2.5 Gbit/s $LiNbO_3$ Modulator Driver GD16076A

General Description

The GD16076A is a 2.5 Gbit/s laser modulator driver designed for providing a controllable drive current to an optical modulator ($LiNbO_3$) circuit properly biased and with 25 Ω or 50 Ω characteristic input impedance.

The GD16076A features differential ECL compatible, wide common mode range inputs (DIN, NDIN) with loop through termination capability for optimal input reflection coefficient.

The pins OUT and NOUT are open drain outputs designed for driving an external load with a characteristic impedance of:

- 25 Ω (GD16076A-25SLP)
- 50 Ω (GD16076A-50SLP)

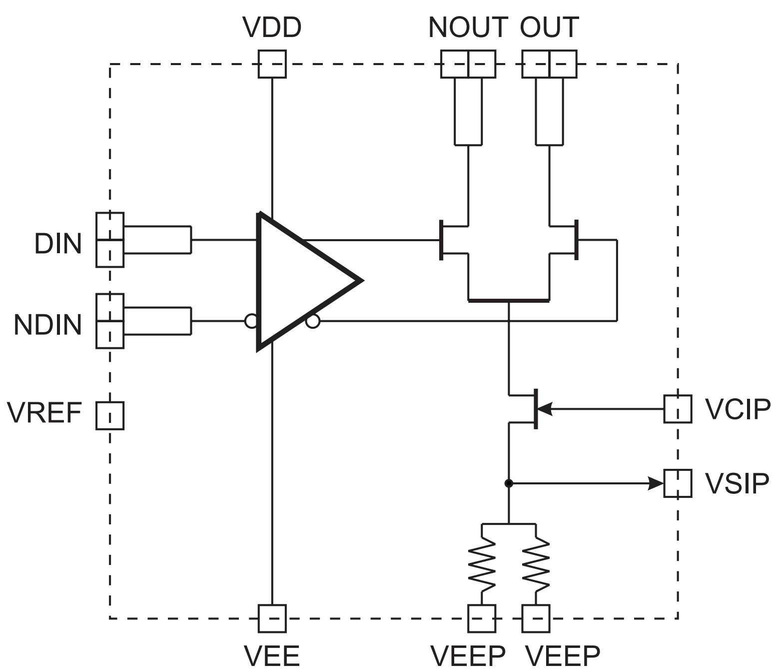
The outputs can sink a current that can be controlled in the range 40mA - 180mA by VCIP. The output voltage swing across an external load may be varied accordingly.

For the 25 Ω version the output voltage swing may be adjusted in the range 1.0 V_{P-P} - 4.5 V_{P-P}.

For the 50 Ω version, the output swing may be adjusted within the range 2.0 V_{P-P} - 6.0 V_{P-P} (typ.).

The output current may be monitored at pin SIP.

The part is housed in a high speed 40 pin leaded Multi Layer Ceramic (MLC) package.



Features

- 2.5 Gbit/s operation.
- 180 mA maximum modulator current.
- ECL compatible differential inputs.
- Power dissipation: 1.5 - 2.3 W (typ.)
- Available in two versions for:
  – 25 Ω (GD16076A-25SLP)
  – 50 Ω (GD16076A-50SLP)
- Housed in a leaded 40 pin MLC package.

Applications

- Tele Communications systems:
  – SDH STM-16
  – SONET OC-48
- Data Communications.
- $LiNbO_3$ Modulator Driver.
- High current laser driver.
- High-speed clock buffer.

GD16076A is designed to drive external loads with a characteristic impedance of:

- 25 Ω (GD16076A-25SLP)
- 50 Ω (GD16076A-50SLP).

With DIN high the sink current into OUT will be high.

In order to avoid reflections, and thereby to obtain optimum performance, connections from OUT and/or NOUT must be made with a transmission line of 25 Ω (50 Ω), terminated at the device end into a matched load. This is because OUT and NOUT are unterminated open drain outputs and effectively can be regarded as modulated current sources.

The termination voltage on an output is determined by the load impedance Z_L (25 Ω or 50 Ω) and the output current I_{OUT}. The optimum termination voltage V_{CC} is:

$$V_{CC} = V_{DD} - 2V + Z_L \times I_{OUT}$$

see: “Thermal Considerations” in the section *Application Information* below.

