THAT Corporation

Department [Blank]
Subject More Analog Secrets Your Mother Never Told You
Name THAT Corporation
Address 127th AES Convention New York, Oct 2009
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New! THAT1570 Spec Summary

- **Low Noise:**
  - 1 nV/√Hz EIN (60 dB gain)
  - 134.8 dBu (20kHz BW)
  - 18.5 nV/√Hz EIN (0 dB gain)
  - 109.4 dBu (20kHz BW)
- **Low THD+N:**
  - 0.0003% <30 dB gain
  - 0.0008% @ 40 dB gain
- **Low Current:** 7.5 mA typ
- **Wide BW:** 4.2MHz @ 40 dB gain
- **High Slew Rate:** 53 V/μs
- **Wide Signal Swing:** >28.7 dBu (±18V supplies)
- **Gain adjustable from 0 to > 60 dB**
- **Differential output**
- **Small 4 x 4 mm QFN16 package**
THAT1570 Features

• External $R_F$ ($R_A$ and $R_B$) allows impedances to be optimized
• Lowest noise monolithic audio preamp available today
• Extremely high dynamic range:
  - 127dB (0dB gain, ±18V supplies)
  - 103dB (60dB gain, ±18V supplies)
• Tiny 4x4mm QFN16 package
THAT1570 Basic Circuit

- $G_{\text{DIFF}} = 1 + \frac{(R_A + R_B)}{R_G}$
- $G_{\text{COMMON-MODE}} = 1$

- $Z_{\text{IN}}$ (Differential) = 2kΩ
- Set by R1 & R2

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THAT1570 Improved Circuit

- Dual-gang pot reduces low-gain noise by reducing $R_A$ and $R_B$ while increasing $R_G$

- But... DC coupling is impractical
- Offset change with gain
- Wipers losing contact with pot tracks

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AC-Coupling $R_G$ Addresses DC Offset

- $C_G$ sets DC gain to unity
- Causes LF rolloff
  - Worst at highest gain
- $C_G = \frac{1}{(2\pi \times R_{GF} \times f_{-3dB})}$
- Note larger resistor values, which helps keep $C_G$ down.

![Diagram of AC-coupling circuit](image)
AC-Coupling In Dual-Gang Circuit

- $C_G$ sets DC gain to unity
- $C_G = 1 / (2\pi \times R_{GF} \times f_{-3\text{dB}})$
- Sets output DC offset constant

![Circuit Diagram]
"Real" Microphone Preamp Circuit
Phantom Power Switching

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Phantom Power Switching

**TYPE A**
- R1 and R2 always in circuit
- Maintains constant $Z_{IN}$
- Differential $Z_{IN}$ is $R1+R2||R8+R9$

**TYPE B**
- Higher $Z_{IN}$ when phantom is off
  - R8+R9 only
- Useful when one mic feeds >1 preamp
- Longer discharge time constant

**TYPE C**
- Same $Z_{IN}$ as Type B, but
- Burns more power
- Shorter discharge time

**Related Diagrams**

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Phantom Power Start-up

- The phantom power-on transient (0 to +48V) is divided by input bias resistors R8 & R9 (1k2) working against R1 & R2 (6k81).
- The inputs jump by ~ 7.2V, which won't damage the 1570.
- But, it's a pretty big thump, so muting when phantom turns on is appropriate.
Phantom Power Protection

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Phantom Power Faults

• Shorting input pins with phantom turned on
  - C1 & C2 start charged to 48V
  - Positive end of C1, C2 connect to ground
  - Negative end of C1, C2 driven to -48V!

• The shorting sequence can vary
  - “Single-ended”: One input to ground
  - “Common-mode”: both inputs to ground simultaneously
  - “Differential: One input to ground, then the other
  - Differential is worst

• Big currents flow as C1, C2 discharge
  - Currents over 3 amperes flow in the capacitors

• See “Phantom Menace Returns”: Sunday 12:30pm, Session P12
Phantom Faults: How Bad Can It Be?

- Green LEDs on XLR
  - Create phantom fault
  - Indicate magnitude of current
- Red LED on positive supply
  - Mounted to circuit board
  - Monitors supply voltage

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Phantom Power Fault Voltage

Voltage waveform at IC inputs during a common-mode fault.
Note -48V peak!
Phantom Power Fault Current

The current flows through the IC and out the negative supply pin. It can easily exceed 3 Amperes!
Protecting Against Phantom Power Faults

- Limit the current with small resistors
  - Can increase high-gain noise
- Steer the current around the IC
  - Input diodes steer current away from internal protect diodes
    - This current varies with gain setting
  - Diode bridge dumps current to rails
- Consider impact on supply rails
  - Minimize transient with capacitance
  - Isolate preamp rails from others
Phantom Fault Current Limiting

- R6 and R7 limit the current
- @10Ω, current is ~2.4A
- Higher R increases noise at high gains
Phantom Power Protection

