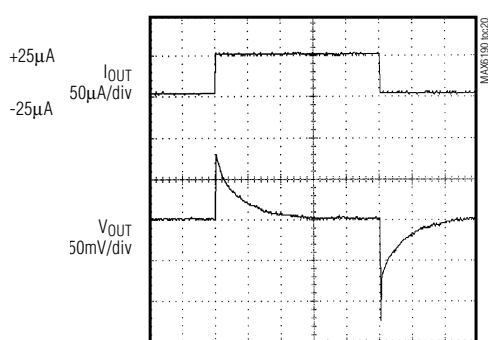
( $V_{IN} = 5V$  for MAX6190/1/2/3/4/8,  $V_{IN} = 5.5V$  for MAX6195;  $I_{OUT} = 0$ ;  $T_A = +25^\circ C$ ; unless otherwise noted.) (Note 5)

MAX6190-MAX6195/MAX6198

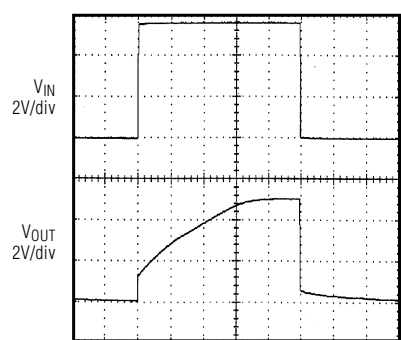
**MAX6190  
LOAD-TRANSIENT RESPONSE**



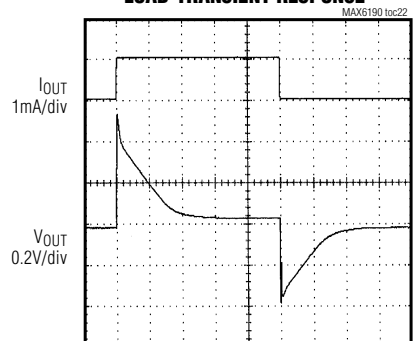
**MAX6195  
LOAD-TRANSIENT RESPONSE**



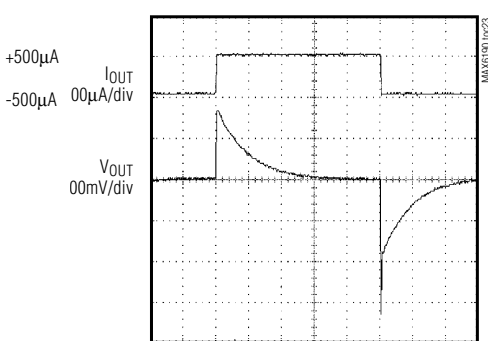
**MAX6195  
TURN-ON TRANSIENT**



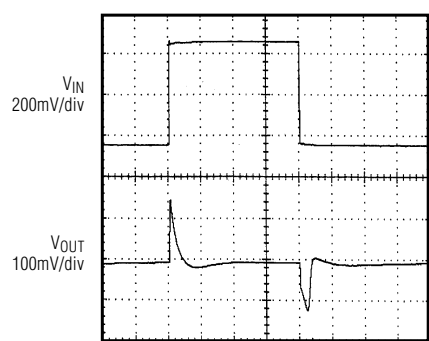
**MAX6190  
LOAD-TRANSIENT RESPONSE**



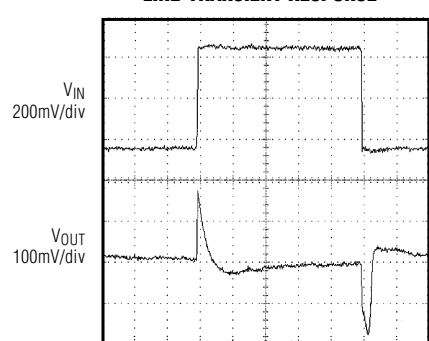
**MAX6195  
LOAD-TRANSIENT RESPONSE**



**MAX6190  
LINE-TRANSIENT RESPONSE**



**MAX6195  
LINE-TRANSIENT RESPONSE**



**Note 5:** Many of the *Typical Operating Characteristics* of the MAX6190 family are extremely similar. The extremes of these characteristics are found in the MAX6190 (1.2V output) and the MAX6195 (5.0V output) devices. The *Typical Operating Characteristics* of the remainder of the MAX6190 family typically lie between these two extremes and can be estimated based on their output voltage.

# Precision, Micropower, Low-Dropout Voltage References

## Pin Description

| PIN           | NAME | FUNCTION                                 |
|---------------|------|------------------------------------------|
| 1, 3, 5, 7, 8 | N.C. | No Connection. Not internally connected. |
| 2             | IN   | Supply Voltage Input                     |
| 4             | GND  | Ground                                   |
| 6             | OUT  | Reference Voltage Output                 |

## Detailed Description

The MAX6190-MAX6195/MAX6198 precision bandgap references use a proprietary curvature-correction circuit and laser-trimmed thin-film resistors, resulting in a low temperature coefficient of  $<5\text{ppm}/^{\circ}\text{C}$  and initial accuracy of better than 0.1%. These devices can sink and source up to  $500\mu\text{A}$  with  $<200\text{mV}$  of dropout voltage, making them attractive for use in low-voltage applications.

