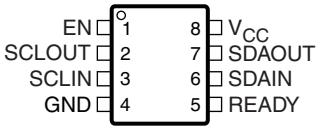
可热插拔型双线式总线缓冲器

查询样品: TCA4311A

特性

- 工作电源电压范围： **2.7V** 至 **5.5V**
- 支持 **I²C** 总线信号的双向数据传输
- 对 **SDA** 及 **SCL** 线路进行了缓冲，因而增加了扇出数
- 在所有的 **SDA** 及 **SCL** 线路上均进行了 **1V** 预充电，可防止在背板上进行带电电路板的插拔操作时发生损坏
- **SDA** 及 **SCL** 输入线路与输出隔离
- 可适应标准模式及快速模式 **I²C** 器件
- 抗噪声性能有所改善
- 其应用包括带电电路板插入及总线扩展
- 低 I_{CC} 芯片停用模式： **<1μA**
- **READY** 开漏输出
- 支持时钟展宽、仲裁及同步
- 断电高阻抗 **I²C** 引脚
- 开漏 **I²C** 引脚
- 闭锁性能超过 **100mA**，符合 **JESD 78 Class II** 标准
- **ESD** 保护等级超过了 **JESD 22** 规范
  - **8000V** 人体模型 **(A114-A)**
  - **200V** 机器模型 **(A115-A)**
  - **1000V** 充电器件模型 **(C101)**

D 封装或 **DGK** 封装
(顶视图**)**



说明/订购信息

TCA4311A 是一款可热插拔型 I²C 总线缓冲器，支持在带电背板上进行 I/O 板卡的插拔操作，而不会损坏数据和时钟总线。 控制电路可防止背板与板卡相连接（直到背板上出现停止命令或总线空闲为止），而不会在板卡上发生总线争用的情况。 当建立连接时，该器件可提供双向缓冲，从而使背板及板卡电容保持隔离。 在板卡插入过程中，SDA 及 SCL 线路被预充电至 1V，以最大限度地减小对芯片的寄生电容进行充电所需的电流。

当 I²C 总线空闲时，可通过将EN引脚设定为低电平来把 TCA4311A 置于停机模式之中。 当 EN 引脚为高电平时，TCA4311 将恢复正常运作。 该器件还包括一个开漏 READY 输出引脚，该引脚负责在背板与板卡侧相连时发出指示信号。 当 READY 引脚为高电平时，SDAIN 和 SCLIN 被连接至 SDAOUT 和 SCLOUT。 当两侧断接时，READY 引脚为低电平。

背板及板卡均可采用 2.7V 至 5.5V 的电源电压来供电，而对于它们哪一个的电源电压较高则未做限制。

TCA4311 具有标准的开漏 I/O。 至 I/O 的上拉电阻器的大小取决于系统，不过，该缓冲器的每一侧均必须设有一个上拉电阻器。 这款器件专为与标准模式及快速模式 I²C 器件（而不单是 SMBus 器件）一起工作而设计。 在可以接受标准模式器件和多个主控器的通用型 I²C 系统中，标准模式 I²C 器件只规定了 3mA。 在某些条件下，可以采用高终端电流。

Table 1. ORDERING INFORMATION

T_A	PACKAGE(1) (2)		ORDERABLE PART NUMBER	TOP-SIDE MARKING
–40°C to 85°C	SOIC – D	Tube	TCA4311AD	PREVIEW
		Tape and reel	TCA4311ADR	PREVIEW
	MSOP – DGK	Tape and reel	TCA4311ADGKR	6KS

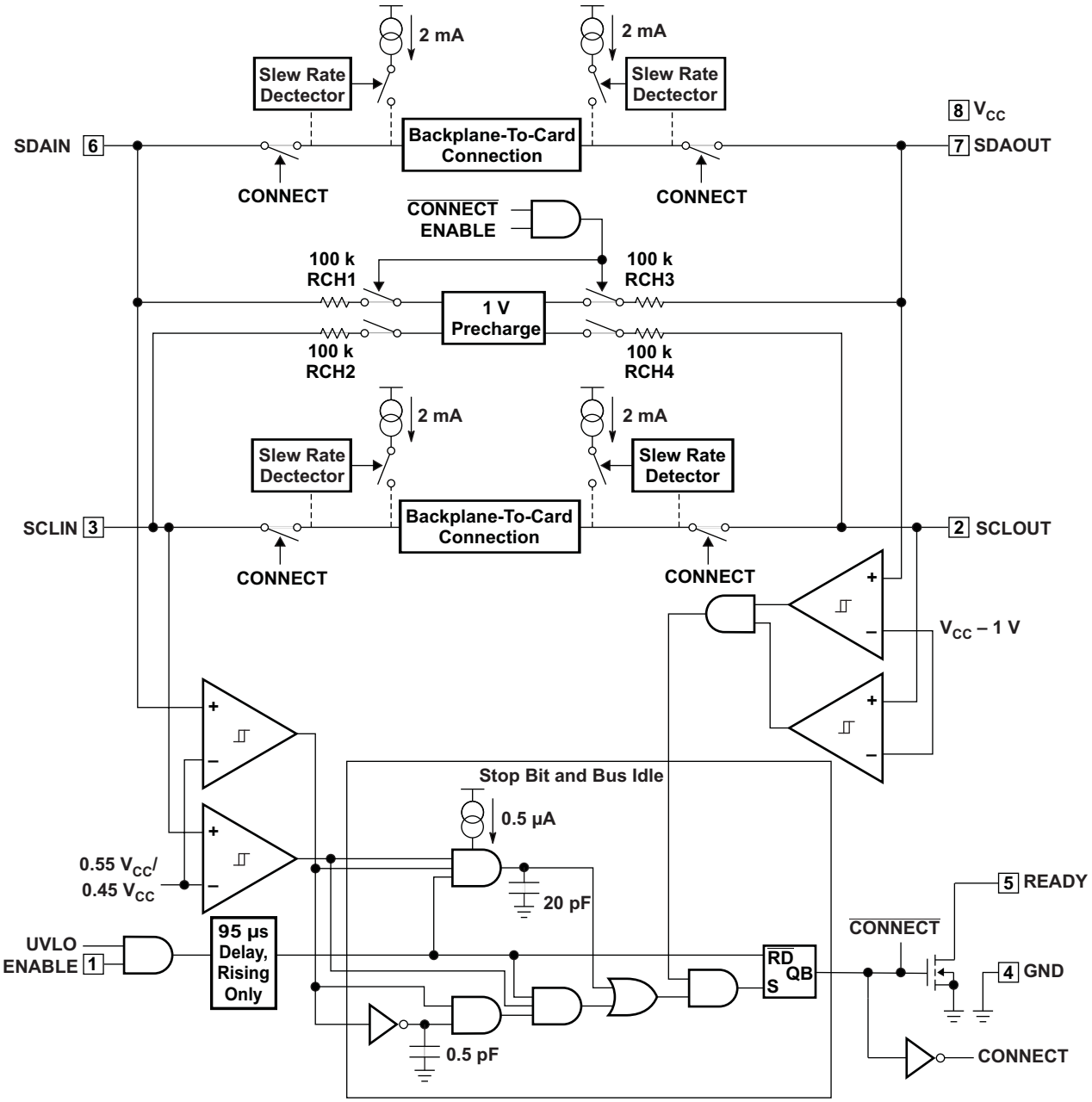
(1) Package drawings, thermal data, and symbolization are available at www.ti.com/packaging.
(2) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI website at www.ti.com.

