**General Description**

The MAX3801 is a +3.3V adaptive cable equalizer designed for coaxial and twin-axial cable point-to-point communications applications. The equalizer includes differential CML data inputs and outputs, a loss-of-signal (LOS) output, and a cable integrity monitor (CIM) output.

The adaptive cable equalizer is capable of equalizing differential or single-ended signals at data rates up to 3.2Gbps. It automatically adjusts to attenuation caused by skin-effect losses of up to 30dB at 1.6GHz. The equalizer effectively extends the usable length of copper cable in high-frequency interconnect applications.

The MAX3801 is available in a 24-pin QFN package with exposed pad and consumes only 125mW at +3.3V.

**Applications**

- High-Speed Links in Communications and Data Systems
- Backplane and Interconnect Applications
- SDH/SONET Transmission Equipment

**Features**

- Single +3.3V Operation
- Typical Power Dissipation = 125mW at +3.3V
- Data Rates Up to 3.2Gbps
- Equalizer Automatically Adjusts for Different Cable Lengths
- 0dB to 30dB Equalization at 1.6GHz (3.2Gbps)
- Loss-of-Signal (LOS) Indicator
- Cable Integrity Monitor (CIM)
- On-Chip Input and Output Terminations
- Low External Component Count
- Operating Temperature Range = 0°C to +85°C
- ESD Protection on Inputs and Outputs

**Ordering Information**

<table>
<thead>
<tr>
<th>PART</th>
<th>TEMP RANGE</th>
<th>PIN PACKAGE</th>
<th>PACKAGE CODE</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAX3801UGG</td>
<td>0°C to +85°C</td>
<td>24 QFN</td>
<td>G2444-1</td>
</tr>
<tr>
<td>MAX3801UTG</td>
<td>0°C to +85°C</td>
<td>24 Thin QFN</td>
<td>T2444-2</td>
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<tr>
<td>MAX3801UTG+</td>
<td>0°C to +85°C</td>
<td>24 Thin QFN</td>
<td>T2444-2</td>
</tr>
</tbody>
</table>

*Denotes lead-free package.

Pin Configuration appears at end of data sheet.

**Typical Application Circuit**

![Typical Application Circuit Diagram]

*This symbol indicates a controlled-impedance transmission line.*
3.2Gbps Adaptive Equalizer

ABSOLUTE MAXIMUM RATINGS

Supply Voltage, VCC .............................................. -0.5V to +6.0V
Voltage at LOS, CIM+, CIM- .............................. -0.5V to (VCC + 0.5V)
Voltage at EIN+, EIN- .............................. (VCC - 1V) to (VCC + 0.5V)
Current Out of EOUT+, EOUT- .............................. 25mA
Continuous Power Dissipation (TA = +85°C) 24-Lead QFN-EP (derate 25.1mW/°C above +85°C) .1630mW

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.

DC ELECTRICAL CHARACTERISTICS

(VCC = +3.14V to +3.46V, TA = 0°C to +85°C. Typical values are at VCC = +3.3V and TA = +25°C, unless otherwise noted.)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SYMBOL</th>
<th>CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Current</td>
<td>ICC</td>
<td>Includes external load current</td>
<td>37</td>
<td>60</td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td>INPUT SPECIFICATIONS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum Cable Input (Differential)</td>
<td>3.2Gbps, 30dB cable loss at 1.6GHz (Note 1)</td>
<td>650</td>
<td>700</td>
<td>MVp-P</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum Cable Input (Differential)</td>
<td></td>
<td>1100</td>
<td></td>
<td>MVp-P</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input Impedance</td>
<td></td>
<td>Single-ended</td>
<td>40</td>
<td>53</td>
<td>62.5</td>
<td>Ω</td>
</tr>
<tr>
<td>OUTPUT SPECIFICATIONS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output Voltage (Differential)</td>
<td></td>
<td>(Note 2)</td>
<td>500</td>
<td>1000</td>
<td>MVp-P</td>
<td></td>
</tr>
<tr>
<td>Output Impedance</td>
<td></td>
<td>Single-ended</td>
<td>50</td>
<td>65</td>
<td>75</td>
<td>Ω</td>
</tr>
<tr>
<td>Voltage at CIM Output (Differential)</td>
<td>VCIM</td>
<td>No external load, VCIM = (VCIM+) - (VCIM-)</td>
<td>-0.5</td>
<td>+0.5</td>
<td>Vp-P</td>
<td></td>
</tr>
<tr>
<td>Voltage at CIM Output (Single-Ended)</td>
<td>VCIM+, VCIM-</td>
<td>No external load</td>
<td>0.5</td>
<td>VCC - 0.5</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Voltage at LOS</td>
<td></td>
<td>Output high (Note 3)</td>
<td>2.4</td>
<td></td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Output low (Note 3)</td>
<td></td>
<td>Output low (Note 3)</td>
<td>0.4</td>
<td></td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Output Common-Mode Voltage</td>
<td></td>
<td>Each output DC-coupled 50Ω to VCC</td>
<td>VCC - 0.2</td>
<td>V</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# 3.2Gbps Adaptive Equalizer

