MC3303 MC3403－MC3503

## LOW POWER QUAD BIPOLAR OPERATIONAL AMPLIFIERS

－SHORT－CIRCUIT PROTECTED OUTPUTS
－CLASS AB OUTPUT STAGE FOR MINIMAL CROSSOVER DISTORTION
－SINGLE SUPPLY OPERATION ：＋ 3 V TO＋36V
－DUAL SUPPLIES ：$\pm 1.5 \mathrm{~V}$ TO $\pm 18 \mathrm{~V}$
－LOW INPUT BIAS CURRENT ：500nA MAX
－INTERNALLY COMPENSATED
－SIMILAR PERFORMANCE TO POPULAR UA741

## DESCRIPTION

The MC3403 is a low－cost，quad operational ampli－ fier with true differential inputs．The device has elec－ trical characteristics similar to the popular UA741． However the MC3403，has several distinct advan－ tages over standard operational amplifier types in single supply applications．The quad amplifier can operate at supply voltages as low as 3.0 volts or as high as 36 volts with quiescent currents about one third of those associated with the UA741（on a per amplifier basis）．The common－mode input range in－ cludes the negative supply，thereby eliminating the necessity for external biasing components in many applications．


ORDER CODES

| Part <br> Number | Temperature <br> Range | Package |  |  |
| :--- | :---: | :---: | :---: | :---: |
|  |  | $-40^{\circ} \mathrm{C},+105^{\circ} \mathrm{C}$ | $\bullet$ | $\bullet$ |
| MC3403 |  | $\bullet$ | $\bullet$ | $\bullet$ |
| MC3503 | $-55^{\circ} \mathrm{C},+125^{\circ} \mathrm{C}$ | $\bullet$ | $\bullet$ | $\bullet$ |
| Example ：MC3403N |  |  |  |  |

PIN CONNECTIONS（top view）


## MC3303 - MC3403 - MC3503

SCHEMATIC DIAGRAM (each amplifier)


SINGLE SUPPLY


DUAL SUPPLIES


ABSOLUTE MAXIMUM RATINGS

| Symbol | Parameter | MC3503 | MC3403 | MC3303 | Unit |
| :---: | :--- | :---: | :---: | :---: | :---: |
| $\mathrm{V}_{\mathrm{CC}}$ | Supply Voltage | $\pm 18$ or 36 | $\pm 18$ or 36 | $\pm 18$ or 36 | V |
| $\mathrm{~V}_{\text {id }}$ | Differential Input Voltage | $\pm 36$ | $\pm 36$ | $\pm 36$ | V |
| $\mathrm{~V}_{\mathrm{i}}$ | Input Voltage (note 1) | $\pm 18$ | $\pm 18$ | $\pm 18$ | V |
| - | Output Short-circuit Duration (note 2) | Infinite |  |  |  |
| $\mathrm{P}_{\text {tot }}$ | Power Dissipation | 500 | 500 | 500 | mW |
| $\mathrm{~T}_{\text {oper }}$ | Operating Free-air Temperature Range | -55 to +125 | 0 to +70 | -40 to +105 | ${ }^{\circ} \mathrm{C}$ |
| $\mathrm{T}_{\text {stg }}$ | Storage Temperature Range | -65 to +150 | -65 to +150 | -65 to +150 | ${ }^{\circ} \mathrm{C}$ |

Notes: 1. For supply voltages less than $\pm 15 \mathrm{~V}$, the absolute maximum input voltage is equal to the supply voltage.
2. Any of the amplifier outputs can be shorted to ground indefinitely; however more than one should not be simultaneously shorted as the maximum junction temperature will be exceeded.

