

TCAN33x 3.3-V CAN Transceivers with CAN FD (Flexible Data Rate)

1 Features

- 3.3-V Single supply operation
- Data rates up to 5 Mbps (TCAN33xG devices)
- Compatible with ISO 11898-2
- SOIC-8 and SOT-23 package options
- Operatinles:
 - Normal mode (all devices)
 - Low power standby mode with wake (TCAN334)
 - Silent mode (TCAN330, TCAN337)
 - Shutdown mode (TCAN330, TCAN334)
- Wide common mode range of operation ± 12 V
- Bus pin fault protection of ± 14 V
- Total loop delay < 135 ns
- Wide ambient operation temperature range: -40°C to 125°C
- Optimized behavior when unpowered:
 - Bus and logic pins are high impedance (no load to operating bus or application)
 - Power up / down glitch free operation
- Excellent EMC performance
- Protection features:
 - ESD Protection of bus terminals
 - HBM ESD Protection exceeds ± 25 kV
 - IEC61000-4-2 ESD Contact discharge protection exceeds ± 12 kV
 - Driver dominant time out (TXD DTO)
 - Receiver dominant time out (RXD DTO)
 - Fault output pin (TCAN337 only)
 - Undervoltage protection on V_{CC}
 - Thermal shutdown protection
 - Current limiting on bus pins

2 Applications

- 5-Mbps operation in CAN with flexible data rate networks (TCAN33xG devices)
- 1-Mbps operation in highly loaded can networks
- Industrial automation, control, sensors and drive systems
- Building, security and climate control automation
- Telecom base station status and control
- CAN Bus standards such as CANopen, DeviceNet, NMEA2000, ARINC825, ISO11783, CANaerospace

3 Description

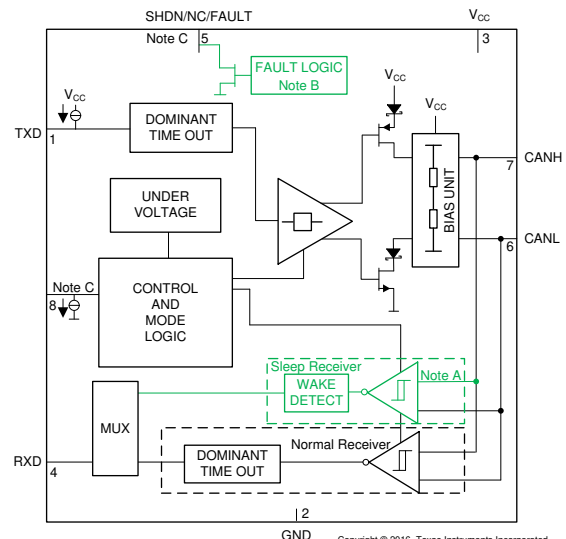
The TCAN33x family of devices is compatible with the ISO 11898 High Speed CAN (Controller Area Network) Physical Layer standard. TCAN330, TCAN332, TCAN334 and TCAN337 are specified for data rates up to 1 Mbps. Pending the release of the updated version of ISO 11898-2 including CAN FD, additional timing parameters defining loop delay symmetry are specified for the TCAN330G, TCAN332G, TCAN334G and TCAN337G devices. The devices include many protection features including driver and receiver Dominant Time Out (DTO) providing CAN network robustness. Integrated 12 kV IEC-61000-4-2 ESD Contact Discharge protection eliminates the need of additional components for system level robustness.

Device Information⁽¹⁾

PART NUMBER	PACKAGE	BODY SIZE (NOM)
TCAN330/G TCAN332/G TCAN334/G TCAN337/G	SOIC (8)	4.90 mm × 3.91 mm
	SOT-23 (8)	2.90 mm × 1.60 mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.

Block Diagram



A: Sleep Receiver and Wake Detect are device dependent options and are only available in TCAN334.
B: Fault Logic are only available in TCAN337.
C: Pin 5 and 8 functions are device dependent. Refer to Device Comparison Table.



Table of Contents

1 Features	1	10.1 Overview	18
2 Applications	1	10.2 Functional Block Diagram	18
3 Description	1	10.3 Feature Description	19
4 Revision History	2	10.4 Device Functional Modes	22
5 Description (continued)	3	11 Application and Implementation	26
6 Device Options	3	11.1 Application Information	26
7 Pin Configuration and Functions	4	11.2 Typical Application	26
8 Specifications	5	11.3 System Examples	28
8.1 Absolute Maximum Ratings	5	12 Power Supply Recommendations	29
8.2 ESD Ratings	5	13 Layout	30
8.3 Recommended Operating Conditions	5	13.1 Layout Guidelines	30
8.4 Thermal Information	5	13.2 Layout Example	31
8.5 Electrical Characteristics	6	14 Device and Documentation Support	32
8.6 Switching Characteristics	8	14.1 Related Links	32
8.7 Typical Characteristics	10	14.2 Support Resources	32
8.8 Typical Characteristics, TCAN330 Receiver	11	14.3 Trademarks	32
8.9 Typical Characteristics, TCAN330 Driver	12	14.4 Electrostatic Discharge Caution	32
9 Parameter Measurement Information	13	14.5 Glossary	32
10 Detailed Description	18	15 Mechanical, Packaging, and Orderable Information	32

4 Revision History

Changes from Revision D (April 2016) to Revision E	Page
• Changed the Pin Configuration image appearance	4
• Changed the titles of Figure 21 and Figure 22	14
Changes from Revision C (April 2016) to Revision D	Page
• Changed From: ARNIC825 To ARINC825 in the Applications list	1
Changes from Revision B (April 2016) to Revision C	Page
• Removed the Preview Note from TCAN337 and TCAN337G in the <i>Device Options</i> table	3
Changes from Revision A (January 2016) to Revision B	Page
• Removed the Preview Note from all device except for TCAN337 and TCAN337G in the <i>Device Comparison</i> table	3
• Changed FAULT Pin I _{CL} MIN value From: 5 mA To: 4 mA in the Electrical Characteristics	7
Changes from Original (December 2015) to Revision A	Page
• Changed Features From: "Total Loop Delay < 150 ns" To: "Total loop delay < 135 ns"	1
• Changed V _{IT(SLEEP)} To: V _{IT(STB)} and added Test conditions in the Electrical Characteristics	7
• Added -12 V < V _{CM} < 12 V to t _{WK_FILTER} in the Test Conditions of Switching Characteristics	8

5 Description (continued)

The use of single 3.3-V supply enables the transceivers to directly interface with 3.3-V CAN controllers/MCUs. In addition, these devices are fully compatible with other 5-V CAN transceivers on the same bus.

These devices have excellent EMC performance due to matched Dominant and Recessive Common Modes. Ultra low power Shutdown and Standby modes make these devices attractive for battery powered applications.

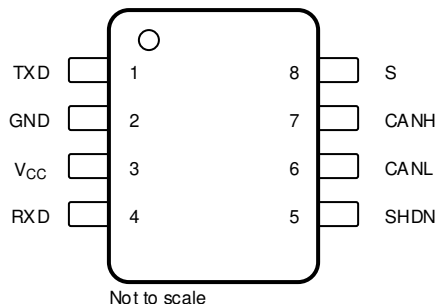
This family of devices is available in standard 8-pin SOIC packages for drop-in compatibility and in small SOT-23 packages for space-constrained applications.

6 Device Options

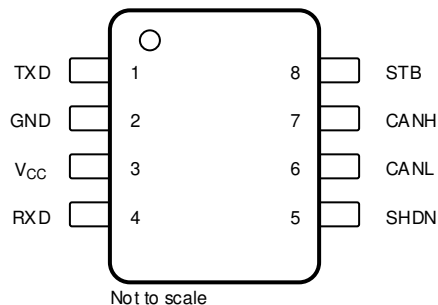
DEVICE	PIN 5	PIN 8	DERATE	DESCRIPTION
TCAN330	SHDN	S	1 Mbps	Shutdown and silent modes
TCAN332	NC	NC	1 Mbps	Normal mode only
TCAN334	SHDN	STB	1 Mbps	Shutdown and standby with wake
TCAN337	FAULT	S	1 Mbps	Fault output and silent mode
TCAN330G	SHDN	S	5 Mbps	Shutdown and silent modes
TCAN332G	NC	NC	5 Mbps	Normal mode only
TCAN334G	SHDN	STB	5 Mbps	Shutdown and standby with wake
TCAN337G	FAULT	S	5 Mbps	Fault output and silent mode

7 Pin Configuration and Functions

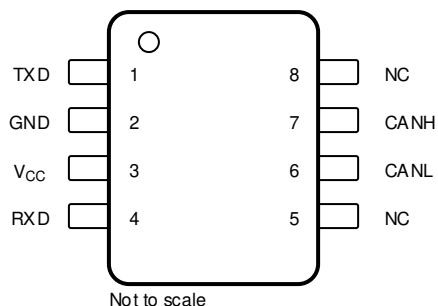
TCAN330 D, DCN Packages
8-Pin SOIC, SOT-23
Top View



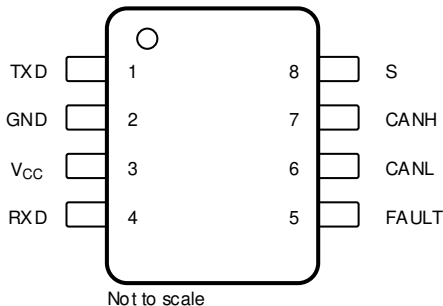
TCAN334 D, DCN Packages
8-Pin SOIC, SOT-23
Top View



TCAN332 D, DCN Packages
8-Pin SOIC, SOT-23
Top View



TCAN337 D, DCN Packages
8-Pin SOIC, SOT-23
Top View



Pin Functions

NAME	PIN				I/O	DESCRIPTION
	TCAN330	TCAN332	TCAN334	TCAN337		
TXD	1	1	1	1	I	CAN transmit data input (LOW for dominant and HIGH for recessive bus states), integrated pull up
GND	2	2	2	2	GND	Ground connection
V _{CC}	3	3	3	3	Supply	3.3-V supply voltage
RXD	4	4	4	4	O	CAN receive data output (LOW for dominant and HIGH for recessive bus states), tri-state
SHDN	5	—	5	—	I	Drive high for shutdown mode. Internal pull-down.
NC	—	5	—	—	NC	No Connect – Not internally connected
FAULT	—	—	—	5	O	Open drain fault output pin.
CANL	6	6	6	6	I/O	Low level CAN bus line
CANH	7	7	7	7	I/O	High level CAN bus line
S	8	—	—	8	I	Drive high for silent mode, integrated pull down
NC	—	8	—	—	NC	No Connect – Not internally connected
STB	—	—	8	—	I	Drive high for low power standby mode, integrated pull down

8 Specifications

8.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)⁽¹⁾⁽²⁾

	MIN	MAX	UNIT
Supply Voltage range, V_{CC}	−0.3	5	V
Voltage at any bus terminal (CANH or CANL), $V_{(BUS)}$	−14	14	V
Logic input terminal voltage range $V_{(Logic_Input)}$	−0.3	5	V
Logic output terminal voltage range, $V_{(Logic_Output)}$	−0.3	5	V
Logic output current, $I_{O(Logic)}$		8	mA
Operating junction temperature range, T_J	−40	150	°C
Storage temperature, T_{stg}		150	°C

- (1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- (2) All voltage values, except differential I/O bus voltages, are with respect to ground terminal.

