

Low-Voltage 1.2V/1.8V CML 1:2 Fanout Buffer, 3.2 Gbps, 3.2 GHz

Features

- 1.2V/1.8V CML 1:2 Fanout Buffer
- Guaranteed AC Performance over Temperature and Voltage:
 - DC-to->3.2 Gbps Throughput
 - <300 ps Propagation Delay (IN-to-Q)
 - <15 ps Within-Device Skew
 - <95 ps Rise/Fall Times
- Ultra-Low Jitter Design
 - 50 fs_{RMS} Typical Additive Phase Jitter
- High Speed CML Outputs
- 2.5V ±5%, 1.2V/1.8V ±5% Power Supply Operation
- Industrial Temperature Range: -40°C to +85°C
- Available in 16-pin (3 mm x 3 mm) QFN Package

Applications

- Data Distribution: OC-48, OC-48+FEC
- SONET Clock and Data Distribution
- Fibre Channel Clock and Data Distribution
- Gigabit Ethernet Clock and Data Distribution

Markets

- Storage
- ATE
- Test and Measurement
- Enterprise Networking Equipment
- High-End Servers
- Access
- Metro Area Network Equipment

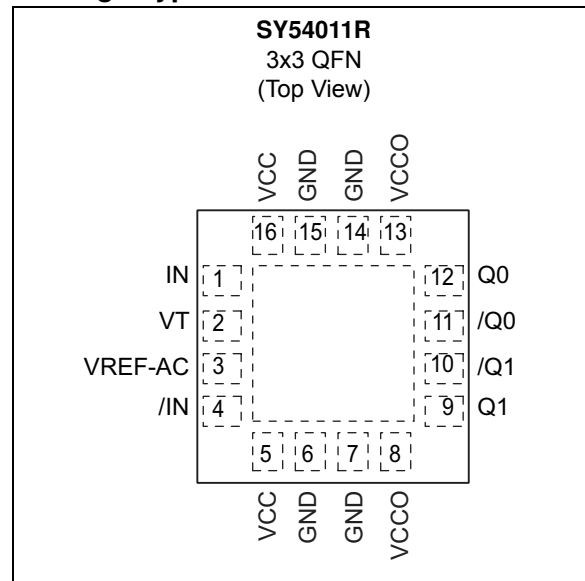
General Description

The SY54011R is a fully differential, low-voltage 1.2V/1.8V CML 1:2 fanout buffer. It is optimized to provide two identical output copies with less than 15 ps of skew and 50 fs_{RMS} of typical additive phase jitter. The SY54011R can process clock signals as fast as 3.2 GHz or data patterns up to 3.2 Gbps.

The differential input includes a unique, 3-pin input termination architecture that interfaces to LVPECL, LVDS or CML differential signals, (AC- or DC-coupled from a 2.5V driver) as small as 100 mV (200 mV_{PP}) without any level-shifting or termination resistor networks in the signal path. For AC-coupled input interface applications, an integrated voltage reference (V_{REF-AC}) is provided to bias the V_T pin. The outputs are CML, with extremely fast rise/fall times less than 95 ps.

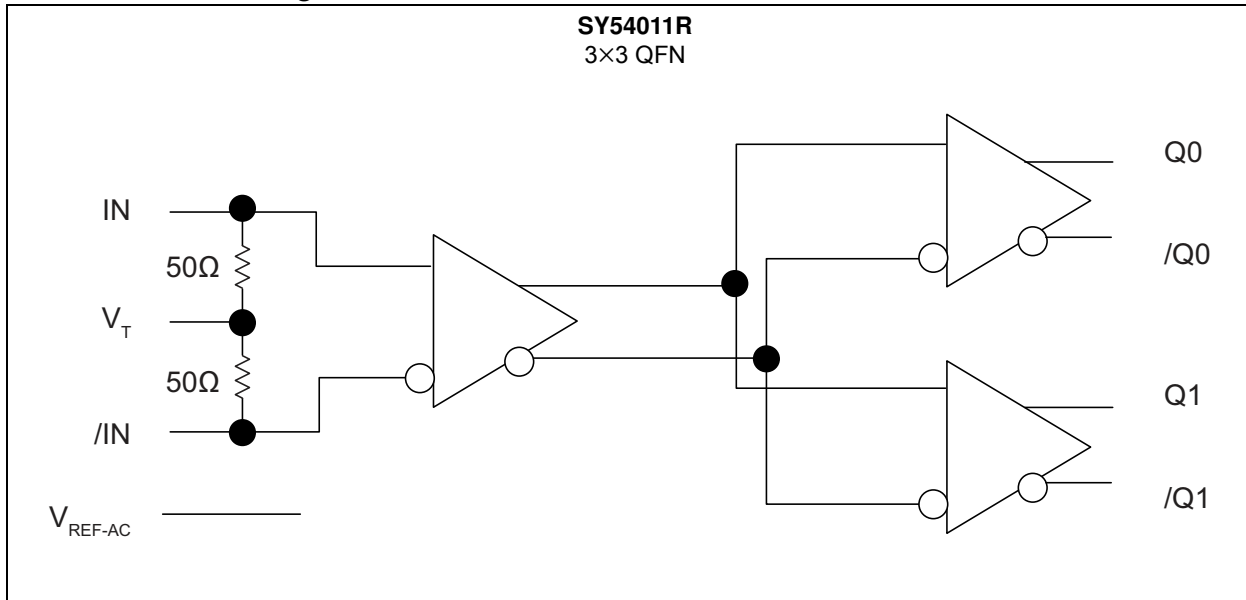
The SY54011R operates from a 2.5V ±5% core supply and a 1.2V or 1.8V ±5% output supply and is guaranteed over the full industrial temperature range (-40°C to +85°C). The SY54011R is part of the high speed, Precision Edge[®] product line.

Package Type



SY54011R

Functional Block Diagram



1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

Supply Voltage (V_{CC})	.....	-0.5V to +3.0V
Supply Voltage (V_{CCO})	.....	-0.5V to +2.7V
$V_{CC} - V_{CCO}$	.....	<1.8V
$V_{CCO} - V_{CC}$	.....	<0.5V
Input Voltage (V_{IN})	.....	-0.5V to V_{CC}
CML Output Voltage (V_{OUT})	.....	0.6V to $V_{CCO}+0.5V$
Current (V_T)		
Source or sink current on V_T pin	.....	±100 mA
Input Current		
Source or sink current on (IN, /IN)	.....	±50 mA
Current (V_{REF-AC})		
Source or sink current on V_{REF-AC} (Note 1)	.....	±0.5 mA

Operating Ratings ††

Supply Voltage (V_{CC})	.....	2.375V to 2.625V
(V_{CCO})	.....	1.14V to 1.9V

† **Notice:** Permanent device damage may occur if absolute maximum ratings are exceeded. This is a stress rating only and functional operation is not implied at conditions other than those detailed in the operational sections of this data sheet. Exposure to absolute maximum ratings conditions for extended periods may affect device reliability.

†† **Notice:** The data sheet limits are not guaranteed if the device is operated beyond the operating ratings.

Note 1: Due to the limited drive capability, use for input of the same package only.

TABLE 1-1: ELECTRICAL CHARACTERISTICS (Note 1)

Electrical Characteristics: Unless otherwise indicated, $T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$.