## ELECTRICAL CHARACTERISTICS

Vcc $= \pm 15 \mathrm{~V}, \mathrm{~T}_{\mathrm{amb}}=+25^{\circ} \mathrm{C}$, (unless otherwise specified)

| Symbol | Parameter | $\begin{gathered} \text { MC3303 - MC3403 } \\ \text { MC3503 } \\ \hline \end{gathered}$ |  |  | Unit |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Min. | Typ. | Max. |  |
| $\mathrm{V}_{10}$ | $\begin{gathered} \text { Input Offset Voltage }\left(R_{s} \leq 10 \mathrm{k} \Omega\right) \\ T_{\text {amb }}=25^{\circ} \mathrm{C} \\ T_{\text {min }} \leq T_{\text {amb }} \leq T_{\text {max }} . \end{gathered}$ |  | 1 | $\begin{aligned} & 5 \\ & 6 \end{aligned}$ | mV |
| 110 | $\begin{gathered} \text { Input Offset Current } \\ T_{\text {amb }}=25^{\circ} \mathrm{C} \\ \mathrm{~T}_{\text {min. }} \leq \mathrm{T}_{\text {amb }} \leq \mathrm{T}_{\text {max }} . \end{gathered}$ |  | 2 | $\begin{gathered} 50 \\ 200 \end{gathered}$ | nA |
| $\mathrm{l}_{\text {b }}$ | $\begin{aligned} & \text { Input Bias Current } \\ & T_{\text {amb }}=25^{\circ} \mathrm{C} \\ & T_{\text {min. }} \leq \mathrm{T}_{\text {amb }} \leq \mathrm{T}_{\text {max }} . \end{aligned}$ |  | 40 | $\begin{aligned} & 500 \\ & 800 \end{aligned}$ | nA |
| Avd | $\begin{aligned} & \text { Large Signal Voltage Gain }\left(\mathrm{V}_{\mathrm{O}}= \pm 10 \mathrm{~V}, \mathrm{R}_{\mathrm{L}}=2 \mathrm{k} \Omega\right) \\ & T_{\text {amb }}=25^{\circ} \mathrm{C} \\ & \mathrm{~T}_{\text {min. }} \leq \mathrm{T}_{\text {amb }} \leq \mathrm{T}_{\text {max }} . \end{aligned}$ | $\begin{aligned} & 50 \\ & 25 \end{aligned}$ | 200 |  | V/mV |
| SVR | Supply Voltage Rejection Ratio ( $\mathrm{Rs}_{\mathrm{S}} \leq 10 \mathrm{k} \Omega$ ) $\begin{aligned} & T_{\text {amb }}=25^{\circ} \mathrm{C} \\ & T_{\text {min. }} \leq T_{\text {amb }} \leq T_{\text {max }} . \end{aligned}$ | $\begin{aligned} & 77 \\ & 77 \end{aligned}$ | 90 |  | dB |
| Icc | Supply Current, all Amp, no Load $\begin{array}{ll} \mathrm{T}_{\text {amb }}=25^{\circ} \mathrm{C} & \text { MC3503 } \\ \mathrm{T}_{\text {min. }} \leq \mathrm{T}_{\text {amb }} \leq \mathrm{T}_{\text {max }} & \text { MC3503 } \end{array}$ |  | 2.8 | 7 4 8 5 | mA |
| $\mathrm{V}_{\mathrm{icm}}$ | Input Common Mode Voltage Range $\begin{aligned} & T_{\text {amb }}=25^{\circ} \mathrm{C} \\ & T_{\text {min. }} \leq T_{\text {amb }} \leq T_{\text {max }} . \end{aligned}$ | $\begin{aligned} & -15 \\ & -15 \end{aligned}$ |  | $\begin{array}{r} +13 \\ +13 \\ \hline \end{array}$ | V |
| CMR | Common Mode Rejection Ratio ( $\mathrm{R} \leq 10 \mathrm{k} \Omega$ ) $\begin{aligned} & T_{\text {amb }}=25^{\circ} \mathrm{C} \\ & T_{\text {min. }} \leq T_{\text {amb }} \leq T_{\text {max }} . \end{aligned}$ | $\begin{aligned} & 70 \\ & 70 \end{aligned}$ | 90 |  | dB |
| los | Output Short-circuit Current | 10 | 30 | 45 | mA |
