

## M02044CG-31

# 3.3/5V Limiting Amplifier for Applications from 100 Mbps to 622 Mbps

The M02044 is a highly integrated high-gain limiting amplifier that can be used with the same board layout and footprint as the MC2044C (refer to 02044-APP-001-A where A is the revision which will change if the application note is revised). Featuring PECL outputs, the M02044 is intended for use in applications from 100 Mbps to 622 Mbps. Full output swing is achieved even at minimum input sensitivity. The M02044 can operate with a 3.3V or 5V supply.

Included in the M02044 is a programmable signal-level detector, allowing the user to set thresholds at which the logic outputs are enabled. The signal detect function has typically 2 dB (optical) of hysteresis which prevents chatter at low input levels. A squelch function, which turns off the output when no signal is present, is provided by externally connecting the LOS Status output to the JAM input.

The M02044 has CMOS Status and LOS outputs.

Other available solutions: M02046-15 3.3/5V Limiting Amplifier for Applications to 1.25 Gbps (PECL outputs)  
 M02040-15 3.3/5V Limiting Amplifier for Applications to 2.125 Gbps (PECL outputs)  
 M02050-15 3.3/5V Limiting Amplifier for Applications to 2.5 Gbps (PECL outputs)  
 M02049-15 3.3/5V Limiting Amplifier for Applications to 4.3 Gbps (CML outputs)  
 M02043-15 3.3/5V Limiting Amplifier for Applications to 4.3 Gbps (CML outputs)

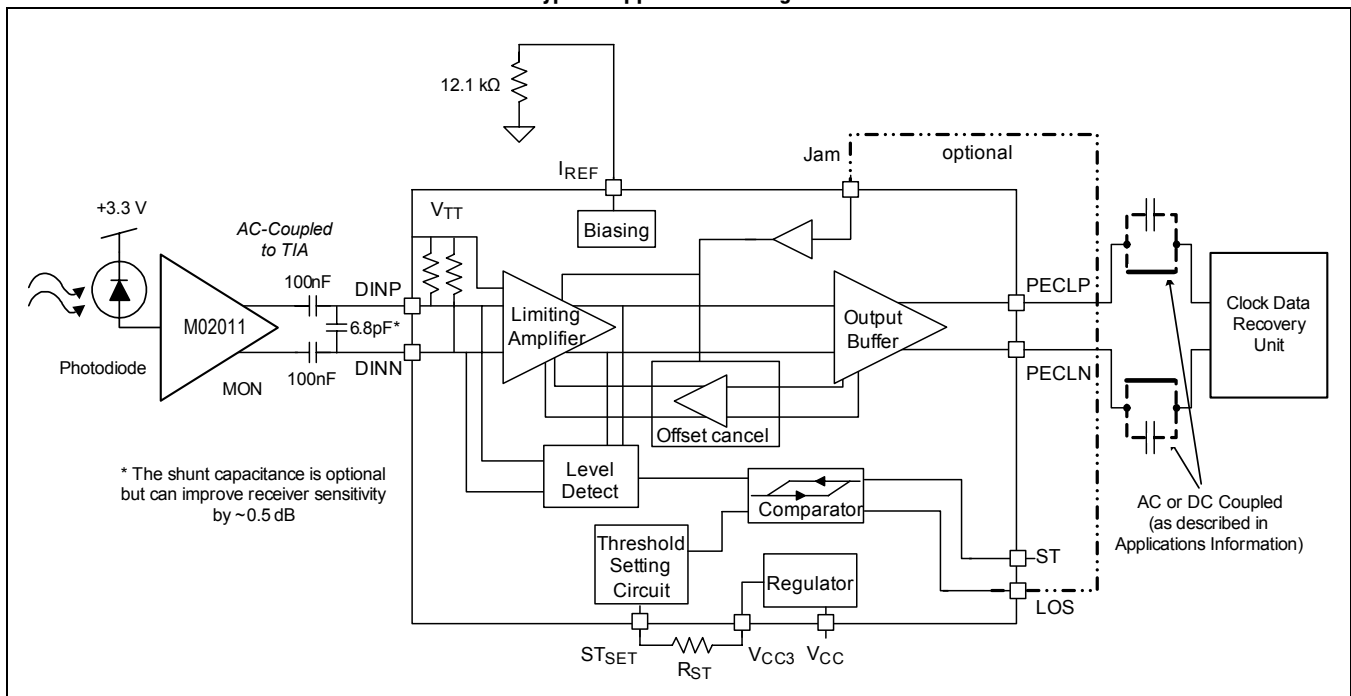
### Applications

- 622 Mbps SDH/SONET
- 100 Mbps Ethernet
- SDH/SONET 155 Mbps Transceivers
- FTTx and Media Converters
- Fast Ethernet Receivers
- FDDI 125 Mbps Receivers
- ESCON Receivers

### Features

- Pin compatible with the MC2044C
- Operates with a 3.3V or 5V supply
- 2.8 mV typical input sensitivity at 622 Mbps
- Programmable input-signal level detect
- On-chip DC offset cancellation circuit
- CMOS Signal Detect and LOS outputs
- Output Jam Function
- Low power (< 200 mW at 3.3V including PECL load)

Typical Applications Diagram



## Ordering Information

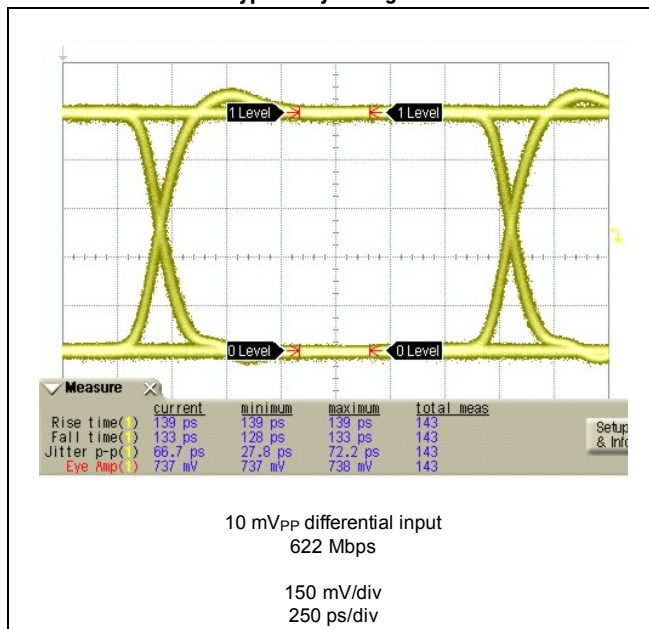
Part Number	Package	Operating Temperature
M02044CG-31*	16 pin QSOP	-40 °C to 85 °C
M02044CG-31EVM	Evaluation board with M02044CG-31	-40 °C to 85 °C

\* The letter "G" designator in the part number indicates that the device is RoHS-compliant. Refer to [www.mindspeed.com](http://www.mindspeed.com) for additional information.

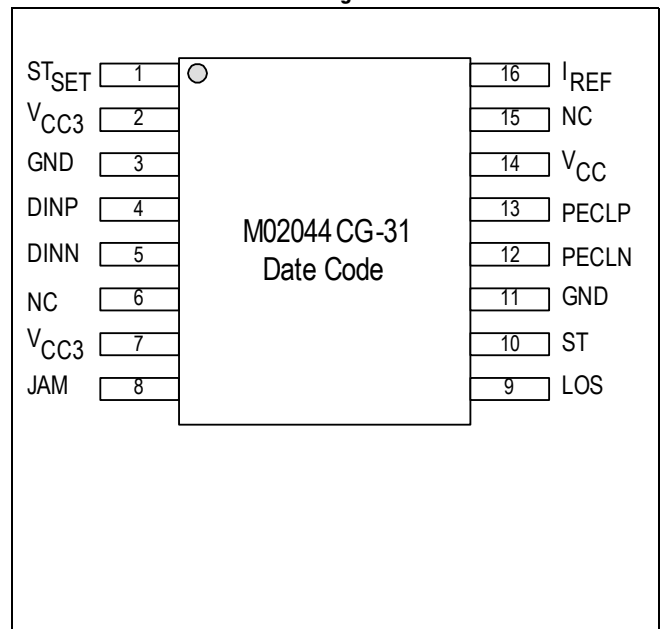
## Revision History

Revision	Level	Date	ASIC Revision	Description
A	Released	March 2008	-31	Initial Release

Typical Eye Diagram



Pin Configuration





# 1.0 Product Specification

## 1.1 Absolute Maximum Ratings

These are the absolute maximum ratings at or beyond which the IC can be expected to fail or be damaged. Reliable operation at these extremes for any length of time is not implied.