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Power Supply Voltage Range	V_{CC}	2.375	2.500	2.625	V	V_{CC}
		1.140	1.200	1.260	V	V_{CCO}
		1.700	1.800	1.900	V	V_{CCO}
Power Supply Current	I_{CC}	—	15	22	mA	Max. V_{CC}
Power Supply Current	I_{CCO}	—	32	42	mA	No Load. V_{CCO}
Input Resistance (IN-to- V_T , /IN-to- V_T)	R_{IN}	45	50	55	Ω	—
Differential Input Resistance (IN-to-/IN)	R_{DIFF_IN}	90	100	110	Ω	—
Input HIGH Voltage (IN, /IN)	V_{IH}	1.2	—	V_{CC}	V	IN, /IN
Input LOW Voltage (IN, /IN)	V_{IL}	0.2	—	$V_{IH} - 0.1$	V	V_{IL} with V_{IH} of 1.2V
Input HIGH Voltage (IN, /IN)	V_{IH}	1.140	—	V_{CC}	V	IN, /IN
Input LOW Voltage (IN, /IN)	V_{IL}	0.66	—	$V_{IH} - 0.10$	V	V_{IL} with V_{IH} of 1.140V, (1.2V-5%)

Note 1: The circuit is designed to meet the DC specifications shown in the above table after thermal equilibrium has been established.

2: Due to the limited drive capability, use for input of the same package only.

SY54011R

TABLE 1-1: ELECTRICAL CHARACTERISTICS (Note 1) (CONTINUED)

Electrical Characteristics: Unless otherwise indicated, $T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$.

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Input Voltage Swing (IN, /IN)	V_{IN}	0.1	—	1.0	V	See Figure 6-3
Differential Input Voltage Swing (/IN, /IN)	V_{DIFF_IN}	0.2	—	2.0	V	See Figure 6-5
Output Reference Voltage	V_{REF_AC}	$V_{CC} - 1.3$	$V_{CC} - 1.15$	$V_{CC} - 1.0$	V	Note 2
Voltage from Input to V_T	V_{T_IN}	—	—	1.28	V	—

Note 1: The circuit is designed to meet the DC specifications shown in the above table after thermal equilibrium has been established.

2: Due to the limited drive capability, use for input of the same package only.

TABLE 1-2: CML OUTPUTS DC ELECTRICAL CHARACTERISTICS (Note 1)

$V_{CCO} = 1.14\text{V}$ to 1.26V , $R_L = 50\Omega$ to V_{CCO} ,
 $V_{CCO} = 1.7\text{V}$ to 1.9V , $R_L = 50\Omega$ to V_{CCO} or 100Ω across the outputs,
 $V_{CC} = 2.375\text{V}$ to 2.625V . $T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$, unless otherwise stated.

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Output HIGH Voltage	V_{OH}	$V_{CCO} - 0.020$	$V_{CCO} - 0.010$	V_{CCO}	V	$R_L = 50\Omega$ to V_{CCO}
Output Voltage Swing	V_{OUT}	300	390	475	mV	See Figure 6-3
Differential Output Voltage Swing	V_{DIFF_OUT}	600	780	950	mV	See Figure 6-5
Output Source Impedance	R_{OUT}	45	50	55	Ω	—

Note 1: The circuit is designed to meet the DC specifications shown in the above table after thermal equilibrium has been established.

TABLE 1-3: AC ELECTRICAL CHARACTERISTICS

$V_{CCO} = 1.14\text{V}$ to 1.26V , $R_L = 50\Omega$ to V_{CCO} ,
 $V_{CCO} = 1.7\text{V}$ to 1.9V , $R_L = 50\Omega$ to V_{CCO} or 100Ω across the outputs,
 $V_{CC} = 2.375\text{V}$ to 2.625V . $T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$, unless otherwise stated.

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Maximum Frequency	f_{MAX}	3.2	—	—	Gbps	NRZ Data
		3.2	—	—	GHz	$V_{OUT} > 200\text{ mV}$
Propagation Delay IN-to-Q	t_{PD}	150	205	300	ps	Figure 6-1
Within Device Skew	t_{SKEW}	—	3	15	ps	Note 1
Part-to-Part Skew		—	—	75	ps	Note 2
Additive Phase Jitter	t_{JITTER}	—	42	—	f_{SRMS}	Carrier = 622 MHz Integration Range: 12 kHz – 20 MHz
		—	250	—		Carrier = 156.25 MHz. Integration Range: 12 kHz – 20 MHz
Output Rise/Fall Times (20% to 80%)	t_R, t_F	30	60	95	ps	At full output swing.
Duty Cycle	—	47	—	53	%	Differential I/O

Note 1: Within device skew is measured between two different outputs under identical input transitions.

2: Part-to-part skew is defined for two parts with identical power supply voltages at the same temperature and no skew at the edges at the respective inputs.

TEMPERATURE SPECIFICATIONS (Note 1)

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Temperature Ranges						
Operating Ambient Temperature Range	T_A	-40	—	+85	°C	—
Junction Operating Temperature	T_J	—	—	+125	°C	—
Storage Temperature Range	T_S	-65	—	+150	°C	—
Lead Temperature	—	—	+260	—	°C	Soldering, 20 sec.
Package Thermal Resistance (Note 2)						
Thermal Resistance, 3 x 3 QFN-16LD	θ_{JA}	—	75	—	°C/W	Still-Air
	Ψ_{JB}	—	33	—	°C/W	Junction-to-board

Note 1: The maximum allowable power dissipation is a function of ambient temperature, the maximum allowable junction temperature and the thermal resistance from junction to air (i.e., T_A , T_J , θ_{JA}). Exceeding the maximum allowable power dissipation will cause the device operating junction temperature to exceed the maximum +125°C rating. Sustained junction temperatures above +125°C can impact the device reliability.

2: Package thermal resistance assumes exposed pad is soldered (or equivalent) to the device's most negative potential on the PCB. θ_{JA} and Ψ_{JB} values are determined for a 4-layer board in still-air number, unless otherwise stated.

SY54011R

2.0 TYPICAL OPERATING CHARACTERISTICS

Note: The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be outside the specified operating range (e.g., outside specified power supply range) and therefore outside the warranted range.

For Figure 2-1 through Figure 2-3, $V_{CC} = 2.5V$, $V_{CCO} = 1.2V$, $GND = 0V$, $V_{IN} = 100\text{ mV}$; $R_L = 50\Omega$ to $1.2V$; $T_A = +25^\circ\text{C}$, unless otherwise stated.

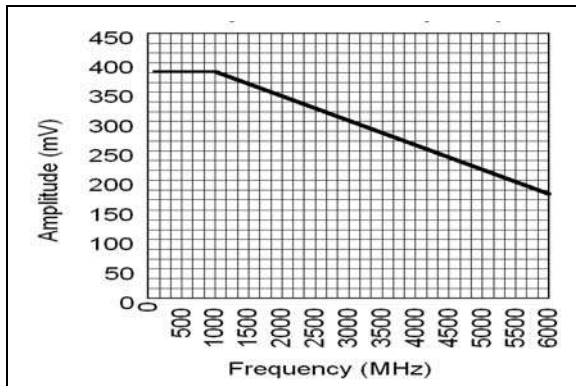


FIGURE 2-1: Amplitude vs. Frequency.

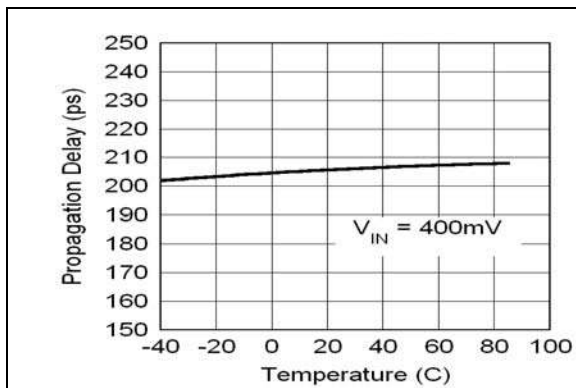


FIGURE 2-2: Propagation Delay vs. Temperature.

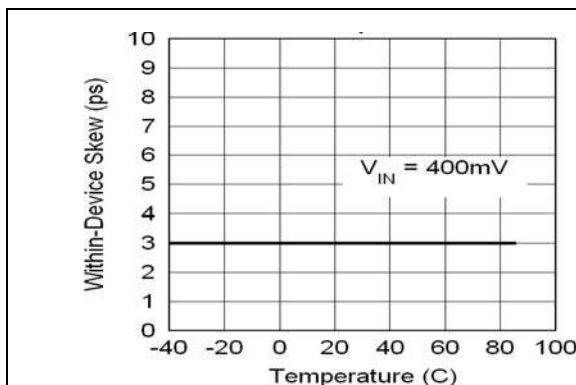


FIGURE 2-3: Within-Device Skew vs. Temperature.