TERMINAL FUNCTIONS

SOIC (D) OR MSOP (DGK) PACKAGE		DESCRIPTION
PIN NUMBER	NAME	
1	EN	Active-high chip enable pin. If EN is low, the TCA4311A is in a low current (<1 µA) mode. It also disables the rise-time accelerators, disables the bus precharge circuitry, drives READY low, isolates SDAIN from SDAOUT and isolates SCLIN from SCLOUT. EN should be high (at V_{CC}) for normal operation. Connect EN to V_{CC} if this feature is not being used.
2	SCLOUT	Serial clock output. Connect this pin to the SCL bus on the card.
3	SCLIN	Serial clock input. Connect this pin to the SCL bus on the backplane.
4	GND	Supply ground
5	READY	Connection flag/rise-time accelerator control. READY is low when either EN is low or the start-up sequence described in the operation section has not been completed. READY goes high when EN is high and start-up is complete. Connect a 10-kΩ resistor from this pin to V_{CC} to provide the pull up.
6	SDAIN	Serial data input. Connect this pin to the SDA bus on the backplane.
7	SDAOUT	Serial data output. Connect this pin to the SDA bus on the card.
8	V_{CC}	Supply power. Main input power supply from backplane. This is the supply voltage for the devices on the backplane I^2C busses. Connect pullup resistors from SDAIN and SCLIN (and also from SDAOUT and SCLOUT) to this pin. Place a bypass capacitor of at least 0.01 µF close to this pin for best results.

BLOCK DIAGRAM

2-Wire Bus Buffer and Hot Swap Controller



ABSOLUTE MAXIMUM RATINGS(1)

over operating free-air temperature range (unless otherwise noted)

			MIN	MAX	UNIT
V_{CC}	Supply voltage range		–0.5	7	V
$V_{I/O}$	I^2C bus voltage range(2)	SDAIN, SCLIN, SDAOUT, SCLOUT	–0.3	7	V
V_I	Input voltage range(2)	EN	–0.3	7	V
I_{IK}	Input clamp current	$V_I < 0$		–50	mA
I_{OK}	Output clamp current	$V_O < 0$		–50	mA
I_O	Continuous output current			±50	mA
I_{CC}	Continuous current through V_{CC} or GND			±100	mA
θ_{JA}	Package thermal impedance(3)	D package		97	°C/W
		DGK package		172	
T_{stg}	Storage temperature range		–65	150	°C

(1) 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 under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) The input negative-voltage and output voltage ratings may be exceeded if the input and output current ratings are observed.
(3) The package thermal impedance is calculated in accordance with JESD 51-7.

RECOMMENDED OPERATING CONDITIONS

			MIN	MAX	UNIT
V_{CC}	Supply voltage		2.7	5.5	V
V_{IH}	High-level input voltage	SDA and SCL inputs	0.7 × V_{CC}	5.5	V
		EN input	2	5.5	
V_{IL}	Low-level input voltage	SDA and SCL inputs	–0.5	0.3 × V_{CC}	V
		EN input	–0.5	0.8	
I_{OL}	Low-level output current	V_{CC} = 3 V		3	mA
		V_{CC} = 4.5 V		3	
T_A	Operating free-air temperature		–40	85	°C

ELECTRICAL CHARACTERISTICS

over operating free-air temperature range (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Power Supply						
V_{CC}	Positive supply voltage		2.7		5.5	V
I_{CC}	Supply current	V_{CC} = 5.5 V, V_{SDAIN} = V_{SCLIN} = 0 V		5.1	7	mA
I_{SD}	Supply current in shutdown mode	V_{EN} = 0 V		0.1		µA
Start-Up Circuitry						
V_{PRE}	Precharge voltage	SDA, SCL floating	0.8	1	1.2	V
t_{IDLE}	Bus idle time		50	95	150	µs
V_{EN}	EN threshold voltage			0.5 × V_{CC}	0.9 × V_{CC}	V
V_{DIS}	Disable threshold voltage	EN Pin	0.1 × V_{CC}	0.5 × V_{CC}		V
I_{EN}	EN input current	EN from 0 V to V_{CC}		±0.1	±1	µA
t_{EN}	Enable time			95		µs
t_{DIS}	Disable time (EN to READY)			30		ns
t_{STOP}	SDAIN to READY delay after STOP			1.2		µs
t_{READY}	SCLOUT/SDAOUT to READY			0.8		µs
I_{OFF}	READY OFF state leakage current			±0.1		µA
V_{OL}	READY output low voltage	I_{PULLUP} = 3 mA			0.4	V
Rise-Time Accelerators						
$I_{PULLUPAC}$	Transient boosted pull-up current	Positive transition on SDA, SCL, V_{CC} = 2.7 V,	1	2		mA
Input-Output Connection						
V_{OS}	Input-output offset voltage	10 kΩ to V_{CC} on SDA, SCL, V_{CC} = 3.3 V,(1)	0	100	175	mV
C_{IN}	Digital input capacitance				10	pF
V_{OL}	Output low voltage, input = 0 V	SDA, SCL pins, I_{SINK} = 3 mA,	0		0.4	V
I_I	Input leakage current	SDA, SCL pins = V_{CC} = 5.5 V			±5	µA

(1) The connection circuitry always regulates its output to a higher voltage than its input. The magnitude of this offset voltage as a function of the pullup resistor and V_{CC} voltage is shown in the Typical Performance Characteristics section.

OPERATION

Start-Up

When the TCA4311A first receives power on its V_{CC} pin, either during power-up or during live insertion, it starts in an undervoltage lockout (UVLO) state, ignoring any activity on the SDA and SCL pins until V_{CC} rises above 2.5 V.