The driver output current I_{OUT} can be measured as the voltage drop across a resistor R_{SIP}, internally on the chip, connected in between the VEEP pin and the SIP pin.

By using an external general purpose operational amplifier, as illustrated in Figure 1, the driver output current I_{OUT} may be controlled accurately and independent of environmental changes. VREF in Figure 1 should be $R_{SIP} \cdot I_{OUT}$, see above. The OP-amp must be able to drive CIP in the range VEEP - 1.2 V to VEEP +1.2 V.

R_{SIP} is made of two resistors of 4 Ω, as shown in Figure on page 1. One of the resistors are connected to the VEEP pins 4 and 5, and the other to the VEEP pins 16 and 17. If all VEEP are connected, R_{SIP} is 2 Ω. Each resistor has been dimensioned to withstand 100 mA. Therefore if the output current I_{OUT} is > 100 mA the VEEP pins on opposite sides must be connected externally in order not to damage the chip.

Notice that the transistors driving OUT and NOUT are susceptible to breakdown. Therefore the peak voltage on OUT and NOUT should never exceed 10.0 V above VEEP as specified in *Maximum Ratings*.

Application Information

In this section the behaviour of GD16076A is described when used in connection with a $LiNbO_3$ Mach Zender Interferometer, for simplicity called “the modulator”. First the modulator and a transfer function from electrical to optical signal is derived. Next a SPICE simulation of the application diagram in Figure 1 is shown. In this simulation the modulator is connected to the output of GD16076A via a transmission line with a characteristic impedance of 25 Ω. Finally some thermal properties of GD16076A are considered.

The Mach Zender Interferometer.

The modulator is typically made as shown in Figure 2. Its function is to intensity modulate the incoming unmodulated light.

In optical data transmission systems, current modulation of the light directly in the semiconductor laser, causes the optical signal from the laser to have chirp (frequency fluctuations of the light frequency). This degrades system performance.