**Table 1-1. Absolute Maximum Ratings**

Symbol	Parameter	Rating	Units
$V_{CC}$	Power supply voltage ( $V_{CC-GND}$ )	-0.5 to +5.75	V
$T_{STG}$	Storage temperature	-65 to +150	°C
PECLP, PECLN	PECL Output pins voltage	$V_{CC} - 2$ to $V_{CC} + 0.4$	V
I(PECLP), I(PECLN)	PECL Output pins maximum continuous current (delivered to load)	30	mA
DINP - DINN	Data input pins differential voltage	0.80	V
DINP, DINN	Data input pins voltage meeting  DINP - DINN  requirement	GND to $V_{CC3} + 0.4$	V
ST <sub>SET</sub>	Signal detect threshold setting pin voltage	GND to $V_{CC3} + 0.4$	V
JAM	Output enable pin voltage	GND to $V_{CC} + 0.4$	V
ST, LOS	Status Output pins voltage	GND to $V_{CC} + 0.4$	V
$I_{REF}$	Current into Reference input	+0 to -120	μA
I(LOS), I(ST)	Current into Status Output pins	+3000 to -100	μA

## 1.2 Recommended Operating Conditions

**Table 1-2. Recommended Operating Conditions**

Parameter	Rating	Units
Power supply: ( $V_{CC-GND}$ ) (apply no potential to $V_{CC3}$ ) or ( $V_{CC3-GND}$ ) (connect $V_{CC}$ to same potential as $V_{CC3}$ )	+5V ± 7.5% or +3.3V ± 7.5%	V
Junction temperature	-40 to +110	°C
Operating ambient	-40 to +85	°C

## 1.3 DC Characteristics

$V_{CC} = +3.3V \pm 7.5\%$  or  $+5V \pm 7.5\%$ ,  $T_A = -40^{\circ}C$  to  $+85^{\circ}C$ , unless otherwise noted.

Typical specifications are for  $V_{CC} = 3.3V$ ,  $T_A = 25^{\circ}C$ , unless otherwise noted.

**Table 1-3. DC Characteristics**

Symbol	Parameter	Conditions	Min	Typ	Max	Units
$I_{CC}$	Supply Current	PECL outputs un-loaded	–	26	38	mA
$V_{OUTH_{pecl}}$	PECL Output High Voltage <sup>(1,2)</sup> (PECLP, PECLN)	Single ended; 50Ω load to $V_{CC} - 2V$	$V_{CC}-1.06$	$V_{CC}-0.952$	$V_{CC}-0.88$	V
$V_{OUTL_{pecl}}$	PECL Output Low Voltage <sup>(1,2)</sup> (PECLP, PECLN)	Single ended; 50Ω load to $V_{CC} - 2V$	$V_{CC}-1.86$	$V_{CC}-1.71$	$V_{CC}-1.62$	V
$R_{INDIFF}$	Differential Input Resistance	Measured between DINP and DINN	90	110	130	Ω
$V_{OH\_CMOS}$	ST, LOS Output High Voltage	External 4.7-10 kΩ pull up to $V_{CC}$	2.75	$V_{CC}$	–	V
$V_{OL\_CMOS}$	ST, LOS Output Low Voltage	External 4.7-10 kΩ pull up to $V_{CC}$	0	–	0.4	V
$I_{OL\_CMOS}$	ST, LOS Output Low Current (into device)	$V_{OL}$ determined by external pull up to $V_{CC}$	–	–	2.0	mA
$V_{IH}$	JAM Input High Voltage		2.7	–	$V_{CC}$	V
$V_{IL}$	JAM Input Low Voltage		–	–	0.8	V

**Notes:**

- Limits apply between  $0^{\circ}C$  to  $+85^{\circ}C$ . Below  $0^{\circ}C$  the minimum decreases by up to 40 mV.
- In most applications the PECL outputs are AC coupled to the following device, so the actual VOH and VOL levels are not meaningful for the PECL outputs. Only the peak to peak swing is transmitted to the load device.

# 1.4 AC Characteristics

$V_{CC} = +3.3V \pm 7.5\%$  or  $+5V \pm 7.5\%$ ,  $T_A = -40^{\circ}C$  to  $+85^{\circ}C$ , input bit rate = 622 Mbps  $2^{23}$ -1 PRBS unless otherwise noted. Typical specifications are for  $V_{CC} = 3.3V$ ,  $T_A = 25^{\circ}C$ , unless otherwise noted.

**Table 1-4. AC Characteristics**

Symbol	Parameter	Conditions	Min	Typ	Max	Units
$V_{IN(MIN)}$	Differential Input Sensitivity	622 Mbps, BER $< 10^{-10}$	-	2.5	4.5	mV
$V_{I(MAX)}$	Input Overload	BER $< 10^{-10}$ , differential input 622 Mbps	1200	-	-	mV
		BER $< 10^{-10}$ , single-ended input, 622 Mbps	600	-	-	mV
$V_{TH}$	LOS Programmable Range <sup>(1)</sup>	Differential inputs	5	-	55	mV
HYS	Signal Detect/LOS Hysteresis	(electrical); across LOS programmable range	2	3.5	5.5	dB
$BW_{LF}$	Small-Signal -3dB Low Frequency Cutoff	Excluding AC coupling capacitors	-	25	-	kHz
DJ	Deterministic Jitter (includes DCD)	K28.5 pattern at 622 Mbps, 10 mV <sub>pp</sub> input	-	0.02	0.1	UI
RJ	Random Jitter	10 mV <sub>pp</sub> input	-	5	-	ps <sub>RMS</sub>
$t_r / t_f$	Data Output Rise and Fall Times	20% to 80%; outputs terminated into 50Ω; 10 mV <sub>pp</sub> input	-	150	250	ps
$T_{LD\_ON}$	Time from LOS state until LOS output is asserted	LOS assert time after 1 V <sub>pp</sub> input signal is turned off; signal detect level set to 10 mV	2.3	-	80	μs
$T_{LD\_OFF}$	Time from non-LOS state until LOS is deasserted	LOS deassert time after input crosses signal detect level; signal detect set to 10 mV with applied input signal of 20 mV <sub>pp</sub>	2.3	-	80	μs
$V_N$	RMS Input Referred Noise	DC to 467 MHz Bessel Filter	-	200	-	μV <sub>RMS</sub>

**Note:**

1. This compares to 20 mV maximum for the MC2044 making the M02044CG compatible with the Mindspeed M02011 622 Mbps TIA without having to use an attenuator between the TIA output and LIA input to set the LOS threshold.

**Figure 1-1. Data Input Requirements**

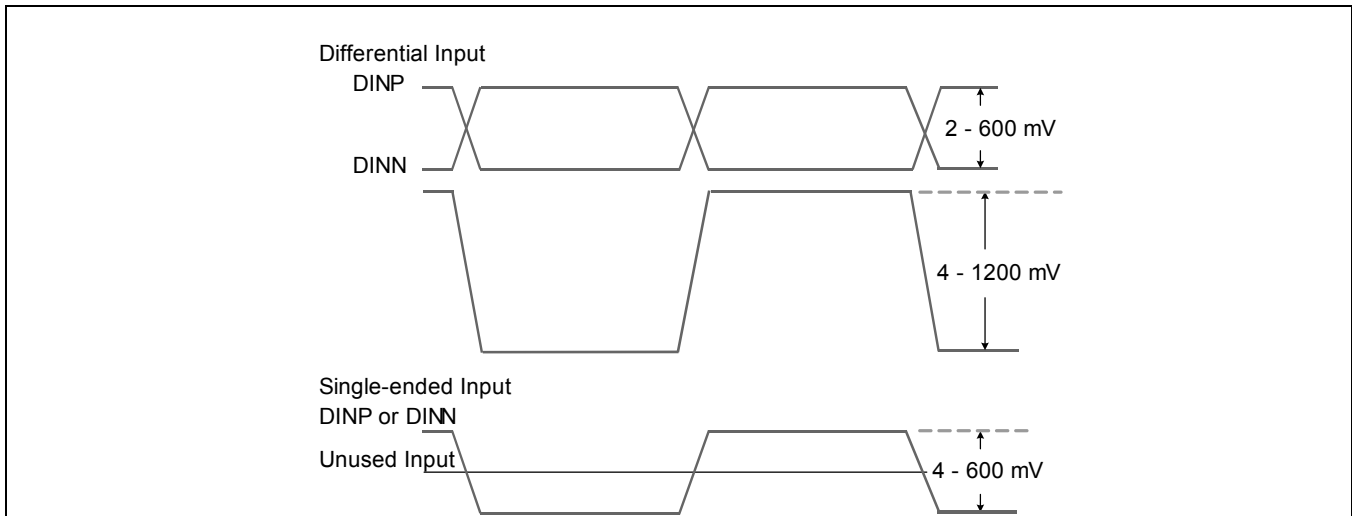
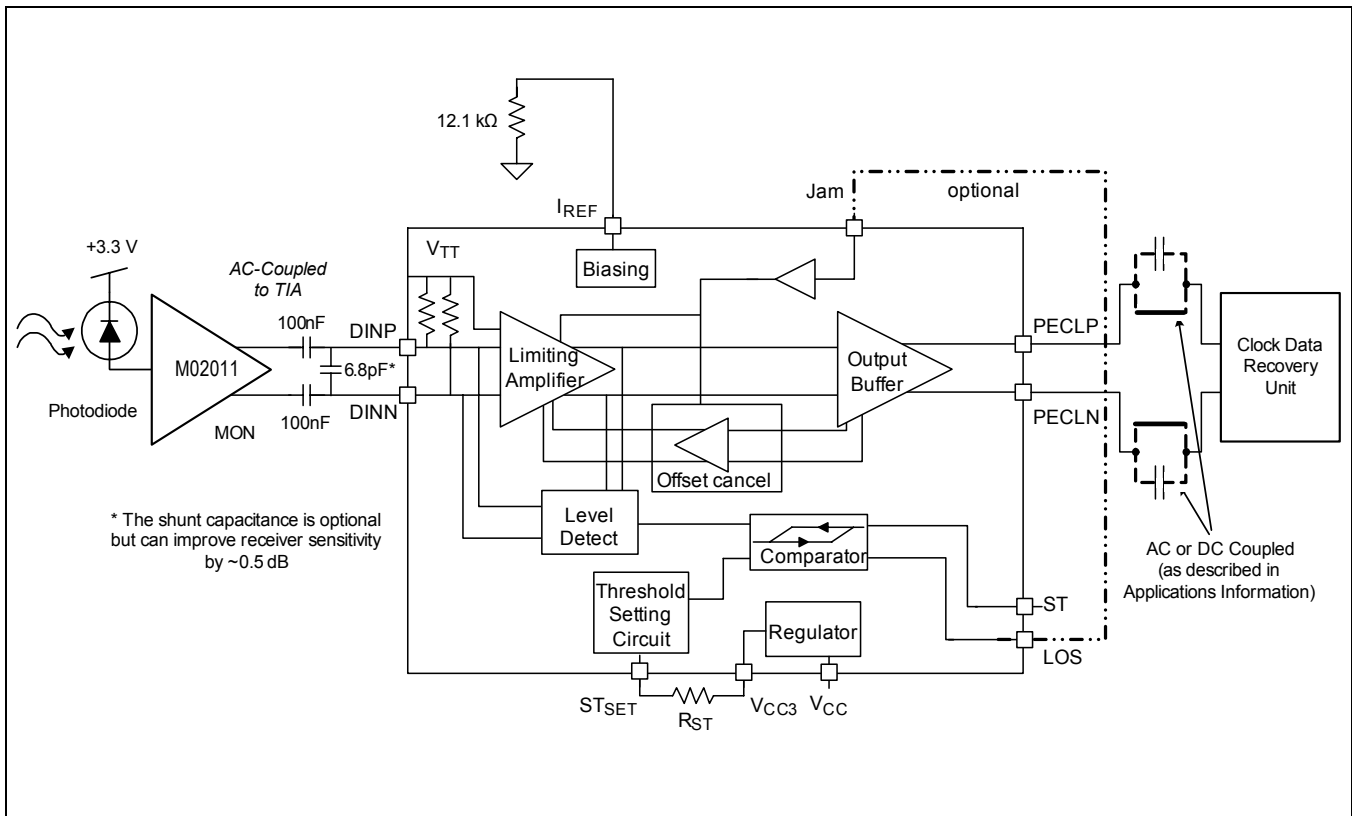