## Applications Information

### Output/Load Capacitance

Devices in this family do not require an output capacitance for frequency stability. They are stable for capacitive loads from 0 to  $2.2\text{nF}$ . However, in applications where the load or the supply can experience step changes, an output capacitor will reduce the amount of overshoot (or undershoot) and assist the circuit's transient response. Many applications do not need an external capacitor, and this family can offer a significant advantage in these applications when board space is critical.

### Supply Current

The quiescent supply current of these series-mode references is a maximum of  $35\mu\text{A}$  and is virtually independent of the supply voltage, with only a  $0.8\mu\text{A/V}$  variation with supply voltage. Unlike series references, shunt-mode references operate with a series resistor connected to the power supply. The quiescent current of a shunt-mode reference is thus a function of the input

voltage. Additionally, shunt-mode references have to be biased at the maximum expected load current, even if the load current is not present all the time. In the series-mode MAX6190 family, the load current is drawn from the input voltage only when required, so supply current is not wasted and efficiency is maximized at all input voltages. This improved efficiency can help reduce power dissipation and extend battery life.

When the supply voltage is below the minimum specified input voltage (as during turn-on), the devices can draw up to  $200\mu\text{A}$  beyond the nominal supply current. The input voltage source must be capable of providing this current to ensure reliable turn-on.

### Output Voltage Hysteresis

Output voltage hysteresis is the change in the output voltage at  $T_A = +25^{\circ}\text{C}$  before and after the device is cycled over its entire operating temperature range. Hysteresis is caused by differential package stress appearing across the bandgap core transistors. The typical temperature hysteresis value is  $75\text{ppm}$ .

### Turn-On Time

These devices typically turn on and settle to within 0.1% of their final value in  $30\mu\text{s}$  to  $220\mu\text{s}$ , depending on the device. The turn-on time can increase up to  $1.5\text{ms}$  with the device operating at the minimum dropout voltage and the maximum load.

### Positive and Negative Low-Power Voltage Reference

Figure 1 shows a typical method for developing a bipolar reference. The circuit uses a MAX681 voltage doubler/inverter charge-pump converter to power an ICL7652, thus creating a positive as well as a negative reference voltage.

# Precision, Micropower, Low-Dropout Voltage References

MAX6190-MAX6195/MAX6198

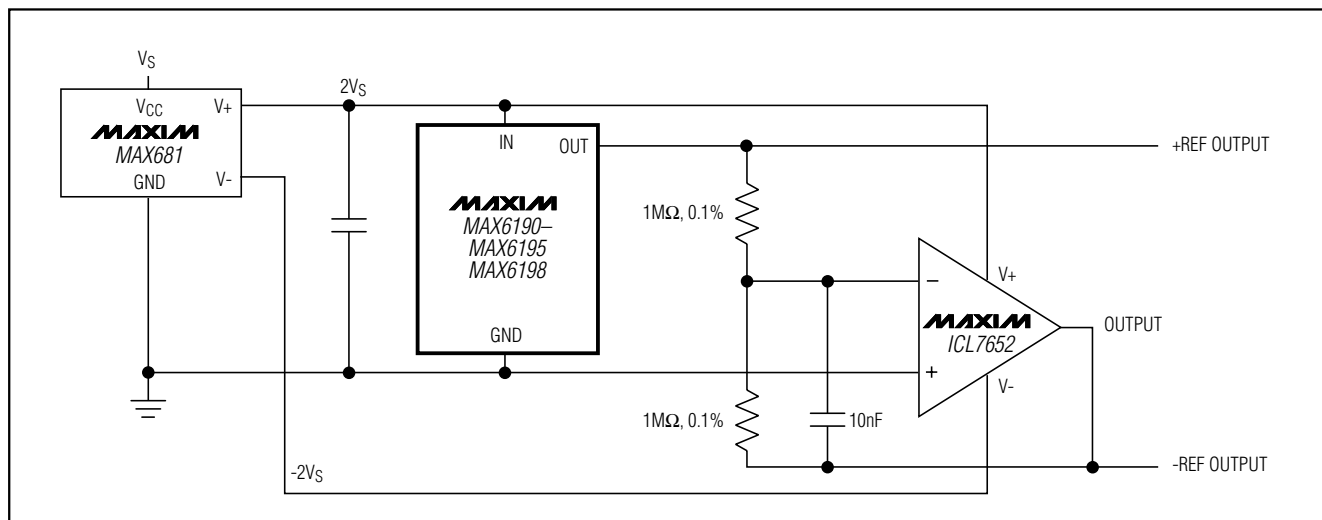
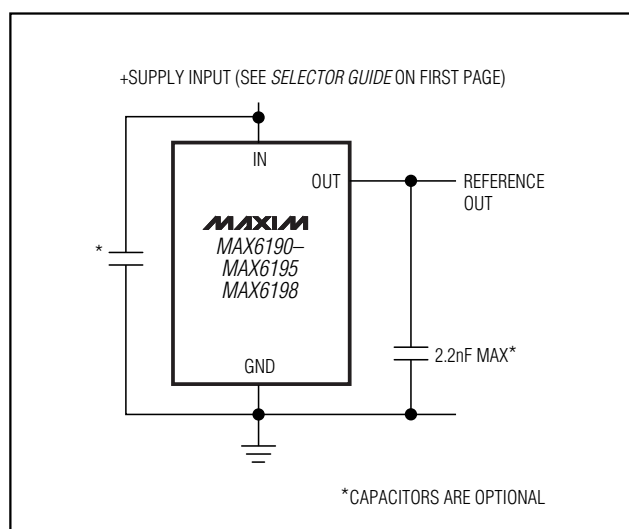