For Figure 2-4 through Figure 2-7, $V_{CC} = 2.5V$, $V_{CC0} = 1.2V$, $GND = 0V$, $V_{IN} = 100\text{ mV}$; $R_L = 50\Omega$ to $1.2V$, Data Pattern: $2^{23}-1$; $T_A = +25^\circ\text{C}$, unless otherwise stated.

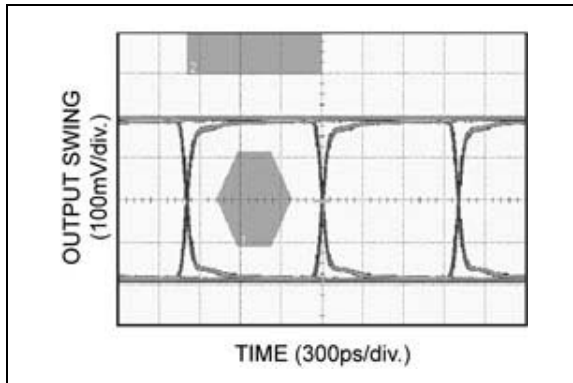


FIGURE 2-4: 1.0 Gbps Data.

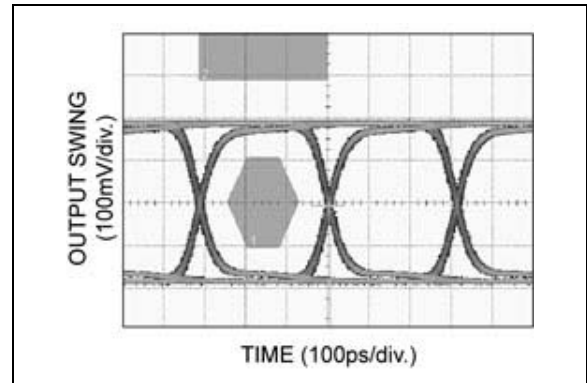


FIGURE 2-6: 3.2 Gbps Data.

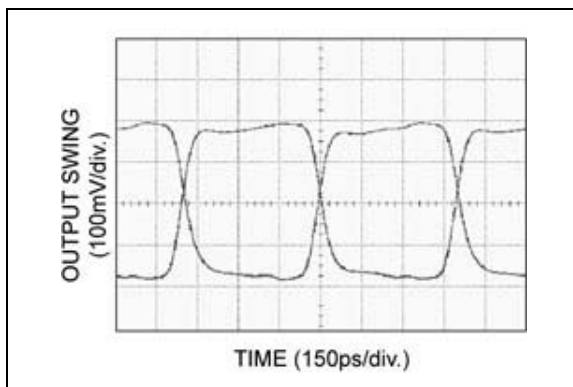


FIGURE 2-5: 1.0 GHz Clock.

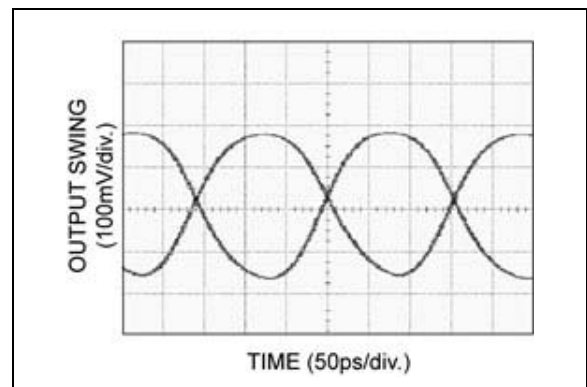


FIGURE 2-7: 3.2 GHz Clock.

SY54011R

3.0 PIN DESCRIPTIONS

The descriptions of the pins are listed in [Table 3-1](#).

TABLE 3-1: PIN FUNCTION TABLE

Pin Number	Symbol	Description
1, 4	IN, /IN	Differential Input: This input pair is the differential signal input to the device. Input accepts differential signals as small as 100 mV (200 mV _{PP}). Each input pin internally terminates with 50Ω to the V _T pin.
2	V _T	Input Termination Center-Tap: Each side of the differential input pair terminates to V _T pin. This pin provides a center-tap to a termination network for maximum interface flexibility. See the Input Interface Applications section.
3	V _{REF-AC}	Reference Voltage: This output biases to V _{CC} – 1.150V. It is used for AC-coupling inputs IN and /IN. Connect V _{REF-AC} directly to the V _T pin. Bypass with 0.1 μF low ESR capacitor to V _{CC} . Maximum sink/source current is ±0.5 mA. See the Input Interface Applications section.
5, 16	V _{CC}	Positive Power Supply: Bypass with 0.1 μF/0.01 μF low ESR capacitors as close to the V _{CC} pins as possible. Supplies input and core circuitry.
8, 13	V _{CCO}	Output Supply: Bypass with 0.1 μF//0.01 μF low ESR capacitors as close to the V _{CCO} pins as possible. Supplies the output buffers.
6, 7, 14, 15	GND, EP	Ground: Exposed pad must be connected to a ground plane that is the same potential as the ground pins.
10, 9 11, 12	/Q1, Q1 /Q0, Q0	CML Differential Output Pairs: Differential buffered copies of the input signal. The output swing is typically 390 mV. See the Input Interface Applications section for termination information.

4.0 INTERFACE APPLICATIONS

For Input Interface Applications see [Figure 7-1](#) through [Figure 7-7](#) and for CML Output Termination see [Figure 8-1](#) through [Figure 8-4](#).

4.1 CML Output Termination with V_{CCO} 1.2V

For V_{CCO} of 1.2V (see [Figure 8-1](#)), terminate the output with 50 Ω -to-1.2V, DC-coupled, not 100 Ω differentially across the outputs.

If AC-coupling is used (see [Figure 8-4](#)), terminate into 50 Ω -to-1.2V before the coupling capacitor and then connect to a high value resistor to a reference voltage.

Do not AC couple with internally terminated receiver. For example, 50 Ω ANY-IN input. AC-coupling will offset the output voltage by 200 mV and this offset voltage will be too low for proper driver operation.

Any unused output pair needs to be terminated when V_{CCO} is 1.2V, do not leave floating.

4.2 CML Output Termination with V_{CCO} 1.8V

For V_{CCO} of 1.8V, [Figure 8-1](#) and [Figure 8-2](#), terminate with either 50 Ω -to- V_{CCO} or 100 Ω differentially across the outputs. AC- or DC-coupling is fine.

4.3 Input AC Coupling

The SY54011R input can accept AC coupling from any driver. Tie V_T to V_{REF-AC} and bypass with a 0.1 μ F capacitor as shown in [Figure 7-3](#) and [Figure 7-4](#).

SY54011R

5.0 ADDITIVE PHASE NOISE PLOTS

$V_{CC} = +2.5V$, $GND = 0V$, $T_A = +25^\circ C$.