During this time, the 1 V precharge circuitry is also active and forces 1 V through 100-kΩ nominal resistors to the SDA and SCL pins. Because the I/O card is being plugged into a live backplane, the voltage on the backplane SDA and SCL busses may be anywhere between 0 V and V_{CC}. Precharging the SCL and SDA pins to 1 V minimizes the worst-case voltage differential these pins will see at the moment of connection, therefore minimizing the amount of disturbance caused by the I/O card.

Once the TCA4311A comes out of UVLO, it assumes that SDAIN and SCLIN have been inserted into a live system and that SDAOUT and SCLOUT are being powered up at the same time as itself. Therefore, it looks for either a stop bit or bus idle condition on the backplane side to indicate the completion of a data transaction. When either one occurs, the part also verifies that both the SDAOUT and SCLOUT voltages are high. When all of these conditions are met, the input-to-output connection circuitry is activated, joining the SDA and SCL busses on the I/O card with those on the backplane, and the rise time accelerators are enabled.

Connection Circuitry

Once the connection circuitry is activated, the functionality of the SDAIN and SDAOUT pins is identical. A low forced on either pin at any time results in both pin voltages being low. For proper operation, logic low input voltages should be no higher than 0.4 V with respect to the ground pin voltage of the TCA4311A. SDAIN and SDAOUT enter a logic high state only when all devices on both SDAIN and SDAOUT release high. The same is true for SCLIN and SCLOUT. This important feature ensures that clock stretching, clock synchronization, arbitration and the acknowledge protocol always work, regardless of how the devices in the system are tied to the TCA4311A.

Another key feature of the connection circuitry is that it provides bidirectional buffering, keeping the backplane and card capacitances isolated. Because of this isolation, the waveforms on the backplane busses look slightly different than the corresponding card bus waveforms, as described here.

Input to Output Offset Voltage

When a logic low voltage, V_{LOW1}, is driven on any of the TCA4311A's data or clock pins, the TCA4311A regulates the voltage on the other side of the chip (call it V_{LOW2}) to a slightly higher voltage, as directed by the following equation:

$$V_{LOW2} = V_{LOW1} + 75\ mV + (V_{CC}/R) \times 100$$

where R is the bus pullup resistance in ohms (Ω). For example, if a device is forcing SDAOUT to 10 mV where V_{CC} = 3.3 V and the pullup resistor R on SDAIN is 10 kΩ, then the voltage on SDAIN = 10 + 75 + (3.3/10000) × 100 = 118 mV. See the *Typical Performance Characteristics* section for curves showing the offset voltage as a function of V_{CC} and R.

Propagation Delays

During a rising edge, the rise-time on each side is determined by the combined pullup current of the TCA4311A boost current and the bus resistor and the equivalent capacitance on the line. If the pullup currents are the same, a difference in rise-time occurs which is directly proportional to the difference in capacitance between the two sides. This effect is displayed in Figure 1 for V_{CC} = 3.3 V and a 10-kΩ pullup resistor on each side (50 pF on one side and 150 pF on the other). Since the output side has less capacitance than the input, it rises faster and the effective t_{PLH} is negative.

There is a finite propagation delay, t_{PHL}, through the connection circuitry for falling waveforms. Figure 2 shows the falling edge waveforms for the same V_{CC}, pullup resistors and equivalent capacitance conditions as used in Figure 1. An external NMOS device pulls down the voltage on the side with 150 pF capacitance; the TCA4311A pulls down the voltage on the opposite side, with a delay of 55 ns. This delay is always positive and is a function of supply voltage, temperature and the pullup resistors and equivalent bus capacitances on both sides of the bus. The *Typical Performance Characteristics* section shows t_{PHL} as a function of temperature and voltage for

10-kΩ pullup resistors and 100 pF equivalent capacitance on both sides of the part. By comparison with Figure 2, the V_{CC} = 3.3 V curve shows that increasing the capacitance from 50 pF to 100 pF results in a t_{PHL} increase from 55 ns to 75 ns. Larger output capacitances translate to longer delays (up to 150 ns). Users must quantify the difference in propagation times for a rising edge versus a falling edge in their systems and adjust setup and hold times accordingly.

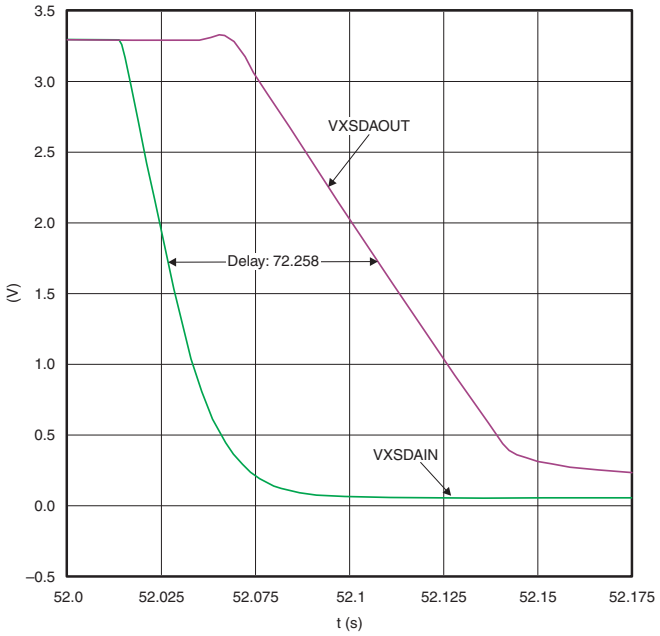


Figure 1. Input-Output Connection t_{PLH}

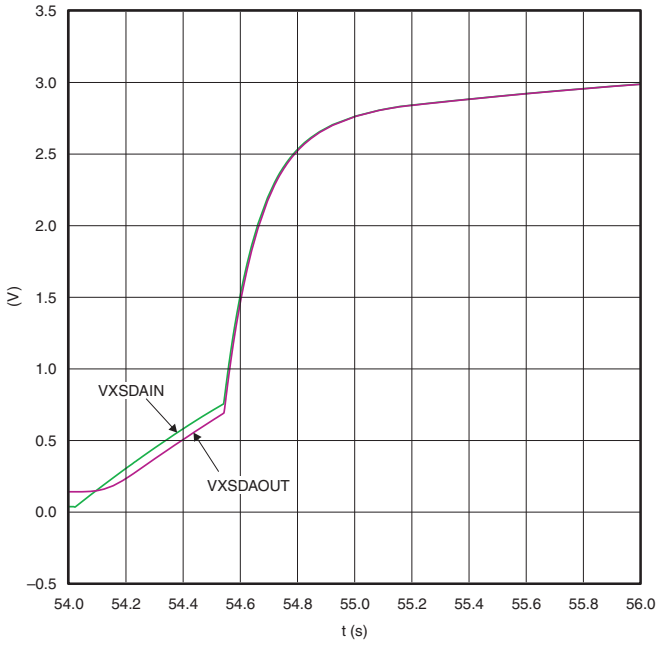


Figure 2. Input-Output Connection t_{PHL}

Rise-Time Accelerators

Once connection has been established, rise-time accelerator circuits on all four SDA and SCL pins are activated. These allow the user to choose weaker DC pullup currents on the bus, reducing power consumption while still meeting system rise-time requirements. During positive bus transitions, the TCA4311A switches in 2 mA (typical) of current to quickly slew the SDA and SCL lines once their DC voltages exceed 0.6 V. Using a general rule of 20 pF of capacitance for every device on the bus (10 pF for the device and 10 pF for interconnect), choose a pullup current so that the bus will rise on its own at a rate of at least 1.25 V/µs to guarantee activation of the accelerators.