8.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$ Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 ⁽¹⁾	All pins except CANH and CANL	±4000	V
		Pins CANH and CANL	±25000	
	Charged-device model (CDM), per JEDEC specification JESD22-C101 ⁽²⁾	All pins	±1500	
		CANH and CANL terminals to GND	±12000	

- (1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process. .
- (2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

8.3 Recommended Operating Conditions

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

		MIN	NOM	MAX	UNIT
V_{CC}	Supply voltage	3		3.6	V
$I_{OH(Logic)}$	Logic terminal HIGH level output current	−2			mA
$I_{OL(Logic)}$	Logic terminal LOW level output current			2	
T_A	Operational free-air temperature	−40		125	°C

8.4 Thermal Information

THERMAL METRIC ⁽¹⁾		TCAN33x	TCAN33x	UNIT
		D (SOIC)	DCN (SOT-23)	
		8 PINS	8 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	114.4	154.4	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	58.7	76.6	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	55.2	49.2	°C/W
Ψ_{JT}	Junction-to-top characterization parameter	11.7	11.9	°C/W
Ψ_{JB}	Junction-to-board characterization parameter	54.6	49.2	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	N/A	N/A	°C/W
P_D	Average power dissipation	$V_{CC} = 3.3\text{ V}$, $T_J = 27^\circ\text{C}$, $R_L = 60\ \Omega$, SHDN, S and STB at 0 V, Input to TXD at 500 kHz, 50% duty cycle square wave, $C_{L(RXD)} = 15\text{ pF}$		mW
T_{SD}	Thermal shutdown temperature	175	175	°C
T_{HYS}	Thermal shutdown hysteresis	5	5	°C

- (1) For more information about traditional and new thermal metrics, see the [Semiconductor and IC Package Thermal Metrics](#) application report.

8.5 Electrical Characteristics

over operating free-air temperature range, $T_J = -40^{\circ}\text{C}$ to 150°C . All typical values are at 25°C and supply voltages of $V_{CC} = 3.3\text{ V}$, $R_L = 60\ \Omega$, (unless otherwise noted)

PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
Supply							
I _{CC}	Supply current Normal Mode	Dominant	See Figure 18 . TXD = 0 V, R _L = 60 Ω, C _L = open, S, STB and SHDN = 0 V. Typical Bus Load.			55	mA
			See Figure 18 . TXD = 0 V, R _L = 50 Ω, C _L = open, S, STB and SHDN = 0 V. High Bus Load.			60	
		Dominant with bus fault	See Figure 18 . TXD = 0 V, S, STB and SHDN = 0 V, CANH = -12 V, R _L = open, C _L = open			180	
		Recessive	See Figure 18 . TXD = V _{CC} , R _L = 50 Ω, C _L = open, S, STB and SHDN = 0 V			3.5	
	Supply Current: Silent Mode		See Figure 18 . TXD = V _{CC} , R _L = 50 Ω, C _L = open, S = V _{CC}			2.5	μA
	Supply Current: Standby Mode		T _A < 85°C, STB at V _{CC} , RXD floating, TXD at V _{CC}			15	
			STB at V _{CC} , RXD floating, TXD at V _{CC}			20	
	Supply Current: Shutdown Mode		T _A < 85°C, SHDN at V _{CC} , RXD floating, TXD at V _{CC}			1	
SHDN = V _{CC} , RXD floating, TXD at V _{CC}					2.5		
UV _(VCC)	Rising under voltage detection on V _{CC} for protected mode				2.2	2.6	V
	Falling under voltage detection on V _{CC} for protected mode			1.65	2	2.5	
V _{HYS(UVVCC)}	Hysteresis voltage on UV _(VCC)				200		mV
Driver							
V _{O(D)}	Bus output voltage (dominant)	CANH	See Figure 31 and Figure 19 , TXD = 0 V, S, STB and SHDN = 0 V, R _L = 60 Ω, C _L = open	2.45		V _{CC}	V
		CANL		0.5		1.25	
V _{O(R)}	Bus output voltage (recessive)		See Figure 31 and Figure 19 , TXD = V _{CC} , STB, SHDN = 0 V, S = 0 V or V _{CC} ⁽¹⁾ , R _L = open (no load)		1.85		V
V _{OD(D)}	Differential output voltage (dominant)		See Figure 31 and Figure 19 , TXD = 0 V, S, STB and SHDN = 0 V, 50 Ω ≤ R _L ≤ 65 Ω, C _L = open	1.6		3	V
			See Figure 31 and Figure 19 , TXD = 0 V, S, STB and SHDN = 0 V, 45 Ω ≤ R _L < 50 Ω, C _L = open	1.5		3	
V _{OD(R)}	Differential output voltage (recessive)		See Figure 31 and Figure 19 , TXD = V _{CC} , S, STB and SHDN = 0 V, R _L = 60 Ω, C _L = open	-120		12	mV
			T _A < 85°C, See Figure 31 and Figure 19 , TXD = V _{CC} , S, STB and SHDN = 0 V, R _L = open (no load), C _L = open	-50		50	
			See Figure 31 and Figure 19 , TXD = V _{CC} , S, STB and SHDN = 0 V, R _L = open (no load), C _L = open	-50		100	
V _(SYM)	Output symmetry (dominant and recessive) (CANH _{REC} + CANL _{REC} – CANH _{DOM} – CANL _{DOM})		See Figure 31 and Figure 19 , S, STB and SHDN = 0 V, R _L = 60 Ω, C _L = open	-400		400	mV
I _{OS(DOM)}	Short-circuit steady-state output current, Dominant		See Figure 26 , V _(CANH) = -12 V, CANL = open, TXD = 0 V	-200			mA
			See Figure 26 , V _(CANL) = 12 V, CANH = open, TXD = 0 V			200	
I _{OS(REC)}	Short-circuit steady-state output current, Recessive		See Figure 26 , -12 V ≤ V _{BUS} ≤ 12 V, V _{BUS} = CANH = CANL, TXD = V _{CC}	-5		5	mA

- (1) The bus output voltage (recessive) will be the same if the device is in normal mode with S terminal LOW or if the device is in silent mode with the S terminal is HIGH.

Electrical Characteristics (continued)

over operating free-air temperature range, $T_J = -40^{\circ}\text{C}$ to 150°C . All typical values are at 25°C and supply voltages of $V_{CC} = 3.3\text{ V}$, $R_L = 60\ \Omega$, (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Receiver						
V_{IT}	Input threshold voltage, normal modes and selective wake modes	See Figure 20 and Table 7	500		900	mV
V_{HYS}	Hysteresis voltage for input threshold, normal modes and selective wake modes			120		
V_{CM}	Common Mode Range: normal and silent modes		-12		12	V
$V_{IT(STB)}$	Input Threshold, standby mode	$-2\text{ V} < V_{CM} < 7\text{ V}$ See Figure 20 and Table 7	400		1150	mV
		$-12\text{ V} < V_{CM} < 12\text{ V}$ See Figure 20 and Table 7	400		1350	mV
$I_{IOFF(LKG)}$	Power-off (unpowered) bus input leakage current	$T_A < 85^{\circ}\text{C}$, $CANH = CANL = 3.3\text{ V}$, V_{CC} to GND via $0\text{-}\Omega$ and $47\text{-k}\Omega$ resistor			6	μA
		$CANH = CANL = 3.3\text{ V}$, V_{CC} to GND via $0\text{-}\Omega$ and $47\text{-k}\Omega$ resistor			12	
C_I	Input capacitance to ground (CANH or CANL)				20	pF
C_{ID}	Differential input capacitance				10	
R_{ID}	Differential input resistance	$TXD = V_{CC}$, Normal Mode	30		80	$\text{k}\Omega$
R_{IN}	Input resistance (CANH or CANL)	$TXD = V_{CC}$, Normal mode	15		40	
$R_{IN(M)}$	Input resistance matching: $[1 - (R_{IN(CANH)} / R_{IN(CANL)})] \times 100\%$	$V_{(CANH)} = V_{(CANL)}$	-3%		3%	
TXD Terminal (CAN Transmit Data Input)						
V_{IH}	HIGH level input voltage		2			V
V_{IL}	LOW level input voltage				0.8	V
I_{IH}	HIGH level input leakage current	$TXD = V_{CC} = 3.6\text{ V}$	-2.5	0	3	μA
I_{IL}	LOW level input leakage current	$TXD = 0\text{ V}$, $V_{CC} = 3.6\text{ V}$	-4	0	0	μA
$I_{LKG(OFF)}$	Unpowered leakage current	$TXD = 3.6\text{ V}$, $V_{CC} = 0\text{ V}$	-2	0	2.5	μA
I_{CAP}	Input Capacitance			2.5		pF
RXD Terminal (CAN Receive Data Output)						
V_{OH}	HIGH level output voltage	See Figure 20, $I_O = -2\text{ mA}$	$0.8 \times V_{CC}$			V
V_{OL}	LOW level output voltage	See Figure 20, $I_O = 2\text{ mA}$		0.2	0.4	V
$I_{LKG(OFF)}$	Unpowered leakage current	$RXD = 3.6\text{ V}$, $V_{CC} = 0\text{ V}$	-1	0	1	μA
STB/S/SHDN Terminals						
V_{IH}	HIGH level input voltage		2			V
V_{IL}	LOW level input voltage				0.8	V
I_{IH}	HIGH level input leakage current	$STB, S, SHDN = V_{CC} = 3.6\text{ V}$	-3	0	10	μA
I_{IL}	LOW level input leakage current	$STB, S, SHDN = 0\text{ V}$, $V_{CC} = 3.6\text{ V}$	-4	0	1	μA
$I_{LKG(OFF)}$	Unpowered leakage current	$STB, S, SHDN = 3.6\text{ V}$, $V_{CC} = 0\text{ V}$	-3	0	5	μA
FAULT Pin (Fault Output), TCAN337 only						
I_{CH}	Output current high level	$FAULT = V_{CC}$, See Figure 28	-10			μA
I_{CL}	Output current low level	$FAULT = 0.4\text{ V}$, See Figure 28	4	12		mA