Figure 1-2. Typical Applications Circuit



**NOTE:**

For single-ended input connections. When connecting to the used input with AC-coupling, the unused input should be AC-coupled through 50Ω to the supply voltage of the TIA;

When connecting to the used input with DC-coupling, the unused input should be DC-coupled through 50Ω to a voltage equal to the common mode level of the used input.



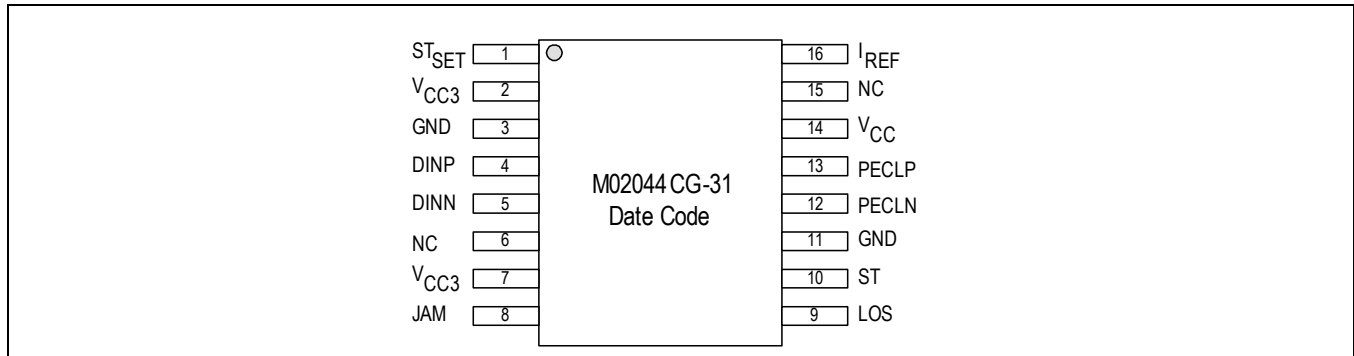
## 2.0 Pin Definitions

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**Table 2-1. Pin Descriptions**

QSOP Pin#	Name	Function
1	ST <sub>SET</sub>	Loss of signal threshold setting input. Connect a 1% resistor between this pin and V <sub>CC3</sub> (pin 2) to set loss of signal threshold.
2	V <sub>CC3</sub>	Power supply input for 3.3V applications or the output of the internally regulated 3.3V voltage when V <sub>CC</sub> = 5V. Connect directly to supply for 3.3V applications (internal regulator not in use). Do not connect to power supply if V <sub>CC</sub> = 5V.
3	GND	Ground.
4	DINP	Non-inverting data input. Internally terminated with 50Ω to V <sub>TT</sub> (see Figure 3-2).
5	DINN	Inverting data input. Internally terminated with 50Ω to V <sub>TT</sub> (see Figure 3-2).
6	NC	No Connect. Leave Floating.
7	V <sub>CC3</sub>	Power supply input for 3.3V applications or the output of the internally regulated 3.3V voltage when V <sub>CC</sub> = 5V. Connect directly to supply for 3.3V applications (internal regulator not in use). Do not connect to power supply if V <sub>CC</sub> = 5V.
8	JAM	Output disable. When high, data outputs are disabled (with non-inverting output held high and inverting output held low). Connect to LOS output to disable outputs with loss of signal. Outputs are enabled when JAM is low or floating. Internal 150 kΩ resistor to ground.
9	LOS	Loss of signal output. Goes high when input signal falls below threshold set by ST <sub>SET</sub> . This output is an open collector TTL with internal 80 kΩ pull-up resistor to V <sub>CC</sub> . Leave floating if not used.
10	ST	Signal detect output. Goes high when input signal amplitude is above threshold set by ST <sub>SET</sub> . In M02044, this output is an open collector TTL with internal 80 kΩ pull-up resistor to V <sub>CC</sub> . Leave floating if not used.
11	GND	Ground.
12	PECLN	Inverting data output (PECL).
13	PECLP	Non-inverting data output (PECL).
14	V <sub>CC</sub>	Power supply. Connect to either +5V or +3.3V.
15	NC	No Connect. Leave Floating.
16	I <sub>REF</sub>	Internal reference current for the LOS threshold. Must be connected to ground through a 12.1 kΩ 1% resistor.

Figure 2-1. M02044 Pinout







## 3.0 Functional Description

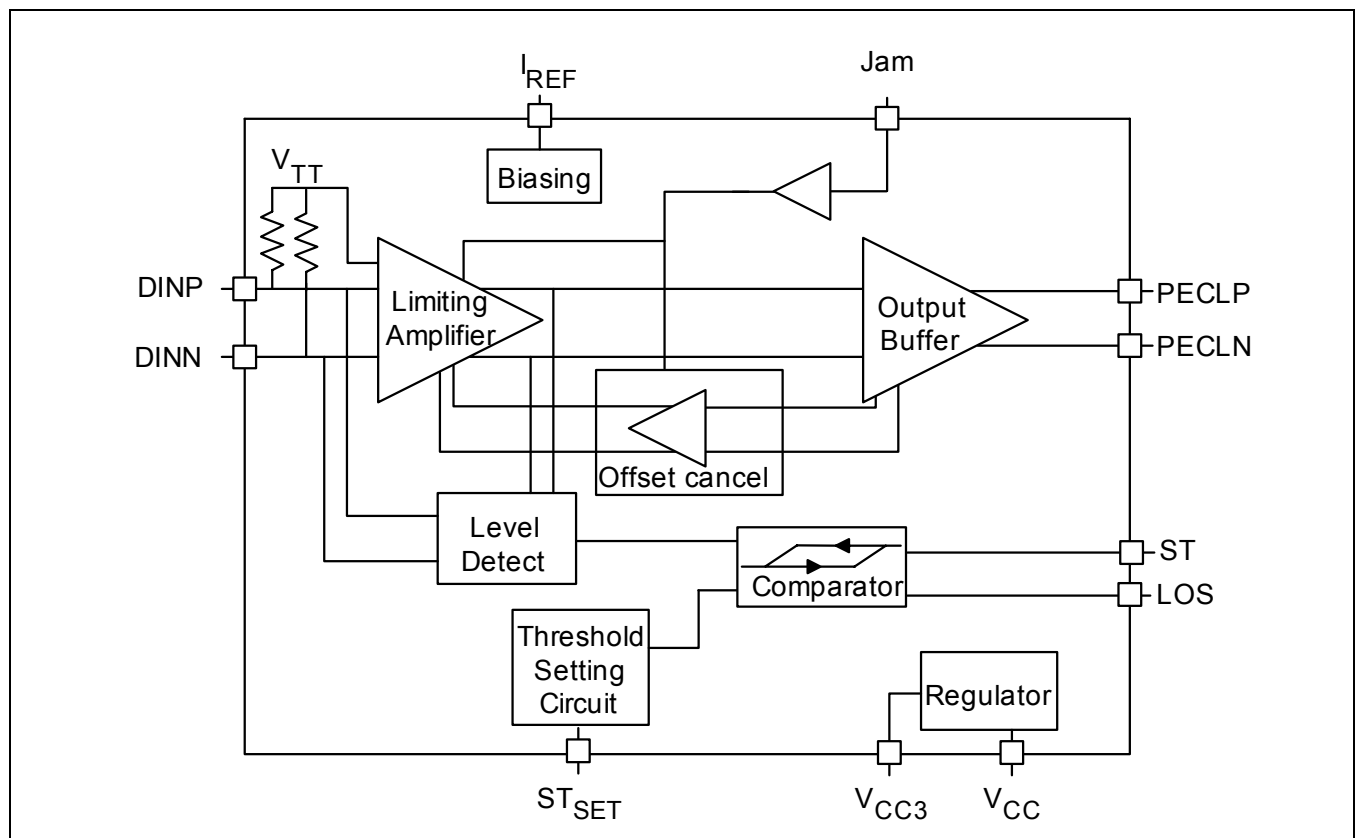
### 3.1 Overview

The M02044 is a highly integrated high-gain limiting amplifier that can be used with the same board layout and footprint as the MC2044C. Featuring PECL outputs, the M02044 is intended for use in applications from 100 Mbps to 622 Mbps. Full output swing is achieved even at minimum input sensitivity. The M02044 can operate with a 3.3V or 5V supply.