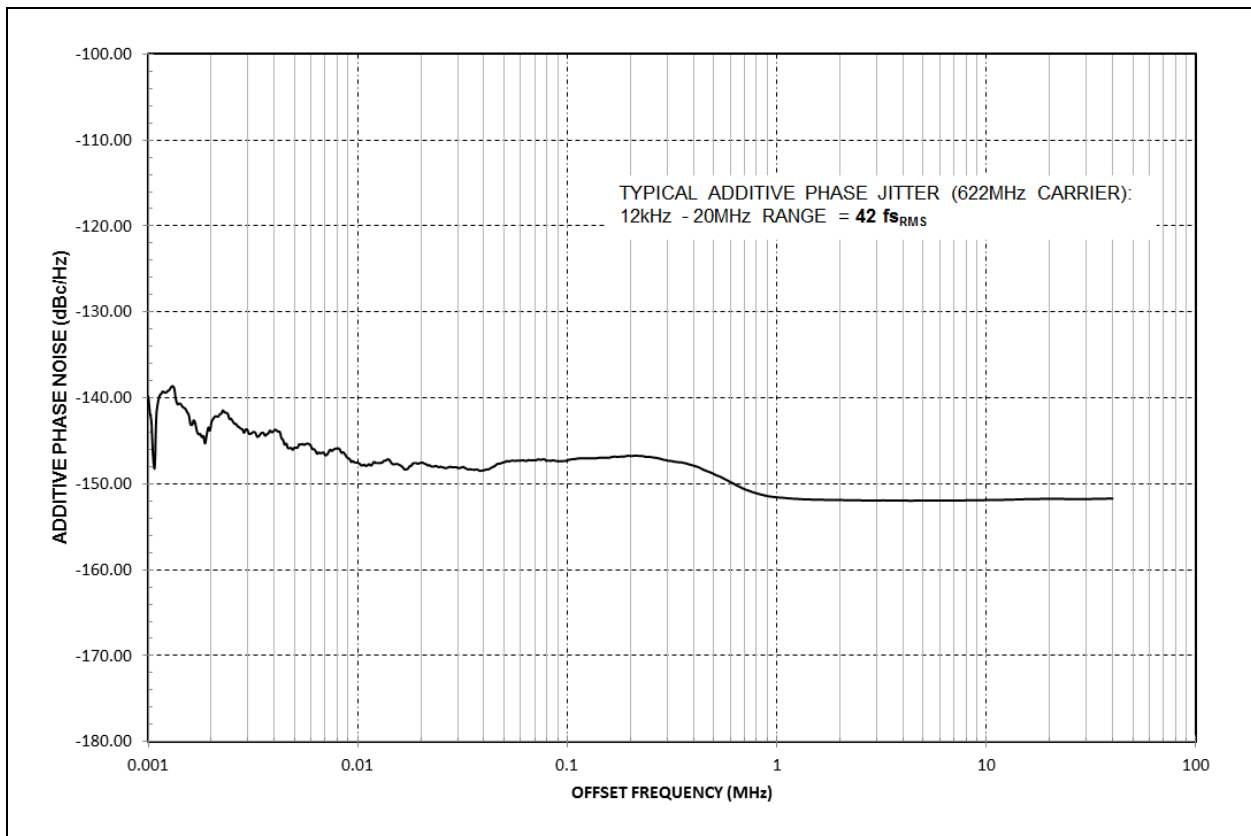


FIGURE 5-1: Typical Additive Phase Jitter: 622 MHz Carrier, 12 kHz to 20 MHz Range, 42 fs_{RMS}.

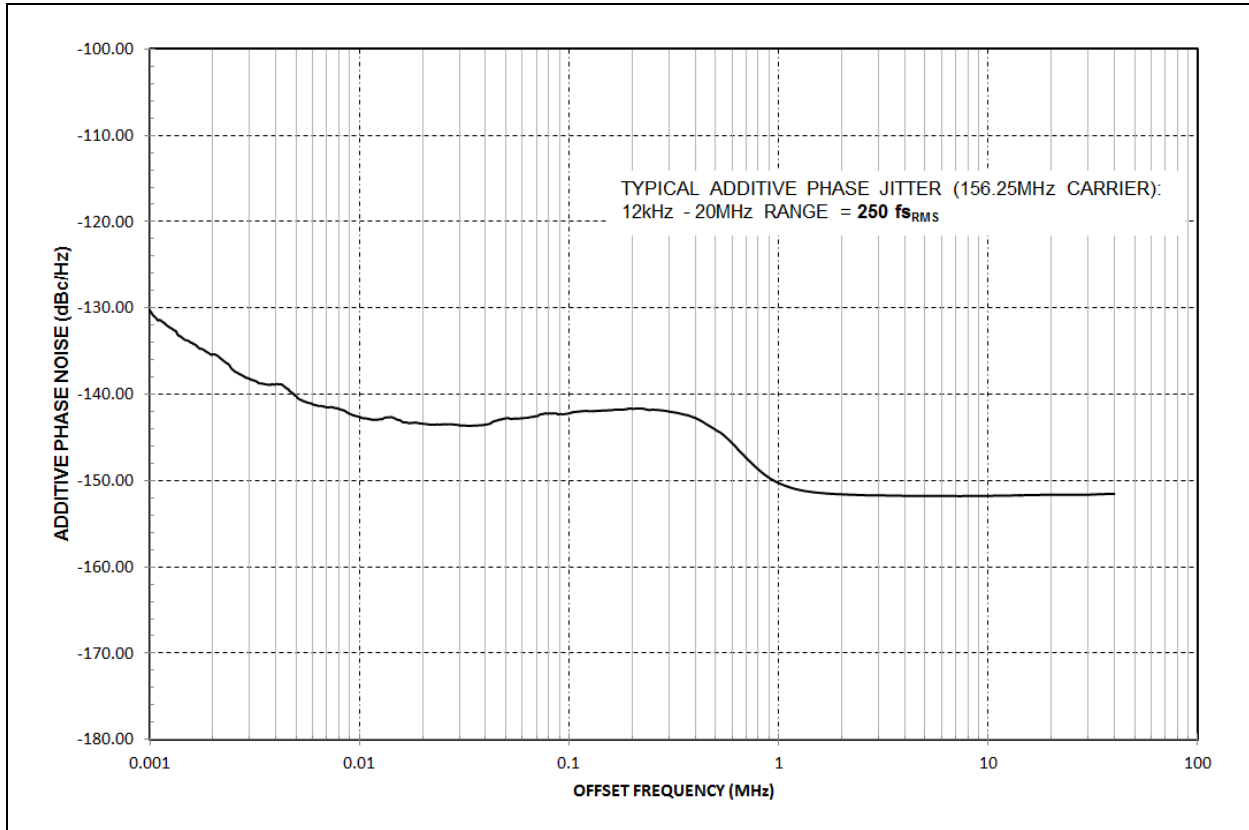


FIGURE 5-2: Typical Additive Phase Jitter: 156.25 MHz Carrier, 12 kHz to 20 MHz Range, 250 fs_{RMS}.

SY54011R

6.0 TIMING DIAGRAMS

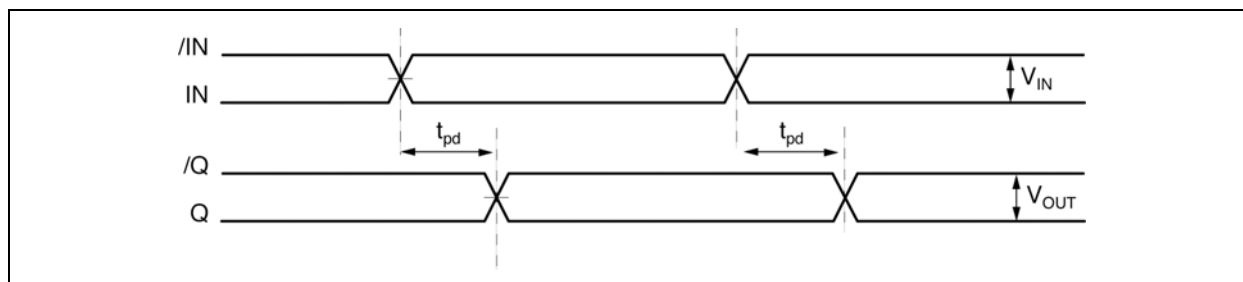


FIGURE 6-1: Propagation Delay.