| $\pm \mathrm{V}_{\text {opp }}$ | Output Voltage Swing $\begin{aligned} & \mathrm{T}_{\mathrm{amb}}=25^{\circ} \mathrm{C} \\ & \mathrm{~T}_{\text {min. }} \leq \mathrm{T}_{\mathrm{amb}} \leq \mathrm{T}_{\text {max }} \end{aligned}$ $R_{\mathrm{L}}=10 \mathrm{k} \Omega$ $\begin{aligned} & R_{L}=2 \mathrm{k} \Omega \\ & \mathrm{R}_{\mathrm{L}}=2 \mathrm{k} \Omega \\ & \mathrm{R}_{\mathrm{L}}=1 \mathrm{k} \Omega \end{aligned}$ | $\begin{aligned} & 12 \\ & 10 \\ & 10 \\ & 12 \\ & \hline \end{aligned}$ | $\begin{gathered} 13.5 \\ 13 \end{gathered}$ |  | V |
| SR | Slew Rate ( $\mathrm{V}_{\mathrm{I}}= \pm 10 \mathrm{~V} \mathrm{R}_{\mathrm{L}}=2 \mathrm{k} \Omega, \mathrm{C}_{\mathrm{L}}=100 \mathrm{pF}$, <br> $\mathrm{T}_{\mathrm{amb}}=25^{\circ} \mathrm{C}$, unity gain) | 0.35 | 0.5 |  | V/ $\mu \mathrm{s}$ |
| $\mathrm{tr}_{\text {r }} \mathrm{t}_{\mathrm{f}}$ | Rise Time and Fall Time ( $\mathrm{V}_{\mathrm{O}}= \pm 20 \mathrm{mV}, \mathrm{R}_{\mathrm{L}}=2 \mathrm{k} \Omega, \mathrm{C}_{\mathrm{L}}=100 \mathrm{pF}$ $\mathrm{T}_{\mathrm{amb}}=25^{\circ} \mathrm{C}$, unity gain) |  | 0.18 |  | $\mu \mathrm{s}$ |
| Kov | Overshoot ( $\mathrm{V}_{\mathrm{I}}= \pm 20 \mathrm{mV}, \mathrm{R}_{\mathrm{L}}=2 \mathrm{k} \Omega, \mathrm{C}_{\mathrm{L}}=100 \mathrm{pF}$, $\mathrm{T}_{\mathrm{amb}}=25^{\circ} \mathrm{C}$, unity gain) |  | 10 |  | \% |
| Z 1 | Input Impedance | 0.3 | 1 |  | $\mathrm{M} \Omega$ |
| Zo | Output Impedance |  | 75 |  | $\Omega$ |
| Bom | Power Bandwidth ( $R_{L}=2 \mathrm{k} \Omega, C_{L}=100 \mathrm{pF}, \mathrm{A}_{\mathrm{v}}=1, \mathrm{~T}_{\text {amb }}=25^{\circ} \mathrm{C}$, $\mathrm{V}_{\mathrm{O}}=2 \mathrm{~V}_{\mathrm{pp}}, \mathrm{THD} \leq 5 \%$ ) |  | 9 |  | kHz |
| B | Unity Gain Bandwidth ( $\mathrm{V}_{\mathrm{O}}=10 \mathrm{mV}, \mathrm{R}_{\mathrm{L}}=2 \mathrm{k} \Omega, \mathrm{C}_{\mathrm{L}}=100 \mathrm{pF}$, $\mathrm{T}_{\mathrm{amb}}=25^{\circ} \mathrm{C}$, unity gain) |  | 1 |  | MHz |
| GBP | $\begin{aligned} & \text { Gain Bandwidth Product }\left(\mathrm{V}_{\mathrm{O}}=10 \mathrm{mV}, \mathrm{R}_{\mathrm{L}}=2 \mathrm{k} \Omega, \mathrm{C}_{\mathrm{L}}=100 \mathrm{pF}\right. \text {, } \\ & \left.\mathrm{f}=100 \mathrm{kHz}, T_{\text {amb }}=25^{\circ} \mathrm{C}\right) \end{aligned}$ | 0.7 | 1 |  | MHz |
| THD | Total Harmonic Distortion ( $f=1 \mathrm{kHz}, \mathrm{A}_{\mathrm{v}}=20 \mathrm{~dB}, \mathrm{R}_{\mathrm{L}}=2 \mathrm{k} \Omega$, $\mathrm{V}_{\mathrm{O}}=2 \mathrm{~V}_{\mathrm{pp}}, \mathrm{C}_{\mathrm{L}}=100 \mathrm{pF}, \mathrm{T}_{\mathrm{amb}}=25^{\circ} \mathrm{C}$ ) |  | 0.02 |  | \% |
| $e_{n}$ | Equivalent Input Noise Voltage ( $f=1 \mathrm{kHz}, \mathrm{R}_{\mathrm{s}}=100 \Omega$ ) |  | 43 |  | $\frac{n \mathrm{~V}}{\sqrt{\mathrm{~Hz}}}$ |