Included in the M02044 is a programmable signal-level detector, allowing the user to set thresholds at which the logic outputs are enabled. The signal detect function has typically 2 dB (optical) of hysteresis which prevents chatter at low input levels. A squelch function, which turns off the output when no signal is present, is provided by externally connecting the LOS Status output to the JAM input.

The M02044 has CMOS Status and LOS outputs.

Figure 3-1. Block Diagram Example



### 3.2 Features

- Pin compatible with the MC2044C
- Operates with a 3.3V or 5V supply
- 2.8 mV typical input sensitivity at 622 Mbps
- Programmable input-signal level detect
- On-chip DC offset cancellation circuit
- CMOS Signal Detect and LOS outputs
- Output Jam Function
- Low power (< 200 mW including PECL outputs)

### 3.3 General Description

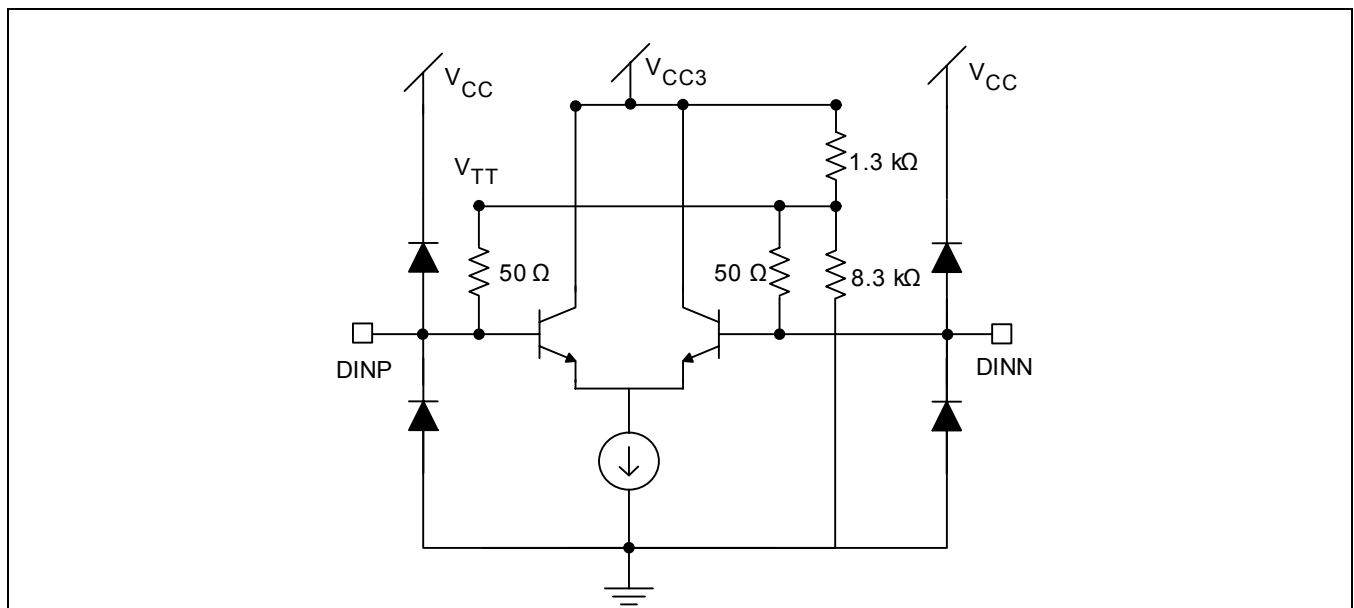
The M02044 is a high-gain limiting amplifier for applications up to 622 Mbps, and incorporates a limiting amplifier, an input signal level detection circuit and also a fully integrated DC-offset cancellation loop that does not require any external components. The M02044 features PECL high-speed data outputs.

The M02044 provides the user with the flexibility to set the signal detect threshold and features CMOS status and LOS outputs. Optional output buffer disable (squelch/jam) can be implemented using the JAM input.

#### 3.3.1 Inputs

The data inputs are internally connected to  $V_{TT}$  via 50Ω resistors, and generally need to be AC coupled. Referring to Figure 3-2, the nominal  $V_{TT}$  voltage is 2.85V because of the internal resistor divider to  $V_{CC3}$ , which means this is the DC potential on the data inputs. See the applications information section for further details on choosing the AC-coupling capacitor.

Figure 3-2. CML Data Inputs



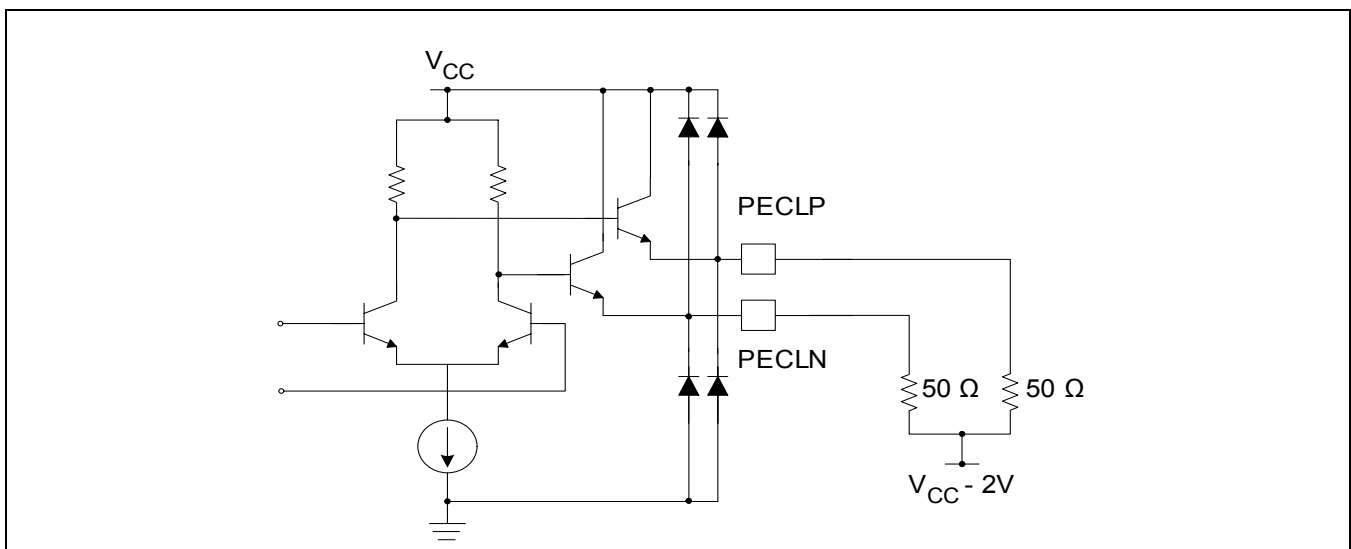
### 3.3.2 DC Offset Compensation

The M02044 contain an internal DC autozero circuit that can remove the effect of DC offsets without using external components. This circuit is configured such that the feedback is effective only at frequencies well below the lowest frequency of interest. The low frequency cut off is typically 25 kHz.

### 3.3.3 Data Outputs

The M02044 features PECL outputs as shown in Figure 3-3. The outputs may be terminated using any standard AC or DC-coupling PECL termination technique. AC-coupling can be used for compatibility with non-PECL interfaces.

Figure 3-3. PECL Data Outputs

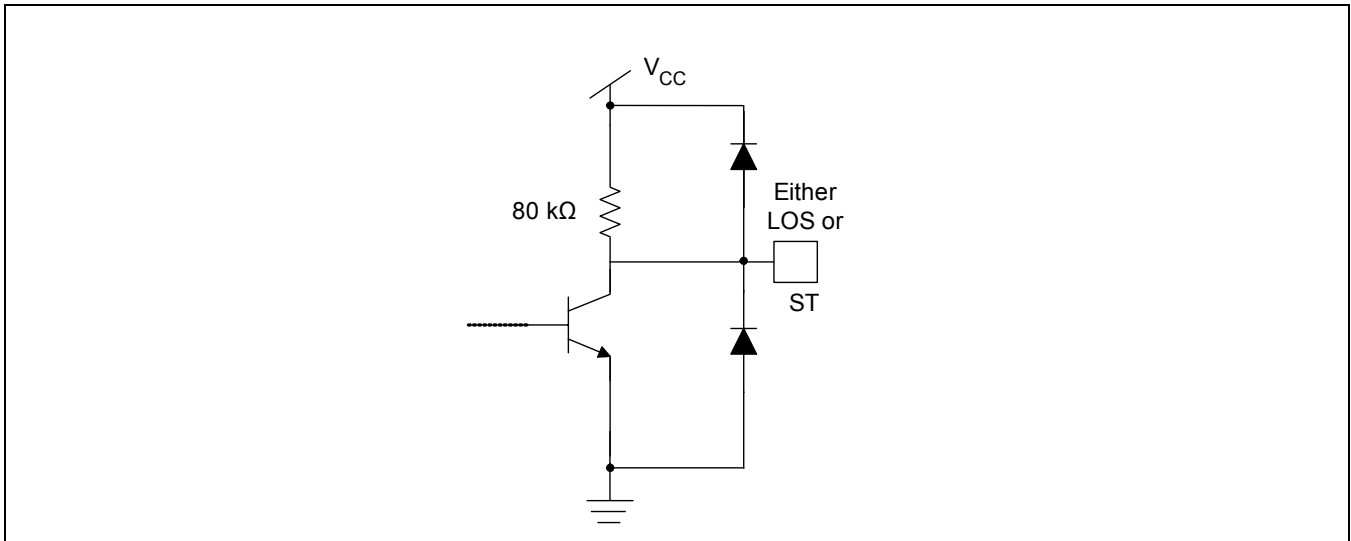


### 3.3.4 Signal Detect (ST) and Loss of Signal (LOS)

The M02044 features input signal level detection over an extended range. Using an external resistor, R<sub>ST</sub>, between pin ST<sub>SET</sub> and V<sub>CC3</sub> (Figure 3-5) the user can program the input signal threshold. The signal detect status is indicated on the both the Signal Detect (ST) and LOS output pins. Figure 3-4 shows the ST and LOS output structure.

