

# Precision Measurement Central (4)

## Part 4: RS485, or networking the MSC1210 micro

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The RS485 port on the MSC1210 board provides great opportunities for communication with other systems. For example, it allows a number of MSC1210 boards to be connected up into a network and talk to one another over distances of several kilometres.

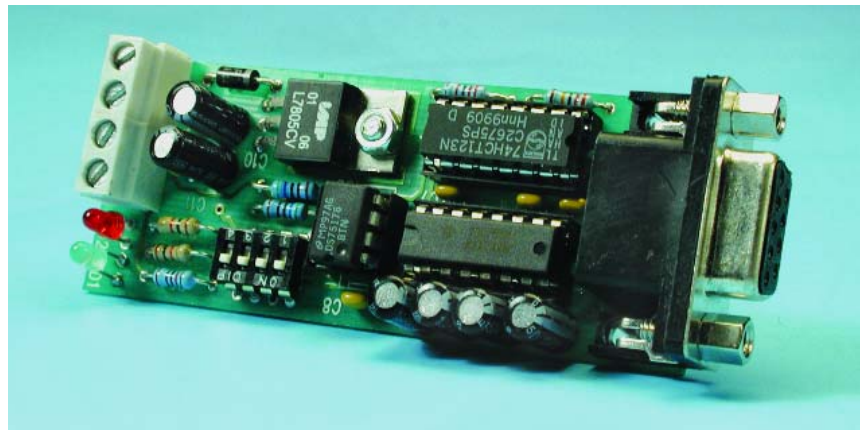
This fourth instalment in the series on the MSC1210-based Precision Measurement Central (kicked off in the July/August 2003 issue) is entirely devoted to the RS485 interface. This month we will cover the theory and hardware. The December 2003 issue, finally, will discuss the practical use of the RS485 interface in a small project that goes to show how up to 255 MSC1210 boards can communicate with a single PC through an RS485 link. The converter required for the job is discussed in this article instalment.

### RS485

Although the RS485 interface has been around virtually since the earliest days of the PC era, it is rarely seen in real life, that is, on the PC's connector panel. That's why we take this opportunity to present a suitable converter for RS232 to RS485, which has been tailored for use in combination with the MSC1210 board. First, however, we need to wade through some theory.

#### Bus topology

Normally an RS485 network consists of a long cable (bus) of which the ends are terminated with resistors. Up to 32 devices may be connected to the bus, or even 256 if a suitable driver chip is used. Ideally, all devices are connected to form a long thread. In practice, however, individual bus participants may also be connected via branches of several metres (**Figure 1**). In 'minimum' cases only



the two wires designated 'A' and 'B' are required, although it is recommended to implement potential cancellation using a third wire and an optional resistor. Another popular variant has four wires and allows the devices to be powered over the bus.

The digital information conveyed over the RS485 bus comprises the voltage difference between line 'A' and 'B'. If the difference is positive, the bus is said to convey a logic 1. In the other case, a logic 0 is conveyed. The use of differential voltages makes the bus rather immune to noise, provided a number of conditions are satisfied. **Figure 2** shows a bus with two devices on it, where the signal is to be carried from IN to

OUT over a long cable. An oscilloscope is connected to the bus at the indicated position. Any cable will have a more or less distinctive impedance — values of 60 to 200  $\Omega$  being typical. The signal on the cable will remain undistorted only if the cable is terminated with a resistor whose value is approximately equal to the cable impedance. Wrong termination values cause signal distortion that can lead to data corruption and increased susceptibility of the bus to noise.

Fortunately, correct cable termination is really critical only in those cases where signals with a high data rate ( $> 57,600$  bits/s) are conveyed over cable lengths exceeding

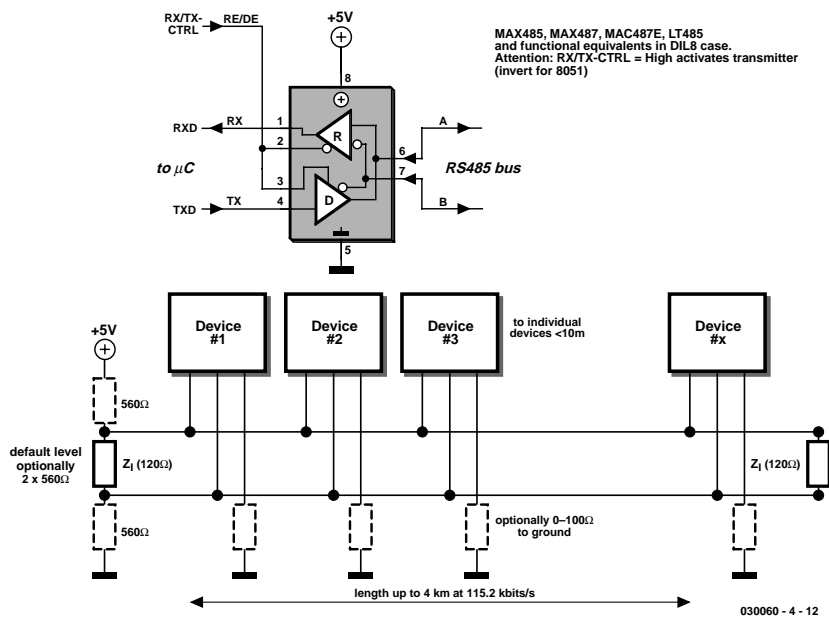


Figure 1. RS485 topology.

500 m, when the propagation times start to approach the bit rates (the signal travels 100-300 m in 1  $\mu$ s). With cable lengths under 50 m and bit rates under 57,600, a cheap cable with no specified impedance but terminated with 120  $\Omega$  at both ends should be adequate.

#### Overvoltage Protection 'lite'

An RS485 driver must be capable of withstanding line voltages between -7 V and +12 V at its input(s). Fair

enough, but longish cables in particular are prone to pick up (by induction) much higher peak voltages caused by electrostatic fields, discharges, EMI transients and so on. Consequently it makes sense to protect all RS485 against voltage surges. With suitable protection, short and not too powerful transients can not harm the drivers ICs (Figure 3).

#### Data traffic

The drawing in Figure 1 includes all

optional resistors. These resistors serve to pull the bus to a fixed logic level when there is no traffic (that is, all devices are receiving and none is putting data on the bus). Unfortunately, this variant is rather wasteful in terms of energy usage and at the same time likely to cause problems with long cables.

A better alternative is shown in Figure 4. In this configuration, the initial level of the bus is not known. If a device wants to put a data block on the bus, it has to activate its transmitter section first. However, as a result of improper termination as illustrated in Figure 2, it may happen that activation of the transmitter alone is sufficient for receiving devices on the bus to recognise data, when in fact no valid data has been sent as yet (see block marked ???).

This leads to the absolute requirement for a pause to be inserted immediately after activation of each transmitter section. This 'dead' period needs to be much longer than prescribed for the transmission of a single byte ( $t_{\text{byte}}$ ). The time needed to convey a byte over the bus is roughly ten times the reciprocal of the baud rate, or about 1 ms per byte when a rate of 9,600 bits/s is used.