## AC ELECTRICAL CHARACTERISTICS

(VCC = +3.14V to +3.46V, TA = 0°C to +85°C. Typical values are at VCC = +3.3V and TA = +25°C, unless otherwise noted.) (Note 4)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SYMBOL</th>
<th>CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Input Data Rate</td>
<td></td>
<td></td>
<td>3.2</td>
<td></td>
<td></td>
<td>Gbps</td>
</tr>
<tr>
<td>Residual Jitter (Note 5)</td>
<td></td>
<td>0dB cable loss (Note 6)</td>
<td>120</td>
<td>240</td>
<td></td>
<td>mUIp-P</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24dB cable loss (Note 6)</td>
<td>140</td>
<td>240</td>
<td></td>
<td>mUIp-P</td>
</tr>
<tr>
<td></td>
<td></td>
<td>30dB cable loss (Note 6)</td>
<td>100</td>
<td>200</td>
<td></td>
<td>mUIp-P</td>
</tr>
<tr>
<td>Output Edge Speed</td>
<td></td>
<td>20% to 80%</td>
<td>64</td>
<td>90</td>
<td></td>
<td>ps</td>
</tr>
<tr>
<td>Input Return Loss (Single-Ended)</td>
<td></td>
<td>≤3.2GHz</td>
<td>15</td>
<td></td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td>Output Return Loss (Single-Ended)</td>
<td></td>
<td>≤3.2GHz</td>
<td>15</td>
<td></td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td>Equalization Compensation</td>
<td></td>
<td>1.6GHz (skin-effect losses only)</td>
<td>30</td>
<td></td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td>Equalization Time Constant</td>
<td></td>
<td></td>
<td>5</td>
<td></td>
<td></td>
<td>µs</td>
</tr>
</tbody>
</table>

**Note 1:** Minimum cable input for LOS to assert high.
**Note 2:** Input voltage within specification limits, 50Ω to VCC at each output.
**Note 3:** 100kΩ load to ground.
**Note 4:** AC electrical characteristics are guaranteed by design and characterization.
**Note 5:** Includes random jitter and deterministic jitter.
**Note 6:** Differential cable input voltage = 700mVP-P, 3.2Gbps 2^13 - 1PRBS with 100 consecutive ones and 100 consecutive zeros substituted. Cable loss is due to skin effect only.
3.2Gbps Adaptive Equalizer

Typical Operating Characteristics

(Vcc = +3.3V, all jitter measurements done at 3.2Gbps, 700mV cable input with 2¹³–1 PRBS pattern with 100 consecutive ones and 100 consecutive zeros substituted, Ta = +25°C. Note: Test pattern produces near worst-case jitter results. Results vary with pattern, unless otherwise noted.)
3.2Gbps Adaptive Equalizer

Typical Operating Characteristics (continued)

(Vcc = +3.3V, all jitter measurements done at 3.2Gbps, 700mV cable input with 2^13 - 1 PRBS pattern with 100 consecutive ones and 100 consecutive zeros substituted, TA = +25°C. Note: Test pattern produces near worst-case jitter results. Results vary with pattern, unless otherwise noted.)
**Detailed Description**

The adaptive cable equalizer accepts differential CML input data at rates up to 3.2Gbps and is capable of equalizing differential or single-ended signals. It automatically adjusts to attenuation levels of up to 30dB at 1.6GHz (because of skin-effect losses in copper cable). The equalizer consists of a CML input buffer, a loss-of-signal detector, a flat response amplifier, a skin-effect compensation amplifier, a current-steering network, a dual power-detector feedback loop, an output limiting amplifier, and a CML output buffer (Figure 1).

**General Theory of Operation**

The shape of the power spectrum of a random bit stream can be described by the square of the sinc function, \( \text{sinc} f = (\sin \pi f) / \pi f \). For sufficiently long bit patterns (nonrandom bit streams), \( \text{sinc}^2(f) \) is a good approximation. From the shape of the \( \text{sinc}^2(f) \) function, we can estimate the ratio of the power densities at any two frequencies. The MAX3801 adaptive equalizer employs this principle by incorporating a feedback loop that continuously monitors the power at two frequencies and dynamically adjusts the equalizer to maintain the correct power ratio.

**CML Input and Output Buffers**

The input and output buffers are implemented using current-mode logic (CML). Equivalent circuits are shown in Figures 2 and 3. For details on interfacing with CML, refer to Maxim application note HFAN-1.0, Introduction to LVDS, PECL, and CML.

**Flat Response and Skin-Effect Compensation Amplifiers**

The buffered input waveform is fed equally to two amplifiers—the flat response amplifier and the skin-effect compensation amplifier. The flat response amplifier has a constant gain over the entire frequency range of the device, and the skin-effect compensation amplifier has a gain characteristic that approximates the inverse of the skin-effect attenuation inherent in copper cable. The skin-effect attenuation, in dB per unit length, is proportional to the square root of the frequency. The output currents from the two amplifiers are supplied to the current-steering network. Note that, when LOS asserts low, equalization is minimized.