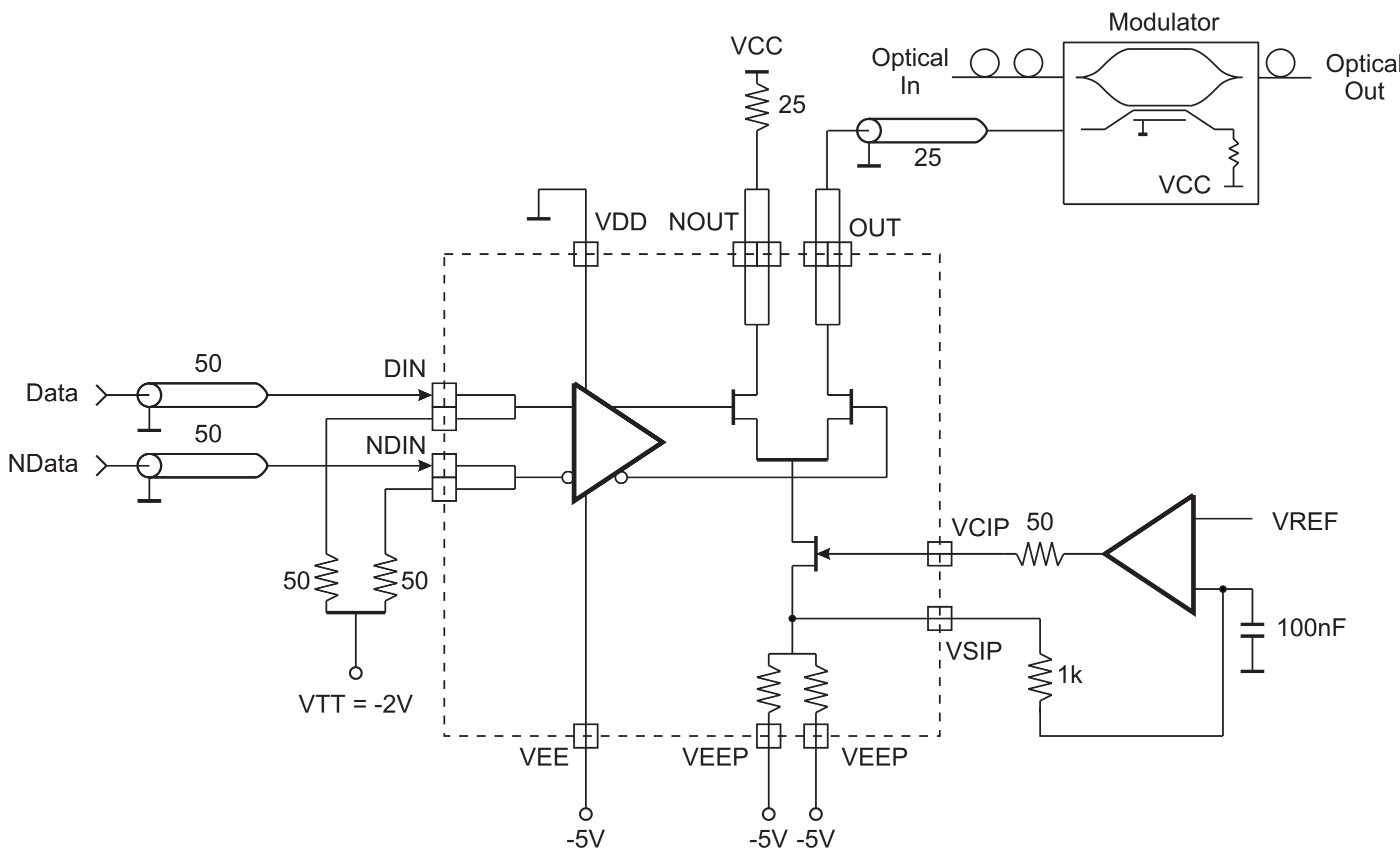


Figure 1. *Application Diagram*

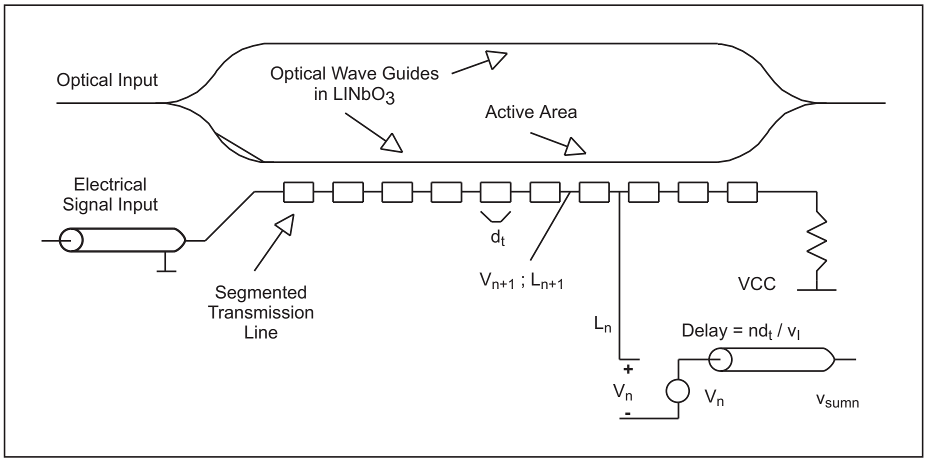


Figure 2. *Optical Modulator with Segmented Transmission Line.*

The incoming light to the modulator is an unmodulated continuous light wave, and therefore does not suffer from chirp. The signal treatment within the modulator is linear, see below. Consequently the modulated light signal does not suffer from chirp.

High speed optical communication systems using a Mach Zender Interferometer therefore has better system performance than systems using direct current modulation.

Characterisation of The Modulator

When the light enters the modulator it is split into two branches, as shown in Figure 2. On the output it is combined again.

The propagation delay of the light wave can be adjusted through one (or both) of the branches by applying a voltage to the substrate near the optical wave-guide. This is because the refractive index of the material changes proportional to the voltage applied to the substrate and because the velocity of light is proportional to the refractive index. Changing the refractive index in one branch therefore gives a tuneable delay variation between the two branches. Thereby the light can be combined in phase, making the light pass through to the output without attenuation, or in counter phase, thereby turning off the light.

Typically the electrical data signal for a high-speed modulator is connected into the modulator via a transmission line, traveling along one of the optical branches. On the output the transmission line is terminated in order to obtain a good input impedance.