For example, assume an SMBus system with V_{CC} = 3 V, a 10-kΩ pullup resistor and equivalent bus capacitance of 200 pF. The rise-time of an SMBus system is calculated from ($V_{IL(MAX)}$ – 0.15 V) to ($V_{IH(MIN)}$ + 0.15 V), or 0.65 V to 2.25 V. It takes an RC circuit 0.92 time constants to traverse this voltage for a 3 V supply; in this case, 0.92 × (10 kΩ × 200 pF) = 1.84 µs. Thus, the system exceeds the maximum allowed rise-time of 1 µs by 84%. However, using the rise-time accelerators, which are activated at a DC threshold of below 0.65 V, the worst-case rise-time is: (2.25 V – 0.65 V) × 200 pF/1 mA = 320 ns, which meets the 1 µs rise-time requirement.

READY Digital Output

This pin provides a digital flag which is low when either EN is low or the start-up sequence described earlier in this section has not been completed. READY goes high when EN is high and start-up is complete. The pin is driven by an open drain pull-down capable of sinking 3 mA while holding 0.4 V on the pin. Connect a resistor of 10 kΩ to V_{CC} to provide the pullup.

EN Low Current Disable

Grounding the EN pin disconnects the backplane side from the card side, disables the rise-time accelerators, drives READY low, disables the bus precharge circuitry and puts the part in a near-zero current state. When the pin voltage is driven all the way to V_{CC}, the part waits for data transactions on both the backplane and card sides to be complete (as described in the Start-Up section) before reconnecting the two sides.

Resistor Pull-Up Value Selection

The system pullup resistors must be strong enough to provide a positive slew rate of 1.25 V/μs on the SDA and SCL pins, in order to activate the boost pullup currents during rising edges. Choose maximum resistor value R using the formula:

$R \leq (V_{CC(MIN)} - 0.6)\ (800{,}000) / C$

where R is the pullup resistor value in ohms, $V_{CC(MIN)}$ is the minimum V_{CC} voltage and C is the equivalent bus capacitance in picofarads (pF).

In addition, regardless of the bus capacitance, always choose R ≤ 16 kΩ for V_{CC} = 5.5 V maximum, R ≤ 24 kΩ for V_{CC} = 3.6 V maximum. The start-up circuitry requires logic high voltages on SDAOUT and SCLOUT to connect the backplane to the card, and these pullup values are needed to overcome the precharge voltage.

Systems With Disparate Supply Voltages

In large 2-wire systems, the V_{CC} voltages seen by devices at various points in the system can differ by a few hundred millivolts or more. This situation is well modeled by a series resistor in the V_{CC} line, as shown in Figure 15. For proper operation of the TCA4311A, make sure that $V_{CC(BUS)} \geq V_{CC(TCA4311A)} - 0.5$ V.