The data packet proper always starts with a special marker byte (START). Note, however, that START may never occur within the actual data (more about this in the next instalment).

Because only one device can transmit at a time ('half duplex') a strict protocol is needed describing who's allowed to transmit what and when. If the protocol is not observed, data contention, collision and corruption is imminent. The practical application dis-

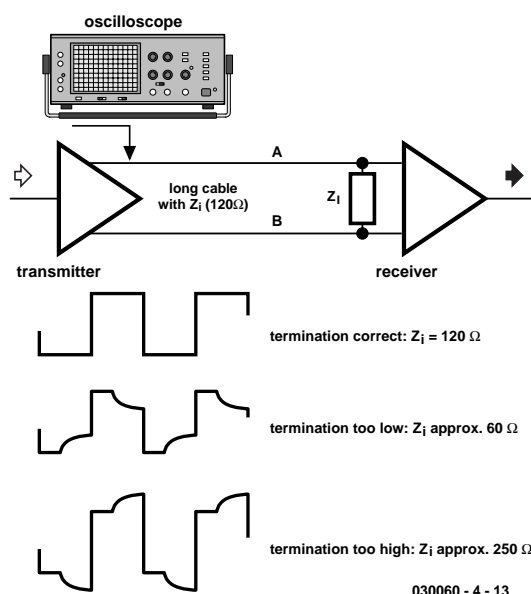


Figure 2. Why terminate?

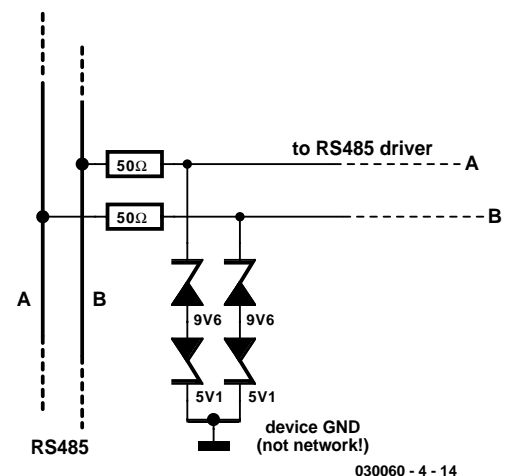


Figure 3. Surge protection by means of two zener diodes.

cussed in next month's instalment employs a simple but effective protocol.

## A PC on the RS485 bus

If the two 560-Ω resistors shown in Figure 1 are used, the risk of 'undesired databytes' is greatly reduced. Problems may only occur with long cables (>50 m) and higher baud rates (>57,600 bits/s), particularly when the transmitting junction and the resistors are relatively far apart. Unfortunately, a PC can not exercise exact control over the pulse timing on its serial interface and so activate the transmitting device using an appropriate delay. After all, most PCs employ a UART (RS232 driver) with an internal transmitter FIFO. This prevents the PC from 'knowing' whether or not a databyte was actually sent or not. Consequently it is the task of the PC converter to ensure that the RS485 bus is at a valid logic level when there is no traffic.

## The converter

The converter, of which the circuit diagram is given in Figure 5, operates largely as a 'dumb' extension which has the benefit of it supporting different protocols and, of course,

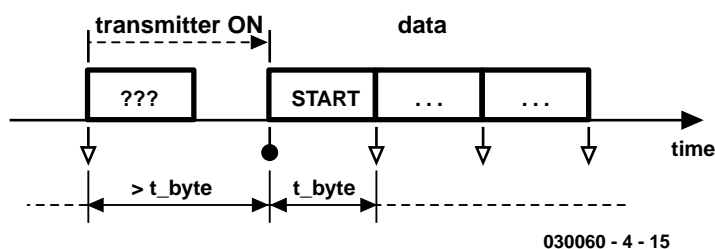


Figure 4. Transmit timing.

bit rates. The design consists of an RS232 and an RS485 converter separated by good old TTL levels.

Bits arriving at the RS485 bus are copied directly to the PC irrespective of the bit rate. Once the PC sends a character, the converter immediately switches on its transmitter via a retriggerable monostable (IC1.A). The transmitter remains active for the time it takes to convey the byte. In the case of our circuit, two times may be selected: 20 ms for 1200 bits/s (S1 opened) or 2 ms for 9600 bits/s and higher (S1 closed).

In addition, switch S1.4 may be

used to include the terminator resistor, and/or S1.2/3 (operate at the same time) for the 560-Ω resistors to set the default level on the bus. These provisions on the converter allow several PCs or a combination of PCs and MSC1210 boards to be included in a network.

The construction of the converter on the printed circuit board shown in Figure 6 should be an uncomplicated affair as there are no pitfalls with regard to soldering etc. The introductory photograph shows the author's prototype. The converter operates from an external supply voltage of

