LMH6502
Wideband, Low Power, Linear-in-dB Variable Gain Amplifier

General Description
The LMH™6502 is a wideband DC coupled differential input voltage controlled gain stage followed by a high-speed current feedback Op Amp which can directly drive a low impedance load. Gain adjustment range is more than 70dB for up to 10MHz.

Maximum gain is set by external components and the gain can be reduced all the way to cut-off. Power consumption is 300mW with a speed of 130MHz. Output referred DC offset voltage is less than 350mV over the entire gain control voltage range. Device-to-device Gain matching is within ±0.6dB at maximum gain. Furthermore, gain at any V_G is tested and the tolerance is guaranteed. The output current feedback Op Amp allows high frequency large signals (Slew Rate = 1800V/µs) and can also drive heavy load current (75mA). Differential inputs allow common mode rejection in low level amplification or in applications where signals are carried over relatively long wires. For single ended operation, the unused input can easily be tied to ground (or to a virtual half-supply in single supply application). Inverting or non-inverting gains could be obtained by choosing one input polarity or the other.

To provide ease of use when working with a single supply, V_G range is set to be from 0V to +2V relative to pin 11 potential (ground pin). In single supply operation, this ground pin is tied to a "virtual" half supply.

LMH6502 gain control is linear in dB for a large portion of the total gain control range. This makes the device suitable for AGC circuits among other applications. For linear gain control applications, see the LMH6503 datasheet. The LMH6502 is available in the SOIC-14 and TSSOP-14 package.

Features
-3dB BW 130MHz
Gain control BW 100MHz
Adjustment range (typical over temp) 70dB
Gain matching (limit) ±0.6dB
Slew rate 1800V/µs
Supply current (no load) 27mA
Linear output current ±75mA
Output voltage (R_L = 100Ω) ±3.2V
Input voltage noise 7.7nV/√Hz
Input current noise 2.4pA/√Hz
THD (20MHz, R_L = 100Ω, V_O = 2Vpp) −53dBc
Replacement for CLC520

Applications
- Variable attenuator
- AGC
- Voltage controller filter
- Video imaging processing

Typical Application

Gain vs. V_G for Various Temperature

Typical Application
Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

ESD Tolerance (Note 4):
- Human Body: 2kV
- Machine Model: 200V
- Input Current: ±10mA
- \( V_{IN} \) Differential: ±(\( V^* - V^- \))
- Output Current: 120mA (Note 3)
- Supply Voltages (\( V^* - V^- \)): 12.6V
- Voltage at Input/Output pins: \( V^* +0.8V, V^- - 0.8V \)
- Storage Temperature Range: −65˚C to +150˚C

Junction Temperature: +150˚C

Soldering Information:
- Infrared or Convection (20 sec): 235˚C
- Wave Soldering (10 sec): 260˚C

Operating Ratings (Note 1)

Supply Voltages (\( V^* - V^- \)): 5V to 12V

Temperature Range: −40˚C to +85˚C

Thermal Resistance: \( \theta_{JC} \) (Note 2)
- 14-Pin SOIC: 45˚C/W
- 14-Pin TSSOP: 51˚C/W

Electrical Characteristics (Note 2)