The ST (LOS) signal is active (not asserted) when the signal is above the threshold value. The signal detection circuitry has the equivalent of 3.5 dB (typical) electrical hysteresis.

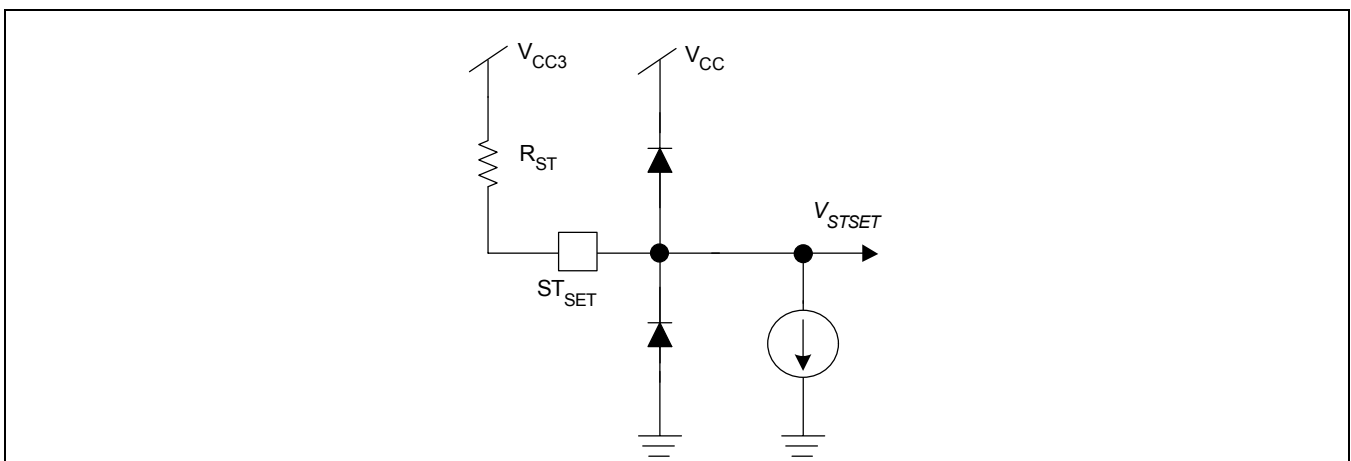
Figure 3-4. ST and LOS Output



$R_{ST}$  establishes a threshold voltage at the  $ST_{SET}$  pin as shown in Figure 3-5. Internally, the input signal level is monitored by the Level Detector which creates a DC voltage proportional to the input signal peak to peak value. The voltage at  $ST_{SET}$  is internally compared to the signal level from the Level Detector. When the Level Detect voltage is less than  $V_{(STSET)}$ , LOS is asserted and will stay asserted until the input signal level increases by a predefined amount of hysteresis. When the input level increases by more than this hysteresis above  $V_{(STSET)}$ , LOS is deasserted. See the applications information section for the selection of  $R_{ST}$ .

Note that  $ST_{SET}$  can be left open if the loss of signal detector function is not required. In this case LOS would be low.

Figure 3-5. STset Input



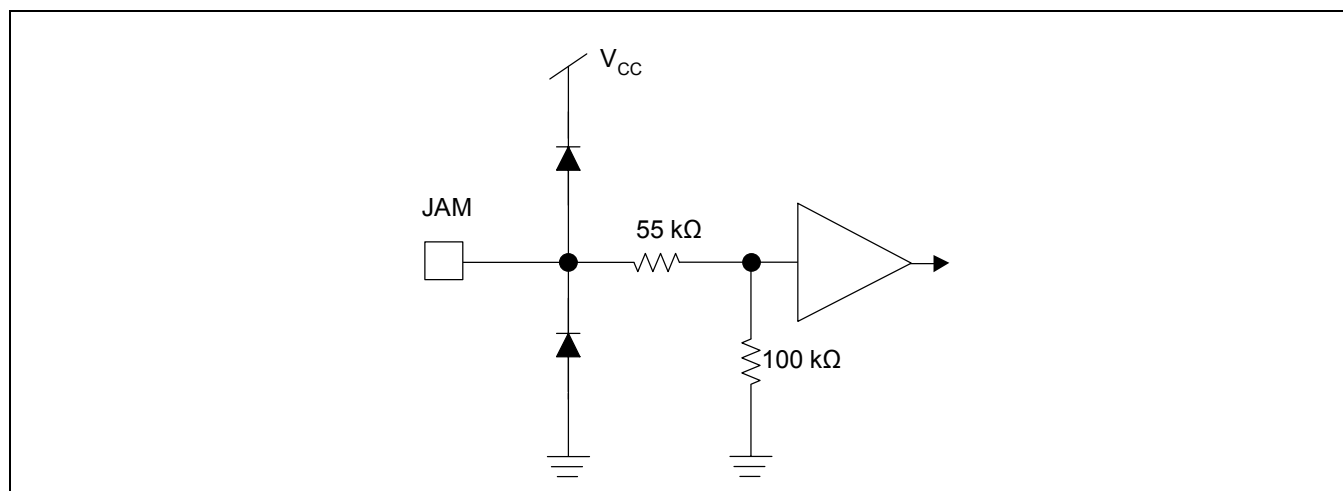
### 3.3.5 JAM Function

When asserted, the active high power down (JAM) pin forces the outputs to a logic “one” state. This ensures that no data is propagated through the system. The loss of signal detection circuit can be used to automatically force the data outputs to a high state when the input signal falls below the threshold. The function is normally used to

allow data to propagate only when the signal is above the user's bit-error-rate requirement. It therefore inhibits the data outputs toggling due to noise when there is no signal present (“squelch”).

In order to implement this function, LOS should be connected to the JAM pin shown in [Figure 3-6](#), thus forcing the data outputs to a logic “one” state when the signal falls below the threshold.

**Figure 3-6. JAM Input**



### 3.3.6 Voltage Regulation

The M02044 contain an on-chip voltage regulator to allow both 5V and 3.3V operation. When used at 5V, the on-chip regulator is enabled and the digital inputs and outputs are compatible with TTL 5V logic levels.