8.6 Switching Characteristics

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Device Switching Characteristics						
t _{PROP(LOOP)}	Total loop delay, driver input (TXD) to receiver output (RXD), recessive to dominant and dominant to recessive	See Figure 23, S, STB and SHDN = 0 V, R _L = 60 Ω, C _L = 100 pF, C _{L(RXD)} = 15 pF		100	135	ns
t _{PROP(LOOP)}	Total Loop delay in highly loaded network	See Figure 23, S, STB and SHDN = 0 V, R _L = 120 Ω, C _L = 200 pF, C _{L(RXD)} = 15 pF		120	180	ns
t _{BUS_SYM_2}	2 Mbps transmitted recessive bit width	See Figure 24, S or STB = 0 V, R _L = 60 Ω, C _L = 100 pF, C _{L(RXD)} = 15 pF, t _{BIT} = 500 ns TCAN330G, TCAN332G, TCAN334G and TCAN337G only		435	530	ns
t _{REC_SYM_2}	2 Mbps received recessive bit width			400	550	ns
Δt _{SYM_2}	2 Mbps receiver timing symmetry (t _{REC_SYM_2} - t _{BUS_SYM_2})			−65	40	ns
t _{BUS_SYM_5}	5 Mbps transmitted recessive bit width	See Figure 24, S or STB = 0 V, R _L = 60 Ω, C _L = 100 pF, C _{L(RXD)} = 15 pF, t _{BIT} = 200 ns TCAN330G, TCAN332G, TCAN334G and TCAN337G only		155	210	ns
t _{REC_SYM_5}	5 Mbps received recessive bit width			120	220	ns
Δt _{SYM_5}	5 Mbps receiver timing symmetry (t _{REC_SYM_5} - t _{BUS_SYM_5})			−45	15	ns
t _{MODE}	Mode change time	See Figure 21 and Figure 22. R _L = 60 Ω, C _L = 100 pF, C _{L(RXD)} = 15 pF		5	10	μs
t _{UV_RE-ENABLE}	Re-enable time after UV event	Time for device to return to normal operation from UV(V _{CC}) under voltage event			1000	μs
t _{WK_FILTER}	Bus time to meet Filtered Bus Requirements for Wake Up Request	See Figure 33, Standby mode. −12 V < V _{CM} < 12 V		0.5	4	μs
Driver Switching Characteristics						
t _{pHR}	Propagation delay time, HIGH TXD to Driver Recessive	See Figure 19, S, STB and SHDN = 0 V. R _L = 60 Ω, C _L = 100 pF,		25	ns	
t _{pLD}	Propagation delay time, LOW TXD to Driver Dominant			20		
t _{sk(p)}	Pulse skew (t _{pHR} - t _{pLD})			5		
t _r	Differential output signal rise time			17		
t _f	Differential output signal fall time			9		
t _{TXD_DTO}	Driver dominant time out ⁽¹⁾	See Figure 25, R _L = 60 Ω, C _L = 100 pF	1.2	2.6	3.8	ms
Receiver Switching Characteristics						
t _{pRH}	Propagation delay time, bus recessive input to high RXD output	See Figure 20, C _{L(RXD)} = 15 pF CANL = 1.5 V, CANH = 3.5 V		62	ns	
t _{pDL}	Propagation delay time, bus dominant input to RXD low output			56		
t _r	Output signal rise time (RXD)			7		
t _f	Output signal fall time (RXD)			6		
t _{RXD_DTO}	Receiver dominant time out ⁽²⁾	See Figure 27, C _{L(RXD)} = 15 pF	1.6	3	5	ms

- (1) The TXD dominant time out ($t_{\text{TXD_DTO}}$) disables the driver of the transceiver once the TXD has been dominant longer than $t_{\text{TXD_DTO}}$, which releases the bus lines to recessive, preventing a local failure from locking the bus dominant. The driver may only transmit dominant again after TXD has been returned HIGH (recessive). While this protects the bus from local faults, locking the bus dominant, it limits the minimum data rate possible. The CAN protocol allows a maximum of eleven successive dominant bits (on TXD) for the worst case, where five successive dominant bits are followed immediately by an error frame. This, along with the $t_{\text{TXD_DTO}}$ minimum, limits the minimum bit rate. The minimum bit rate may be calculated by: Minimum Bit Rate = $11 / t_{\text{TXD_DTO}} = 11\ \text{bits} / 1.2\ \text{ms} = 9.2\ \text{kbps}$.
- (2) The RXD timeout ($t_{\text{RXD_DTO}}$) disables the RXD output in the case that the bus has been dominant longer than $t_{\text{RXD_DTO}}$, which releases RXD pin to the recessive state (high), thus preventing a dominant bus failure from permanently keeping the RXD pin low. The RXD pin will automatically resume normal operation once the bus has been returned to a recessive state. While this protects the protocol controller from a permanent dominant state, it limits the minimum data rate possible. The CAN protocol allows a maximum of eleven successive dominant bits (on RXD) for the worst case, where five successive dominant bits are followed immediately by an error frame. This, along with the $t_{\text{RXD_DTO}}$ minimum, limits the minimum bit rate. The minimum bit rate may be calculated by: Minimum Bit Rate = $11 / t_{\text{RXD_DTO}} = 11\ \text{bits} / 1.6\ \text{ms} = 6.9\ \text{kbps}$.