TYPICAL PERFORMANCE CHARACTERISTICS

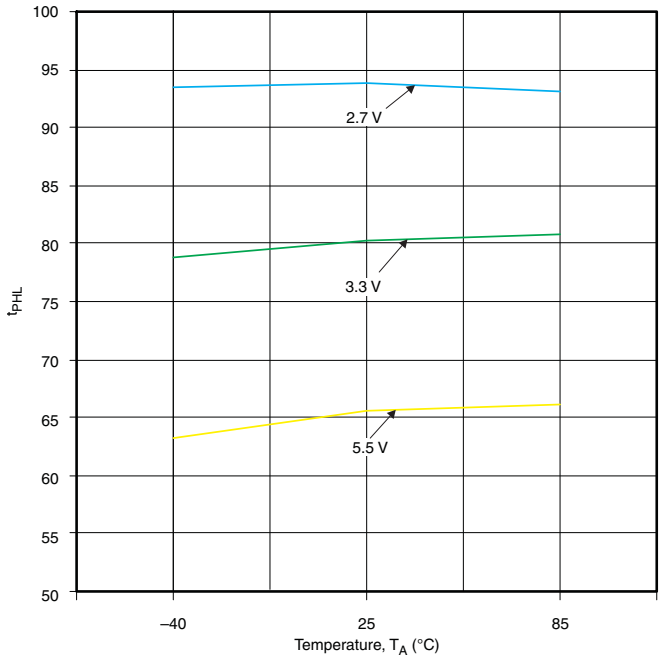


Figure 3. Input/Output t_{PLH} vs Temperature

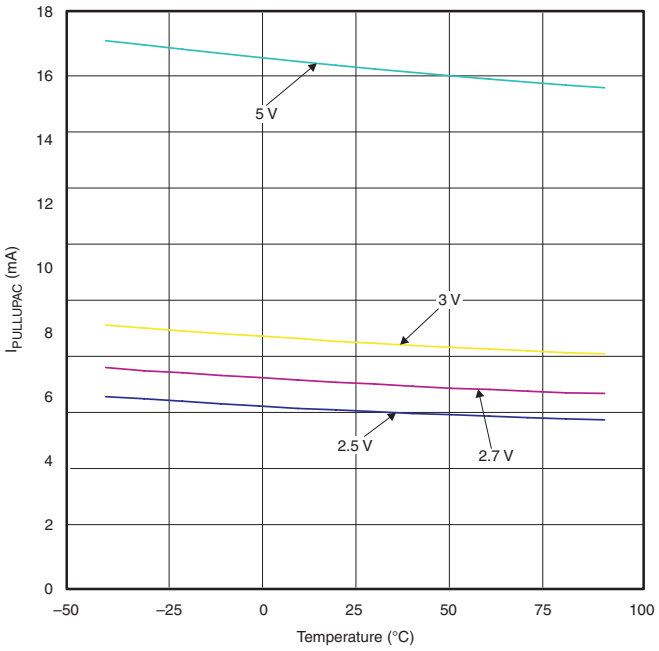


Figure 4. $I_{PULLUPAC}$ vs Temperature

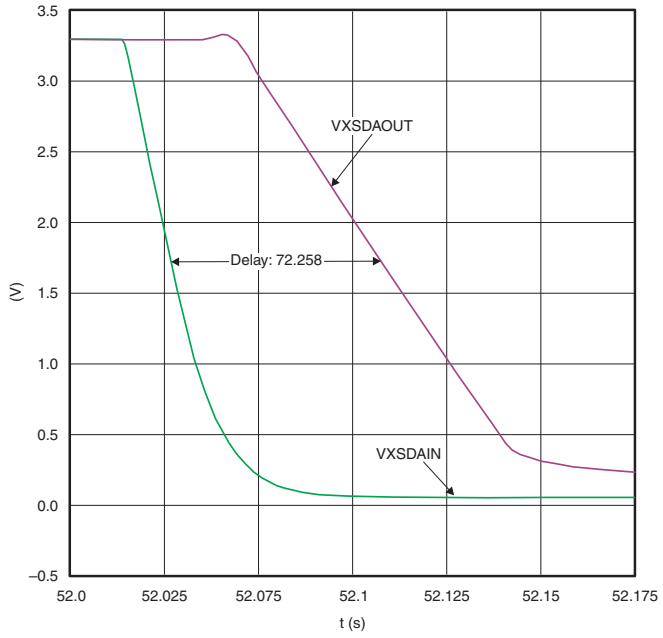


Figure 5.

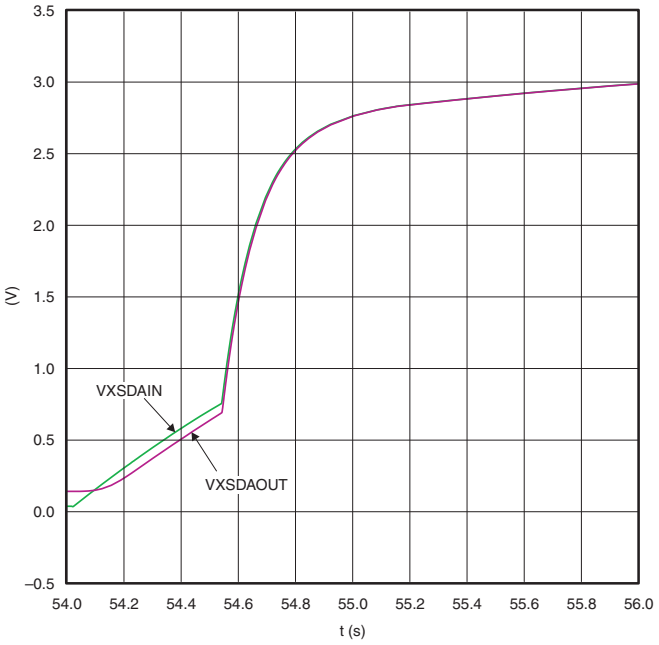


Figure 6.

TYPICAL PERFORMANCE CHARACTERISTICS (continued)

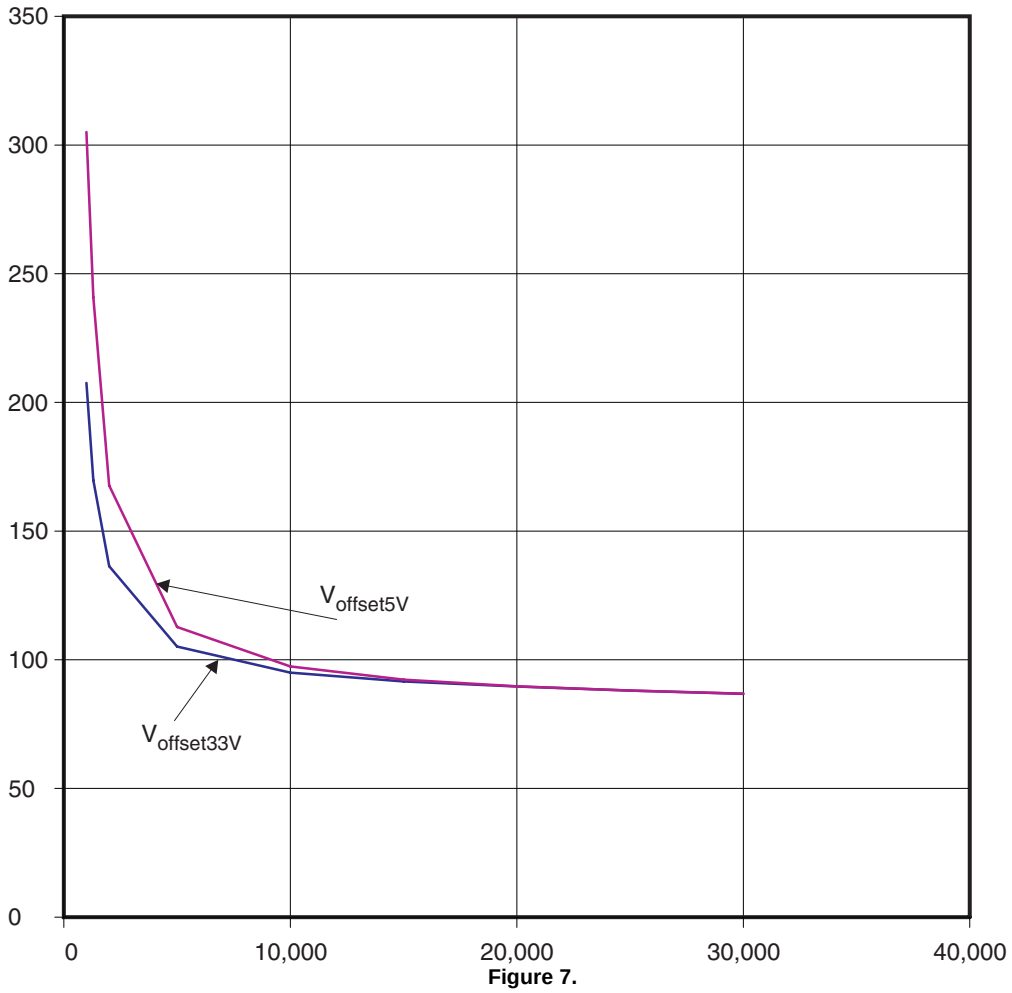
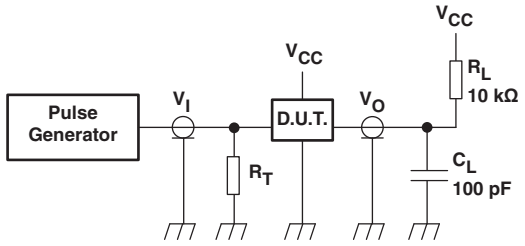


Figure 7.