Figure 1. Positive and Negative References from Single 3V or 5V Supply

## Ordering Information (continued)

| PART                | TEMP RANGE     | PIN-PACKAGE |
|---------------------|----------------|-------------|
| <b>MAX6193</b> AESA | -40°C to +85°C | 8 SO        |
| MAX6193BESA         | -40°C to +85°C | 8 SO        |
| MAX6193CESA         | -40°C to +85°C | 8 SO        |
| <b>MAX6194</b> AESA | -40°C to +85°C | 8 SO        |
| MAX6194BESA         | -40°C to +85°C | 8 SO        |
| MAX6194CESA         | -40°C to +85°C | 8 SO        |
| <b>MAX6195</b> AESA | -40°C to +85°C | 8 SO        |
| MAX6195BESA         | -40°C to +85°C | 8 SO        |
| MAX6195CESA         | -40°C to +85°C | 8 SO        |
| <b>MAX6198</b> AESA | -40°C to +85°C | 8 SO        |
| MAX6198BESA         | -40°C to +85°C | 8 SO        |
| MAX6198CESA         | -40°C to +85°C | 8 SO        |

## Typical Operating Circuit

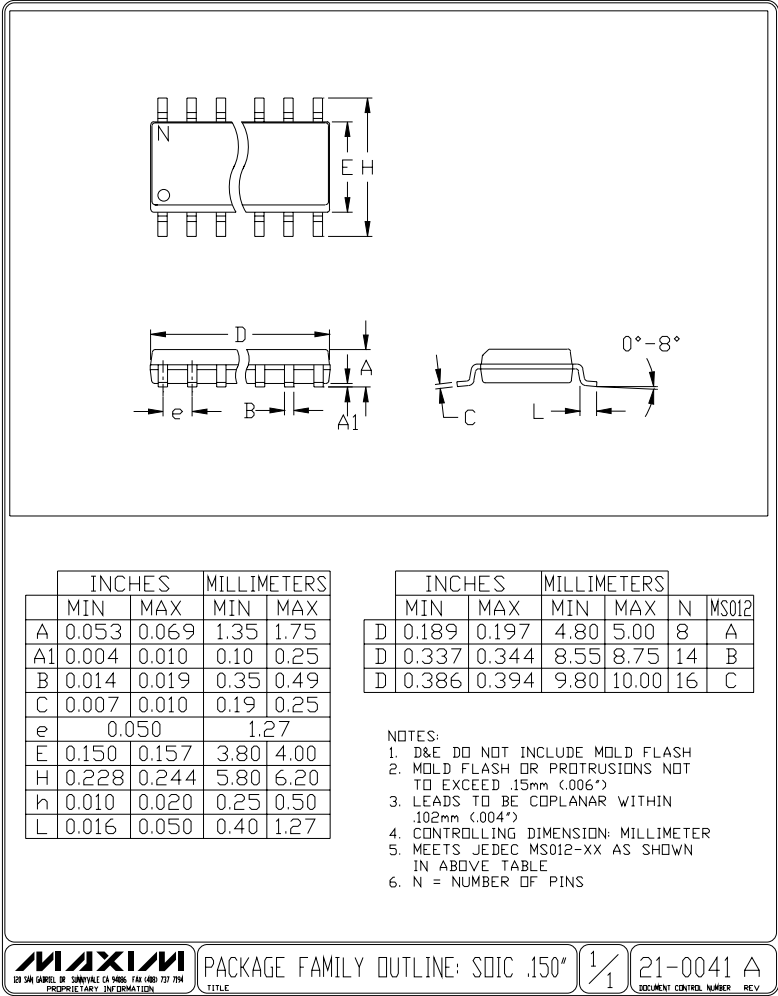


## Chip Information

TRANSISTOR COUNT: 70

Precision, Micropower,  
Low-Dropout Voltage References

Package Information



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