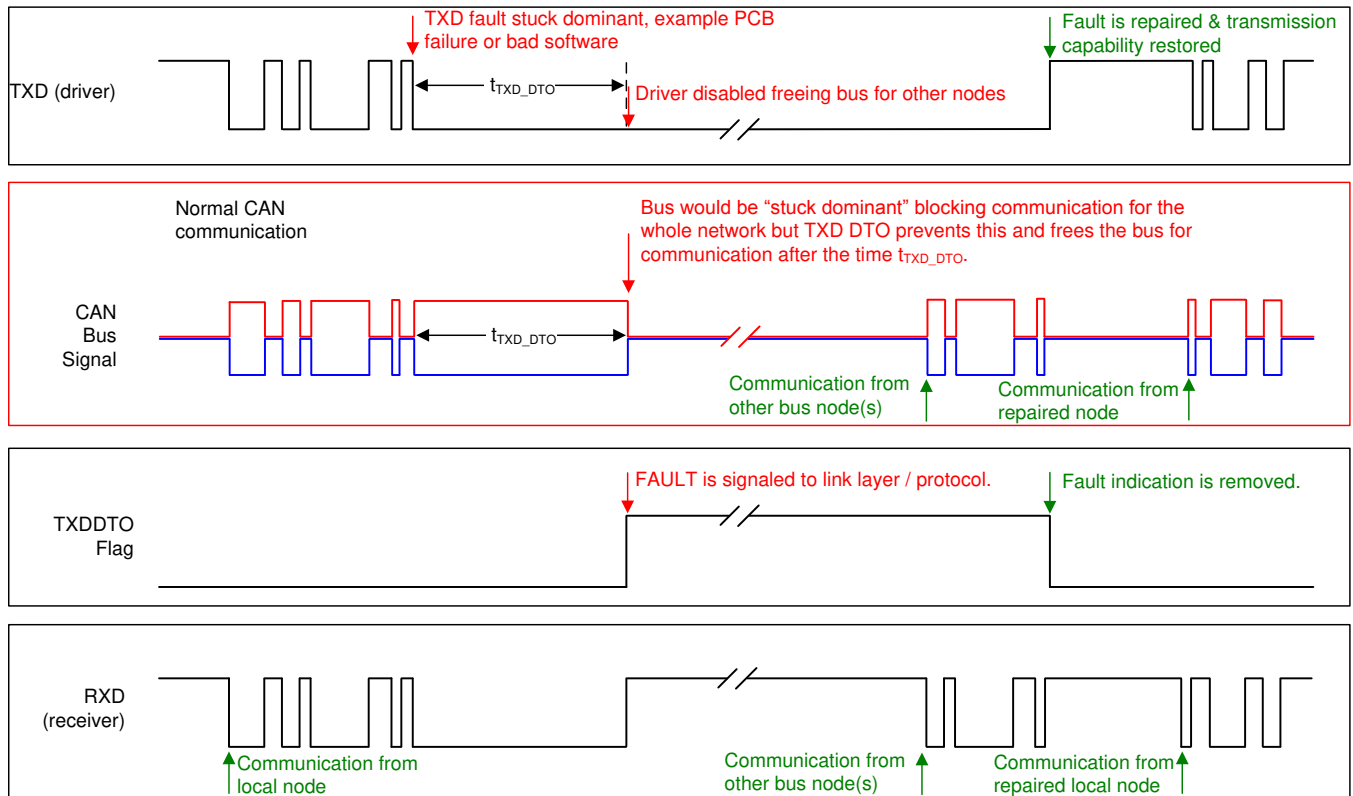


Figure 1. Example Timing Diagram for TXD DTO and FAULT Pin

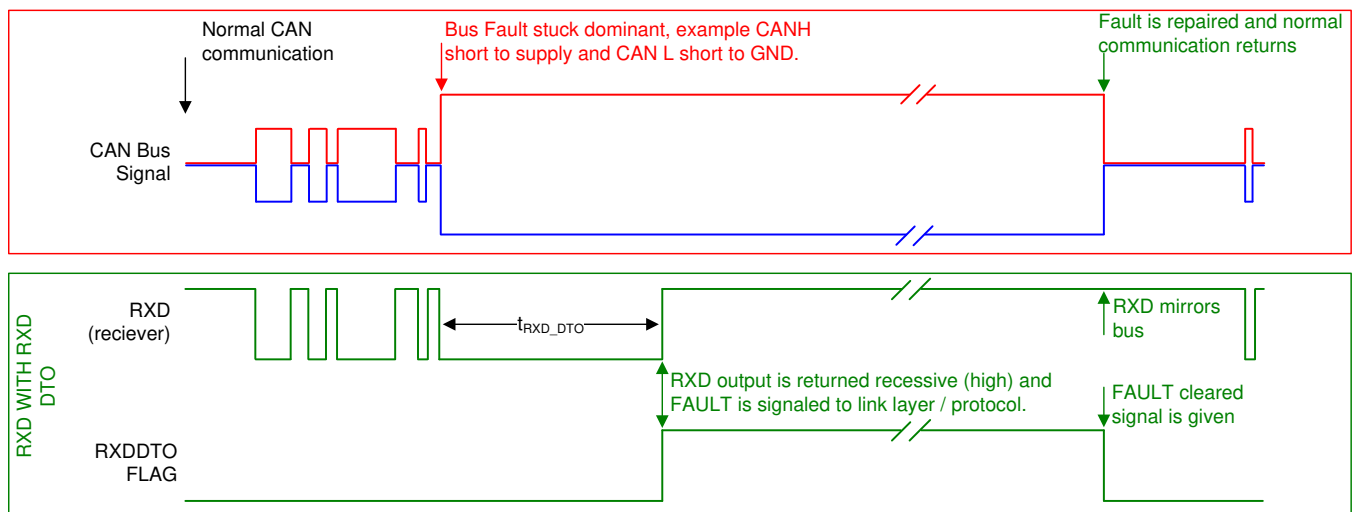


Figure 2. Example Timing Diagram for RXD DTO and FAULT Pin

8.7 Typical Characteristics

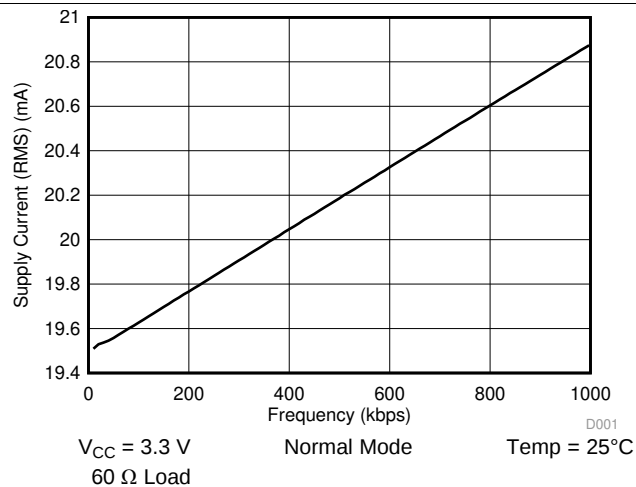


Figure 3. Supply Current (RSM) vs Frequency

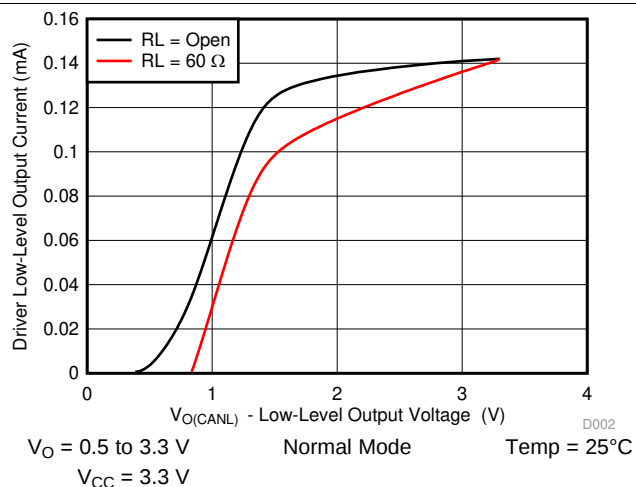


Figure 4. Driver Low-Level Output Current vs Low-level Output Voltage

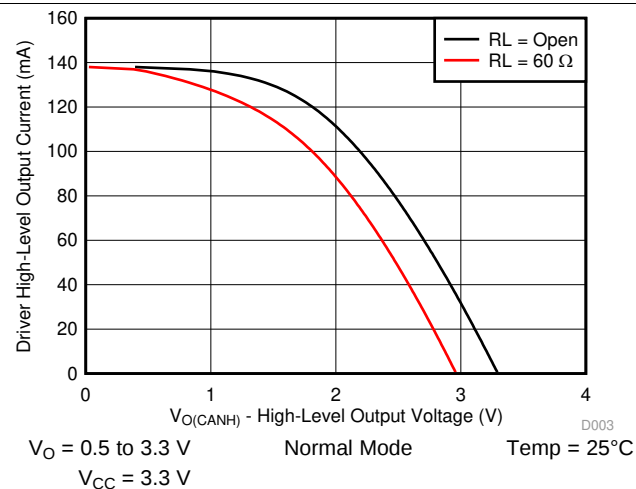


Figure 5. Driver High-Level Output Current vs High-level Output Voltage

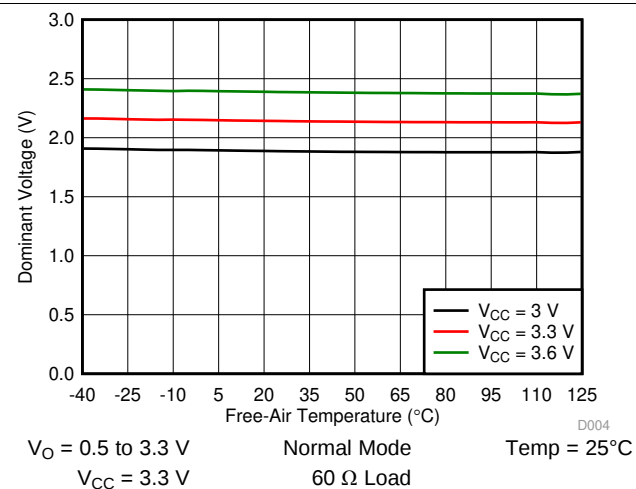


Figure 6. Dominant Voltage (V_{OD}) vs Free-Air Temperature

8.8 Typical Characteristics, TCAN330 Receiver

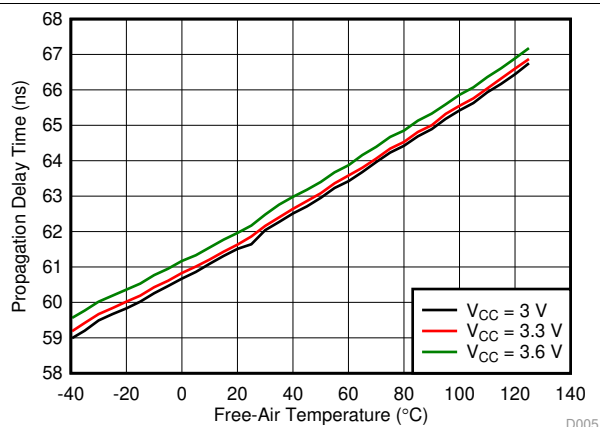


Figure 7. Receiver Bus Recessive Input to High RXD Output Propagation Delay Time vs Free-Air Temperature

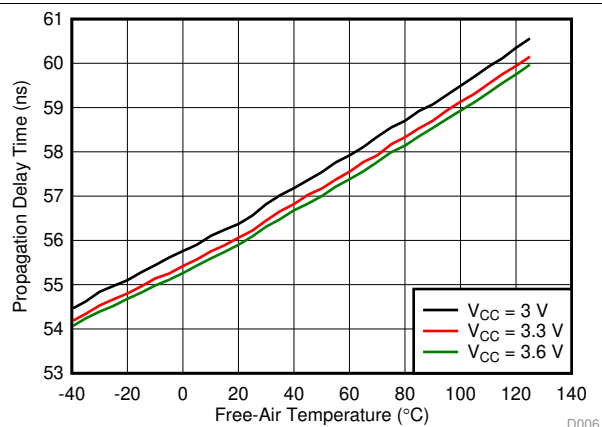


Figure 8. Receiver Bus Dominant Input to Low RXD Output Propagation Delay Time vs Free-Air Temperature

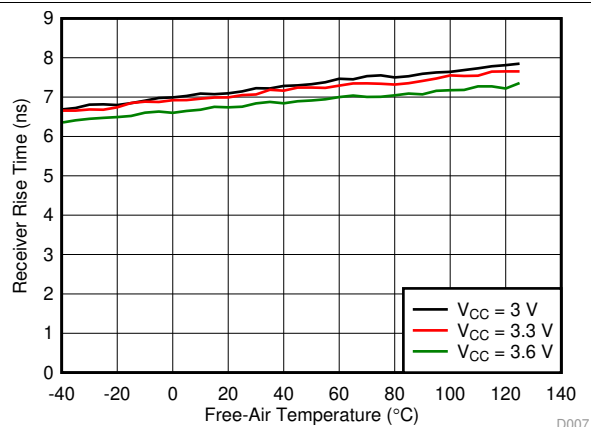


Figure 9. Receiver Rise Time vs Free-Air Temperature

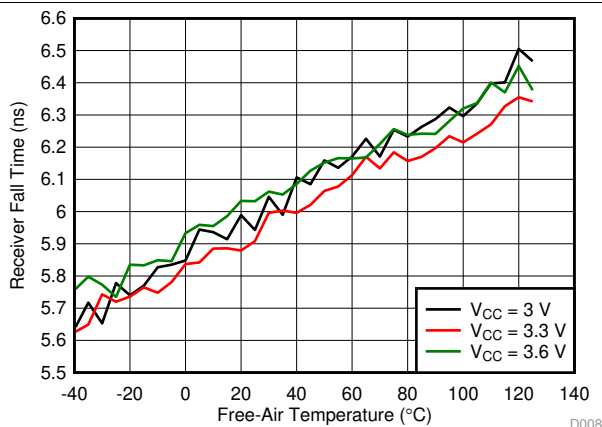


Figure 10. Receiver Fall Time vs Free-Air Temperature

8.9 Typical Characteristics, TCAN330 Driver

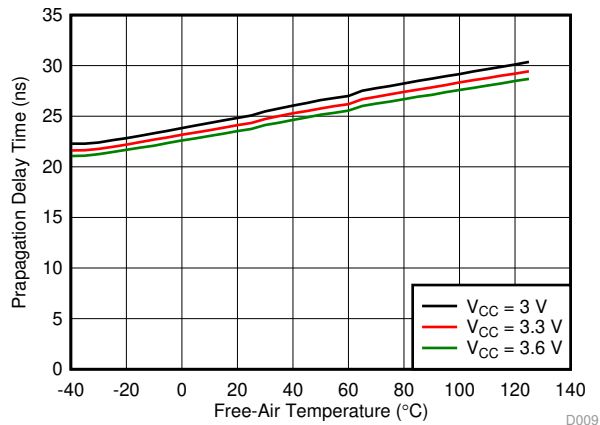


Figure 11. Driver High TXD Input to Driver Recessive Output Propagation Delay Time vs Free-Air Temperature