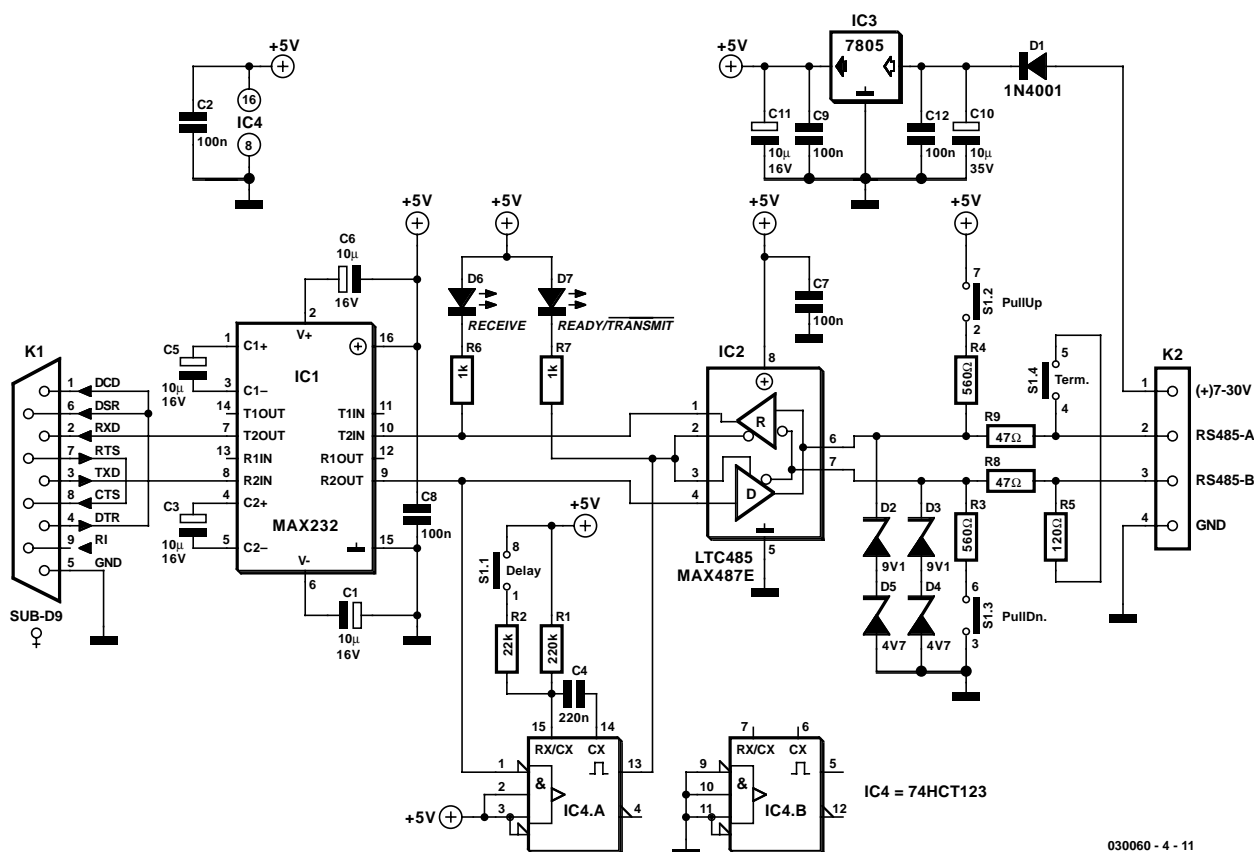


Figure 5. Circuit diagram of the RS232/RS485 converter.

## COMPONENTS LIST

### Resistors:

R1 = 220k $\Omega$   
 R2 = 22k $\Omega$   
 R3,R4 = 560 $\Omega$   
 R5 = 120 $\Omega$   
 R6,R7 = 1k $\Omega$   
 R8,R9 = 47 $\Omega$

### Capacitors:

C1,C3,C5,C6,C11 = 10 $\mu$ F 16V radial  
 C2,C7,C8,C9,C12 = 100nF  
 C4 = 220nF (10% tolerance)  
 C10 = 10 $\mu$ F 35V radial

### Semiconductors:

D1 = 1N4001 (DO41 case)  
 D2,D3 = 9V1 zener diode

D4,D5 = 4V7 zener diode  
 D6 = LED, low current, green, 3mm  
 D7 = LED, low current, red, 3mm  
 IC1 = MAX232 (DIL case)  
 IC2 = LTC485 or MAX487E  
 (ESD/EMI-optimised) (DIL case)  
 IC3 = 7805 (TO220 case)  
 IC4 = 74HCT123 (DIL case) (Philips preferred)

### Miscellaneous:

K1 = 9-way sub-D socket, PCB mount, angled pins  
 K2 = 4-way PCB terminal block, 5mm lead pitch  
 S1 = 4-way DIL switch

between 7 V and 30 V and draws a modest 20 mA or so. In case the supply voltage is not obtained from the bus, the RS485 ground is connected to the circuit ground using a 100- $\Omega$  resistor for potential equalisation.

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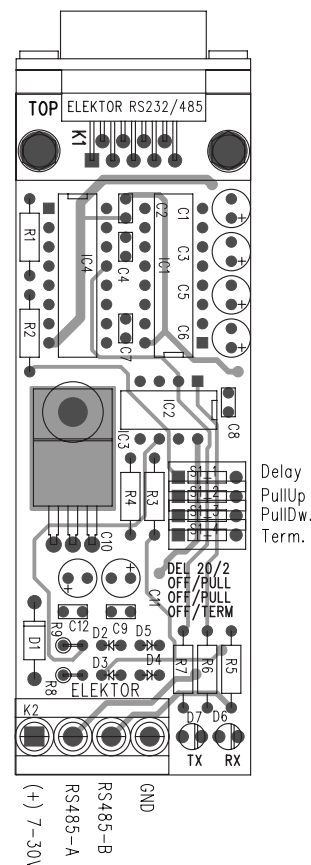
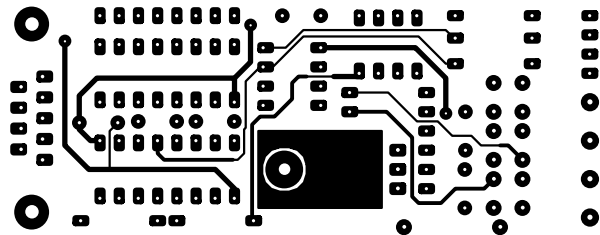
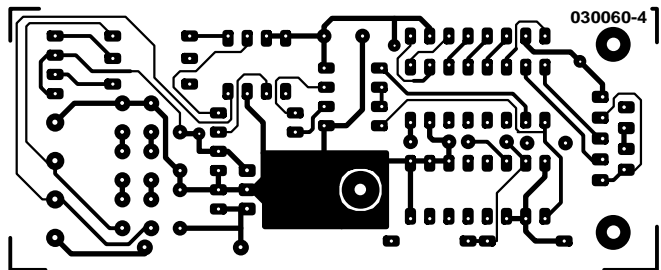
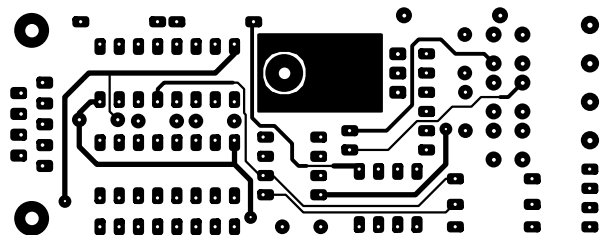
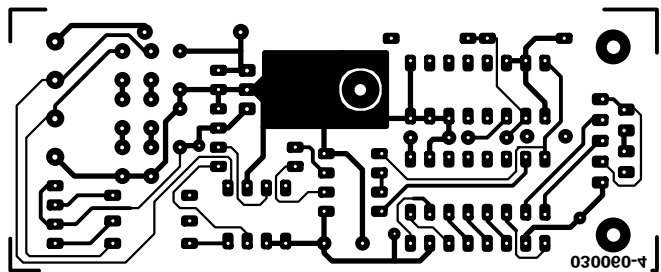


Figure 6. PCB design for the RS232/RS485 converter.



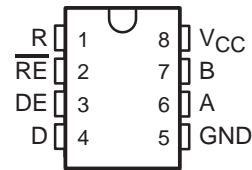
non reflected



reflected

- Bidirectional Transceivers
- Meet or Exceed the Requirements of ANSI Standards TIA/EIA-422-B and TIA/EIA-485-A and ITU Recommendations V.11 and X.27
- Designed for Multipoint Transmission on Long Bus Lines in Noisy Environments
- 3-State Driver and Receiver Outputs
- Individual Driver and Receiver Enables
- Wide Positive and Negative Input/Output Bus Voltage Ranges
- Driver Output Capability . . .  $\pm 60$  mA Max
- Thermal Shutdown Protection
- Driver Positive and Negative Current Limiting
- Receiver Input Impedance . . . 12 k $\Omega$  Min
- Receiver Input Sensitivity . . .  $\pm 200$  mV
- Receiver Input Hysteresis . . . 50 mV Typ
- Operate From Single 5-V Supply

D OR P PACKAGE  
(TOP VIEW)



## description

The SN65176B and SN75176B differential bus transceivers are monolithic integrated circuits designed for bidirectional data communication on multipoint bus transmission lines. They are designed for balanced transmission lines and meet ANSI Standards TIA/EIA-422-B and TIA/EIA-485-A and ITU Recommendations V.11 and X.27.