## 4.0 Applications Information

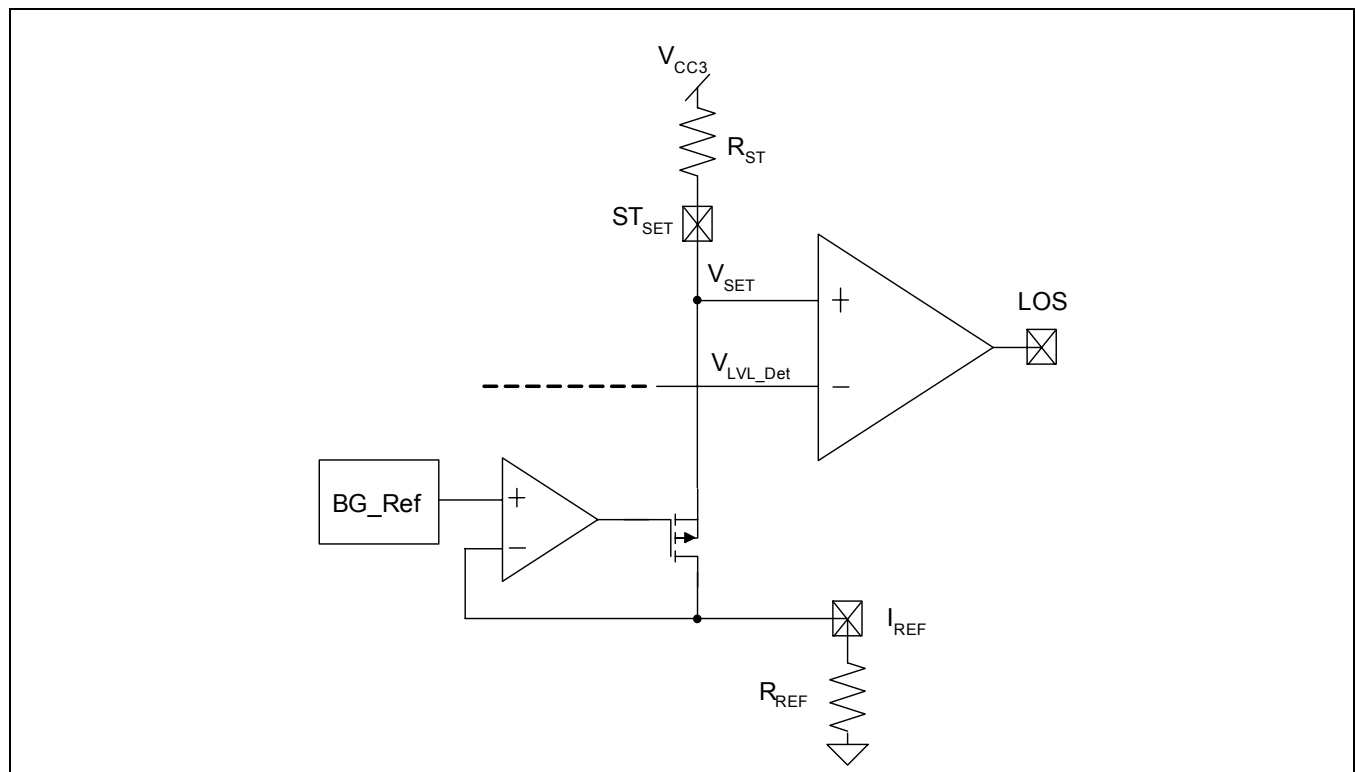
### 4.1 Applications

- 622 Mbps SDH/SONET
- 100 Mbps Ethernet
- SDH/SONET 155 Mbps Transceivers
- FTTx and Media Converters
- Fast Ethernet Receivers
- FDDI 125 Mbps Receivers
- ESCON Receivers

#### 4.1.1 Reference Current Generation

The M02044 contain an accurate on-chip bias circuit that requires an external 12.1 k $\Omega$  1% resistor,  $R_{REF}$  from pin  $I_{REF}$  to ground to set the LOS threshold voltage at  $ST_{SET}$  precisely.

**Figure 4-1. Reference Current Generation**



### 4.1.2 Connecting V<sub>CC</sub> and V<sub>CC3</sub>

For 5V operation, the V<sub>CC</sub> pin is connected to an appropriate 5V ± 7.5% supply. No potential should be applied to the V<sub>CC3</sub> pin. The only connection to V<sub>CC3</sub> should be R<sub>ST</sub> as shown in [Figure 3-5](#).

When V<sub>CC</sub> = 5V all logic outputs and the data outputs are 5V compatible. For low power operation, V<sub>CC</sub> and V<sub>CC3</sub> should be connected to an appropriate 3.3V ± 7.5% supply. In this case all I/Os are 3.3V compatible.

### 4.1.3 Choosing an Input AC-Coupling Capacitor

When AC-coupling the input the coupling capacitor should be of sufficient value to pass the lowest frequencies of interest, bearing in mind the number of consecutive identical bits, and the input resistance of the part. For SONET data, a good rule of thumb is to choose a coupling capacitor that has a cut-off frequency less than 1/10,000 of the input data rate. For example, for 622 Mbps data, the coupling capacitor should be chosen as:

$$f_{\text{CUTOFF}} \leq (622 \times 10^6 / 10 \times 10^3) = 62.2 \text{ kHz}$$

The -3 dB cutoff frequency of the low pass filter at the input is found as (assuming that the TIA output is also 50Ω single-ended):

$$f_{3\text{dB}} = 1 / (2 * \pi * 100\Omega * C_{\text{AC}})$$

so solving for C where  $f_{3\text{dB}} = f_{\text{CUTOFF}}$

$$C_{\text{AC}} = 1 / (2 * \pi * 100\Omega * f_{\text{CUTOFF}}) \quad \text{EQ.1}$$

and in this case the minimum capacitor is 25.6 nF.

For Ethernet or Fibre Channel, there are less consecutive bits in the data, and the recommended cut-off frequency is 1/(1,000) of the input data rate. This results in a minimum capacitor of 16 nF (or greater) for 100 Mbps Ethernet.

In all cases, a high quality coupling capacitor should be used as to pass the high frequency content of the input data stream. It is also important that the ROSA bandwidth is sufficiently low and high enough to also support the required data rate, for its lower and upper cutoff bandwidth impact the receiver bandwidth as much as does the limiting amp's lower and upper cutoff bandwidth.

### 4.1.4 Setting the Signal Detect Level

Using [Figure 4-2](#), the value for R<sub>ST</sub> is chosen to set the LOS threshold at the desired value. The resulting hysteresis is also shown in [Figure 4-2](#).

From [Figure 4-2](#), it is apparent that small variations in R<sub>ST</sub> cause significant variation in the LOS threshold level, particularly for low input signal levels. This is because of the logarithmic relationship between the internal level detect voltage and the input signal level. It is recommended that a 1% resistor be used for R<sub>ST</sub> and that allowance is provided for LOS variation, particularly when the LOS threshold is near the sensitivity limit of the M02044.

Example R<sub>ST</sub> resistor values are given in [Table 4-1](#).

**Table 4-1. Typical LOS Assert and De-assert Levels for Various 1% R<sub>ST</sub> Resistor Values**

R <sub>ST</sub> (kΩ)	VIN (mV pp) differential	
	LOS Assert	LOS De-Assert
7.50	4.9	7.8
6.81	11.7	17.0
6.19	23.2	33.4
5.49	55.0	77.3

**Figure 4-2. Typical Loss of Signal Characteristic (Full Input Signal Range)**

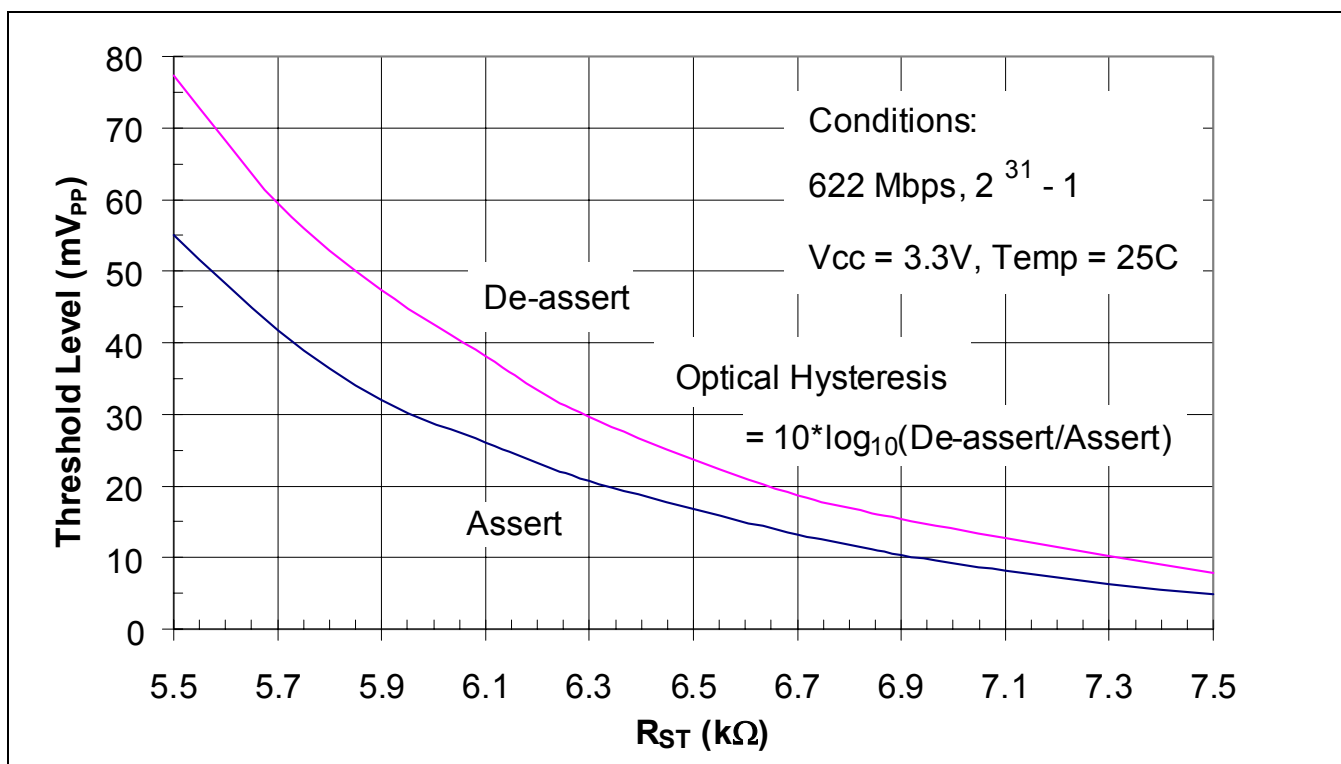




Figure 4-3. Typical Loss of Signal Characteristic (Low Input Signal Range)