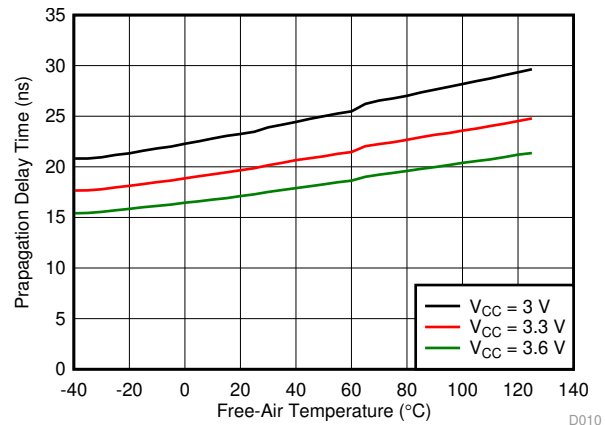


Figure 12. Driver Low TXD Input to Driver Dominant Output Propagation Delay Time vs Free-Air Temperature

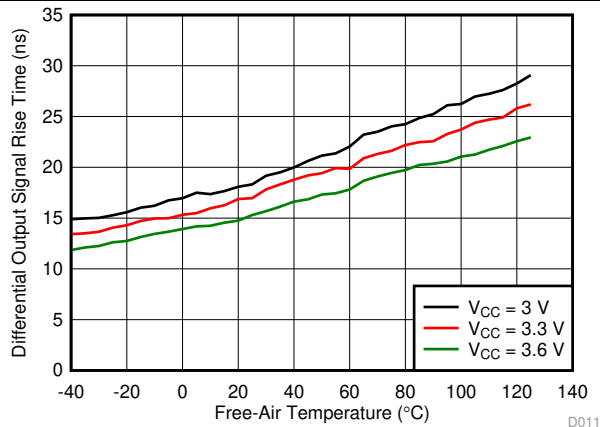


Figure 13. Differential Output Signal Rise Time vs Free-Air Temperature

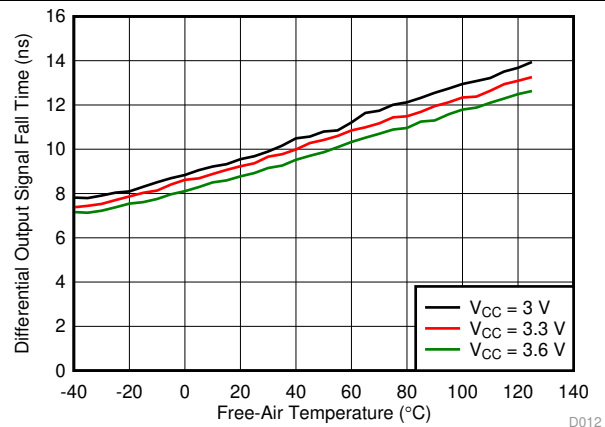


Figure 14. Differential Output Signal Fall Time vs Free-Air Temperature

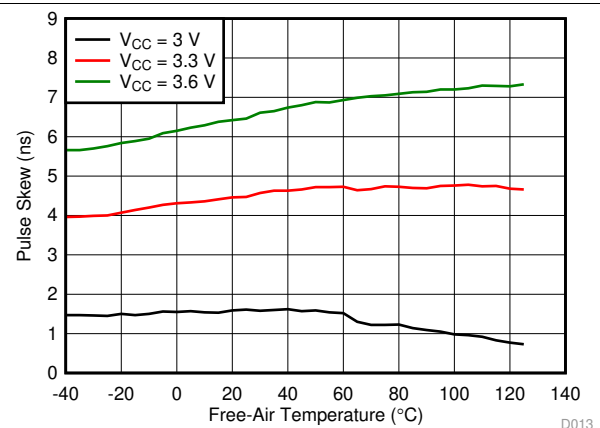


Figure 15. Pulse Skew ($t_{PHR} - t_{PLD}$) vs Free-Air Temperature

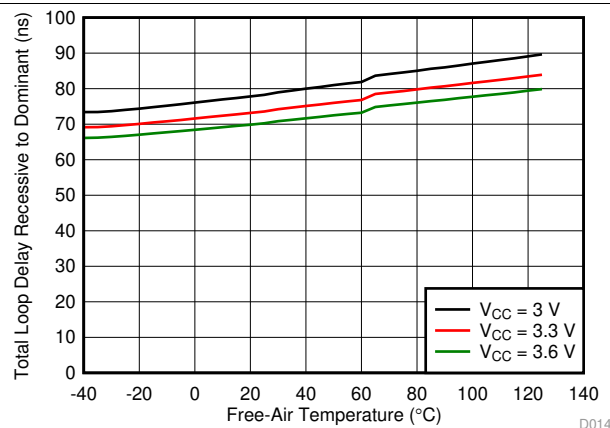


Figure 16. Total Loop Delay Recessive to Dominant $t_{PROP(LOOP1)}$ vs Free-Air Temperature

Typical Characteristics, TCAN330 Driver (continued)

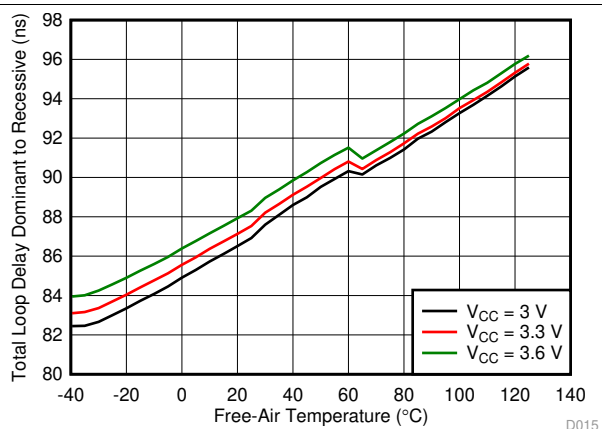


Figure 17. Total Loop Delay Dominant to Recessive $t_{PROP(LOOP2)}$ vs Free-Air Temperature

9 Parameter Measurement Information

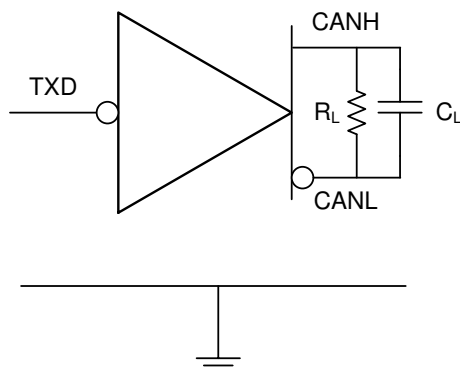


Figure 18. Supply Test Circuit

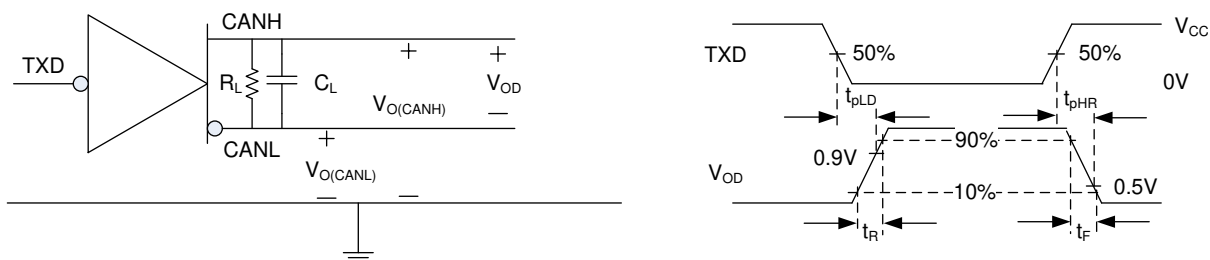


Figure 19. Driver Test Circuit and Measurement

Parameter Measurement Information (continued)

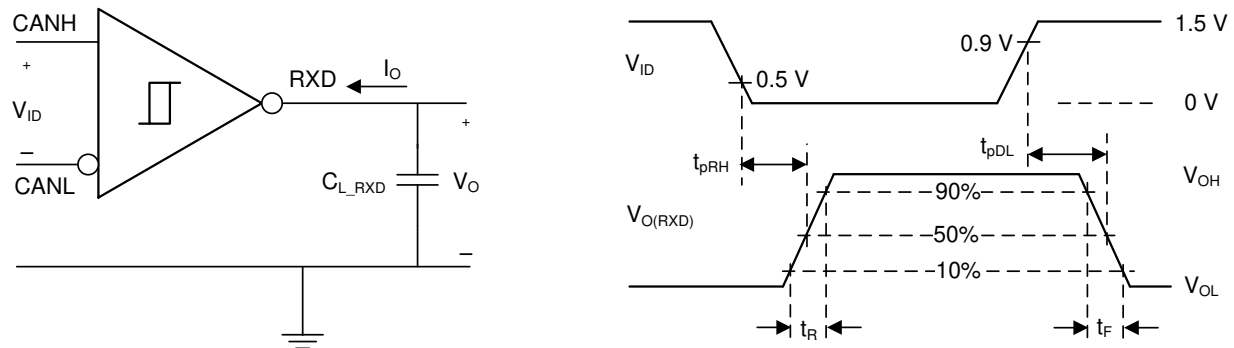


Figure 20. Receiver Test Circuit and Measurement

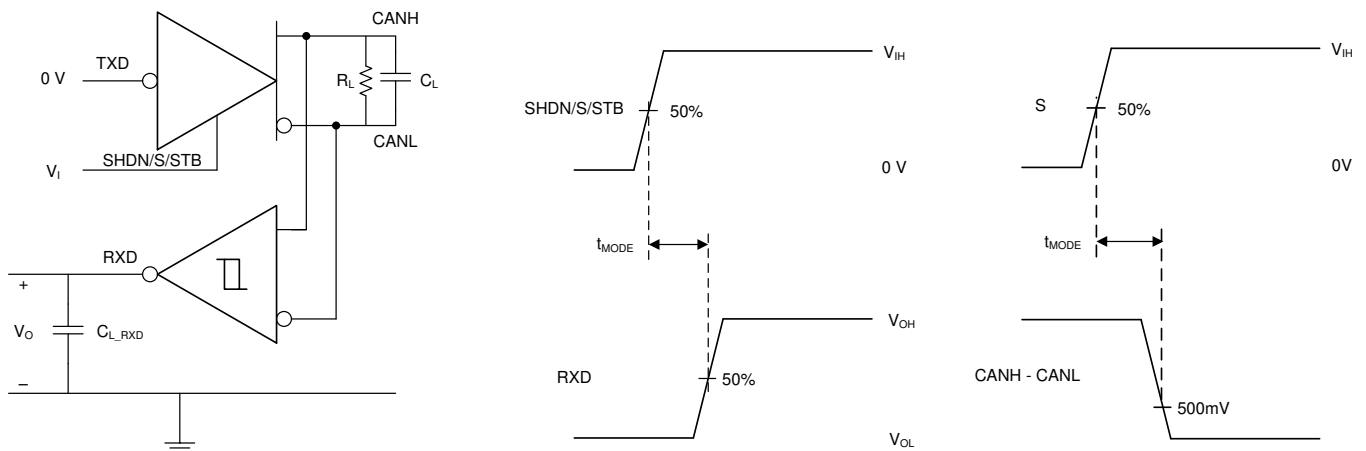


Figure 21. t_{MODE} Test Circuit and Measurement, from Normal to Shutdown, Standby or Silent Mode