- D3 and D4 route current around the IC's input protection diodes
- Current path is through $R_G$
  - Worst-case is high gain (low $R_G$)
Phantom Power Protection

- Bridge steers current to the supply rails (mostly negative side)
- Results in transient overload on Vee
Phantom Power Protection

- $C_{\text{PROT}}$ absorbs transient
  - Must be large to be significant
- D1 and D2 isolate preamp rails from other circuitry
Microphone Input Pads

- Pad allows preamp to accept larger inputs
- Needed if input signal will exceed supply rails
- 20dB pad shown allows ~40dBu inputs!
Microphone Input Pads

- U-pad design for constant input impedance
  - Same $Z_{IN}$ with pad as without: $\sim 2k\Omega$
  - U-pad prevents degrading CMR
- 20 dB attenuation shown
  - 20 dB more headroom
  - Other levels are possible
- Little sacrifice to noise floor and dynamic range
  - Better noise, less headroom with less attenuation
- Maintains low source impedance to IC inputs $\sim 240\Omega$
  - 1570, 1512, & 1510 are optimized for low noise with low source impedances
RFI Protection

- RFI protection is required in any practical design
RFI Protection

- \( C_{\text{RFI1}} \) and \( C_{\text{RFI2}} \) stop RF at the enclosure input
- Must be located right at the input connector
- Affects differential and common-mode RFI

- \( C_{\text{RFI3}} \) reduces differential RFI
- Affects incoming and internally generated RFI:
  - Clocks
  - Switching power supplies
  - Other digital signals
- Should be located right at the IC input pins
## Line Inputs

- **Should have higher $Z_{IN}$ than Mic inputs**
  - $\geq 10k\Omega$?
  - Can switch, use combo connector, or let user select between two connectors
- **For variable gain**
  - Can use mic preamp to control gain
  - Pad input and increase $Z_{IN}$
  - Attenuation and $Z_{IN}$ are related
- **For fixed gain**
  - Can switch after mic preamp
Variable-Gain Line Inputs

- R12 & R13 form an “L-pad” attenuator with R8 & R9
- Zin = R12+R13+R8+R9 || R25+R26 = 20k
- 20dB attenuation shown

- L-pad attenuation differs with source
  - Differential vs single ended
- CMR depends on resistor matching

- Switch keeps phantom away from line inputs
- Is AC-coupling needed for switch?
  - Prevents switching “pops”
### Variable-Gain Line Input Performance

Specs for the proposed LINE input, 20 dB attenuation, $R_{12} \& R_{13} = 11 \, k\Omega$, $Z_{in} = 20 \, k\Omega$ ($R_A = R_B = 2.21 \, k\Omega$)

<table>
<thead>
<tr>
<th>System Gain (dB)</th>
<th>IC Preamp Gain (dB)</th>
<th>RG (Ω)</th>
<th>Maximum Input Signal (dBu)</th>
<th>Input Referred Noise (dBu)</th>
<th>Dynamic Range (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>20</td>
<td>487</td>
<td>26.6</td>
<td>-96.7</td>
<td>123.3</td>
</tr>
<tr>
<td>-3</td>
<td>17</td>
<td>732</td>
<td>29.6</td>
<td>-96.2</td>
<td>125.8</td>
</tr>
<tr>
<td>-6</td>
<td>14</td>
<td>1,100</td>
<td>32.6</td>
<td>-95.5</td>
<td>128.1</td>
</tr>
</tbody>
</table>

Specs for the proposed LINE input, 12 dB attenuation, $R_{12} \& R_{13} = 3.57 \, k\Omega$, $Z_{in} = 10 \, k\Omega$ ($R_A = R_B = 2.21 \, k\Omega$)

<table>
<thead>
<tr>
<th>System Gain (dB)</th>
<th>IC Preamp Gain (dB)</th>
<th>RG (Ω)</th>
<th>Maximum Input Signal (dBu)</th>
<th>Input Referred Noise (dBu)</th>
<th>Dynamic Range (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>12</td>
<td>1,470</td>
<td>26.6</td>
<td>-103.6</td>
<td>130.2</td>
</tr>
<tr>
<td>-3</td>
<td>9</td>
<td>2,430</td>
<td>29.6</td>
<td>-102.3</td>
<td>131.9</td>
</tr>
<tr>
<td>-6</td>
<td>6</td>
<td>4,420</td>
<td>32.6</td>
<td>-100.7</td>
<td>133.3</td>
</tr>
</tbody>
</table>
Variable-Gain Line In with Combo Connector

- “Combo” connectors don’t need MIC/LINE switching
- Same 20 dB attenuation (different R12 and R13)
- TYPE A phantom switch should be used
- CMR depends on resistor ratio matching
Fixed-Gain Line In