Unless otherwise specified, all limits guaranteed for \( T_J = 25˚C, V_S = \pm 5V, A_{V(MAX)} = 10, V_{CM} = 0V, R_F = 1k\Omega, R_G = 174\Omega, V_{IN,DIFF} = \pm 0.1V, R_L = 100\Omega, V_G = +2V. \) Boldface limits apply at the temperature extremes.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Min (Note 6)</th>
<th>Typ (Note 6)</th>
<th>Max (Note 6)</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>BW</td>
<td>-3dB Bandwidth</td>
<td>( V_{OUT} &lt; 0.5V_{PP} )</td>
<td>130</td>
<td></td>
<td></td>
<td>MHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( V_{OUT} &lt; 0.5V_{PP}, A_{V(MAX)} = 100 )</td>
<td>50</td>
<td></td>
<td></td>
<td>MHz</td>
</tr>
<tr>
<td>GF</td>
<td>Gain Flatness</td>
<td>( V_{OUT} &lt; 0.5V_{PP} )</td>
<td>30</td>
<td></td>
<td></td>
<td>MHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( 0.6V \leq V_{G} \leq 2V, \pm 0.3dB )</td>
<td>16</td>
<td></td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td>Att Range</td>
<td>Flat Band (Relative to Max Gain)</td>
<td>±0.2dB, ( f &lt; 30MHz )</td>
<td>7.5</td>
<td></td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td></td>
<td>Attenuation Range (Note 14)</td>
<td>( \pm 0.1dB, \ f &lt; 30MHz )</td>
<td>100</td>
<td></td>
<td></td>
<td>MHz</td>
</tr>
<tr>
<td>BW</td>
<td>Control</td>
<td>( V_G = 1V ) (Note 13)</td>
<td>100</td>
<td></td>
<td></td>
<td>MHz</td>
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<tr>
<td>PL</td>
<td>Linear Phase Deviation</td>
<td>DC to 60MHz</td>
<td>1.5</td>
<td></td>
<td></td>
<td>deg</td>
</tr>
<tr>
<td>G Delay</td>
<td>Group Delay</td>
<td>DC to 130MHz</td>
<td>2.5</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>CT (dB)</td>
<td>Feed-through</td>
<td>( V_G = 0V, 30MHz ) (Output Referred)</td>
<td>−47</td>
<td></td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td>GR</td>
<td>Gain Adjustment Range</td>
<td>( f &lt; 10MHz )</td>
<td>72</td>
<td></td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( f &lt; 30MHz )</td>
<td>67</td>
<td></td>
<td></td>
<td>dB</td>
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</table>

Time Domain Response

| Symbol | Rise and Fall Time | 0.5V Step | 2.2 | | ns |
| OS % | Overshoot | 0.5V Step | 10 | | % |
| SR | Slew Rate | 4V Step | 1800 | | V/µs |
| Δ G Rate | Gain Change Rate | \( V_{IN} = 0.3V, 10%-90\% \) of Final Output | 4.8 | | dB/ns |

Distortion & Noise Performance

| Symbol | 2nd Harmonic Distortion | 2VPP, 20MHz | −55 | | dB |
| HD3 | 3rd Harmonic Distortion | 2VPP, 20MHz | −57 | | dB |
| THD | Total Harmonic Distortion | 2VPP, 20MHz | −53 | | dB |
| En tot | Total Equivalent Input Noise | 1MHz to 150MHz | 7.7 | | nV/√Hz |
| \( l_N \) | Input Noise Current | 1MHz to 150MHz | 2.4 | | pA/√Hz |
| DG | Differential Gain | \( f = 4.43MHz, R_L = 150\Omega, Neg. Sync \) | 0.34 | | % |
| DP | Differential Phase | \( f = 4.43MHz, R_L = 150\Omega, Neg. Sync \) | 0.10 | | deg |

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Unless otherwise specified, all limits guaranteed for $T_J = 25^\circ C$, $V_S = \pm 5V$, $A_{V(MAX)} = 10$, $V_{CM} = 0V$, $R_F = 1k\Omega$, $R_G = 174\Omega$, $V_{IN\_DIFF} = \pm 0.1V$, $R_L = 100\Omega$, $V_G = \pm 2V$. **Boldface** limits apply at the temperature extremes.