6.1 Input and Output Stage

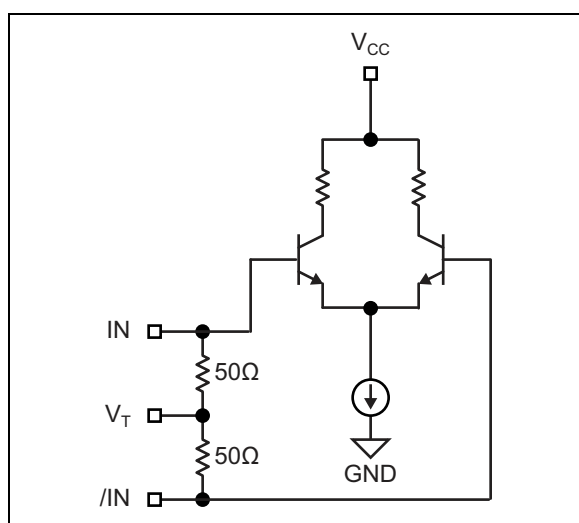


FIGURE 6-2: Simplified Differential Input Buffer.

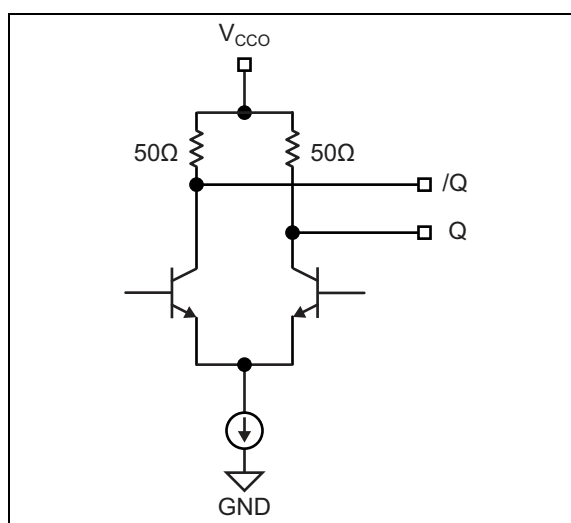


FIGURE 6-4: Simplified CML Output Buffer.

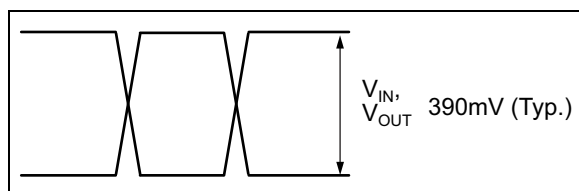


FIGURE 6-3: Single-Ended Swing.

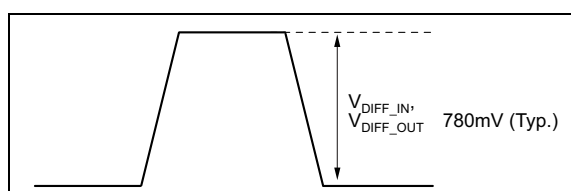


FIGURE 6-5: Differential Swing.

7.0 INPUT INTERFACE APPLICATIONS

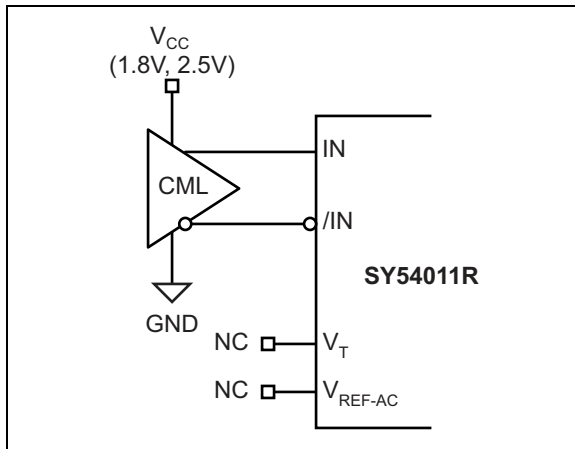


FIGURE 7-1: CML Interface (DC-Coupled, 1.8V, 2.5V).

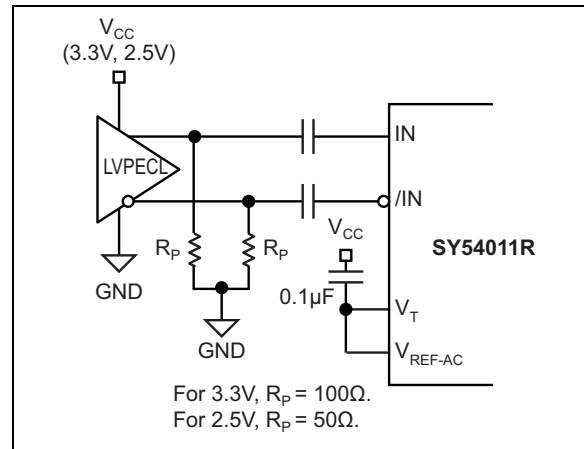


FIGURE 7-4: LVPECL Interface (AC-Coupled).

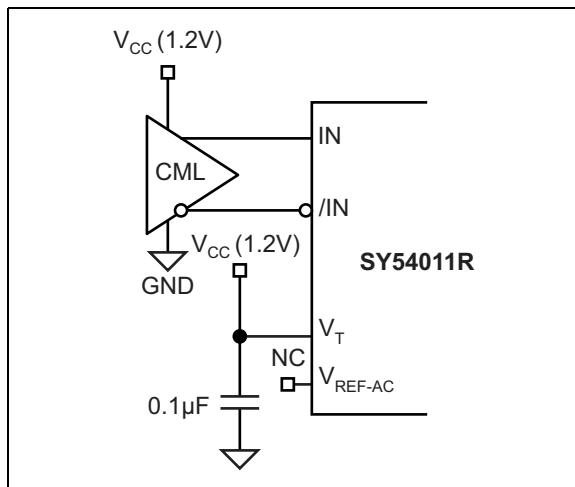


FIGURE 7-2: CML Interface (DC-Coupled, 1.2V).

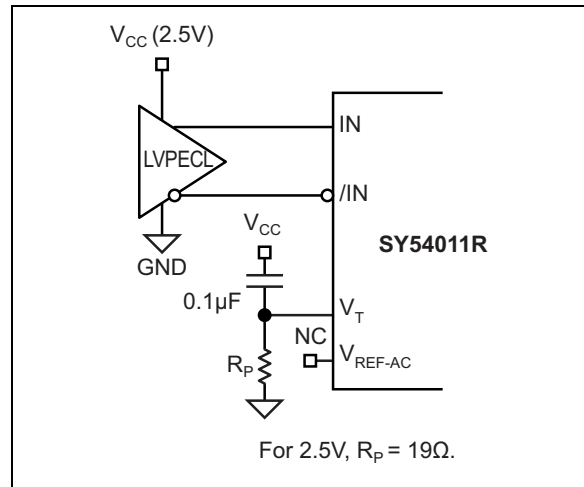


FIGURE 7-5: LVPECL Interface (DC-Coupled).

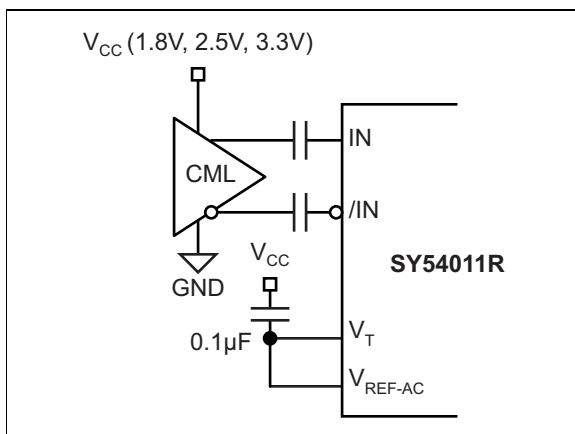


FIGURE 7-3: CML Interface (AC-Coupled).