The SN65176B and SN75176B combine a 3-state differential line driver and a differential input line receiver, both of which operate from a single 5-V power supply. The driver and receiver have active-high and active-low enables, respectively, that can be connected together externally to function as a direction control. The driver differential outputs and the receiver differential inputs are connected internally to form differential input/output (I/O) bus ports that are designed to offer minimum loading to the bus when the driver is disabled or  $V_{CC} = 0$ . These ports feature wide positive and negative common-mode voltage ranges, making the device suitable for party-line applications.

The driver is designed for up to 60 mA of sink or source current. The driver features positive and negative current limiting and thermal shutdown for protection from line-fault conditions. Thermal shutdown is designed to occur at a junction temperature of approximately 150°C. The receiver features a minimum input impedance of 12 k $\Omega$ , an input sensitivity of  $\pm 200$  mV, and a typical input hysteresis of 50 mV.

The SN65176B and SN75176B can be used in transmission-line applications employing the SN75172 and SN75174 quadruple differential line drivers and SN75173 and SN75175 quadruple differential line receivers.

The SN65176B is characterized for operation from  $-40^{\circ}\text{C}$  to  $105^{\circ}\text{C}$  and the SN75176B is characterized for operation from  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .



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**TEXAS  
INSTRUMENTS**

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# SN65176B, SN75176B

## DIFFERENTIAL BUS TRANSCEIVERS

SLLS101B – JULY 1985 – REVISED JUNE 1999

### Function Tables

#### DRIVER

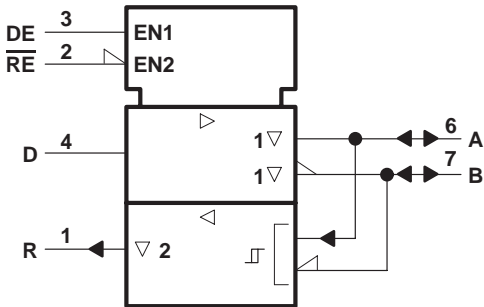
INPUT D	ENABLE DE	OUTPUTS	
		A	B
H	H	H	L
L	H	L	H
X	L	Z	Z

#### RECEIVER

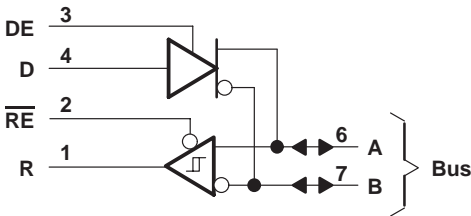
DIFFERENTIAL INPUTS A–B	ENABLE RE	OUTPUT R
$V_{ID} \geq 0.2\text{ V}$	L	H
$-0.2\text{ V} < V_{ID} < 0.2\text{ V}$	L	?
$V_{ID} \leq -0.2\text{ V}$	L	L
X	H	Z
Open	L	?

H = high level, L = low level, ? = indeterminate,  
X = irrelevant, Z = high impedance (off)

### logic symbol†

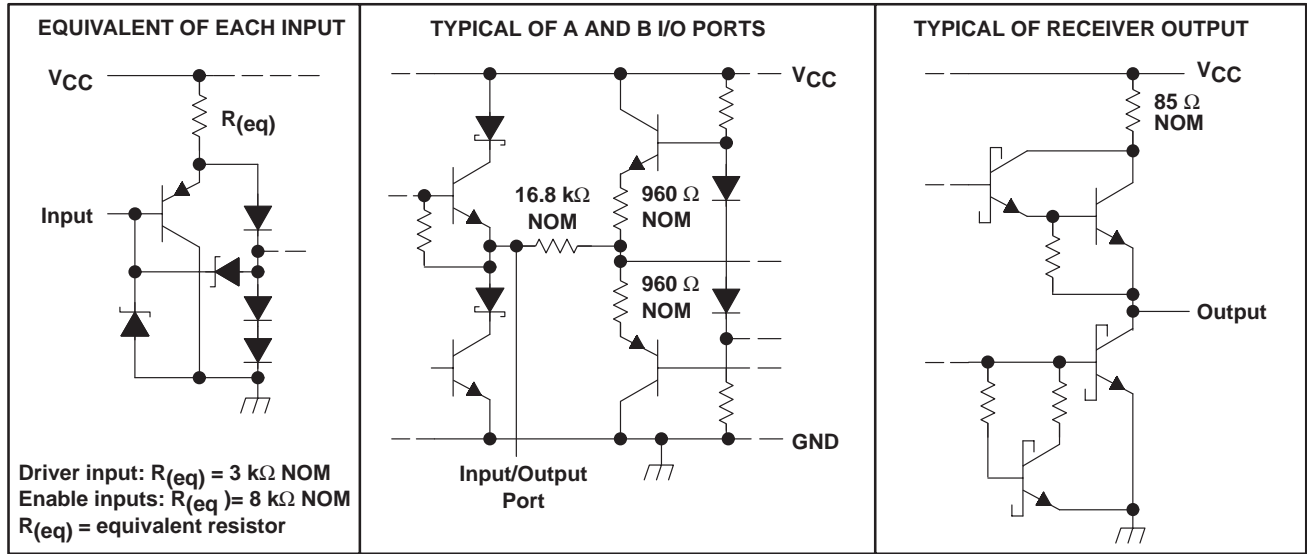


### logic diagram (positive logic)



† This symbol is in accordance with ANSI/IEEE Std 91-1984 and IEC Publication 617-12.

## schematics of inputs and outputs



## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)<sup>†</sup>

Supply voltage, $V_{CC}$ (see Note 1)	7 V
Voltage range at any bus terminal	–10 V to 15 V
Enable input voltage, $V_I$	5.5 V
Package thermal impedance, $\theta_{JA}$ (see Note 2): D package	197°C/W
P package	104°C/W
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260°C
Storage temperature range, $T_{stg}$	–65°C to 150°C

<sup>†</sup> 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.

- NOTES: 1. All voltage values, except differential input/output bus voltage, are with respect to network ground terminal.  
 2. The package thermal impedance is calculated in accordance with JESD 51, except for through-hole packages, which use a trace length of zero.