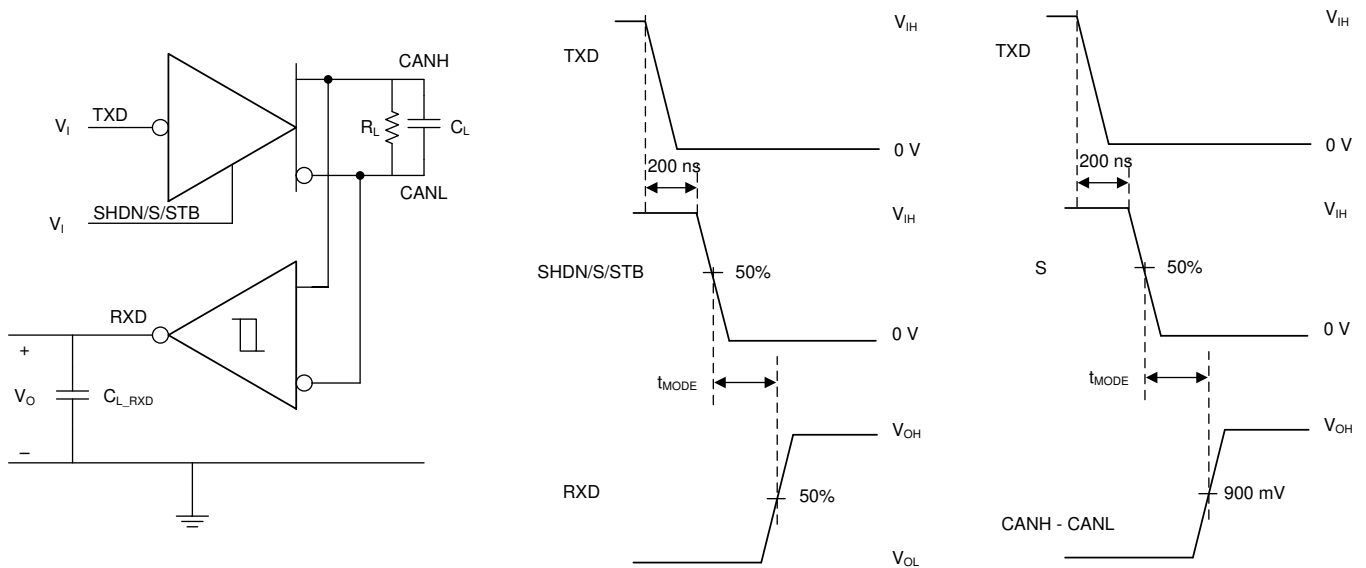


Figure 22. t_{MODE} Test Circuit and Measurement, from Shutdown, Standby or Silent to Normal Mode

Parameter Measurement Information (continued)

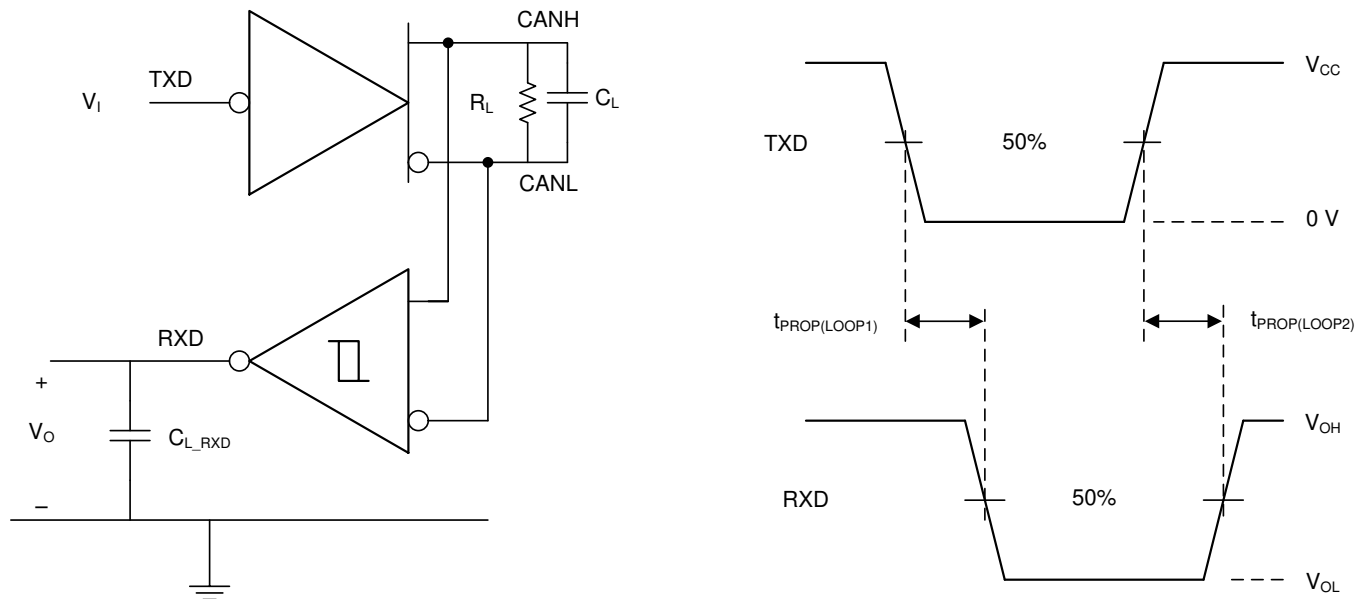


Figure 23. $t_{\text{PROP(LOOP)}}$ Test Circuit and Measurement

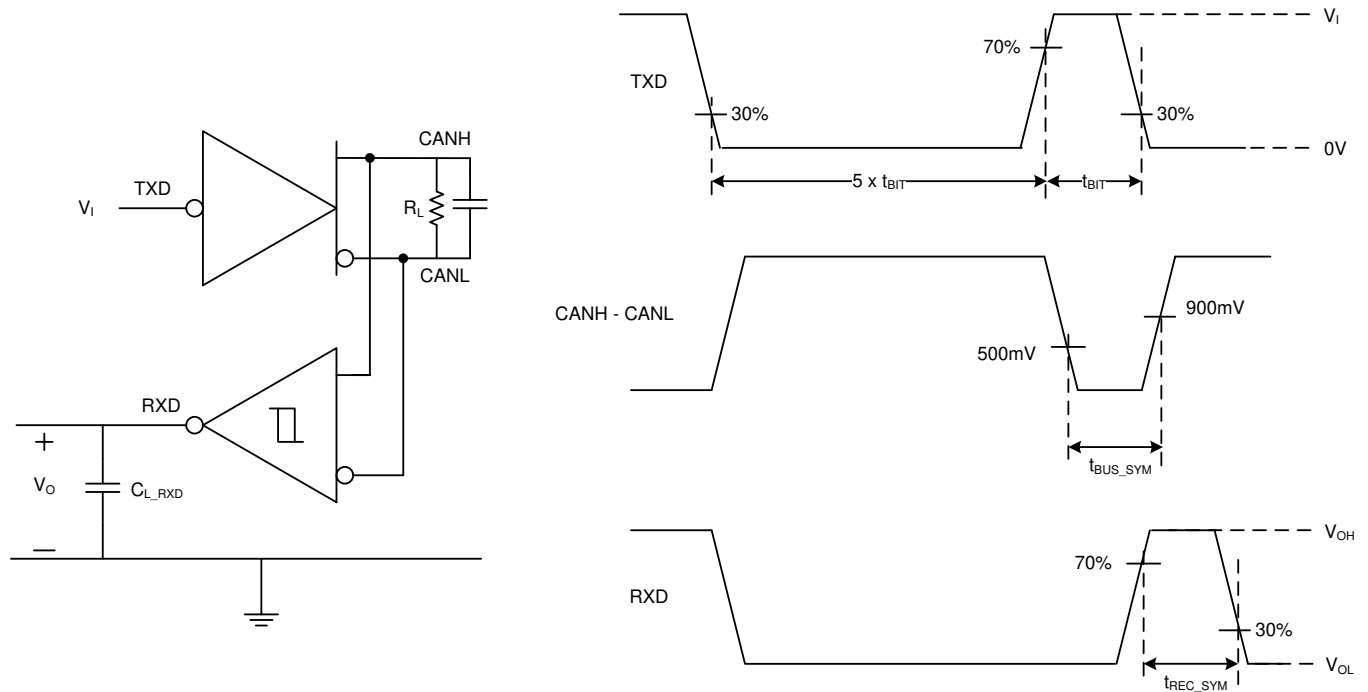


Figure 24. Loop Delay Symmetry Test Circuit and Measurement

Parameter Measurement Information (continued)