PARAMETER MEASUREMENT INFORMATION



R_L = Load resistor

C_L = Load capacitance includes jig and probe capacitance

R_T = Termination resistance should be equal to the output impedance Z_0 of the pulse generators.

Figure 8. Test Circuitry for Switching Times

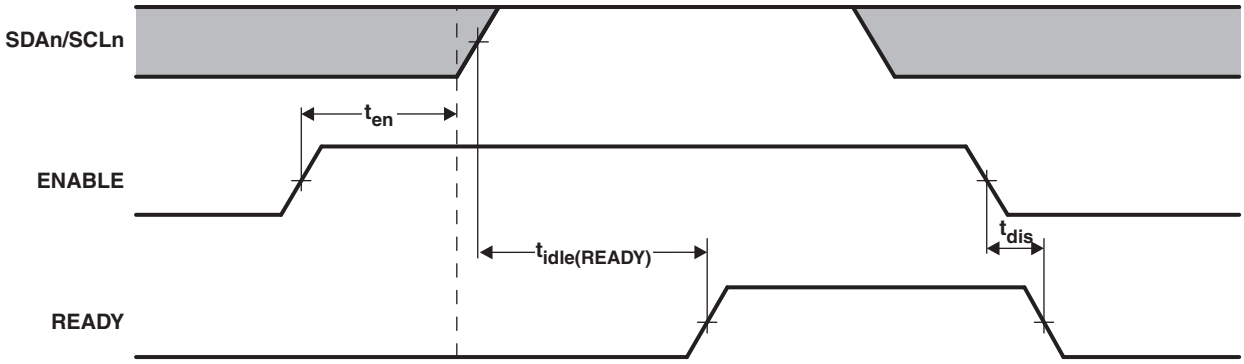


Figure 9. Timing for t_{en}, $t_{idle(READY)}$, and t_{dis}

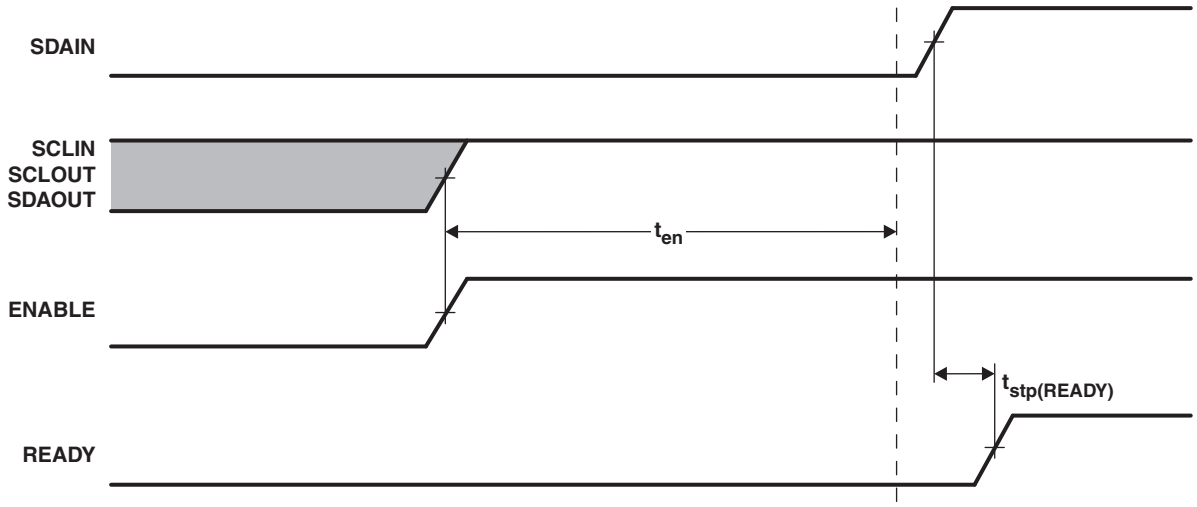


Figure 10. $t_{stp(READY)}$ That Can Occur After t_{en}

PARAMETER MEASUREMENT INFORMATION (continued)

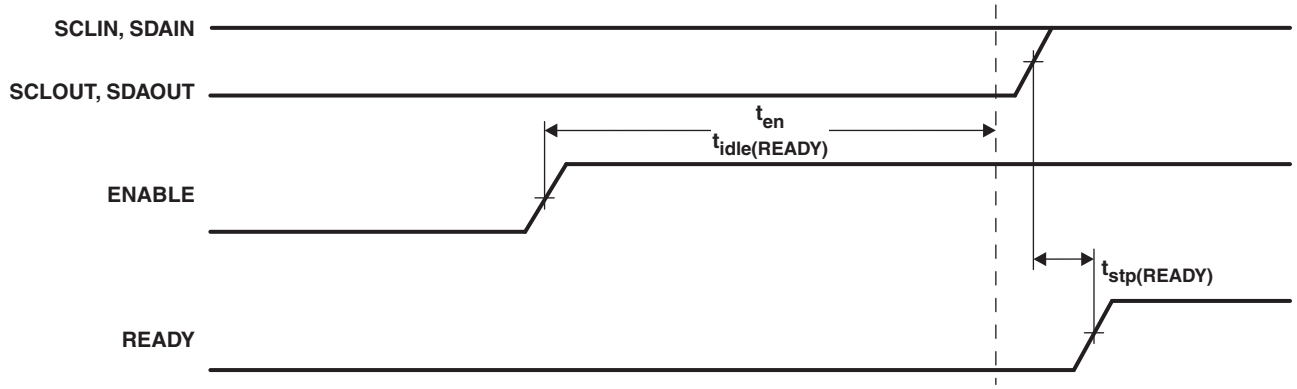


Figure 11. $t_{stp(READY)}$ That Can Occur After t_{en} and $t_{idle(READY)}$

APPLICATION INFORMATION

Live Insertion and Capacitance Buffering Application

Figure 12 through Figure 13 illustrate the usage of the TCA4311A in applications that take advantage of both its hot swap controlling and capacitance buffering features. In all of these applications, note that if the I/O cards were plugged directly into the backplane, all of the backplane and card capacitances would add directly together, making rise- and fall-time requirements difficult to meet. Placing a TCA4311A on the edge of each card, however, isolates the card capacitance from the backplane. For a given I/O card, the TCA4311A drives the capacitance of everything on the card and the backplane must drive only the capacitance of the TCA4311A, which is less than 10 pF.

Figure 12 shows the TCA4311A in a CompactPCI™ configuration. Connect V_{CC} and EN to the output of one of the CompactPCI power supply Hot Swap circuits. Use a pullup resistor to EN for a card side enable/disable.