## recommended operating conditions

		MIN	TYP	MAX	UNIT
Supply voltage, $V_{CC}$		4.75	5	5.25	V
Voltage at any bus terminal (separately or common mode), $V_I$ or $V_{IC}$			12		V
			–7		
High-level input voltage, $V_{IH}$	D, DE, and $\overline{RE}$	2			V
Low-level input voltage, $V_{IL}$	D, DE, and $\overline{RE}$		0.8		V
Differential input voltage, $V_{ID}$ (see Note 3)			±12		V
High-level output current, $I_{OH}$	Driver		–60		mA
	Receiver		–400		μA
Low-level output current, $I_{OL}$	Driver		60		mA
	Receiver		8		
Operating free-air temperature, $T_A$	SN65176B	–40		105	°C
	SN75176B	0		70	

NOTE 3: Differential-input/output bus voltage is measured at the noninverting terminal A with respect to the inverting terminal B.



# SN65176B, SN75176B

## DIFFERENTIAL BUS TRANSCEIVERS

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### DRIVER SECTION

**electrical characteristics over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)**

PARAMETER	TEST CONDITION†	MIN	TYP‡	MAX	UNIT
$V_{IK}$ Input clamp voltage	$I_I = -18 \text{ mA}$			-1.5	V
$V_O$ Output voltage	$I_O = 0$	0		6	V
$ V_{OD1} $ Differential output voltage	$I_O = 0$	1.5	3.6	6	V
$ V_{OD2} $ Differential output voltage	$R_L = 100 \Omega$ , See Figure 1	$\frac{1}{2} V_{OD1}$ or $2 \text{ V}$ ¶			V
	$R_L = 54 \Omega$ , See Figure 1	1.5	2.5	5	V
$V_{OD3}$ Differential output voltage	See Note 4	1.5		5	V
$\Delta V_{OD} $ Change in magnitude of differential output voltage§	$R_L = 54 \Omega$ or $100 \Omega$ , See Figure 1			$\pm 0.2$	V
$V_{OC}$ Common-mode output voltage				+3 -1	V
$\Delta V_{OC} $ Change in magnitude of common-mode output voltage§				$\pm 0.2$	V
$I_O$ Output current	Output disabled, See Note 5	$V_O = 12 \text{ V}$		1	mA
		$V_O = -7 \text{ V}$		-0.8	
$I_{IH}$ High-level input current	$V_I = 2.4 \text{ V}$			20	$\mu\text{A}$
$I_{IL}$ Low-level input current	$V_I = 0.4 \text{ V}$			-400	$\mu\text{A}$
$I_{OS}$ Short-circuit output current	$V_O = -7 \text{ V}$			-250	mA
	$V_O = 0$			150	
	$V_O = V_{CC}$			250	
	$V_O = 12 \text{ V}$			250	
$I_{CC}$ Supply current (total package)	No load	Outputs enabled		42 70	mA
		Outputs disabled		26 35	

† The power-off measurement in ANSI Standard TIA/EIA-422-B applies to disabled outputs only and is not applied to combined inputs and outputs.

‡ All typical values are at  $V_{CC} = 5 \text{ V}$  and  $T_A = 25^\circ\text{C}$ .

§  $\Delta|V_{OD}|$  and  $\Delta|V_{OC}|$  are the changes in magnitude of  $V_{OD}$  and  $V_{OC}$ , respectively, that occur when the input is changed from a high level to a low level.

¶ The minimum  $V_{OD2}$  with a  $100\text{-}\Omega$  load is either  $\frac{1}{2} V_{OD1}$  or  $2 \text{ V}$ , whichever is greater.

NOTES: 4. See ANSI Standard TIA/EIA-485-A, Figure 3.5, Test Termination Measurement 2.

5. This applies for both power on and off; refer to ANSI Standard TIA/EIA-485-A for exact conditions. The TIA/EIA-422-B limit does not apply for a combined driver and receiver terminal.

**switching characteristics,  $V_{CC} = 5 \text{ V}$ ,  $R_L = 110 \text{ k}\Omega$ ,  $T_A = 25^\circ\text{C}$  (unless otherwise noted)**

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{d(OD)}$ Differential-output delay time	$R_L = 54 \Omega$ , See Figure 3		15	22	ns
$t_{t(OD)}$ Differential-output transition time			20	30	ns
$t_{pZH}$ Output enable time to high level	See Figure 4		85	120	ns
$t_{pZL}$ Output enable time to low level	See Figure 5		40	60	ns
$t_{PHZ}$ Output disable time from high level	See Figure 4		150	250	ns
$t_{PLZ}$ Output disable time from low level	See Figure 5		20	30	ns



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SN65176B, SN75176B  
DIFFERENTIAL BUS TRANSCEIVERS

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STATEMENTS

# SN65176B, SN75176B DIFFERENTIAL BUS TRANSCEIVERS

SLLS101B – JULY 1985 – REVISED JUNE 1999

switching characteristics,  $V_{CC} = 5\text{ V}$ ,  $C_L = 15\text{ pF}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{PLH}$ Propagation delay time, low- to high-level output	$V_{ID} = 0\text{ to }3\text{ V}$ , See Figure 6		21	35	ns
$t_{PHL}$ Propagation delay time, high- to low-level output			23	35	ns
$t_{PZH}$ Output enable time to high level	See Figure 7		10	20	ns
$t_{PZL}$ Output enable time to low level			12	20	ns
$t_{PHZ}$ Output disable time from high level	See Figure 7		20	35	ns
$t_{PLZ}$ Output disable time from low level			17	25	ns

## PARAMETER MEASUREMENT INFORMATION

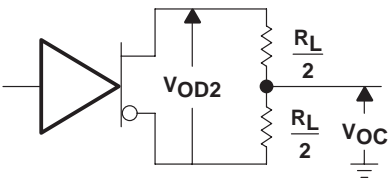


Figure 1. Driver  $V_{OD}$  and  $V_{OC}$

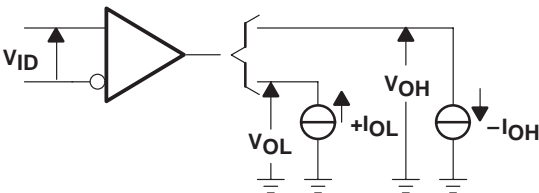
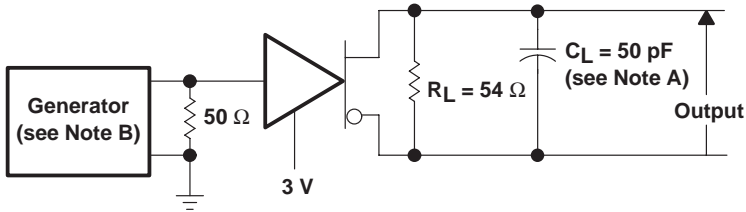
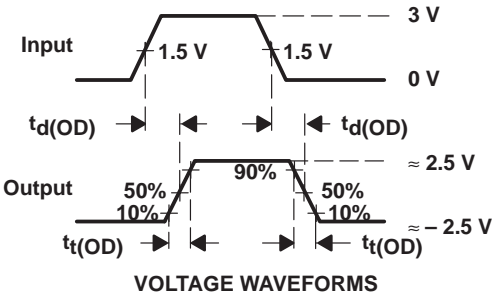