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<th>Max (Note 6)</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GACCU</strong></td>
<td>Gain Accuracy (See Application Note)</td>
<td>$V_G = 2.0V$; $1V &lt; V_G &lt; 2V$; $V_G = 2.0V$; $1 &lt; V_G &lt; 2V$</td>
<td>0.0; $+0.6$</td>
<td>$+0.6$; $+3.1$</td>
<td>$+0.3$; $-3.6$</td>
<td>dB</td>
</tr>
<tr>
<td><strong>G Match</strong></td>
<td>Gain Matching (See Application Note)</td>
<td>$V_G = 2.0V$; $1 &lt; V_G &lt; 2V$</td>
<td>$-\pm0.6$</td>
<td>$\pm0.6$</td>
<td>$+2.8$; $-3.9$</td>
<td>dB</td>
</tr>
<tr>
<td><strong>K</strong></td>
<td>Gain Multiplier (See Application Notes)</td>
<td>1.61; 1.58; 1.72; 1.84</td>
<td>$\pm1.70$</td>
<td>$\pm2.2$</td>
<td>$\pm1.91$</td>
<td>V/V</td>
</tr>
<tr>
<td><strong>$V_{CM}$</strong></td>
<td>Input Voltage Range</td>
<td>Pin 3 &amp; 6 Common Mode, $</td>
<td>CMRR</td>
<td>&gt; 55$dB (Note 9)</td>
<td>$\pm2.0$</td>
<td>$\pm1.70$</td>
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<tr>
<td><strong>$V_{IN_DIFF}$</strong></td>
<td>Differential Input Voltage</td>
<td>Between pins 3 &amp; 6</td>
<td>$\pm0.3$; $\pm0.12$</td>
<td>$\pm0.39$</td>
<td>$\pm0.37$</td>
<td>V</td>
</tr>
<tr>
<td><strong>$I_{RG_MAX}$</strong></td>
<td>$R_G$ Current</td>
<td>Pins 4 &amp; 5</td>
<td>$\pm1.70$; $\pm1.56$</td>
<td>$\pm2.22$</td>
<td>$\pm2.20$</td>
<td>mA</td>
</tr>
<tr>
<td><strong>$I_{BIAS}$</strong></td>
<td>Bias Current</td>
<td>Pins 3 &amp; 6 (Note 7)</td>
<td>9; 18; 20</td>
<td>2.5; 5</td>
<td>6</td>
<td>mA</td>
</tr>
<tr>
<td><strong>$I_{OFF}$</strong></td>
<td>Offset Current</td>
<td>Pin 3 &amp; 6 (Note 8)</td>
<td>0.01; 2.0</td>
<td>3.6</td>
<td>$\mu$A</td>
<td></td>
</tr>
<tr>
<td><strong>$R_{IN}$</strong></td>
<td>Input Resistance</td>
<td>Pin 3 &amp; 6</td>
<td>750</td>
<td>$\Omega$</td>
<td>$\k$Ω</td>
<td></td>
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<tr>
<td><strong>$C_{IN}$</strong></td>
<td>Input Capacitance</td>
<td>Pin 3 &amp; 6</td>
<td>5</td>
<td>$\mu$F</td>
<td>$\mu$F</td>
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<tr>
<td><strong>$I_{VG}$</strong></td>
<td>$V_G$ Bias Current</td>
<td>Pin 2, $V_G = 0V$ (Note 7)</td>
<td>$-300$</td>
<td>$\mu$A</td>
<td>$\mu$A</td>
<td></td>
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<tr>
<td><strong>$TC_{I_{VG}}$</strong></td>
<td>$V_G$ Bias Drift</td>
<td>Pin 2 (Note 8)</td>
<td>20</td>
<td>nA/°C</td>
<td>nA/°C</td>
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<tr>
<td><strong>$R_{VG}$</strong></td>
<td>$V_G$ Input Resistance</td>
<td>Pin 2</td>
<td>10</td>
<td>$\k$Ω</td>
<td>$\k$Ω</td>
<td></td>
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<tr>
<td><strong>$C_{VG}$</strong></td>
<td>$V_G$ Input Capacitance</td>
<td>Pin 2</td>
<td>1.3</td>
<td>$\mu$F</td>
<td>$\mu$F</td>
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<tr>
<td><strong>$V_{OUT}$</strong></td>
<td>Output Voltage Range</td>
<td>$R_L = 100\Omega$; $R_L = \text{Open}$</td>
<td>$\pm3.00$; $\pm3.95$</td>
<td>$\pm3.20$; $\pm3.82$</td>
<td>$\pm4.00$</td>
<td>V</td>
</tr>
<tr>
<td><strong>$R_{OUT}$</strong></td>
<td>Output Impedance</td>
<td>DC</td>
<td>0.1</td>
<td>$\Omega$</td>
<td>$\Omega$</td>
<td></td>
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<tr>
<td><strong>$I_{OUT}$</strong></td>
<td>Output Current</td>
<td>$V_{OUT} = \pm 4V$ from Rails</td>
<td>$\pm80$</td>
<td>$\pm90$</td>
<td>$\pm90$</td>
<td>mA</td>
</tr>
<tr>
<td><strong>$V_{O_OFFSET}$</strong></td>
<td>Output Offset Voltage</td>
<td>$0V &lt; V_G &lt; 2V$</td>
<td>$\pm80$; $\pm300$</td>
<td>$\pm380$</td>
<td>$\pm380$</td>
<td>mV</td>
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<tr>
<td><strong>$+PSRR$</strong></td>
<td>+Power Supply Rejection Ratio (Note 10)</td>
<td>Input Referred, $1V$ change, $V_G = 2.2V$</td>
<td>$-69$</td>
<td>$-47$</td>
<td>$-45$</td>
<td>dB</td>
</tr>
<tr>
<td><strong>$-PSRR$</strong></td>
<td>–Power Supply Rejection Ratio (Note 10)</td>
<td>Input Referred, $1V$ change, $V_G = 2.2V$</td>
<td>$-58$</td>
<td>$-41$</td>
<td>$-40$</td>
<td>dB</td>
</tr>
<tr>
<td><strong>CMRR</strong></td>
<td>Common Mode Rejection Ratio (Note 9)</td>
<td>Input Referred, $V_G = 2V$; $V_G = 1.8V$</td>
<td>$-72$</td>
<td>$-72$</td>
<td>$-72$</td>
<td>dB</td>
</tr>
<tr>
<td><strong>$I_S$</strong></td>
<td>Supply Current</td>
<td>No Load</td>
<td>27; 38</td>
<td>38; 41</td>
<td>38; 41</td>
<td>mA</td>
</tr>
</tbody>
</table>