## ELECTRICAL CHARACTERISTICS (continued)

| Symbol | Parameter | MC3303-MC3403-MC3503 |  |  | Unit |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Min. | Typ. | Max. |  |
| $\varnothing \mathrm{m}$ | Phase Margin |  | 60 |  | Degrees |
| DVIO | Input Offset Voltage Drift $\mathrm{T}_{\text {min. }} \leq \mathrm{T}_{\text {amb }} \leq \mathrm{T}_{\text {max }}$. |  | 10 |  | $\mu \mathrm{V} /{ }^{\circ} \mathrm{C}$ |
| Dlı | Input Offset Current Drift <br> $\mathrm{T}_{\text {min. }} \leq \mathrm{T}_{\text {amb }} \leq 25^{\circ} \mathrm{C}$ |  | 50 |  | $\mathrm{pA} /{ }^{\circ} \mathrm{C}$ |
| $\mathrm{V}_{01} / \mathrm{V}_{02}$ | Channel Separation |  | 120 |  | dB |

## ELECTRICAL CHARACTERISTICS

$\mathrm{V}_{\mathrm{cc}}{ }^{+}=5 \mathrm{~V}, \mathrm{~V}_{\mathrm{CC}}{ }^{-}=$Ground, $\mathrm{T}_{\mathrm{amb}}=25^{\circ} \mathrm{C}$ (unless otherwise specified)