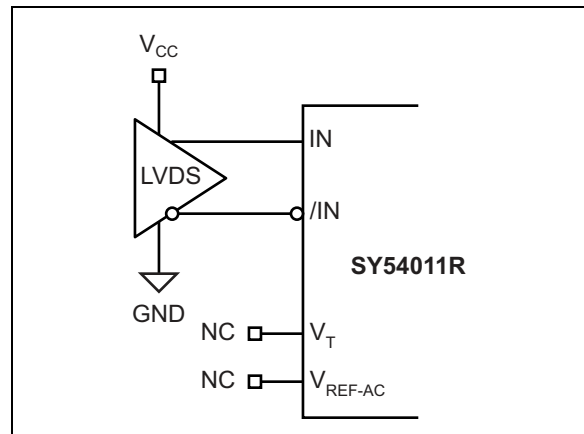


FIGURE 7-6: LVDS Interface.

SY54011R

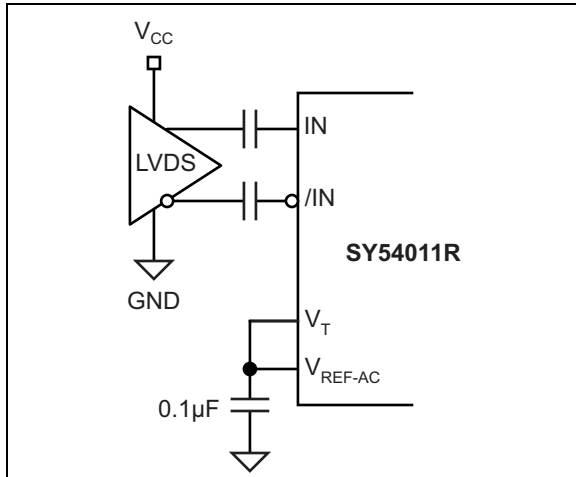


FIGURE 7-7: LVDS Interface (AC-Coupled).

8.0 CML OUTPUT TERMINATION

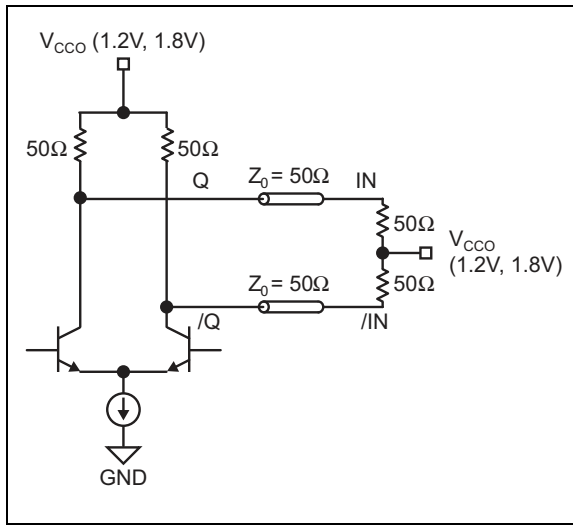


FIGURE 8-1: 1.2V or 1.8V CML DC-Coupled Termination.

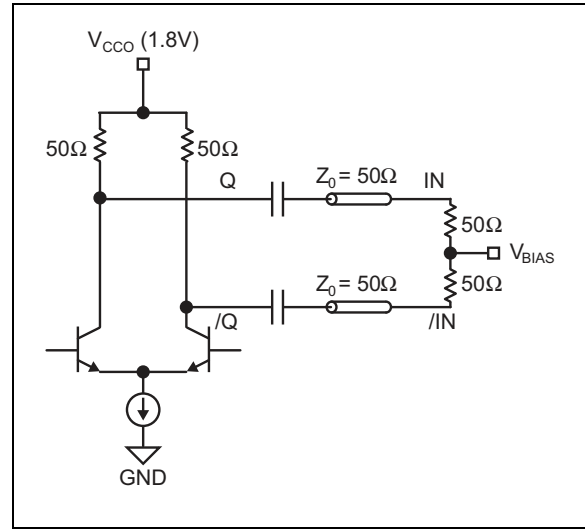


FIGURE 8-3: CML AC-Coupled Termination (V_{CCO} 1.8V Only).

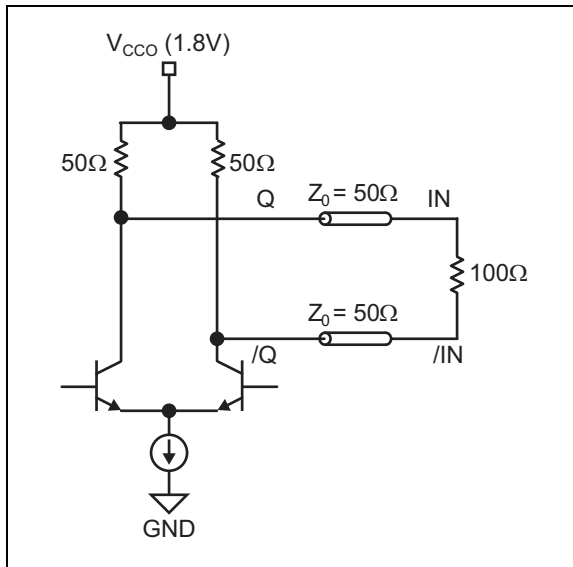


FIGURE 8-2: 1.8V CML DC-Coupled Termination.

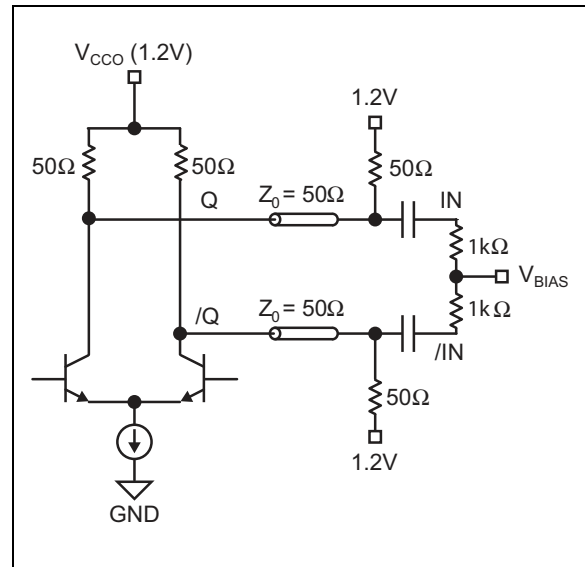


FIGURE 8-4: CML AC-Coupled Termination (V_{CCO} 1.2V Only).

SY54011R

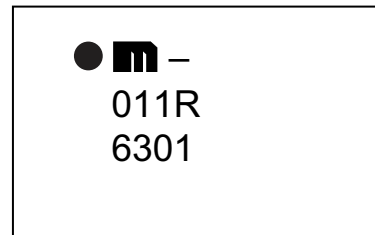
9.0 PACKAGING INFORMATION

9.1 Package Marking Information

16-Pin QFN*



Example



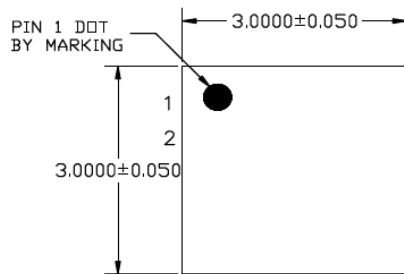
Legend:	XX...X	Product code or customer-specific information
	Y	Year code (last digit of calendar year)
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week '01')
	NNN	Alphanumeric traceability code
	(e3)	Pb-free JEDEC® designator for Matte Tin (Sn)
	*	This package is Pb-free. The Pb-free JEDEC designator ((e3)) can be found on the outer packaging for this package.
	●, ▲, ▼	Pin one index is identified by a dot, delta up, or delta down (triangle mark).
Note:	In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information. Package may or may not include the corporate logo.	
	Underbar (¯) and/or Overbar (¯) symbol may not be to scale.	