| $V_S$ | $\pm 2.5V$, $R_L = \text{Open}$ | 9.3 | 16 | 19 | |
Electrical Characteristics (Note 2) (Continued)

Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is intended to be functional, but specific performance is not guaranteed. For guaranteed specifications, see the Electrical Characteristics tables.

Note 2: Electrical Table values apply only for factory testing conditions at the temperature indicated. Factory testing conditions result in very limited self-heating of the device such that T_J = T_A. No guarantee of parametric performance is indicated in the electrical tables under conditions of internal self-heating where T_J > T_A.

Note 3: The maximum output current (I_OUT) is determined by device power dissipation limitations or value specified, whichever is lower.

Note 4: Human body model: 1.5kΩ in series with 100pF. Machine model: 0Ω in series with 200pF.

Note 5: Slew Rate is the average of the rising and falling rates.

Note 6: Typical values represent the most likely parametric norm. Bold numbers refer to over temperature limits.

Note 7: Positive current corresponds to current flowing in the device.

Note 8: Drift determined by dividing the change in parameter distribution average at temperature extremes by the total temperature change.

Note 9: CMRR definition: \( |\Delta V_{OUT}/\Delta V_{CM}|/AV \) with 0.1V differential input voltage.

Note 10: +PSRR definition: \( |\Delta V_{OUT}/\Delta V^+|/AV \), −PSRR definition: \( |\Delta V_{OUT}/\Delta V^-|/AV \) with 0.1V differential input voltage.

Note 11: Gain/Phase normalized to low frequency value at 25°C.

Note 12: Gain/Phase normalized to low frequency value at each AV.

Note 13: Gain Control Frequency Response Schematic:

Note 14: Flat Band Attenuation (Relative to Max Gain) Range Definition: Specified as the attenuation range from maximum which allows gain flatness specified (either ±0.2dB or ±0.1dB) relative to AV_MAX gain. For example, for f < 30MHz, here are the Flat Band Attenuation ranges:

- ±0.2dB 20dB down to 4dB = 16dB range
- ±0.1dB 20dB down to 12.5 dB = 7.5dB range