Figure 2. Receiver  $V_{OH}$  and  $V_{OL}$

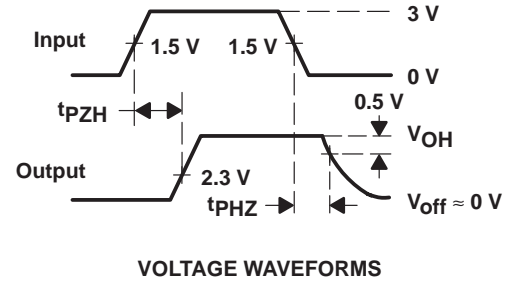
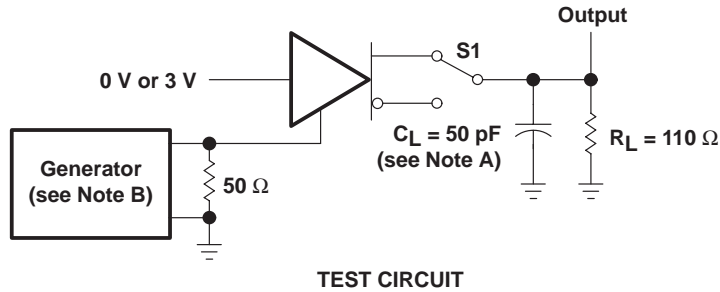


TEST CIRCUIT



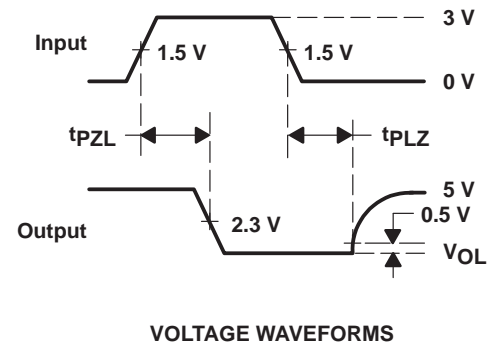
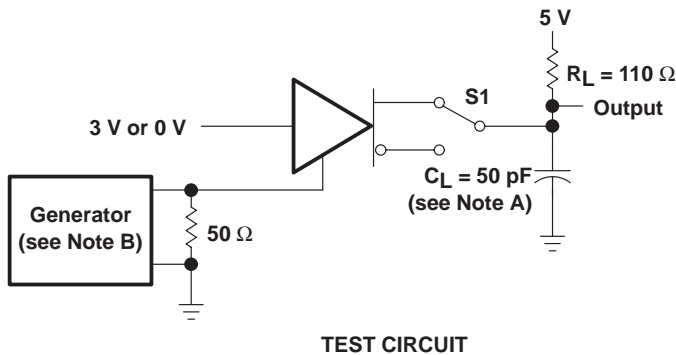
- NOTES: A.  $C_L$  includes probe and jig capacitance.  
 B. The input pulse is supplied by a generator having the following characteristics:  $PRR \leq 1\text{ MHz}$ , 50% duty cycle,  $t_r \leq 6\text{ ns}$ ,  $t_f \leq 6\text{ ns}$ ,  $Z_O = 50\text{ }\Omega$ .

Figure 3. Driver Test Circuit and Voltage Waveforms



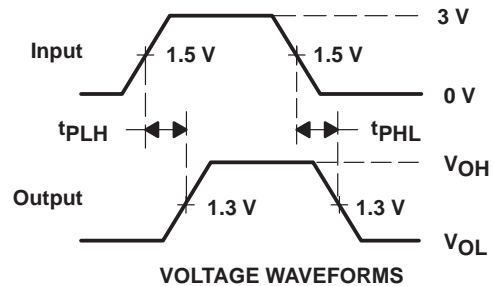
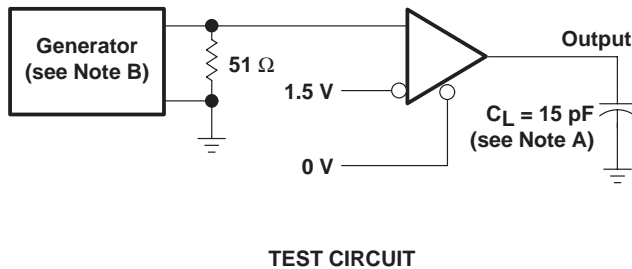
- NOTES: A.  $C_L$  includes probe and jig capacitance.  
B. The input pulse is supplied by a generator having the following characteristics:  $PRR \leq 1$  MHz, 50% duty cycle,  $t_r \leq 6$  ns,  $t_f \leq 6$  ns,  $Z_O = 50 \Omega$ .

**Figure 4. Driver Test Circuit and Voltage Waveforms**



- NOTES: A.  $C_L$  includes probe and jig capacitance.  
B. The input pulse is supplied by a generator having the following characteristics:  $PRR \leq 1$  MHz, 50% duty cycle,  $t_r \leq 6$  ns,  $t_f \leq 6$  ns,  $Z_O = 50 \Omega$ .