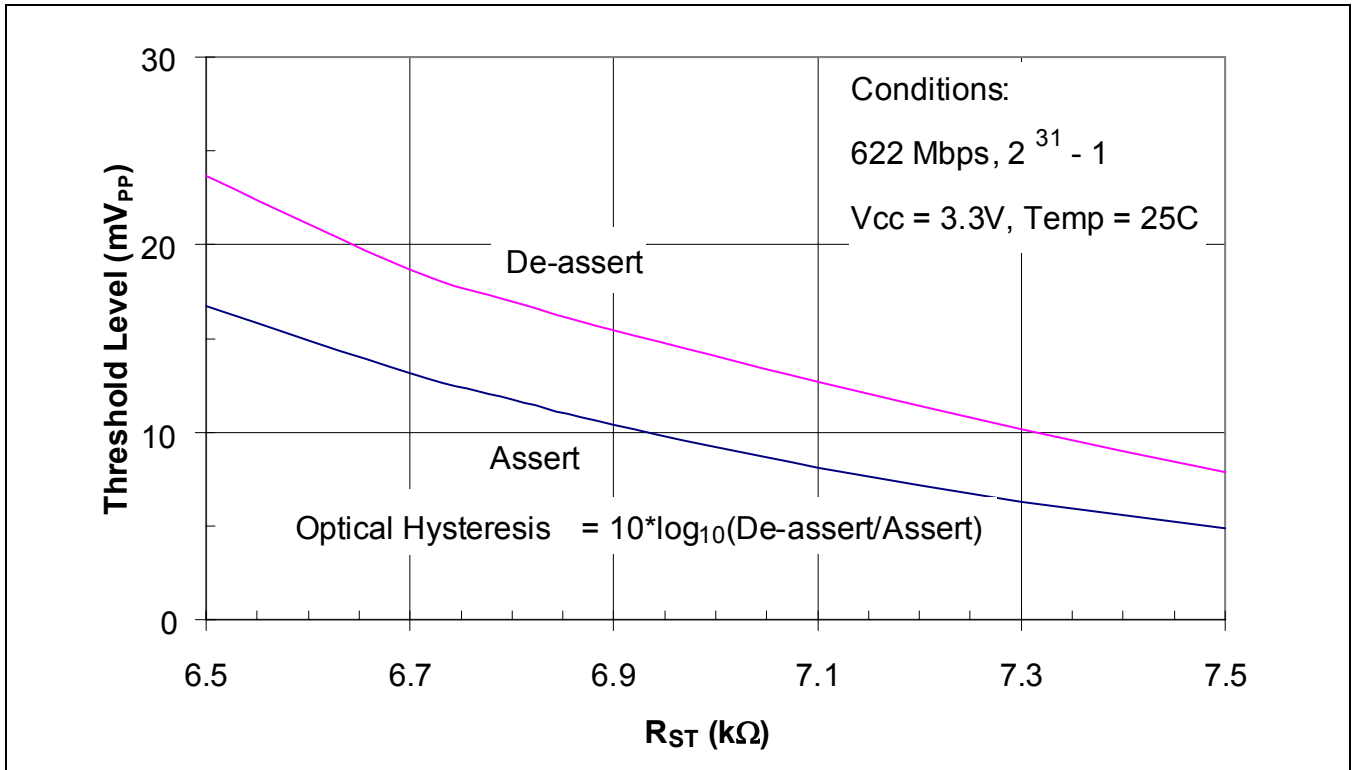


Figure 4-4. Typical Loss of Signal Characteristic (High Input Signal Range)

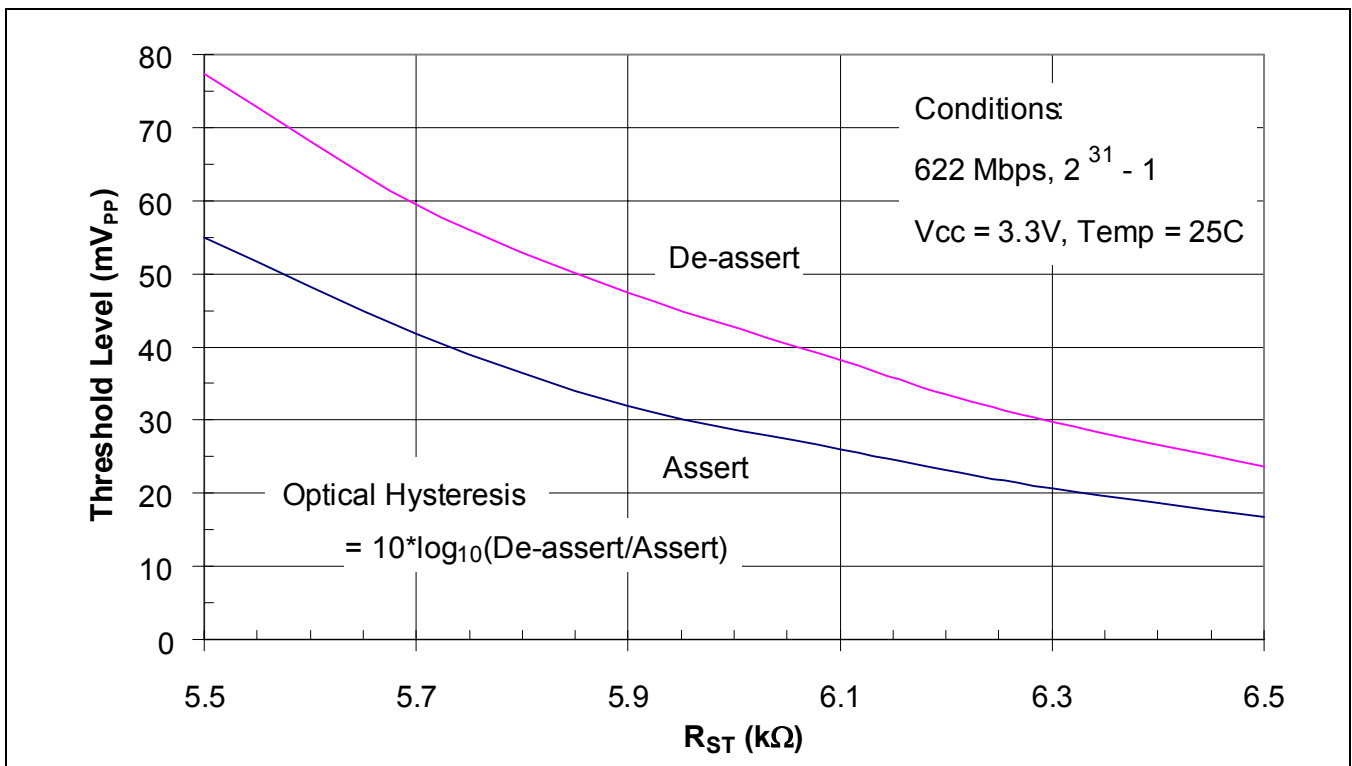
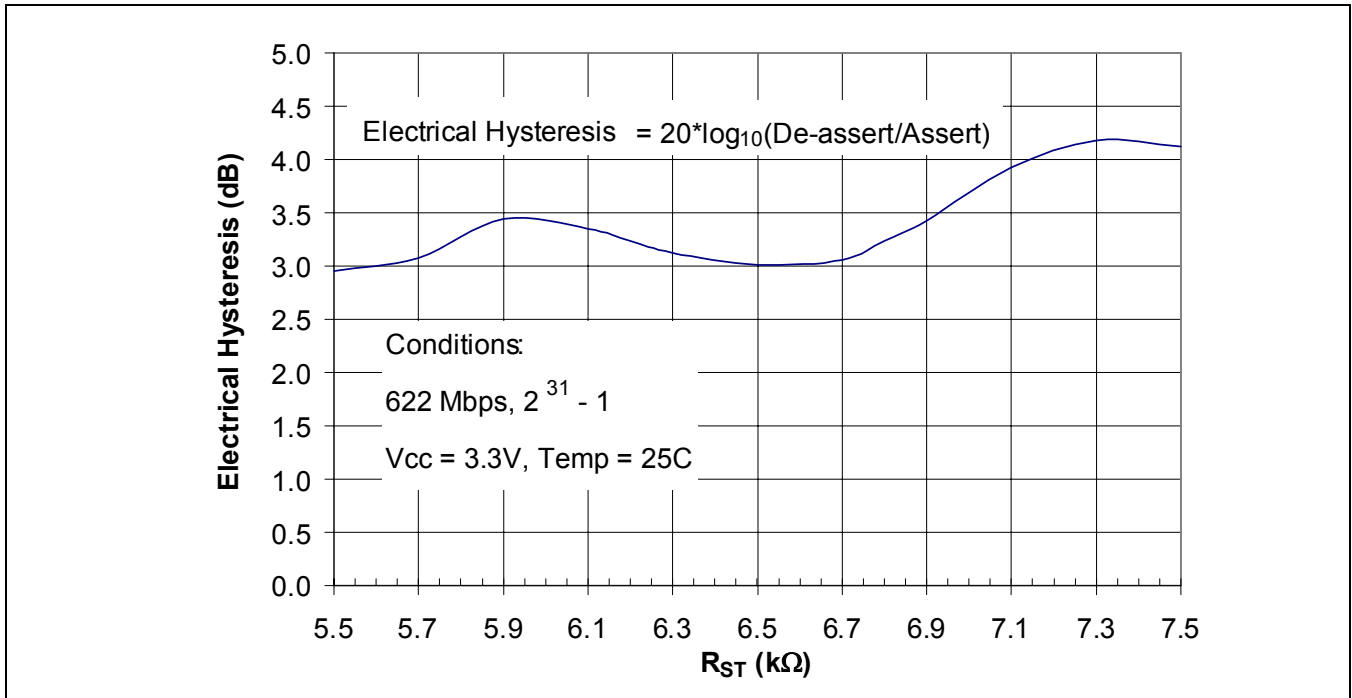


Figure 4-5. Typical Loss of Signal Hysteresis Characteristic (Full Input Signal Range)



### 4.1.5 PECLP and PECLN Termination

The data outputs of the M02044 are PECL. Figure 4-6 illustrates PECL compliant PECL termination. This is the only termination where PECL specifications are guaranteed (this is level shifted ECL100k/300k ECL termination).