Connection Diagram

Ordering Information

<table>
<thead>
<tr>
<th>Package</th>
<th>Part Number</th>
<th>Package Marking</th>
<th>Transport Media</th>
<th>NSC Drawing</th>
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</thead>
<tbody>
<tr>
<td>14-pin SOIC</td>
<td>LMH6502MA</td>
<td>LMH6502MA</td>
<td>55 Units/Rail</td>
<td>M14A</td>
</tr>
<tr>
<td></td>
<td>LMH6502MAX</td>
<td></td>
<td>2.5k Units Tape and Reel</td>
<td></td>
</tr>
<tr>
<td>14-Pin TSSOP</td>
<td>LMH6502MT</td>
<td>LMH6502MT</td>
<td>94 Units/Rail</td>
<td>MTC14</td>
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<tr>
<td></td>
<td>LMH6502MTX</td>
<td></td>
<td>2.5k Units Tape and Reel</td>
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</tbody>
</table>
Typical Performance Characteristics  Unless otherwise specified: $V_S = \pm 5\text{V}$, $25^\circ\text{C}$, $V_G = V_{G\text{MAX}}$. $V_{CM} = 0\text{V}$, $R_F = 1\text{k}\Omega$, $R_G = 174\Omega$, both inputs terminated in $50\Omega$, $R_L = 100\Omega$. Typical values, results referred to device output.
Typical Performance Characteristics

Unless otherwise specified: $V_S = \pm 5V$, 25$^\circ$C, $V_G = V_{G\text{MAX}}$, $V_{CM} = 0V$, $R_F = 1\,\text{k}\Omega$, $R_G = 174\,\Omega$, both inputs terminated in 50$\Omega$, $R_L = 100\,\Omega$, Typical values, results referred to device output. (Continued)

Large Signal Frequency Response for Various $A_{V\text{MAX}}$

Frequency Response for Various $V_G$ ($A_{V\text{MAX}} = 100$) (Small Signal)

Frequency Response for Various $V_G$ ($A_{V\text{MAX}} = 100$) (Large Signal)

$I_S$ vs. $V_S$

Input Bias Current vs. $V_S$
Typical Performance Characteristics

Unless otherwise specified: $V_S = \pm 5V$, $25^\circ C$, $V_G = V_{G_{MAX}}$, $V_{CM} = 0V$, $R_F = 1\, k\Omega$, $R_G = 174\, \Omega$, both inputs terminated in $50\, \Omega$, $R_L = 100\, \Omega$. Typical values, results referred to device output. (Continued)

- $A_{VMAX}$ vs. $V_{CM}$
- PSRR ±5V
- CMRR ±5V
- $A_{VMAX}$ vs. $V_{CM}$
- PSRR ±2.5V
- CMRR ±2.5V
Typical Performance Characteristics

Unless otherwise specified: $V_S = \pm 5\,\text{V}$, $25\,\text{°C}$, $V_G = V_{G\text{MAX}}$, $V_{CM} = 0\,\text{V}$, $R_F = 1\,k\Omega$, $R_G = 174\,\Omega$, both inputs terminated in $50\,\Omega$, $R_L = 100\,\Omega$, Typical values, results referred to device output. (Continued)
Typical Performance Characteristics

Unless otherwise specified: $V_S = \pm 5V$, $25^\circ C$, $V_G = V_{\text{GMAX}}$, $V_{\text{CM}} = 0V$, $R_F = 1k\Omega$, $R_G = 174\Omega$, both inputs terminated in $50\Omega$, $R_L = 100\Omega$, Typical values, results referred to device output. (Continued)
Typical Performance Characteristics  Unless otherwise specified: $V_S = \pm 5V$, $25^\circ C$, $V_G = V_{GMAX}$, $V_{CM} = 0V$, $R_F = 1k\Omega$, $R_G = 174\Omega$, both inputs terminated in $50\Omega$, $R_L = 100\Omega$. Typical values, results referred to device output. (Continued)
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Typical Performance Characteristics

Unless otherwise specified: $V_S = \pm 5V$, $25^\circ C$, $V_G = V_{GMAX}$, $V_{CM} = 0V$, $R_F = 1k\Omega$, $R_G = 174\Omega$, both inputs terminated in 50$\Omega$, $R_L = 100\Omega$, Typical values, results referred to device output. (Continued)
Typical Performance Characteristics

Unless otherwise specified: $V_S = \pm 5V$, $25^\circ C$, $V_G = V_{G_{MAX}}$, $V_{CM} = 0V$, $R_F = 1k\Omega$, $R_G = 174\Omega$, both inputs terminated in $50\Omega$, $R_L = 100\Omega$, Typical values, results referred to device output. (Continued)