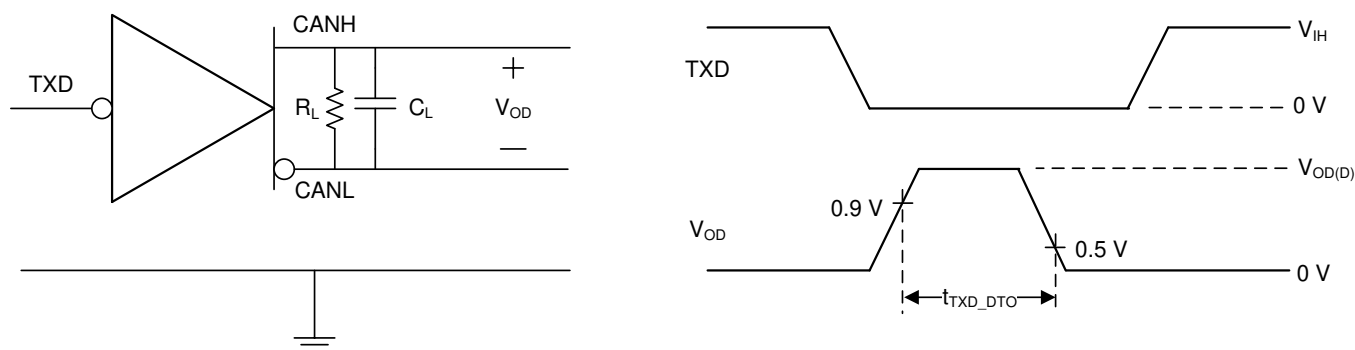


Figure 25. TXD Dominant Time Out Test Circuit and Measurement

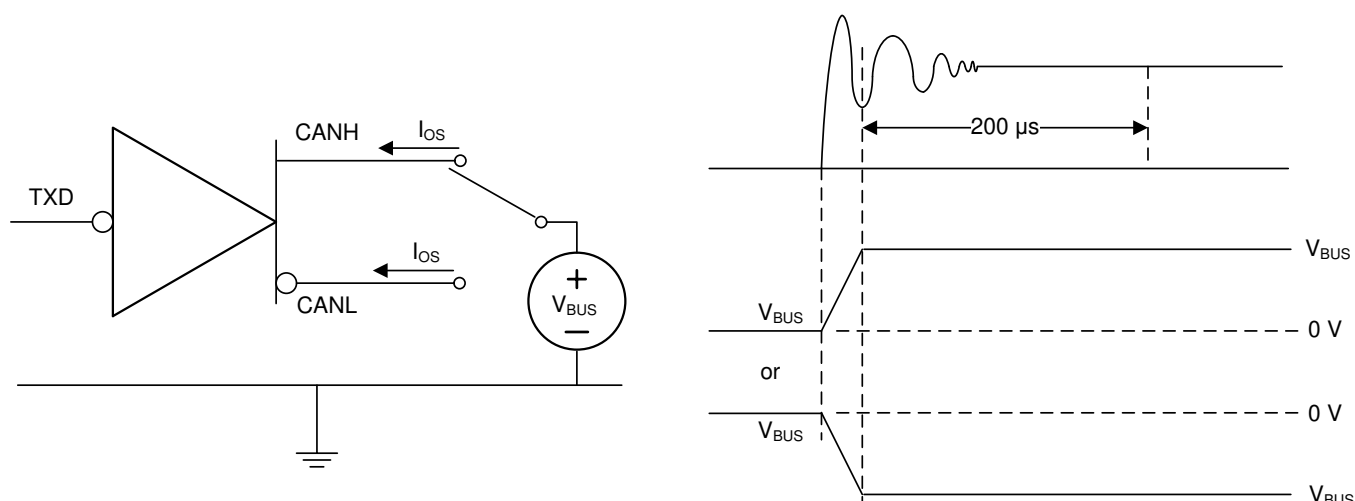


Figure 26. Driver Short-Circuit Current Test and Measurement

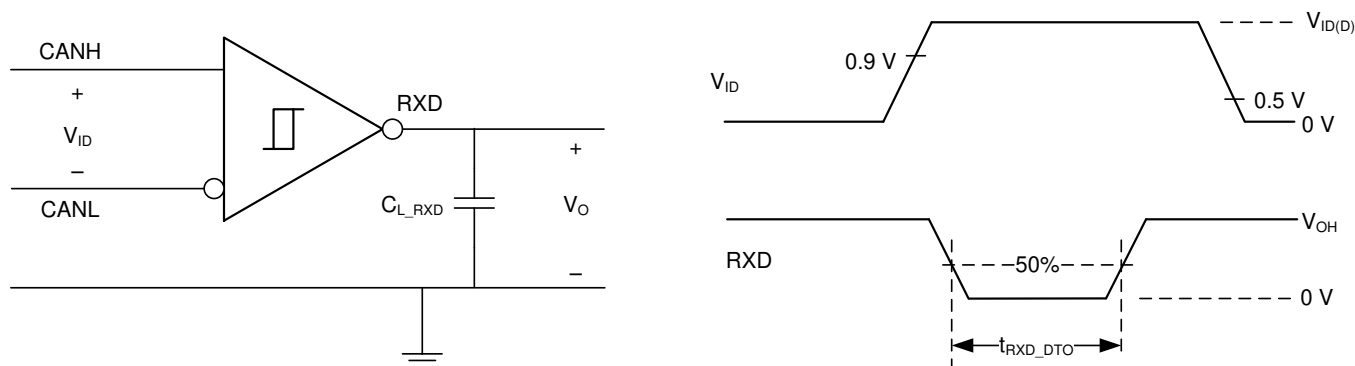


Figure 27. RXD Dominant Timeout Test Circuit and Measurement

Parameter Measurement Information (continued)

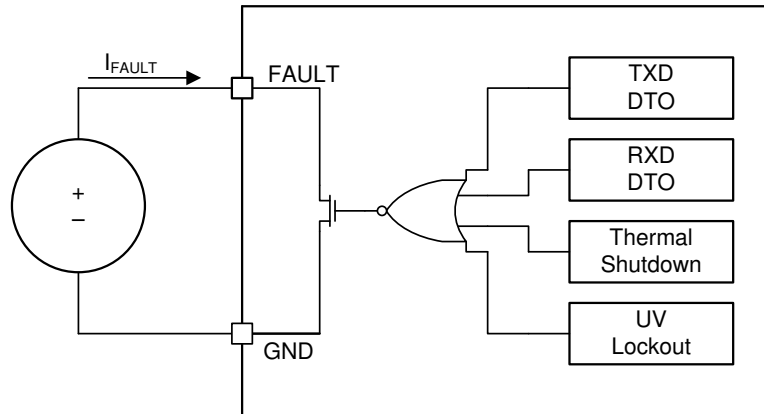


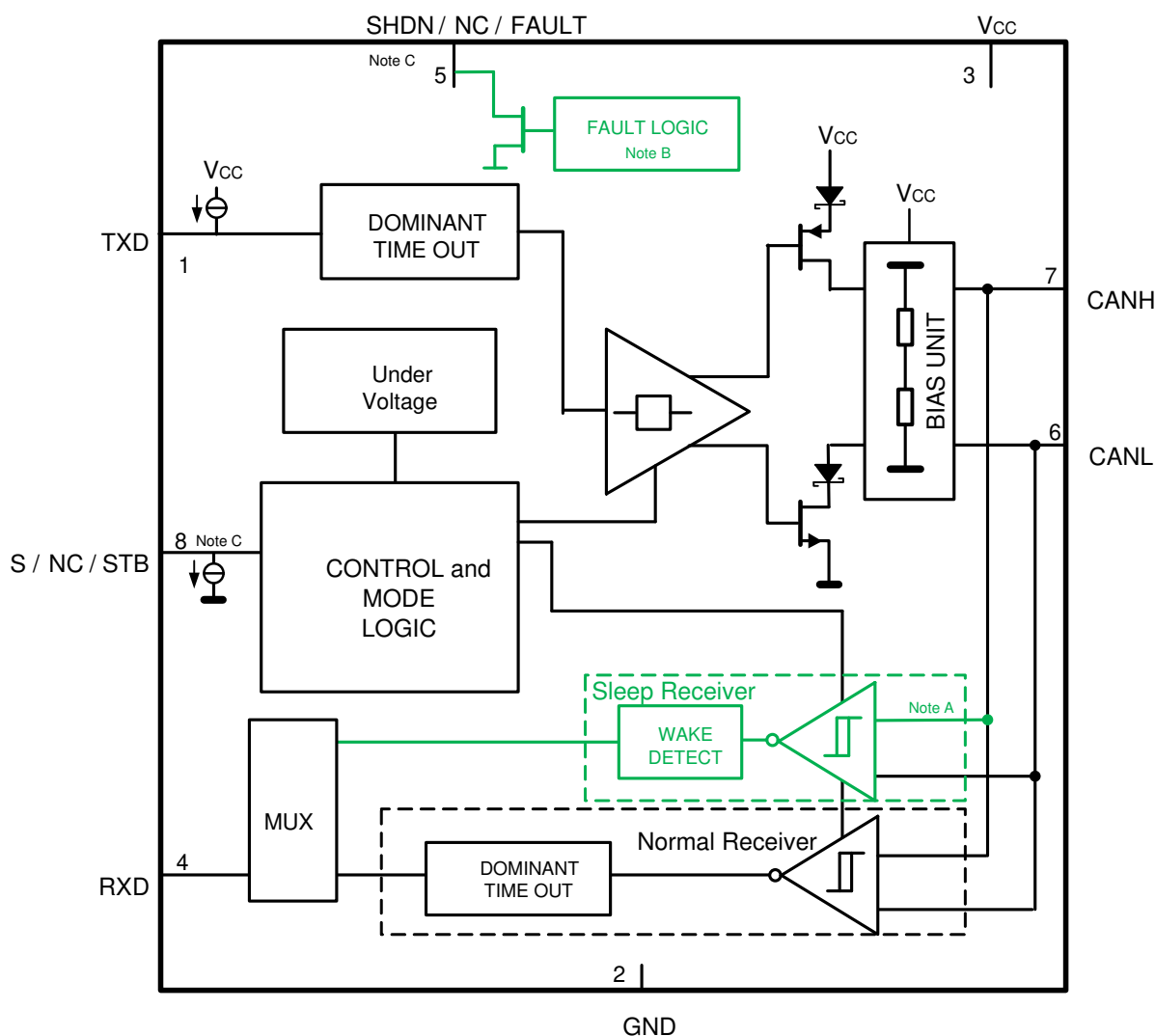
Figure 28. FAULT Test and Measurement

10 Detailed Description

10.1 Overview

This family of CAN transceivers is compatible with the ISO11898-2 High-Speed CAN (controller area network) physical layer standard. They are designed to interface between the differential bus lines in CAN and the CAN protocol controller.