For the high speed PECLP and PECLN outputs any standard AC or DC-coupling termination technique can be used. Figure 4-7 illustrates the most common PECL termination in use today and Table 4-2 lists the pull down resistor values. Since this type of termination is AC coupled, the actual VOH and VOL levels are not meaningful for the PECL outputs. Only the peak to peak swing is transmitted to the load device.

Figure 4-6. True PECL Termination

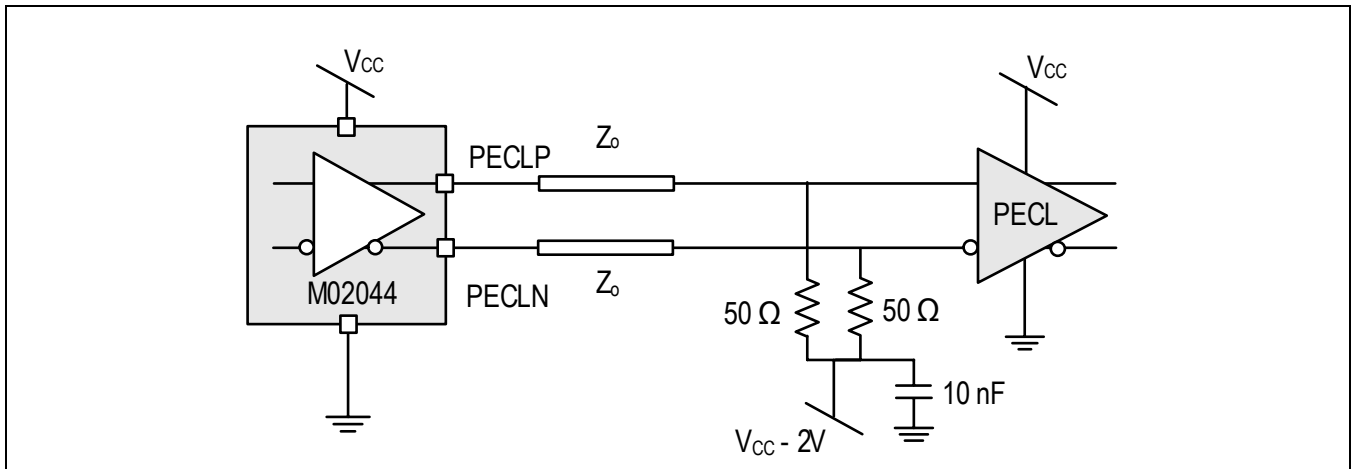


Figure 4-7. AC-Coupled PECL Termination

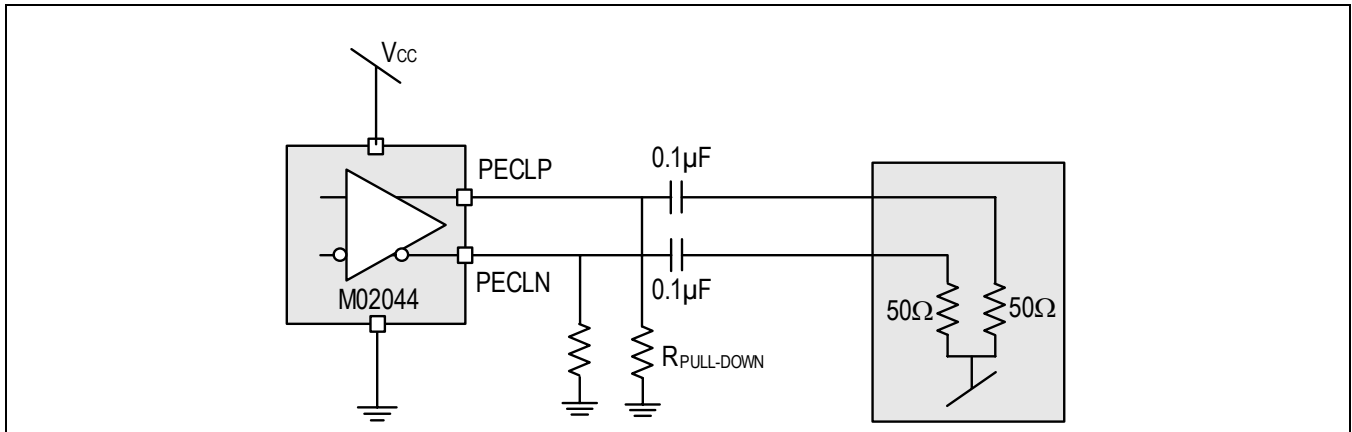


Table 4-2. PECL Termination Resistor Values

Supply	R <sub>PULL-DOWN</sub>
5V	270 Ω
3.3V	150 Ω

### 4.1.6 Using JAM

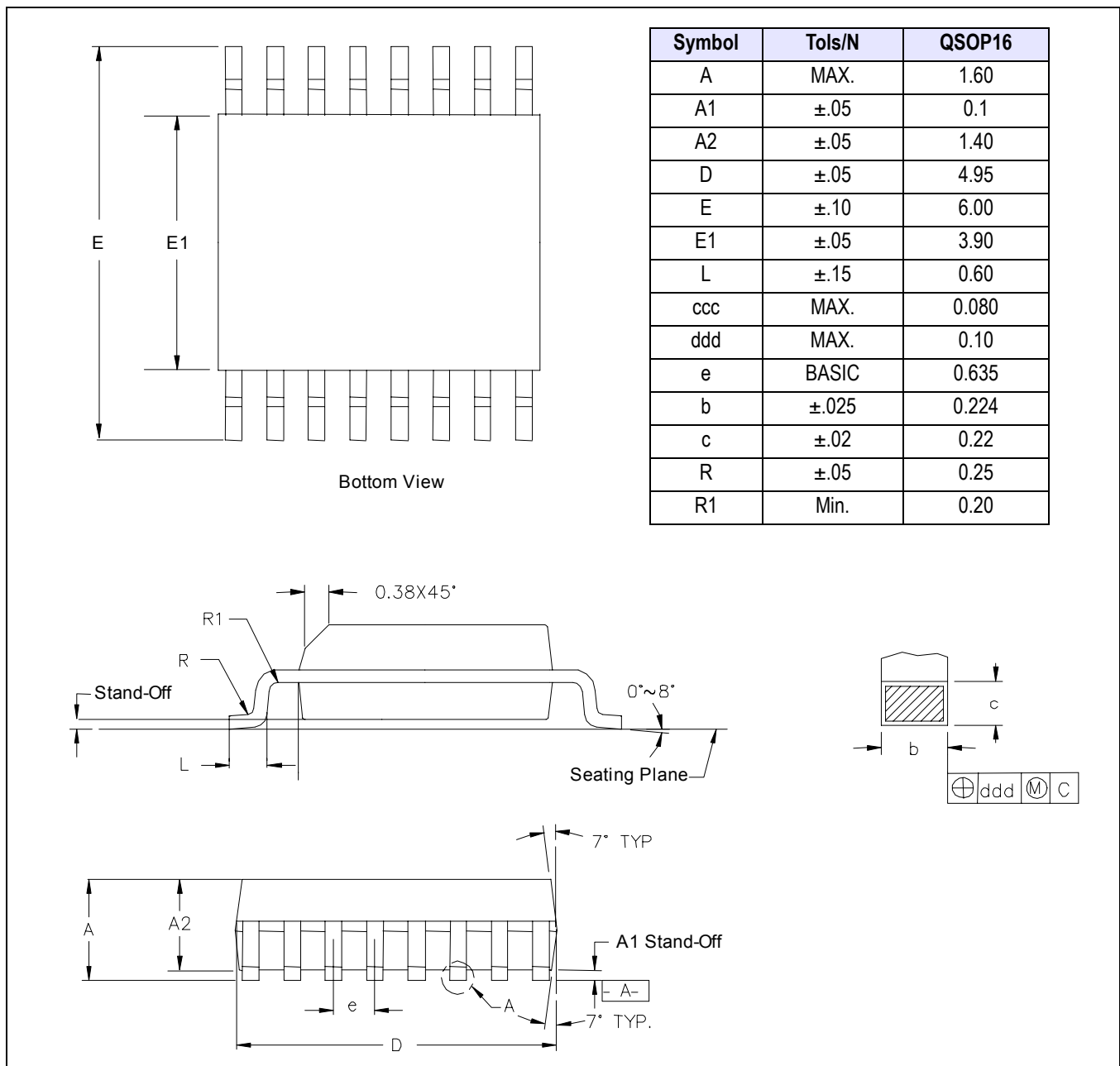
As shown in the typical applications circuit (Figure 1-2), the LOS output pin can optionally be connected to the Jam input pin. When LOS asserts the Jam function sets the data outputs to a fixed “one” state (PECLP is held high and PECLN is held low). This is normally used to allow data to propagate only when the signal is above the users' bit error rate (BER) requirement. It prevents the outputs from toggling due to noise when no signal is present.

From the LOS assert and deassert figures above (Figure 4-2 - Figure 4-4), when an input signal is below the LOS assert threshold, LOS asserts (LOS high) causing Jam to assert. When Jam asserts, the data outputs and the internal servo loop of the M02044 are disabled. If the input signal reaches or exceeds the LOS deassert threshold, LOS deasserts (LOS low) causing Jam to deassert, and hence enables the data outputs and the internal servo loop. If, however, the input signal is slowly increasing to a level that does not exceed the LOS deassert threshold (operating in the hysteresis region), the internal servo loop may not be fully established and this may cause partial enabling of the data outputs. To avoid this the input signal needs to fully reach or exceed the LOS deassert level to fully enable the data outputs.



# 5.0 Package Specification

Figure 5-1. Package Information



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