16-Lead QFN 3 mm x 3 mm Package Outline and Recommended Land Pattern

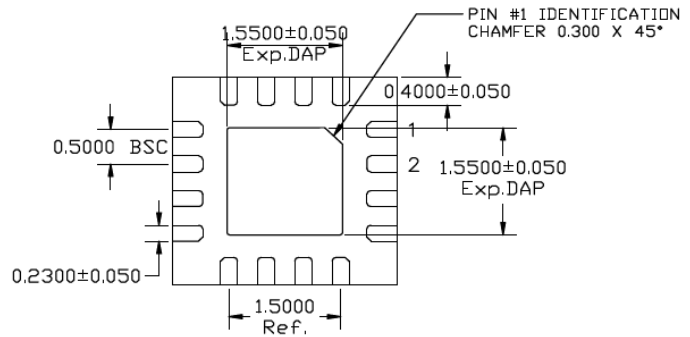
TITLE

16 LEAD QFN 3x3mm PACKAGE OUTLINE & RECOMMENDED LAND PATTERN

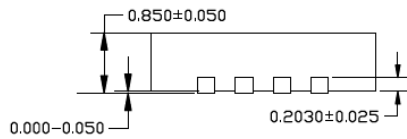
DRAWING #	QFN33-16LD-PL-1	UNIT	MM
-----------	-----------------	------	----



TOP VIEW
NOTE: 1, 2, 3



BOTTOM VIEW
NOTE: 1, 2, 3



SIDE VIEW
NOTE: 1, 2, 3

NOTE:

1. MAX PACKAGE WARPAGE IS 0.05 MM
2. MAX ALLOWABLE BURR IS 0.076 MM IN ALL DIRECTIONS
3. PIN #1 IS ON TOP WILL BE LASER MARKED
4. RED CIRCLE IN LAND PATTERN INDICATE THERMAL VIA. SIZE SHOULD BE 0.30-0.35 MM IN DIAMETER AND SHOULD BE CONNECTED TO GND FOR MAX THERMAL PERFORMANCE
5. GREEN RECTANGLES (SHADED AREA) indicate SOLDER STENCIL OPENING ON EXPOSED PAD AREA. SIZE SHOULD BE 0.60x0.60 MM IN SIZE, 0.20 MM SPACING.

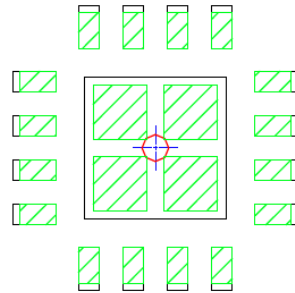
Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>.

SY54011R

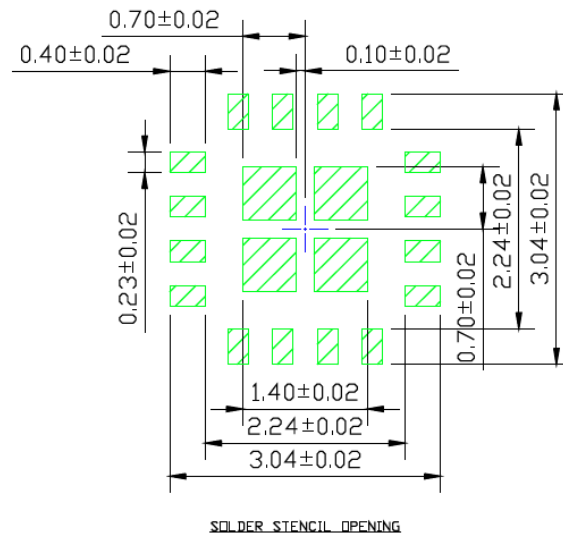
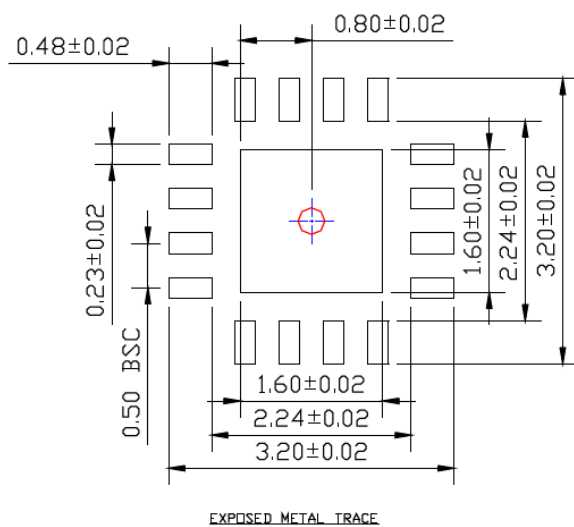
POD-Land Pattern drawing # QFN33-16LD-PL-1

RECOMMENDED LAND PATTERN

NOTE: 4, 5



STACKED-UP



Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>.

APPENDIX A: REVISION HISTORY

Revision A (January 2018)

- Converted to Micrel data sheet SY54011R to Microchip data sheet template DS20005525A.
- Minor text changes throughout.
- Updated [Additive Phase Noise Plots](#) images.

SY54011R

NOTES:

PRODUCT IDENTIFICATION SYSTEM

To order or obtain information, e.g., on pricing or delivery, contact your local Microchip representative or sales office.

<u>PART NO.</u>	X	X	X	-XX
Device	Voltage Option	Package	Temperature Range	Media Type
Device:	SY54011:	Low Voltage 1.2V/1.8V CML 1:2 Fanout Buffer, 3.2 Gbps, 3.2 GHz		
Voltage Option:	R =	1.2V/1.8V/2.5V		
Package:	M =	16-Lead 3 mm x 3 mm QFN		
Temperature Range:	G =	-40°C to +85°C (NiPdAu Lead Free)		
Media Type:	<blank> =	100/Tube		
	TR =	1,000/Reel		

Examples:	
a) SY54011RMG:	1.2V, 1.8V, and 2.5V Output Voltage, 16-Lead 3 mm x 3 mm QFN, -40°C to +85°C, 100/Tube
b) SY54011RMG-TR:	1.2V, 1.8V, and 2.5V Output Voltage, 16-Lead 3 mm x 3 mm QFN, -40°C to +85°C, 1,000/Reel

Note 1:	
Tape and Reel identifier only appears in the catalog part number description. This identifier is used for ordering purposes and is not printed on the device package.	

SY54011R

NOTES:

Note the following details of the code protection feature on Microchip devices:

- Microchip products meet the specification contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is one of the most secure families of its kind on the market today, when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods used to breach the code protection feature. All of these methods, to our knowledge, require using the Microchip products in a manner outside the operating specifications contained in Microchip's Data Sheets. Most likely, the person doing so is engaged in theft of intellectual property.
- Microchip is willing to work with the customer who is concerned about the integrity of their code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of their code. Code protection does not mean that we are guaranteeing the product as “unbreakable.”

Code protection is constantly evolving. We at Microchip are committed to continuously improving the code protection features of our products. Attempts to break Microchip's code protection feature may be a violation of the Digital Millennium Copyright Act. If such acts allow unauthorized access to your software or other copyrighted work, you may have a right to sue for relief under that Act.

Information contained in this publication regarding device applications and the like is provided only for your convenience and may be superseded by updates. It is your responsibility to ensure that your application meets with your specifications. MICROCHIP MAKES NO REPRESENTATIONS OR WARRANTIES OF ANY KIND WHETHER EXPRESS OR IMPLIED, WRITTEN OR ORAL, STATUTORY OR OTHERWISE, RELATED TO THE INFORMATION, INCLUDING BUT NOT LIMITED TO ITS CONDITION, QUALITY, PERFORMANCE, MERCHANTABILITY OR FITNESS FOR PURPOSE. Microchip disclaims all liability arising from this information and its use. Use of Microchip devices in life support and/or safety applications is entirely at the buyer's risk, and the buyer agrees to defend, indemnify and hold harmless Microchip from any and all damages, claims, suits, or expenses resulting from such use. No licenses are conveyed, implicitly or otherwise, under any Microchip intellectual property rights unless otherwise stated.