**Figure 5. Driver Test Circuit and Voltage Waveforms**



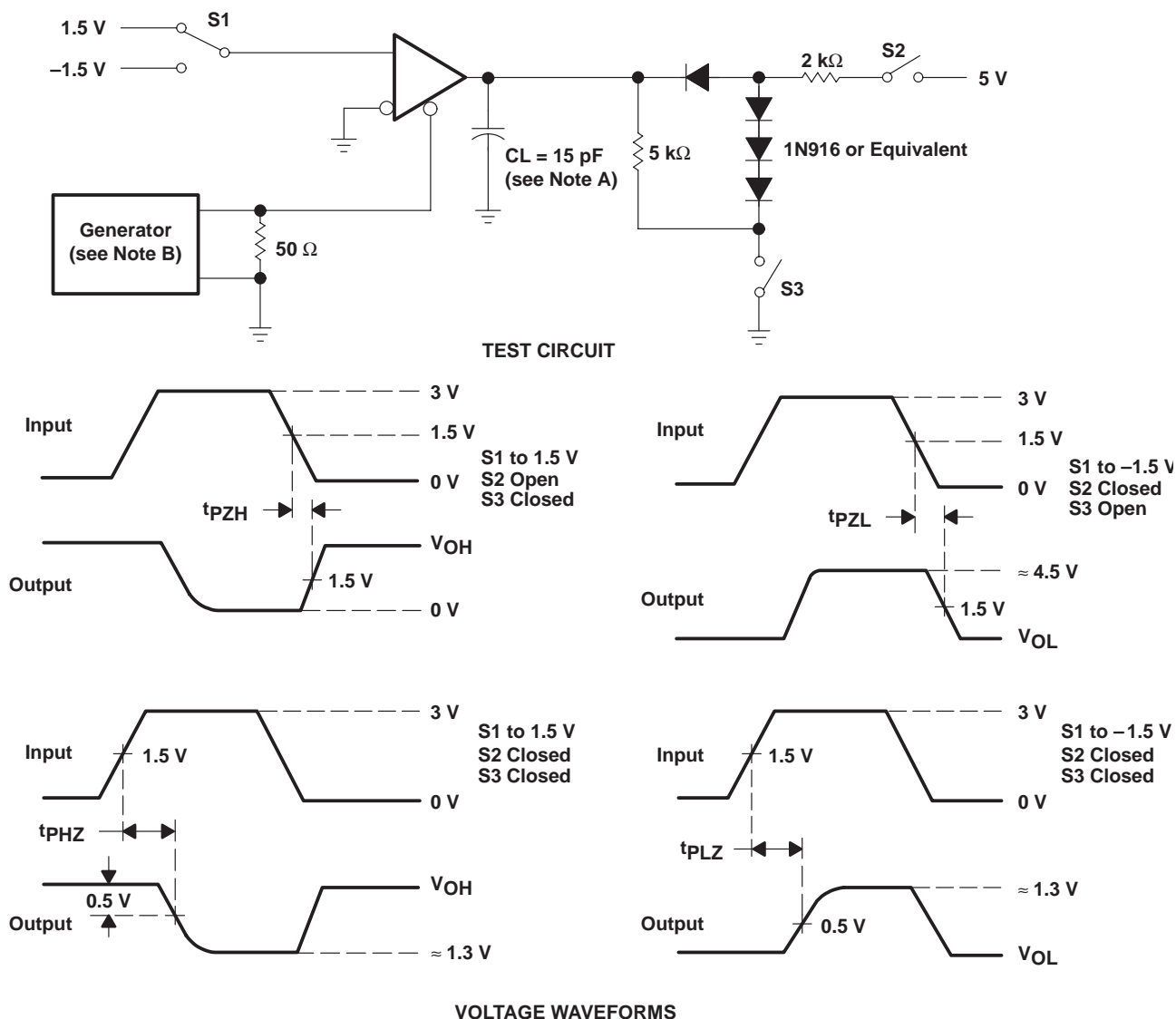
- NOTES: A.  $C_L$  includes probe and jig capacitance.  
B. The input pulse is supplied by a generator having the following characteristics:  $PRR \leq 1$  MHz, 50% duty cycle,  $t_r \leq 6$  ns,  $t_f \leq 6$  ns,  $Z_O = 50 \Omega$ .

**Figure 6. Receiver Test Circuit and Voltage Waveforms**

# SN65176B, SN75176B DIFFERENTIAL BUS TRANSCEIVERS

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## PARAMETER MEASUREMENT INFORMATION



- NOTES: A.  $C_L$  includes probe and jig capacitance.  
B. The input pulse is supplied by a generator having the following characteristics:  $PRR \leq 1$  MHz, 50% duty cycle,  $t_r \leq 6$  ns,  $t_f \leq 6$  ns,  $Z_O = 50 \Omega$ .

Figure 7. Receiver Test Circuit and Voltage Waveforms



SN65176B, SN75176B  
DIFFERENTIAL BUS TRANSCEIVERS

SLLS101B – JULY 1985 – REVISED JUNE 1999

TYPICAL CHARACTERISTICS

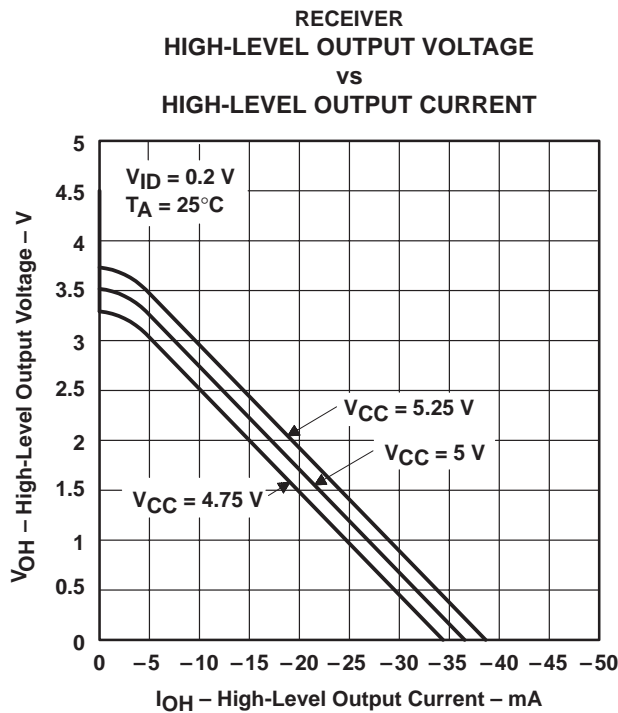
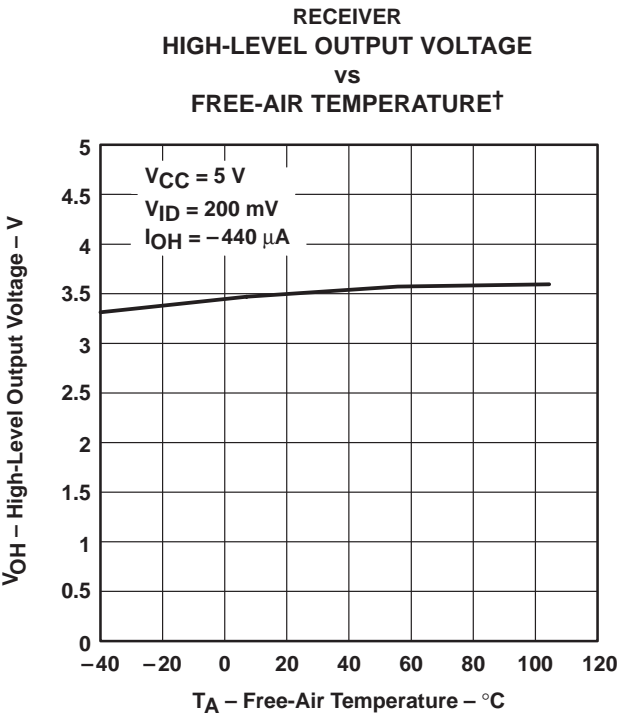


Figure 11



† Only the 0°C to 70°C portion of the curve applies to the SN75176B.