THD vs. $V_G$

- $0.25V_{PP}$
- $1V_{PP}$
- $2V_{PP}$

$f = 1MHz$

0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 $V_G$ (V)

THD vs. $V_G$

- $0.25V_{PP}$
- $1V_{PP}$
- $2V_{PP}$

$f = 20MHz$

0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 $V_G$ (V)

$V_G$ Bias Current vs. $V_G$

-350
-250
-150
-50

0 0.5 1 1.5 2 2.5 $V_G$ (V)

Step Response Plot

- $0.5V_{PP}$ SMALL SIGNAL
- SS REF
- LS REF
- $5V_{PP}$ LARGE SIGNAL

4 ns/DIV

Gain vs. $V_G$ Step

$V_G = V_{G_{MAX}}$

$V_{IN} = 0.3V$

$A_{V_{MAX}} = 10$

$R_F = 100\Omega$

$V_G$ Stepped From 0.6V To 1.6V

GAIN vs. $V_G$

0 1 1.5 2 3 4 5 6 7 8 9 10

4 ns/DIV
Typical Performance Characteristics

Unless otherwise specified: $V_S = \pm 5V$, $25^\circ\text{C}$, $V_G = V_{G\text{MAX}}$, $V_{CM} = 0V$, $R_F = 1k\Omega$, $R_G = 174\Omega$, both inputs terminated in $50\Omega$, $R_L = 100\Omega$, Typical values, results referred to device output. (Continued)

Feedthrough from $V_G$

Application Information

THEORY OF OPERATION

A simplified schematic is shown in Figure 1. $+V_{IN}$ and $-V_{IN}$ are buffered with closed loop voltage followers inducing a signal current in $R_G$ proportional to $(+V_{IN}) - (-V_{IN})$, the differential input voltage. This current controls a current source which supplies two well-matched transistor, $Q_1$ and $Q_2$. The current flowing through $Q_2$ is converted to the final output voltage using $R_F$ and the output amplifier, $U_1$. By changing the fraction of the signal current "I" which flows through $Q_2$, the gain is changed. This is done by changing the voltage applied differentially to the bases of $Q_1$ and $Q_2$. For example, with $V_G = 0V$, $Q_1$ conducts heavily and $Q_2$ is off. With none of "I" flowing through $R_F$, the LMH6502's input to output gain is strongly attenuated. With $V_G = +2V$, $Q_1$ is off and the entire signal current flows through $Q_2$ to $R_F$ producing maximum gain. With $V_G$ set to $1V$, the bases of $Q_1$ and $Q_2$ are set to approximately the same voltage, $Q_1$ and $Q_2$ have the same collector currents - equal to one half of the signal current "I", thus the gain is approximately one half the maximum gain.

CHOOSING $R_F$ & $R_G$

Maximum input amplitude and maximum gain are the two key specifications that determine component values in a LMH6502 application. The output stage op amp is a current-feedback type amplifier optimized for $R_F = 1k\Omega$. $R_G$ can then be computed as:

$$R_G = \frac{R_F}{A_{V\text{MAX}}} - 3\Omega \text{ WITH } R_F = 1k\Omega$$

To determine whether the maximum input amplitude will overdrive the LMH6502, compute:

$$V_{DMAX} = (R_G + 3.0\Omega) \times 1.70mA$$

the maximum differential input voltage for linear operation. If the maximum input amplitude exceeds the above $V_{DMAX}$ limit, then LMH6502 should either be moved to a location in the signal chain where input amplitudes are reduced, or the LMH6502 gain $A_{V\text{MAX}}$ should be reduced or the values for $R_G$ and $R_F$ should be increased. The overall system performance impact is different based on the choice made. If the input amplitude is reduced, re-compute the impact on signal-to-noise ratio. If $A_{V\text{MAX}}$ is reduced, post LMH6502 amplifier gain, should be increased, or another gain stage added to make up for reduced system gain. To increase $R_G$ and $R_F$, compute the lowest acceptable value for $R_G$:

$$R_G > 590 \times V_{DMAX} - 3\Omega$$

Operating with $R_G$ larger than this value insures linear operation of the input buffers. $R_F$ may be computed from selected $R_G$ and $A_{V\text{MAX}}$: $R_F$ should be $\geq 1k\Omega$ for overall best performance, however $R_F < 1k\Omega$ can be implemented if necessary using a loop gain reducing resistor to ground on the inverting summing node of the output amplifier (see application note QA-13 for details).