| Symbol | Parameter | MC3303-MC3403-MC3503 |  |  | Unit |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Min. | Typ. | Max. |  |
| $\mathrm{V}_{10}$ | $\begin{aligned} & \text { Input Offset Voltage }\left(R_{\mathrm{S}} \leq 10 \mathrm{k} \Omega\right) \\ & T_{\text {amb }}=25^{\circ} \mathrm{C} \\ & T_{\min } \leq T_{\text {amb }} \leq T_{\max } \\ & \end{aligned}$ |  | 1 | $\begin{aligned} & 5 \\ & 6 \end{aligned}$ | mV |
| 1 O | $\begin{aligned} & \text { Input Offset Current } \\ & T_{\text {amb }}=25^{\circ} \mathrm{C} \\ & \mathrm{~T}_{\text {min. }} \leq \mathrm{T}_{\mathrm{amb}} \leq \mathrm{T}_{\text {max }} . \end{aligned}$ |  | 2 | $\begin{gathered} 50 \\ 200 \end{gathered}$ | nA |
| l l | $\begin{aligned} & \text { Input Bias Current } \\ & T_{\text {amb }}=25^{\circ} \mathrm{C} \\ & T_{\text {min }} \leq \mathrm{T}_{\text {amb }} \leq \mathrm{T}_{\text {max }} . \end{aligned}$ |  | 40 | $\begin{aligned} & 500 \\ & 800 \end{aligned}$ | nA |
| Avd | $\begin{aligned} & \text { Large Signal Voltage Gain }\left(\mathrm{V}_{\mathrm{O}}=1.4 \text { to } 2.4 \mathrm{~V}, \mathrm{R}_{\mathrm{L}}=2 \mathrm{k} \Omega\right) \\ & T_{\text {amb }}=25^{\circ} \mathrm{C} \\ & T_{\text {min. }} \leq \mathrm{T}_{\text {amb }} \leq \mathrm{T}_{\text {max }} . \end{aligned}$ | $\begin{gathered} 10 \\ 5 \end{gathered}$ | 200 |  | V/mV |
| SVR | $\begin{aligned} & \text { Supply Voltage Rejection Ratio }\left(\mathrm{Rs}_{\mathrm{s}} \leq 10 \mathrm{k} \Omega\right) \\ & T_{\text {amb }}=25^{\circ} \mathrm{C} \\ & T_{\text {min. }} \leq \mathrm{T}_{\text {amb }} \leq \mathrm{T}_{\text {max }} . \end{aligned}$ | $\begin{aligned} & 77 \\ & 77 \end{aligned}$ | 90 |  | dB |
| Icc | Supply Current (All Amp) MC3503 |  | 2.5 | $\begin{aligned} & 7 \\ & 4 \\ & \hline \end{aligned}$ | mA |
| $\mathrm{V}_{\text {opp }}$ | $\begin{aligned} & \text { Output Voltage Range }\left(R_{\mathrm{L}}=10 \mathrm{k} \Omega\right) \\ & V_{\mathrm{CC}}=+5 \mathrm{~V} \\ & +5<\mathrm{V}_{\mathrm{CC}} \leq+30 \mathrm{~V} \end{aligned}$ | $\begin{gathered} 3.3 \\ \mathrm{~V}_{\mathrm{CC}}{ }^{+}-2 \mathrm{~V} \end{gathered}$ | $\begin{gathered} 3.5 \\ \mathrm{VCC}^{+}-1.7 \mathrm{~V} \end{gathered}$ |  | V |

## CIRCUIT DESCRIPTION

The MC3403 is made using four internally compensated, two-stage operational amplifiers. The first stage of each consists of differential input devices Q24 and Q22 with input buffer transistors Q25 and Q21 and the differential to single ended converter Q3 and Q4. The first stage performs not only the first stage gain function but also performs the level shifting and transconductance reduction functions. By reducing the transconductance a smaller compensation capacitor (only 8 pF ) can be employed, thus saving chip area.
The transconductance reduction is accomplished by splitting the collectors of Q24 and Q22. Another feature of this input stage is that the input commonmode range can include the negative supply of
ground, in single supply operation, without saturation either the input devices or the differential to sin-gle-ended converter.

The second stage consists of a standard current source load amplifier stage. The output stage is unique because it allows the output to swing to ground in single supply operation and yet does not exhibit any crossover distortion in split supply operations. This is possible because class AB operation is utilized.

Each amplifier is biased from an internal voltage regulator which has a low temperature coefficient thus giving each amplifier good temperature characteristics as well as excellent power supply rejection.

TYPICAL PERFORMANCE CURVES


APPLICATION INFORMATION
VOLTAGE REFERENCE


WIEN BRIDGE OSCILLATOR


## APPLICATION INFORMATION (continued)

HIGH IMPEDANCE DIFFERENTIAL
AMPLIFIER


COMPARATOR WITH HYSTERESIS


BI-QUAD FILTER


## APPLICATION INFORMATION (continued)

## FUNCTION GENERATOR



MULTIPLE FEEDBACK BANDPASS FILTER


Given $\quad f_{0}=$ Center frequency ; choose values $f_{0}, C$ then

$$
\begin{aligned}
& R 3=\frac{Q}{\pi f_{0} C} \cdot \\
& R 1=\frac{R 3}{2 A\left(f_{0}\right)} \cdot \\
& R 2=\frac{R 1 R 5}{4 Q^{2} R 1-R 5} .
\end{aligned}
$$