Microchip received ISO/TS-16949:2009 certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona; Gresham, Oregon and design centers in California and India. The Company's quality system processes and procedures are for its PIC® MCUs and dsPIC® DSCs, KEELoC® code hopping devices, Serial EEPROMs, microperipherals, nonvolatile memory and analog products. In addition, Microchip's quality system for the design and manufacture of development systems is ISO 9001:2000 certified.

**QUALITY MANAGEMENT SYSTEM
CERTIFIED BY DNV
= ISO/TS 16949 =**

Trademarks

The Microchip name and logo, the Microchip logo, AnyRate, AVR, AVR logo, AVR Freaks, BeaconThings, BitCloud, CryptoMemory, CryptoRF, dsPIC, FlashFlex, flexPWR, Helder, JukeBlox, KEELoC, KEELoC logo, Klear, LANCheck, LINK MD, maXStylus, maXTouch, MediaLB, megaAVR, MOST, MOST logo, MPLAB, OptoLyzer, PIC, picoPower, PICSTART, PIC32 logo, Prochip Designer, QTouch, RightTouch, SAM-BA, SpyNIC, SST, SST Logo, SuperFlash, tinyAVR, UNI/O, and XMEGA are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

ClockWorks, The Embedded Control Solutions Company, EtherSynch, Hyper Speed Control, HyperLight Load, IntelliMOS, mTouch, Precision Edge, and Quiet-Wire are registered trademarks of Microchip Technology Incorporated in the U.S.A.

Adjacent Key Suppression, AKS, Analog-for-the-Digital Age, Any Capacitor, AnyIn, AnyOut, BodyCom, chipKIT, chipKIT logo, CodeGuard, CryptoAuthentication, CryptoCompanion, CryptoController, dsPICDEM, dsPICDEM.net, Dynamic Average Matching, DAM, ECAN, EtherGREEN, In-Circuit Serial Programming, ICSP, Inter-Chip Connectivity, JitterBlocker, KlearNet, KlearNet logo, Mindi, MiWi, motorBench, MPASM, MPF, MPLAB Certified logo, MPLIB, MPLINK, MultiTRAK, NetDetach, Omniscient Code Generation, PICDEM, PICDEM.net, PICKit, PICtail, PureSilicon, QMatrix, RightTouch logo, REAL ICE, Ripple Blocker, SAM-ICE, Serial Quad I/O, SMART-I.S., SQI, SuperSwitcher, SuperSwitcher II, Total Endurance, TSHARC, USBCheck, VariSense, ViewSpan, WiperLock, Wireless DNA, and ZENA are trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

SQTP is a service mark of Microchip Technology Incorporated in the U.S.A.

Silicon Storage Technology is a registered trademark of Microchip Technology Inc. in other countries.

GestIC is a registered trademark of Microchip Technology Germany II GmbH & Co. KG, a subsidiary of Microchip Technology Inc., in other countries.

All other trademarks mentioned herein are property of their respective companies.

© 2018, Microchip Technology Incorporated, All Rights Reserved.
ISBN: 978-1-5224-2521-2



MICROCHIP

Worldwide Sales and Service

AMERICAS

Corporate Office
2355 West Chandler Blvd.
Chandler, AZ 85224-6199
Tel: 480-792-7200
Fax: 480-792-7277
Technical Support:
<http://www.microchip.com/support>
Web Address:
www.microchip.com

Atlanta
Duluth, GA
Tel: 678-957-9614
Fax: 678-957-1455

Austin, TX
Tel: 512-257-3370

Boston
Westborough, MA
Tel: 774-760-0087
Fax: 774-760-0088

Chicago
Itasca, IL
Tel: 630-285-0071
Fax: 630-285-0075

Dallas
Addison, TX
Tel: 972-818-7423
Fax: 972-818-2924

Detroit
Novi, MI
Tel: 248-848-4000

Houston, TX
Tel: 281-894-5983

Indianapolis
Noblesville, IN
Tel: 317-773-8323
Fax: 317-773-5453
Tel: 317-536-2380

Los Angeles
Mission Viejo, CA
Tel: 949-462-9523
Fax: 949-462-9608
Tel: 951-273-7800

Raleigh, NC
Tel: 919-844-7510

New York, NY
Tel: 631-435-6000

San Jose, CA
Tel: 408-735-9110
Tel: 408-436-4270

Canada - Toronto
Tel: 905-695-1980
Fax: 905-695-2078

ASIA/PACIFIC

Australia - Sydney
Tel: 61-2-9868-6733

China - Beijing
Tel: 86-10-8569-7000

China - Chengdu
Tel: 86-28-8665-5511

China - Chongqing
Tel: 86-23-8980-9588

China - Dongguan
Tel: 86-769-8702-9880

China - Guangzhou
Tel: 86-20-8755-8029

China - Hangzhou
Tel: 86-571-8792-8115

China - Hong Kong SAR
Tel: 852-2943-5100

China - Nanjing
Tel: 86-25-8473-2460

China - Qingdao
Tel: 86-532-8502-7355

China - Shanghai
Tel: 86-21-3326-8000

China - Shenyang
Tel: 86-24-2334-2829

China - Shenzhen
Tel: 86-755-8864-2200

China - Suzhou
Tel: 86-186-6233-1526

China - Wuhan
Tel: 86-27-5980-5300

China - Xian
Tel: 86-29-8833-7252

China - Xiamen
Tel: 86-592-2388138

China - Zhuhai
Tel: 86-756-3210040

ASIA/PACIFIC

India - Bangalore
Tel: 91-80-3090-4444

India - New Delhi
Tel: 91-11-4160-8631

India - Pune
Tel: 91-20-4121-0141

Japan - Osaka
Tel: 81-6-6152-7160

Japan - Tokyo
Tel: 81-3-6880-3770

Korea - Daegu
Tel: 82-53-744-4301

Korea - Seoul
Tel: 82-2-554-7200

Malaysia - Kuala Lumpur
Tel: 60-3-7651-7906

Malaysia - Penang
Tel: 60-4-227-8870

Philippines - Manila
Tel: 63-2-634-9065

Singapore
Tel: 65-6334-8870

Taiwan - Hsin Chu
Tel: 886-3-577-8366

Taiwan - Kaohsiung
Tel: 886-7-213-7830

Taiwan - Taipei
Tel: 886-2-2508-8600

Thailand - Bangkok
Tel: 66-2-694-1351

Vietnam - Ho Chi Minh
Tel: 84-28-5448-2100

EUROPE

Austria - Wels
Tel: 43-7242-2244-39
Fax: 43-7242-2244-393

Denmark - Copenhagen
Tel: 45-4450-2828
Fax: 45-4485-2829

Finland - Espoo
Tel: 358-9-4520-820

France - Paris
Tel: 33-1-69-53-63-20
Fax: 33-1-69-30-90-79

Germany - Garching
Tel: 49-8931-9700

Germany - Haan
Tel: 49-2129-3766400

Germany - Heilbronn
Tel: 49-7131-67-3636

Germany - Karlsruhe
Tel: 49-721-625370

Germany - Munich
Tel: 49-89-627-144-0
Fax: 49-89-627-144-44

Germany - Rosenheim
Tel: 49-8031-354-560

Israel - Ra'anana
Tel: 972-9-744-7705

Italy - Milan
Tel: 39-0331-742611
Fax: 39-0331-466781

Italy - Padova
Tel: 39-049-7625286

Netherlands - Drunen
Tel: 31-416-690399
Fax: 31-416-690340

Norway - Trondheim
Tel: 47-7289-7561

Poland - Warsaw
Tel: 48-22-3325737

Romania - Bucharest
Tel: 40-21-407-87-50

Spain - Madrid
Tel: 34-91-708-08-90
Fax: 34-91-708-08-91

Sweden - Gothenberg
Tel: 46-31-704-60-40

Sweden - Stockholm
Tel: 46-8-5090-4654

UK - Wokingham
Tel: 44-118-921-5800
Fax: 44-118-921-5820