- 6 dB attenuation (1246)
- Requires coupling capacitors (C3, C4, C8, and C9)
- Great CMR (1246)
Output Stages

- Differential mic amp (1570) has unity common-mode gain
- Common-Mode Rejection = differential gain
  - 0dB CMR @ 0dB gain
  - 60dB CMR @ 60dB gain
- Output stage must provide CMR
- Tight component match will be important
Output Stages (Single Ended)

- One-part solutions
  - THAT1246 (dual: 1286) - Great common-mode rejection (~90 dB)
  - THAT1256 (dual: 1296) - Good common-mode rejection (~50 dB)
  - System gain is 0 dB with +6 dB preamp gain
    (-6 dB with 0 dB preamp gain)
- Adds ~8 dB to the 1570 noise at minimum (-6 dB) gain
  ($R_A = R_B = 2.2 \, \Omega$; $R_G$ = open)
- Added noise drops with gain: adds ~4 dB noise at 0 dB gain

![Diagram of output stages](image-url)
Output Stages (Single-Ended)

- To match 1570 noise, must use (much!) quieter opamp and (very) low-value resistors
- 5532 (single: 5534) or 2114 (both duals) are good choices
- -5.6 dB gain shown matches 1570/5171 minimum preamp gain
- The 2114 adds ~2.5 dB to the 1570 noise floor with 0dB system gain
  - Additional noise is negligible for gains above ~7.5 dB
- CMR will be limited compared to 1240/1250/1280/1290 options
  - 54 dB minimum, with 0.1% resistors
  - 34 dB minimum, with 1% resistors
Output Stages (Differential)

- Good (1296) to great (1286) CMR
- 1286/1296 can drive loads below ~2 kΩ
- Compromises noise at low gains (like 1240/1250)
- Provides Vcm input for driving A/D converters
  - To maintain high CMR, ensure Vcm is driven by low source impedance
  - Requires low-Z attenuator between the 1268/1296 and the ADC input (optimizes noise & headroom)
Output Stages (Differential)

- Again, quieter opamp and low-value resistors better matches 1570 noise
- 5532 or 2114 (both duals) are good choices
- -5.6 dB gain shown matches 1570/5171 minimum preamp gain
- Same added noise as single-ended circuits
  - ~+2.5 dB with 0dB system gain
  - Additional noise is negligible for gains above ~7.5 dB
  - Noise of second 2114 is all common-mode
- CMR will be limited compared to 1280/1290 options
  - 54 dB minimum, with 0.1% resistors
  - 34 dB minimum, with 1% resistors
- Vcm doesn’t require buffer
- \( C_5 = C_6 \gg C_7 \) for outstanding transient response

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## Comparing THAT Analog Mic Preamps

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<th>1570</th>
<th>1512</th>
<th>1510</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vcc/Vee, max</strong></td>
<td>±18</td>
<td>±20</td>
<td>±20</td>
</tr>
<tr>
<td><strong>Icc/Iee, typ</strong></td>
<td>±7.5</td>
<td>±6.0</td>
<td>±6.0</td>
</tr>
<tr>
<td><strong>Vinmax</strong></td>
<td>28.7</td>
<td>30.3</td>
<td>24.3</td>
</tr>
<tr>
<td><strong>BW, 40 dB gain</strong></td>
<td>4.2</td>
<td>7.0</td>
<td>7.0</td>
</tr>
<tr>
<td><strong>Slew Rate, typ</strong></td>
<td>53</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td><strong>THD+N, &lt;30 dB</strong></td>
<td>0.0003</td>
<td>0.004</td>
<td>0.0012</td>
</tr>
<tr>
<td><strong>EIN, 60dB gain</strong></td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>EIN, 0 dB gain</strong></td>
<td>18.5</td>
<td>34</td>
<td>57</td>
</tr>
<tr>
<td><strong>Gain Range</strong></td>
<td>0 to +70</td>
<td>-6 to 64</td>
<td>0 to +70</td>
</tr>
<tr>
<td><strong>Gain Equation</strong></td>
<td>$1 + \frac{(R_A + R_B)}{R_G}$</td>
<td>$0.5 + \frac{5 , k\Omega}{R_G}$</td>
<td>$1 + \frac{10 , k\Omega}{R_G}$</td>
</tr>
<tr>
<td><strong>Output</strong></td>
<td>Differential</td>
<td>Single-ended</td>
<td>Single-ended</td>
</tr>
</tbody>
</table>

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Conclusions

- THAT 1570 is the quietest mic preamp
- External Rf resistors and differential output expand possibilities
- Real-world use requires extra protection to the IC
- Perfect match to the THAT 5171
- Look forward to DN140! Will be soon available for download!
Bonus: THAT Corp Legendary Support

- THAT is focused on ICs for pro audio
- THAT engineers have many decades experience in pro audio
- THAT routinely advises customers on design/PCB layout.
- Please let us help you!
More Information

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