For less than $10 \%$ error from operational amplifier
$\frac{Q_{0} f_{0}}{B W}<0.1$ where $f_{0}$ and BW are expressed in Hz
If source impedance varies, filter may be preceded with voltage follower buffer to stabilize filter parameters

TYPICAL PERFORMANCE CURVES



OUTPUT SWING VERSUS SUPPLY VOLTAGE


PACKAGE MECHANICAL DATA
14 PINS - PLASTIC DIP


| Dimensions | Millimeters |  |  | Inches |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Min. | Typ. | Max. | Min. | Typ. | Max. |
| a1 | 0.51 |  |  | 0.020 |  |  |
| B | 1.39 |  | 1.65 | 0.055 |  | 0.065 |
| b |  | 0.5 |  |  | 0.020 |  |
| b1 |  | 0.25 |  |  | 0.010 |  |
| D |  |  | 20 |  |  | 0.787 |
| E |  | 8.5 |  |  | 0.335 |  |
| e |  | 2.54 |  |  | 0.100 |  |
| e3 |  | 15.24 |  |  | 0.600 |  |
| F |  |  | 7.1 |  |  | 0.280 |
| i |  |  | 5.1 |  |  | 0.201 |
| L |  | 3.3 |  |  | 0.130 |  |
| Z | 1.27 |  | 2.54 | 0.050 |  | 0.100 |

## PACKAGE MECHANICAL DATA

14 PINS - PLASTIC MICROPACKAGE (SO)


| Dimensions | Millimeters |  |  | Inches |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Min. | Typ. | Max. | Min. | Typ. | Max. |
| A |  |  | 1.75 |  |  | 0.069 |
| a1 | 0.1 |  | 0.2 | 0.004 |  | 0.008 |
| a2 |  |  | 1.6 |  |  | 0.063 |
| b | 0.35 |  | 0.46 | 0.014 |  | 0.018 |
| b1 | 0.19 |  | 0.25 | 0.007 |  | 0.010 |
| C |  | 0.5 |  |  | 0.020 |  |
| c1 | $45^{\circ}$ (typ.) |  |  |  |  |  |
| D | 8.55 |  | 8.75 | 0.336 |  | 0.334 |
| E | 5.8 |  | 6.2 | 0.228 |  | 0.244 |
| e |  | 1.27 |  |  | 0.050 |  |
| e3 |  | 7.62 |  |  | 0.300 |  |
| F | 3.8 |  | 4.0 | 0.150 |  | 0.157 |
| G | 4.6 |  | 5.3 | 0.181 |  | 0.208 |
| L | 0.5 |  | 1.27 | 0.020 |  | 0.050 |
| M |  |  | 0.68 |  |  | 0.027 |
| S | $8^{\circ}$ (max.) |  |  |  |  |  |

## PACKAGE MECHANICAL DATA

14 PINS - THIN SHRINK SMALL OUTLINE PACKAGE


| Dim. | Millimeters |  |  | Inches |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Min. | Typ. | Max. | Min. | Typ. | Max. |
| A |  |  | 1.20 |  |  | 0.05 |
| A1 | 0.05 |  | 0.15 | 0.01 |  | 0.006 |
| A2 | 0.80 | 1.00 | 1.05 | 0.031 | 0.039 | 0.041 |
| b | 0.19 |  | 0.30 | 0.007 |  | 0.15 |
| c | 0.09 |  | 0.20 | 0.003 |  | 0.012 |
| D | 4.90 | 5.00 | 5.10 | 0.192 | 0.196 | 0.20 |
| E |  | 6.40 |  |  | 0.252 |  |
| E1 | 4.30 | 4.40 | 4.50 | 0.169 | 0.173 | 0.177 |
| e |  | 0.65 |  |  | 0.025 |  |
| k | $0^{\circ}$ |  | $8^{\circ}$ | $0^{\circ}$ |  | $8^{\circ}$ |
| I | 0.50 | 0.60 | 0.75 | 0.09 | 0.0236 | 0.030 |

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