An equivalent diagram for the modulator has been derived. The diagram was made from the physical components of the modulator (input pin, bonding wires and transmission line characteristics), and fitting the component values to measurements.

At low modulation rates the relation between the voltage applied to the modulator and the relative light p on the output can be described as:

$$p = \frac{(1 + \cos(\pi(V_{ACT} + V_{OFF}) / V_{\nabla}))}{2} \qquad (1)$$

Where:
V_{ACT} is the voltage applied to the active region
V_{OFF} is an offset voltage (material dependent)
V_{∇} is the voltage difference between the applied voltages that causes fully on and fully off light on the output respectively.

From (1) some important features of the modulator can bee derived. When $(V_{ACT} + V_{OFF})/V_{\nabla} = 1$ then p = 0.
If $(V_{ACT} + V_{OFF})/V_{\nabla}$ becomes slightly larger than 1 or smaller than 1, p still approximates 0 very closely. 20 % over (under) shoot causes p to be only 0.1. This is due to the sine transformation in (1). Therefore the modulator effectively acts as a pulse shaper on the voltage V_{ACT} defined above and attenuates any small over and/or undershoot in the electrical signal.

However if the over and/or undershoot in the electrical signal becomes larger than approximately 1/3 V_{∇} there will be no limiting effect. Instead two pulses will be created on the optical output. An overshoot of 50 % causes p to be 0.5. I.e. instead of only one optical output pulse a second pulse has been created. Therefore it is important to ensure that the ringing on the electrical signal is less than approximately 20%.

The above formula works well at low modulation rates. However at high speed data rates the formula does not describe the function precisely, because the voltage actually travels as a wave along the active part.

Assuming first that the velocity of light is much higher than the electrical signals propagation velocity, the voltage that any light wave actually sees, will be the average of the voltages along the transmission lines, taking into account that the transmission line represents a loss. Now this voltage can be used as V_{ACT} in the above formula. In reality the velocity of light v_l is approximately c/2.2 for $LiNbO_3$, whereas the electrical signal's propagation velocity is approximately

$$\frac{c}{\sqrt{11.3}} = \frac{c}{3.4}$$

where c is the velocity of light in open air.

This means that instead of just averaging the voltage across the active area, the voltage that the optical wave actually sees is a function of time.

This was modeled by splitting up the active area into 10 parts, see Figure 2. The optical wave present at L_n at time t_n was present at L_{n+1} at time $t_n - d_t / v_l$, where d_t is the distance from L_n to Ln+1. The effective voltage V_{ACT} exposed to the light wave entering the active area at time t - causing the optical refractive index of the $LiNbO_3$ to change, and thereby changing the velocity of the light - therefore can be expressed as:

$$V_{ACT} = \frac{1}{N+1} \sum_{n=0}^{N} V_n(t - ndt / V_l) \qquad (2)$$

where $V_n(t)$ is the voltage at L_n.

The above formulas (1) and (2) were used together with the electrical equivalent diagram for the modulator to make SPICE simulations of the behaviour of GD16076A connected to an optical modulator as shown in Figure 1.

Simulations

In Figure 3 a simulation of the application diagram in Figure 1 is shown. The modulation current is 180 mA. The simulation shows the relative optical output power p as defined above. As shown the optical output has little ringing. Rise and fall times are below 90 ps.

In conclusion the above simulations have shown that GD16076A is capable of driving a Mach Zender Interferometer with a 180 mA drive current into 25 Ω at 2.5 Gbit/s.

Thermal Considerations

As shown in Figure 1 both the modulator and the unused NOUT outputs are terminated to V_{CC}. In order to reduce the chip power consumption it is important that V_{CC} is kept as low as possible. If e.g. the output current is 180 mA into 25 Ω the voltage swing will be 4.5 V.
If V_{CC} = 4.5 V the power consumption P_{OC} due to output current will be:

$$P_{OC} = (V_{CC} - V_{EEP} - 180mA \times 25\Omega) \times 180mA = 900mW \quad (3)$$

If instead V_{CC} = 2.5 V is used the power consumption will be only 540 mW.

Approximately 360 mW of P_{OC} is consumed by the current source and current sense resistors, see Figure on page 1 regardless of V_{CC}. Therefore the power consumption in the output FET's are reduced from 540 mW (270 mW each output FET) down to 180 mW (90 mW each output FET).