**Current-Steering Network**

The function of the current-steering network is to combine adjustable quantities of the output currents from the flat response and skin-effect compensation amplifiers.
3.2Gbps Adaptive Equalizer

Figure 1. Functional Diagram

Figure 2. CML Input Equivalent Circuit

Figure 3. CML Output Equivalent Circuit
3.2Gbps Adaptive Equalizer

The current-steering network is implemented with two variable attenuators that feed into a current-summing node. The variable attenuators attenuate the output currents of the flat response and skin-effect compensation amplifiers under control of the dual power-detector feedback loop. The outputs of the two attenuators are combined at the summing node and then fed to the output limiting amplifier and the feedback loop.

**Dual Power-Detector Feedback Loop**

The output of the current-steering network is applied to the inputs of two frequency-specific power detectors. One of the power detectors is tuned to 200MHz, and the other is tuned to 600MHz. The outputs of the two power detectors are applied to the inverting (200MHz power detector) and noninverting (600MHz power detector) inputs of the differential loop amplifier. The differential outputs of the loop amplifier control the variable attenuators in the current-steering network.

**Output Limiting Amplifier**

The output limiting amplifier amplifies the signal from the current-steering network to achieve the specified output voltage swing.

**Applications Information**

Refer to Maxim application note HFAN-10.0, Equalizing Gigabit Copper Cable Links with the MAX3800 (available at www.maxim-ic.com) for additional applications information.

**Cable Integrity Monitor (CIM)**

The differential CIM output current is directly proportional to the output current of the loop amplifier (which controls the current-steering network—see the Detailed Description). This is an analog current output that indicates the amount of equalization being applied. A convenient way to monitor the CIM current is to connect a 100kΩ resistor from each of the CIM outputs to ground, and then measure the voltage at the CIM pins.

The amount of equalization (and thus the CIM output level) is affected by various factors, including cable type, cable length, signal bandwidth, etc.

**Loss-of-Signal (LOS) Output**

Loss-of-signal is indicated by the LOS output. A low level on LOS indicates that the equalizer input signal power has dropped below a threshold. The LOS output indicates a loss of signal. When the equalizer no longer detects a signal from the channel, the LOS output goes low. When there is sufficient input voltage to the channel (typically greater than 650mV), LOS is high. The LOS output is suitable for indicating problems with the transmission link caused by, for example, a broken cable, a defective driver, or a lost connection to the equalizer.

**Single-Ended Operation**

For single-ended operation of the equalizer, connect the unused input to ground through a series combination of a capacitor (of equal value to other AC-coupling capacitors) and a 50Ω resistor. Note that the MAX3801 is specified for differential operation. The effective range of equalization for single-ended use is approximately 4dB to 30dB at 1.6GHz.

**Layout Considerations**

The MAX3801’s performance significantly can be affected by circuit-board layout and design. Use good high-frequency design techniques, including minimizing ground inductance and using fixed-impedance transmission lines for the high-frequency data signals. Place power-supply decoupling capacitors as close as possible to VCC.

**Pin Configuration**

![Pin Configuration Diagram]
3.2Gbps Adaptive Equalizer

Package Information

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to www.maxim-ic.com/packages.)

NOTES:
1. DIE THICKNESS ALLOWABLE IS 0.305mm MAXIMUM (.012 INCHES MAXIMUM).
3. N IS THE NUMBER OF TERMINALS.
4. M IS THE NUMBER OF TERMINALS IN X-DIRECTION & M IS THE NUMBER OF TERMINALS IN Y-DIRECTION.
5. DIMENSION A APPLIES TO PLATED TERMINAL AND IS MEASURED BETWEEN 0.25 AND 0.30mm FROM TERMINAL TOP.
6. THE PIN #1 IDENTIFIER MUST BE EXISTED ON THE TOP SURFACE OF THE PACKAGE BY USING INK IDENTIFICATION MARK OR INK/LASER MARKED. DETAILS OF PIN #1 IDENTIFIER IS OPTIONAL, BUT MUST BE LOCATED WITHIN ZONE INDICATED.
7. EXACT SHAPE AND SIZE OF THIS FEATURE IS OPTIONAL.
8. ALL DIMENSIONS ARE IN MILLIMETERS.
9. PACKAGE WARPAGE MAX 0.05mm.
10. APPLIES FOR EXPOSED PAD AND TERMINAL. EXCLUDE EXCREEDING PART OF EXPOSED PAD FROM MEASURING.
11. THIS PACKAGE OUTLINE APPLIES TO PUNCHED QFN (STEPPED SIDES).

MAXIM
3.2Gbps Adaptive Equalizer

Package Information (continued)

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to www.maxim-ic.com/packages.)

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