V_{CC} is monitored by a filtered UVLO circuit. With the V_{CC} voltage powering up after all other pins have established connection, the UVLO circuit ensures that the backplane and card data and clock busses are not connected until the transients associated with live insertion have settled. Owing to their small capacitance, the SDAIN and SCLIN pins cause minimal disturbance on the backplane busses when they make contact with the connector.

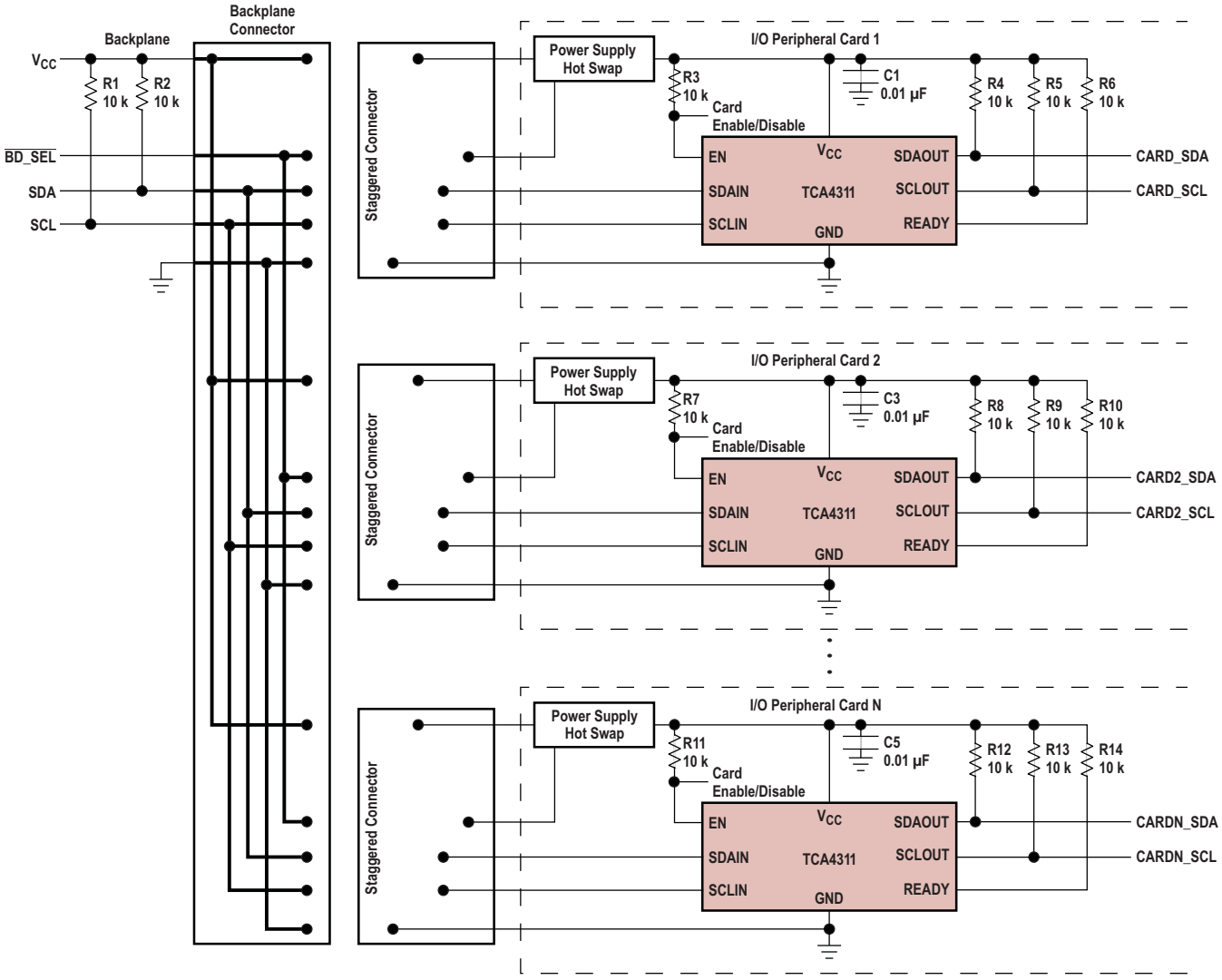


Figure 12. Inserting Multiple I/O Cards into a Live Backplane Using the TCA4311A in a CompactPCI System

Figure 13 shows the TCA4311A in a PCI application, where all of the pins have the same length. In this case, connect an RC series circuit on the I/O card between V_{CC} and EN. An RC product of 10 ms provides a filter to prevent the TCA4311A from becoming activated until the transients associated with live insertion have settled.