Therefore it is recommended to use the lowest possible value for V_{CC}, which does not sacrifice the performance of the modulator driver. The open drain outputs of GD16076A works down to V_{DD} - 2 V. With 180 mA output current into 25 W this means that V_{CC} can be as low as 2.5 V.

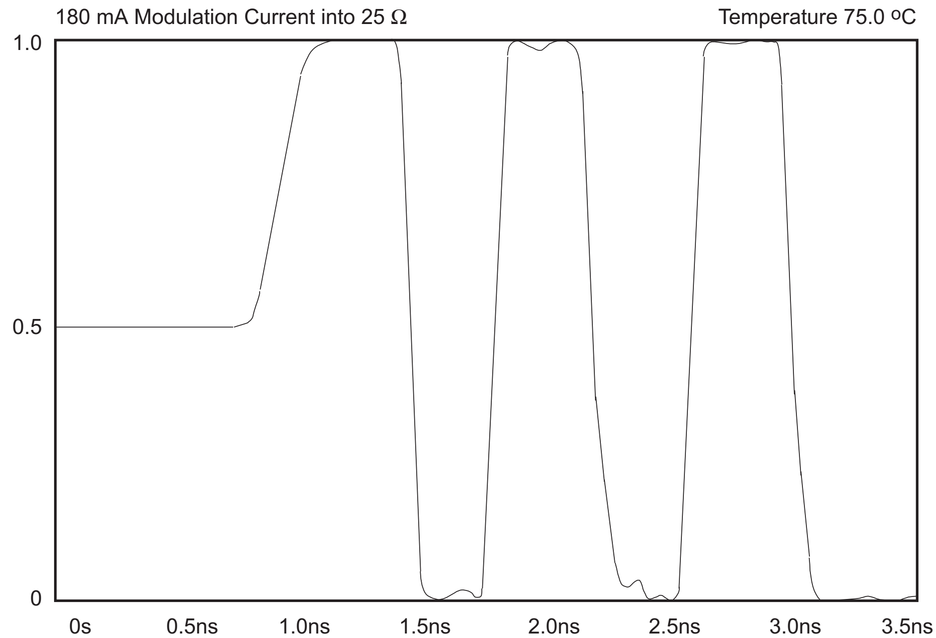


Figure 3. *Simulation of the Optical Output of the Modulator*

Pin List

Mnemonic:	Pin No.:	Pin Type:	Description:
DIN NDIN	32, 32 29, 30	ECL IN	Loop through' data inputs.
OUT NOUT (OUT) (NOUT)	9, 10 11, 12 (9) (12)	OPEN DRAIN	Data Outputs for 25Ω version GD16076A-25SLP. (Data Outputs for 50Ω version GD16076A-50SLP).
VCIP	6, 15	BIAS IN	Driver Current control input.
VSIP	2, 19	Analogue OUT	Driver Current sense output.
VDD	3, 7, 8, 13, 14, 18, 21, 23, 24, 25, 26, 28, 33, 35, 36, 37, 40 (10,11)	PWR	Ground. Common for both 25Ω and 50Ω versions. (Only 50Ω version GD16076A-50SLP)
VEE	1, 20, 22, 27, 34, 39	PWR	Negative Supply.
VEEP	4, 5, 16, 17	PWR	Negative Supply.
VREF	38	Analogue IN	For normal operation leave open.