ADJUSTING OFFSET

Offset can be broken into two parts; an input-referred term and an output-referred term. The input-referred offset shows up as a variation in output voltage as $V_G$ is changed. This can be trimmed using the circuit in Figure 2 by placing a low frequency square wave ($V_{LOW} = 0V$, $V_{HIGH} = 2V$ into $V_G$ with

CHOOSING $R_F$ & $R_G$

Maximum input amplitude and maximum gain are the two key specifications that determine component values in a LMH6502 application. The output stage op amp is a current-feedback type amplifier optimized for $R_F = 1k\Omega$. $R_G$ can then be computed as:

$$R_G = \frac{R_F}{A_{V\text{MAX}}} - 3\Omega \text{ WITH } R_F = 1k\Omega$$

To determine whether the maximum input amplitude will overdrive the LMH6502, compute:

$$V_{DMAX} = (R_G + 3.0\Omega) \times 1.70mA$$

the maximum differential input voltage for linear operation. If the maximum input amplitude exceeds the above $V_{DMAX}$ limit, then LMH6502 should either be moved to a location in the signal chain where input amplitudes are reduced, or the LMH6502 gain $A_{V\text{MAX}}$ should be reduced or the values for $R_G$ and $R_F$ should be increased. The overall system performance impact is different based on the choice made. If the input amplitude is reduced, re-compute the impact on signal-to-noise ratio. If $A_{V\text{MAX}}$ is reduced, post LMH6502 amplifier gain, should be increased, or another gain stage added to make up for reduced system gain. To increase $R_G$ and $R_F$, compute the lowest acceptable value for $R_G$:

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Application Information (Continued)

VIN = 0V, the input referred V_{OS} term shows up as a small square wave riding a DC value. Adjust R_{10} to null the V_{OS} square wave term to zero. After adjusting the input-referred offset, adjust R_{14} (with VIN = 0, VG = 0) until V_{OUT} is zero. Finally, for inverting applications VIN may be applied to pin 6 and the offset adjustment to pin 3. These steps will minimize the output offset voltage. However, since the offset term itself varies with the gain setting, the correction is not perfect and some residual output offset will remain at in-between VG’s. Also, this offset trim does not improve output offset temperature coefficient.

NOISE

Figure 3 describes the LMH6502’s output-referred spot noise density as a function of frequency with AV_{MAX} = 10V/V. The plot includes all the noise contributing terms. However, with both inputs terminated in 50Ω, the input noise contribution is minimal. At AV_{MAX} = 10V/V, the LMH6502 has a typical input-referred spot noise density (e_{n}) of 7.7nV/√Hz flat-band. For applications extending well into the flat-band region, the input RMS voltage noise can be determined from the following single-pole model:

\[
V_{\text{RMS}} = e_{n} \sqrt{1.57 \times (\text{-3dB BANDWIDTH})}
\]

CIRCUIT LAYOUT CONSIDERATIONS & EVALUATION BOARD

A good high frequency PCB layout including ground plane construction and power supply bypassing close to the package are critical to achieving full performance. The amplifier is sensitive to stray capacitance to ground at the I− input (pin 12); keep node trace area small. Shunt capacitance across the feedback resistor should not be used to compensate for this effect. For best performance at low maximum gains (AV_{MAX} < 10) +RG and -RG connections should be treated in a similar fashion. Capacitance to ground should be minimized by removing the ground plane from under the body of RG. Parasitic or load capacitance directly on the output (pin 10) degrades phase margin leading to frequency response peaking.

The LMH6502 is fully stable when driving a 100Ω load. With reduced load (e.g. 1kΩ) there is a possibility of instability at very high frequencies beyond 400MHz especially with a capacitive load. When the LMH6502 is connected to a light load as such, it is recommended to add a snubber network to the output (e.g. 100Ω and 39pF in series tied between the LMH6502 output and ground). C_{L} can also be isolated from the output by placing a small resistor in series with the output (pin 10).