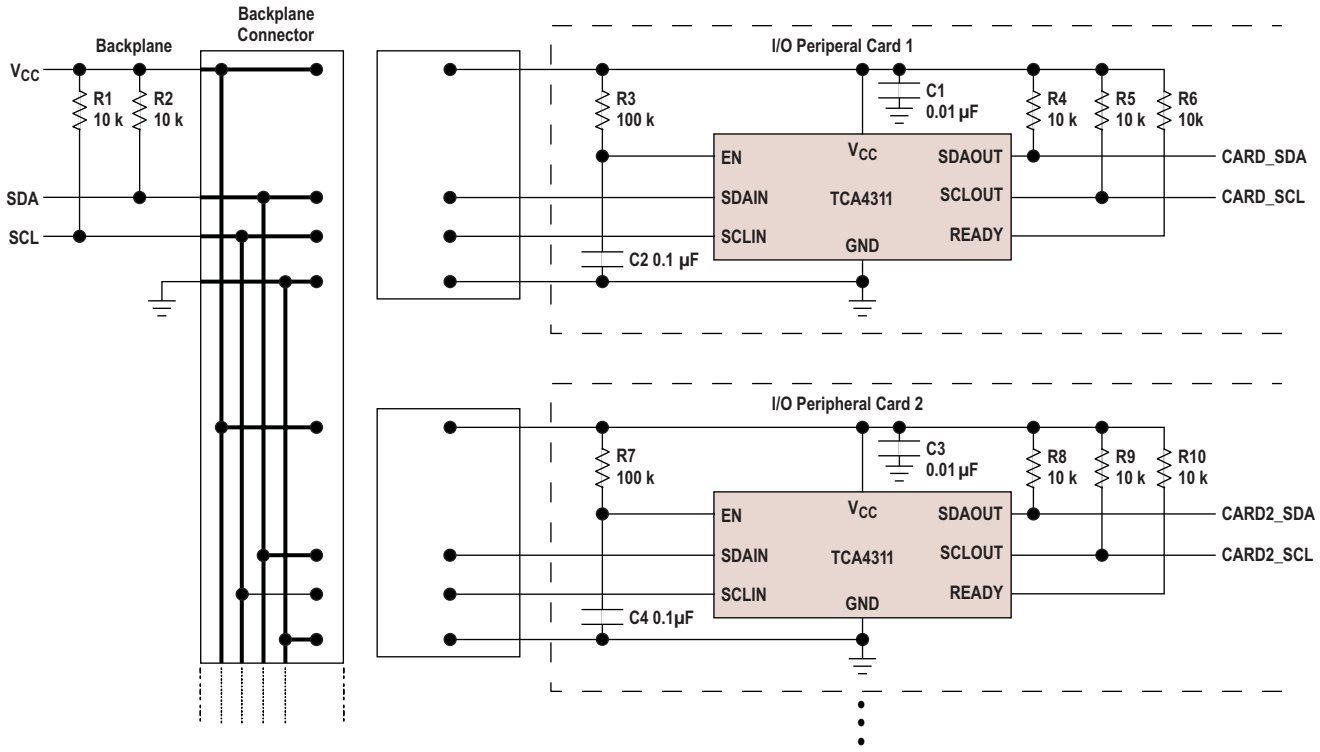


Figure 13. Inserting Multiple I/O Cards into a Live Backplane Using the TCA4311A in a PCI System

Repeater/Bus Extender Application

Users who wish to connect two 2-wire systems separated by a distance can do so by connecting two TCA4311A back-to-back, as shown in Figure 14. The I^2C specification allows for 400 pF maximum bus capacitance, severely limiting the length of the bus. The SMBus specification places no restriction on bus capacitance, but the limited impedances of devices connected to the bus require systems to remain small if rise- and fall-time specifications are to be met. The strong pullup and pulldown impedances of the TCA4311A are capable of meeting rise- and fall-time specifications for one nanofarad of capacitance, thus allowing much more interconnect distance. In this situation, the differential ground voltage between the two systems may limit the allowed distance, because a valid logic low voltage with respect to the ground at one end of the system may violate the allowed V_{OL} specification with respect to the ground at the other end. In addition, the connection circuitry offset voltages of the back-to-back TCA4311A add together, directly contributing to the same problem.

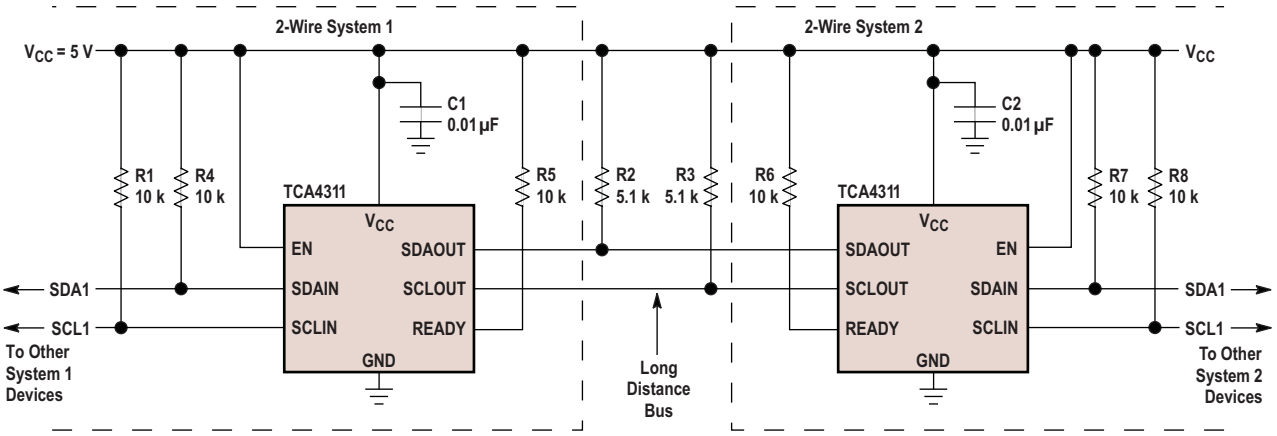


Figure 14. Repeater/Bus Extender Application

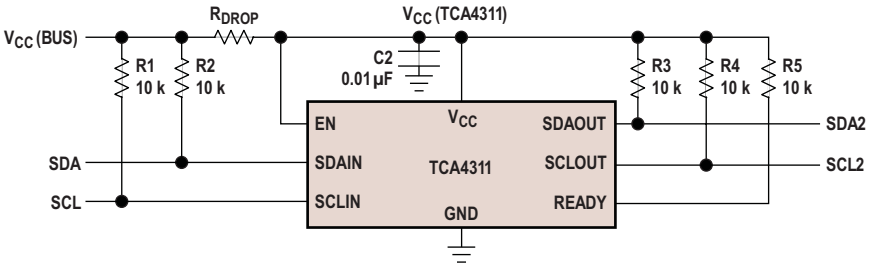
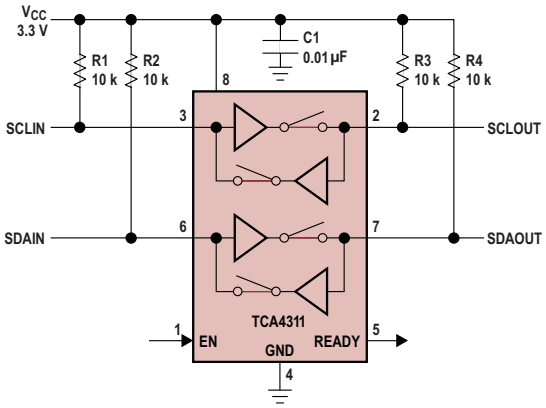
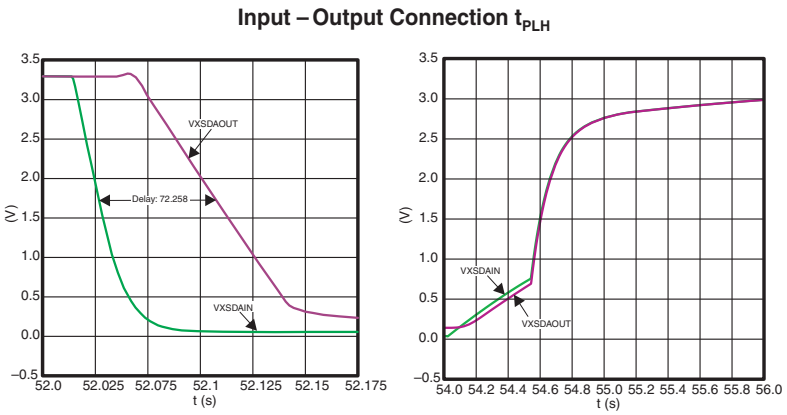


Figure 15. System With Disparate V_{CC} Voltages





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