Package Pinout

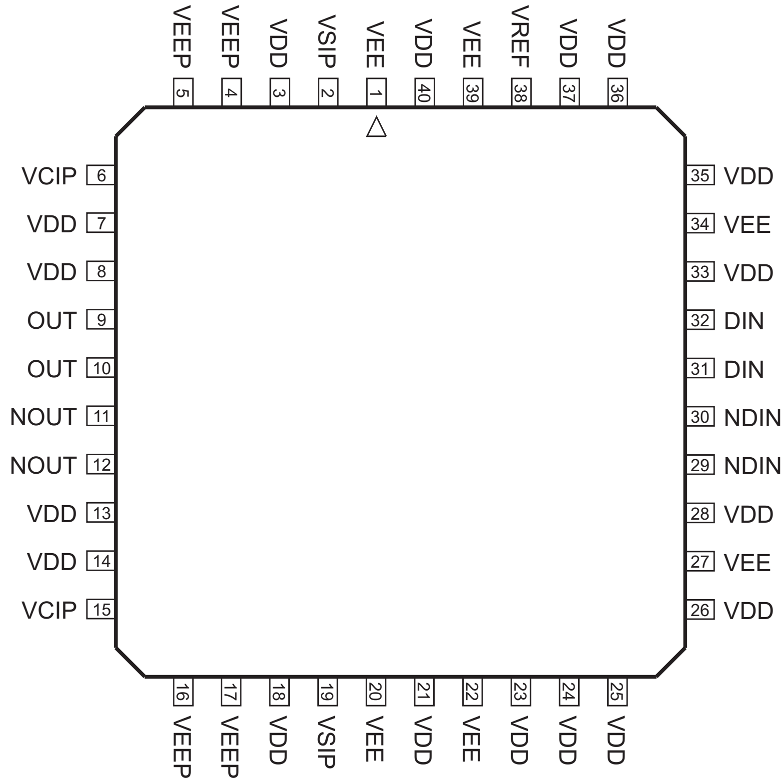


Figure 4. *25 Ω Output Version - Top View*

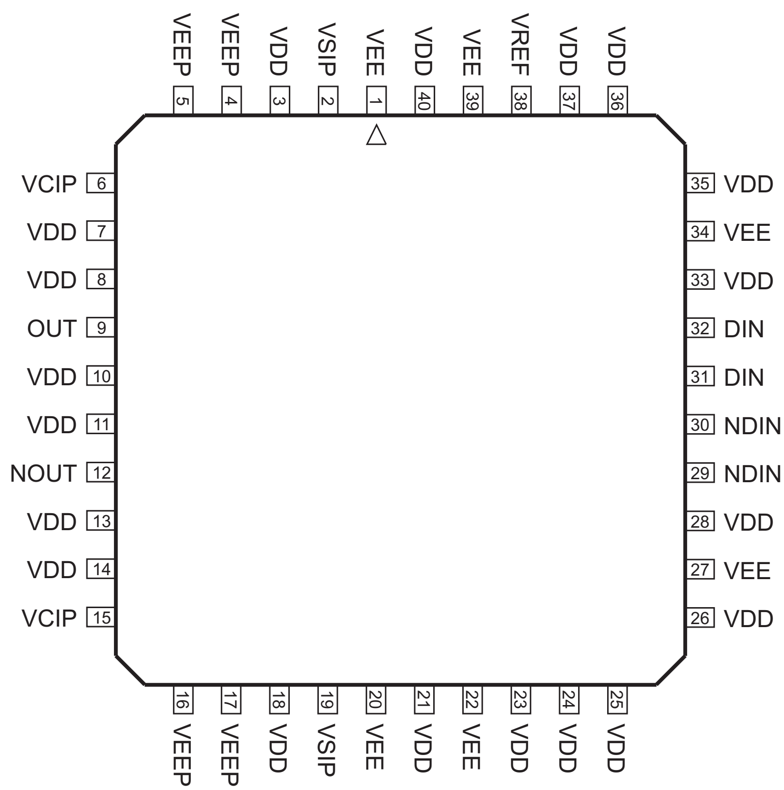


Figure 5. *50 Ω Output Version - Top View*

Maximum Ratings

These are the limits beyond which the component may be damaged.
All voltages in table are referred to *VDD* (GND).
All currents in table are defined positive out of the pin.

Symbol:	Characteristic:	Conditions:	MIN.:	TYP.:	MAX.:	UNIT.:
V_{EEP}	Supply Voltage	Note 1	V_{EE} - 0.5		2.5	V
V_{EE}	Supply Voltage		- 7.0		0	V
$V_{O\ OUT,NOUT}$	Applied Voltage OUT, NOUT		V_{EEP} -0.5		V_{EEP}+10	V
$I_{O\ OUT,NOUT}$	Output Current OUT, NOUT				- 200	mA
$V_{I\ VCIP}$	Output Current Control		V_{EEP} -1.4		V_{EEP}+1.4	V
$V_{I\ DIN,NDIN}$	Applied Voltage DIN, NDIN		V_{EE} -0.5		0.5	V
T_O	Operating Temperature	Channel	- 55		+150	°C
T_S	Storage Temperature		- 65		+175	°C

Note 1: VEEP normally connected to VEE externally.