Figure 12

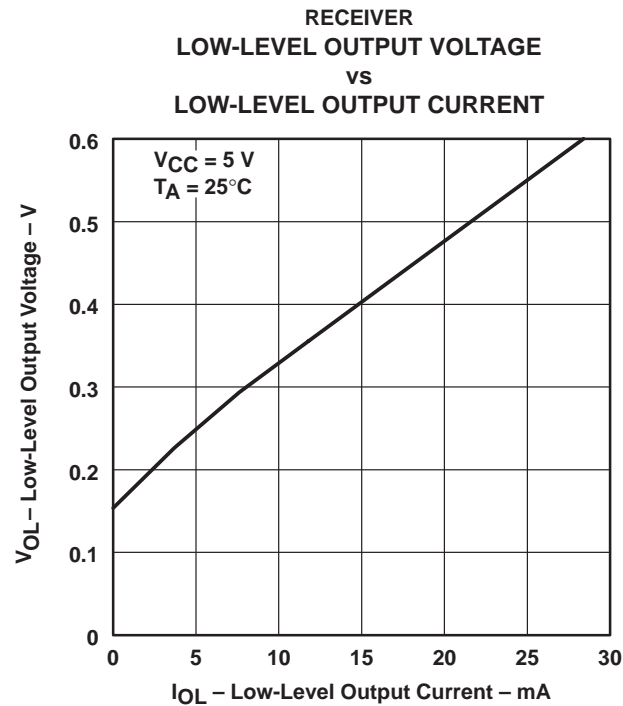


Figure 13

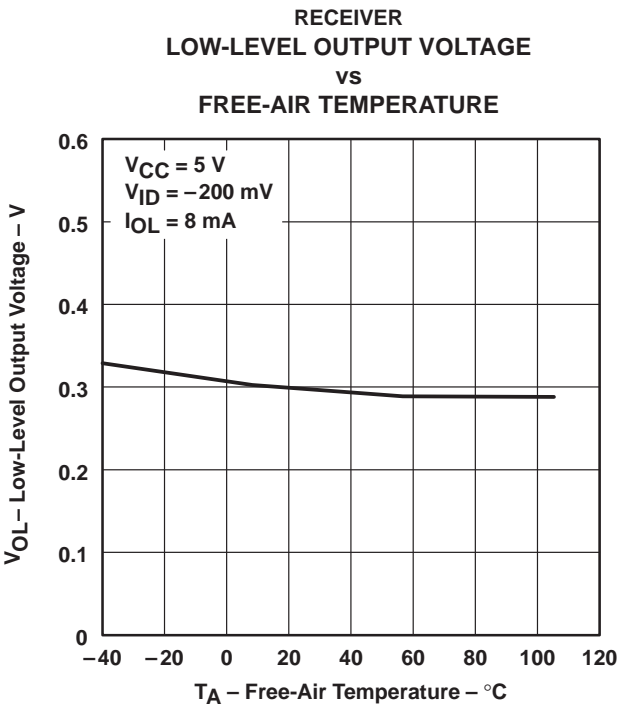


Figure 14

## TYPICAL CHARACTERISTICS

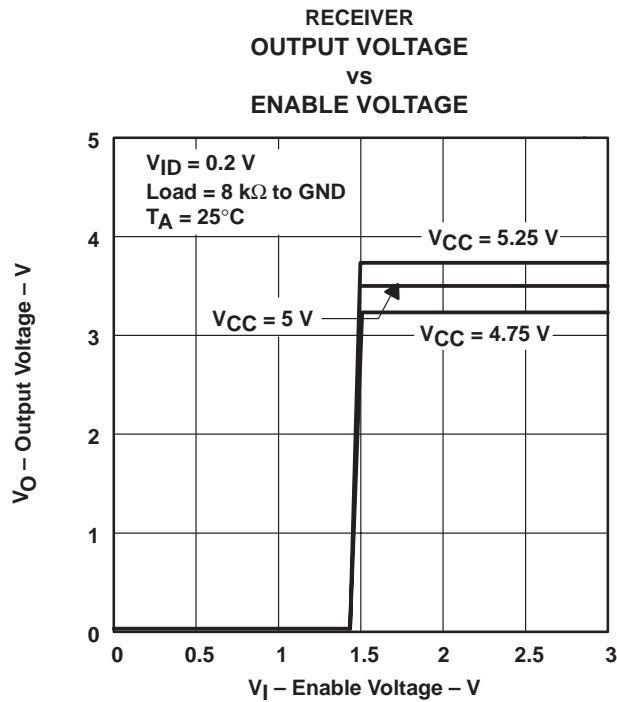


Figure 15

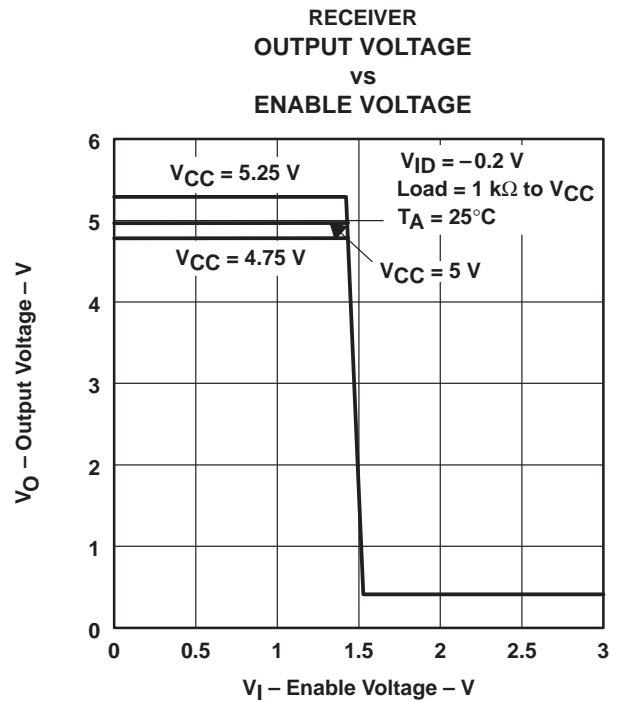
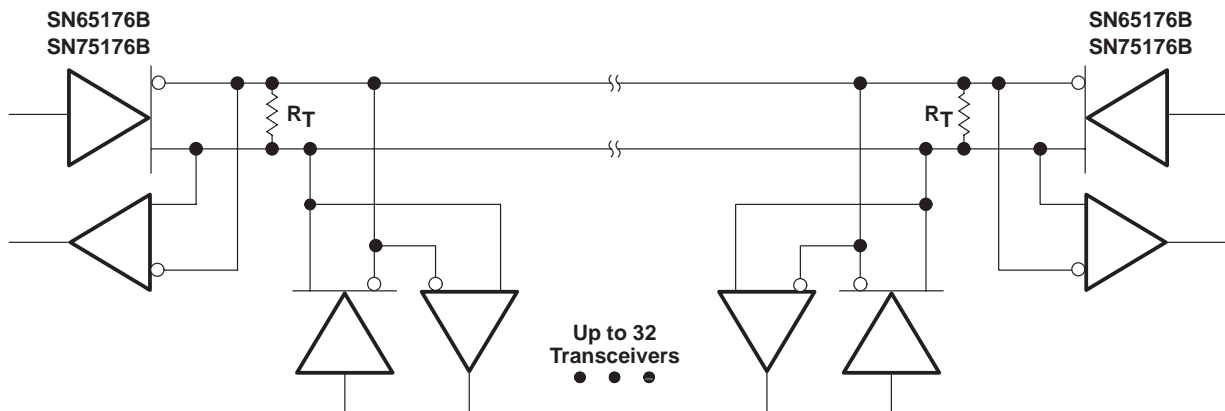


Figure 16

## APPLICATION INFORMATION



NOTE A: The line should be terminated at both ends in its characteristic impedance ( $R_T = Z_0$ ). Stub lengths off the main line should be kept as short as possible.

Figure 17. Typical Application Circuit



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