Component parasitics also influence high frequency results. Therefore it is recommended to use metal film resistors such as RN55D or leadless components such as surface mount devices. High profile sockets are not recommended.
Application Information  (Continued)

National Semiconductor suggests the following evaluation boards as a guide for high frequency layout and as an aid in device testing and characterization:

<table>
<thead>
<tr>
<th>Device</th>
<th>Package</th>
<th>Evaluation Board Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>LMH6502MA</td>
<td>SOIC-14</td>
<td>CLC730033</td>
</tr>
<tr>
<td>LMH6502MT</td>
<td>TSSOP-14</td>
<td>CLC730146</td>
</tr>
</tbody>
</table>

The evaluation board is shipped when a device sample request is placed with National Semiconductor

SINGLE SUPPLY OPERATION

It is possible to operate the LMH6502 with a single supply. To do so, tie pin 11 (GND) to a potential about mid point between V+ and V−. Two examples are shown in Figure 4 & Figure 5.

OPERATING AT LOWER SUPPLY VOLTAGES

The LMH6502 is rated for operation down to 5V supplies (V+ - V−). There are some specifications shown for operation at ±2.5V within the data sheet (i.e. Frequency Response, CMRR, PSRR, Gain vs. VGS, etc.). Compared to ±5V operation, at lower supplies:

a) VGS range shifts lower.

Here are the approximate expressions for various VGS voltages as a function of V+:

<table>
<thead>
<tr>
<th>VGS Definition</th>
<th>Expression (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VGS_MIN</td>
<td>0.2 x V+ - 1</td>
</tr>
<tr>
<td>VGS_MID</td>
<td>VMAX/2</td>
</tr>
<tr>
<td>VGS_MAX</td>
<td>VMAX</td>
</tr>
</tbody>
</table>

b) VGS_LIMIT (maximum permissible voltage on VGS) is reduced. This is due to limitations within the device arising from transistor headroom. Beyond this limit, device performance will be affected (non-destructive). This could reveal itself as premature high frequency response rolloff. With ±2.5V supplies, VGS_LIMIT is below 1.1V whereas VGS = 1.5V is needed to get maximum gain. This means that operating under these conditions has reduced the maximum permissible voltage on VGS to a level below what is needed to get Max gain. If supply voltages are asymmetrical with V+ being lower, further "pinching" of VGS range could result; for example, with V+ = 2V, and V− = -3V, VGS_LIMIT = 0.40V which results in maximum gain being 2.5dB less than what would be expected when VGS is higher.

c) "Max_gain" reduces. There is an intrinsic reduction in max gain when the total supply voltage is reduced (see Typical Performance Characteristics plots for Gain vs. VGS (VSS = ±2.5V). In addition, there is the more drastic mechanism described in "b" above. Beyond VGS_LIMIT, high frequency response is also affected.

Application Circuits

AGC LOOP

Figure 6 shows a typical AGC circuit. The LMH6502 is followed up with a LMH6714 for higher overall gain. The output of the LMH6714 is rectified and fed to an inverting integrator using a LMH6657 (wideband voltage feedback op amp). When the output voltage, VOUT, is too large the integrator output voltage ramps down reducing the net gain of the LMH6502 and VOUT. If the output voltage is too small, the integrator ramps up increasing the net gain and the output voltage. Actual output level is set with R1. To prevent shifts in DC output voltage with DC changes in input signal level, trim pot R2 is provided. AGC circuits are always limited in the range of input signals over which constant output level can be maintained. In this circuit, we would expect that reasonable AGC action could be maintained for at least 40dB. In practice, rectifier dynamic range limits reduce this slightly.
FREQUENCY SHAPING

Frequency shaping and bandwidth extension of the LMH6502 can be accomplished using parallel networks connected across the \( R_{\text{G}} \) ports. The network shown in the Figure 7 schematic will effectively extend the LMH6502’s bandwidth.
Physical Dimensions  
inches (millimeters) unless otherwise noted

14-Pin SOIC  
NS Package Number M14A

14-Pin TSSOP  
NS Package Number MTC14
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2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

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