DC Characteristics

T_{case} = 0 °C to 85 °C.
All voltages in table are referred to *VDD* (GND).
All currents in table are defined positive out of the pin.

Symbol:	Characteristic:	Conditions:	MIN.:	TYP.:	MAX.:	UNIT:
V_{EEP}	Negative Supply Voltage for Output		- 5.5	- 5.2	- 5.0	V
V_{EE}	Negative Supply Voltage		- 5.5	- 5.2	- 5.0	V
I_{VEEP}	Negative Supply Current	Note 1	40		180	mA
I_{VEE}	Negative Supply Current	Note 1		260		mA
$P_{DISS,open}$	Power Dissipation	V_{EEP} unconnected		1.4		W
P_{DISS}	Power Dissipation	Note 1		2.3		W
V_{VCIP}	Output Current Control Voltage		V_{EEP} - 1.4		V_{EEP}+1.4	V
$V_{HI\ DIN,NDIN}$	DIN, NDIN HI Input Voltage		V_{CM} + 0.3			V
$V_{LO\ DIN,NDIN}$	DIN, NDIN LO Input Voltage				V_{CM}-0.3	V
$V_{CM\ DIN,NDIN}$	DIN, NDIN Common Mode Voltage		- 2.0		- 1.0	V
$I_{OH\ OUT,NOUT}$	OUT,NOUT Output HI Current	Note 2, 4	- 180		- 40	mA
$I_{OL\ OUT,NOUT}$	OUT,NOUT Output LO Current	Note 3			1	%

Note 1: R_L = 25 Ω. Maximum amplitude on R_L assumed (180 mA modulation current). R_L connected to VDD + 2.8 V. Duty cycle 50%.
Note 2: HI current is defined as maximum current sink.
Note 3: See $I_{OL\ OUT,NOUT}$ AC Characteristics below.
Note 4: Minimum specification corresponds to maximum amplitude on load. $I_{OH\ OUT,NOUT}$ depends on V_{CIP}.

AC Characteristics

T_{CASE} = 0 °C to 85 °C.

Symbol:	Characteristic:	Conditions:	MIN.:		MAX.:	UNIT:
$f_{max\ DIN,OUT}$	Maximum Data I/O Frequency		2.5			Gbit/s
$t_{r\ OUT}$	OUT Rise Time (20 – 80 %)	Note 1		100	120	ps
$t_{f\ OUT}$	OUT Fall Time (20 – 80 %)	Note 1		100	120	ps
$V_{amp\ OUT}$	OUT Voltage Amplitude (p-p)	Note 1	4.5			V
$\Delta I_{OH OUT,NOUT}$	Relative Deviation of OUT Output HI Current from Current through Sense Resistor R_{SIP}.	Note 1, 2, 3			+/- 5	%
$I_{OL OUT,NOUT}$	OUT Output LO Current Relative to $I_{HI OUT}$	Note 1, 4			1	%
f_{VCS}	Modulation Frequency	Note 5		100		kHz

Note 1: R_L = 25 Ω mounted at package pin (C_L <= 1pF). Differential input signals with t_r, t_f < 140 ps (10 – 90 %) and amplitude > 600 mV_{PP} assumed.

Note 2: Defined as: $\Delta I_{HI OUT} = \frac{1-(V_{SIP}-V_{EEP})}{k \times R_{SIP} \times I_{OH OUT}}$

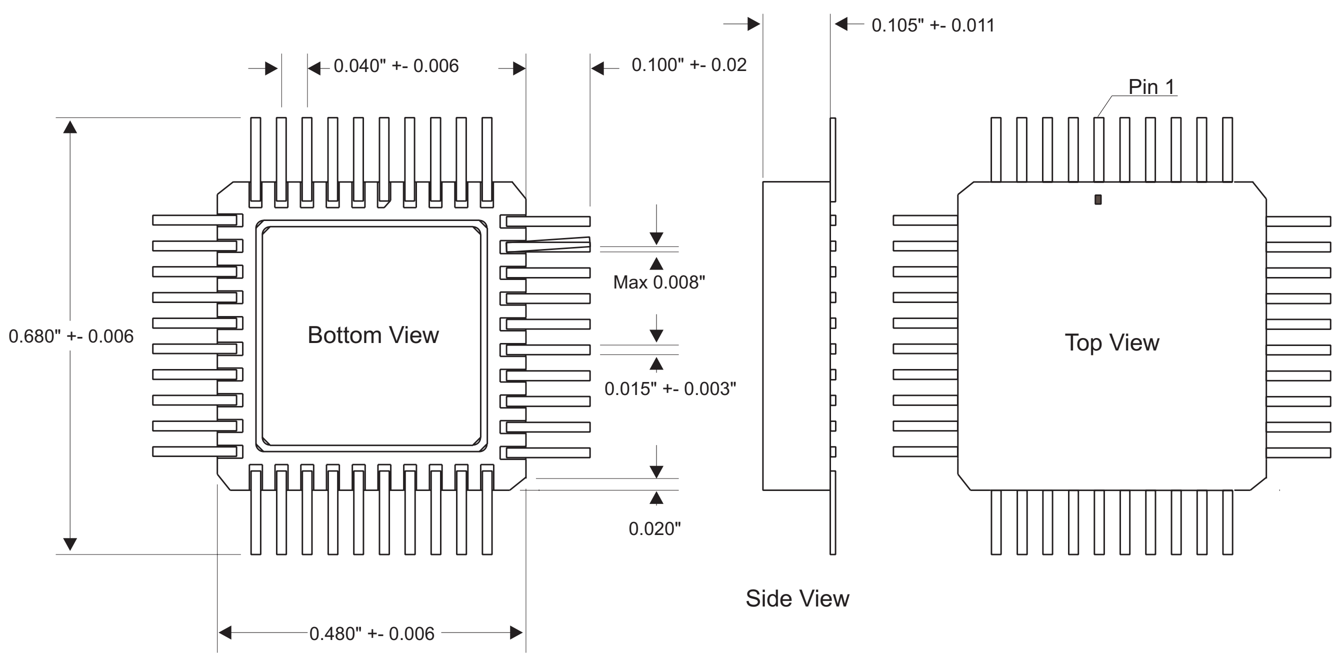
where k takes into account parasitic resistance within the package and the PCB, and process variations on R_{SIP}. R_{SIP} normally is 2 Ω (see functional details above).

Note 3: Guaranteed up to 2.5 Gbit/s.

Note 4: 11001100 2.5 Gbit/s patterns and lower frequency patterns. For a 1010 2.5 Gbit/s pattern the deviation is allowed to be +/-5%.

Note 5: Modulation depth for current at least 5%.

Package Pinout



Note 1: Leads are hot dip soldered before cutting
Note 2: Coplanarity of leads > 0.008"

Figure 6. *Package 40 pin (All dimensions are in inch)*

Device Marking

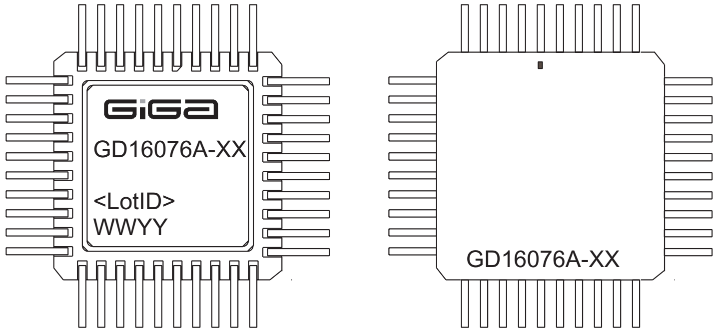


Figure 7. *Device Marking (XX = Option)*

Ordering Information

To order, please specify as shown below:

Product Name:	**Option:**	**Package Type:**	**Case Temperature Range:**
GD16076A-25SLP	25 Ω load	40 pin Straight Leads Tinned	0..85 °C
GD16076A-50SLP	50 Ω load	40 pin Straight Leads Tinned	0..85 °C

Mileparken 22, DK-2740 Skovlunde
Denmark
Telephone : +45 4492 6100
Telefax : +45 4492 5900
E-mail : sales@giga.dk
Web site : http://www.giga.dk

Please check our Internet web site for latest version of this data sheet.

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