10.2 Functional Block Diagram



Copyright © 2016, Texas Instruments Incorporated

- A. Sleep Receiver and Wake Detect are device dependent options and are only available in TCAND334.
- B. Fault Logic is only available in TCAND337.
- C. Pin 5 and 8 functions are device dependent. Refer to *Device Options*.

10.3 Feature Description

10.3.1 TXD Dominant Timeout (TXD DTO)

During normal mode (the only mode where the CAN driver is active), the TXD DTO circuit prevents the transceiver from blocking network communication in the event of a hardware or software failure where TXD is held dominant longer than the timeout period t_{TXD_DTO} . The DTO circuit timer starts on a falling edge on TXD. The DTO circuit disables the CAN bus driver if no rising edge is seen before the timeout period expires. This frees the bus for communication between other nodes on the network. The CAN driver is re-activated when a recessive signal is seen on TXD pin, thus clearing the TXD DTO condition. The receiver and RXD pin still reflect the CAN bus, and the bus pins are biased to recessive level during a TXD dominant timeout.

10.3.2 RXD Dominant Timeout (RXD DTO)

All devices have a RXD DTO circuit that prevents a bus stuck dominant fault from permanently driving the RXD output dominant (low) when the bus is held dominant longer than the timeout period t_{RXD_DTO} . The RXD DTO timer starts on a falling edge on RXD (bus going dominant). If no rising edge (bus returning recessive) is seen before the timeout constant of the circuit expires (t_{RXD_DTO}), the RXD pin returns high (recessive). The RXD output is re-activated to mirror the bus receiver output when a recessive signal is seen on the bus, clearing the RXD dominant timeout. The CAN bus pins are biased to the recessive level during a RXD DTO.

10.3.3 Thermal Shutdown

If the junction temperature of the device exceeds the thermal shutdown threshold, the device turns off the CAN driver circuits thus blocking the TXD-to-bus transmission path. The shutdown condition is cleared when the junction temperature of the device drops below the thermal shutdown temperature of the device. If the fault condition that caused the thermal shutdown is still present, the temperature may rise again and the device will enter thermal shut down again. Prolonged operation with thermal shutdown conditions may affect device reliability. The thermal shutdown circuit includes hysteresis to avoid oscillation of the driver output.

During thermal shutdown the CAN bus drivers are turned off, thus no transmission is possible from TXD to the bus. The CAN bus pins are biased to recessive level during a thermal shutdown and the receiver to RXD path remains operational.

10.3.4 Undervoltage Lockout and Unpowered Device

The V_{CC} supply terminal has under voltage detection which will place the device in protected mode if the supply drops below the UVLO threshold. This protects the bus during an under voltage event on V_{CC} by placing the bus into a high impedance biased to ground state and the RXD terminal into a tri-stated (high impedance) state. During undervoltage the device does not pass any signals from the bus. If the device is in normal mode and V_{CC} supply is lost the device will transition to a protected mode.

The device is designed to be an "ideal passive" or "no load" to the CAN bus if the device is unpowered. The bus terminals (CANH, CANL) have low leakage currents when the device is unpowered, so the device does not load the bus. This is critical if some nodes of the network are unpowered while the rest of the of network remains operational. Logic pins also have low leakage currents when the device is unpowered, so the device does not load other circuits which may remain powered.

Table 1. Undervoltage Protection 3.3-V Single Supply Devices

V_{CC}	DEVICE STATE	BUS	RXD
GOOD	Operational	Per Operating Mode	Per Operating Mode
BAD	Protected	Common mode bias to GND	High Impedance
UNPOWERED	Unpowered	High Impedance (no load)	High Impedance

10.3.5 Fault Pin (TCAN337)

If one or more of the faults (TXD-Dominant Timeout, RXD dominant Timeout, Thermal Shutdown or Undervoltage Lockout) occurs, the FAULT pin (open-drain) turns off, resulting in a high level when externally pulled up to V_{CC} supply.

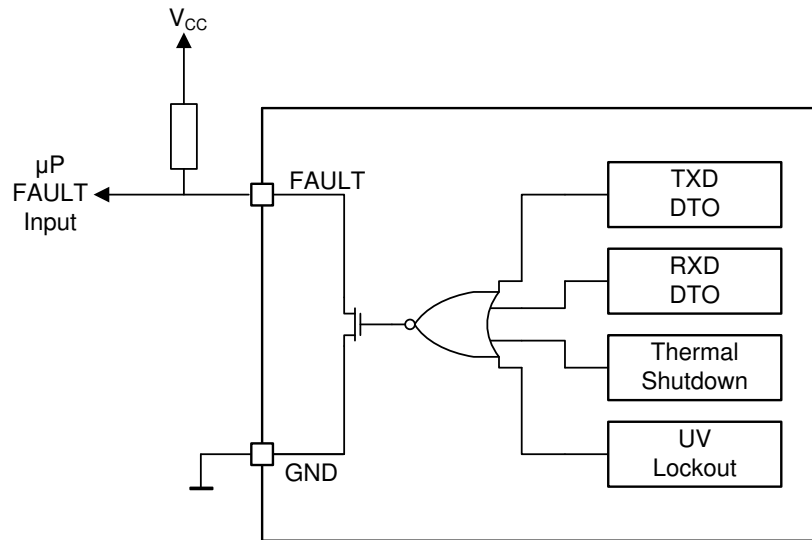


Figure 29. FAULT Pin Function Diagram and Application

10.3.6 Floating Pins

The device has internal pull ups and pull downs on critical terminals to place the device into known states if the pin floats. See [Table 1](#) for details on pin bias conditions.

Table 2. Pin Bias

PIN	PULL UP or PULL DOWN	COMMENT
TXD	Pull up	Weakly biases TXD toward recessive to prevent bus blockage or TXD DTO triggering.
STB	Pull down	Weakly biases STB terminal towards normal mode.
S	Pull down	Weakly biases S terminal towards normal mode.
SHDN	Pull down	Weakly biases SHDN terminal towards normal mode.

The internal bias should not be relied on by design, especially in noisy environments, but should be considered a fall back protection. Special care needs to be taken when the device is used with MCUs using open drain outputs. TXD is weakly internally pulled up. The TXD pull up strength and CAN bit timing require special consideration when this device is used with an open drain TXD output on the microprocessor's CAN controller. An adequate external pull up resistor must be used to ensure that the TXD output of the microprocessor maintains adequate bit timing input to the CAN transceiver.

10.3.7 CAN Bus Short Circuit Current Limiting

The device has several protection features that limit the short circuit current when a CAN bus line is shorted. These include CAN driver current limiting (dominant and recessive). The device has TXD dominant time out which prevents permanently having the higher short circuit current of dominant state in case of a system fault. During CAN communication the bus switches between dominant and recessive states, thus the short circuit current may be viewed either as the current during each bus state or as a DC average current. For system current and power considerations in the termination resistors and common mode choke ratings the average short circuit current should be used. The percentage dominant is limited by the TXD dominant time out and CAN protocol which has forced state changes and recessive bits such as bit stuffing, control fields, and interframe space. These ensure there is a minimum recessive amount of time on the bus even if the data field contains a high percentage of dominant bits.

The short circuit current of the bus depends on the ratio of recessive to dominant bits and their respective short circuit currents. The average short circuit current may be calculated with the following formula:

$$I_{OS(AVG)} = \%Transmit \times [(\%REC_Bits \times I_{OS(SS_REC)}) + (\%DOM_Bits \times I_{OS(SS_DOM)})] + [\%Receive \times I_{OS(SS_REC)}] \quad (1)$$

Where:

- $I_{OS(AVG)}$ is the average short circuit current
- $\%Transmit$ is the percentage the node is transmitting CAN messages
- $\%Receive$ is the percentage the node is receiving CAN messages
- $\%REC_Bits$ is the percentage of recessive bits in the transmitted CAN messages
- $\%DOM_Bits$ is the percentage of dominant bits in the transmitted CAN messages
- $I_{OS(SS_REC)}$ is the recessive steady state short circuit current
- $I_{OS(SS_DOM)}$ is the dominant steady state short circuit current

The short circuit current and possible fault cases of the network should be taken into consideration when sizing the power ratings of the termination resistance and other network components.

10.3.8 ESD Protection

The bus pins of the TCAN33x family possess on-chip ESD protection against ± 25 -kV human body model (HBM) and ± 12 -kV IEC61000-4-2 contact discharge. The IEC-ESD test is far more severe than the HBM-ESD test. The 50% higher charge capacitance, C_S , and 78% lower discharge resistance, R_D of the IEC model produce significantly higher discharge currents than the HBM-model.

As stated in the IEC 61000-4-2 standard, contact discharge is the preferred test method; although IEC air-gap testing is less repeatable than contact testing, air discharge protection levels are inferred from the contact discharge test results.

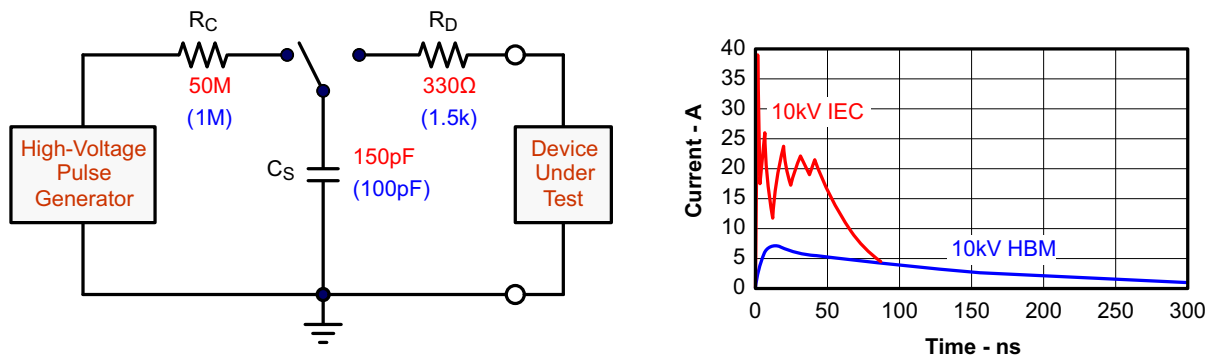


Figure 30. HBM and IEC-ESD Models and Currents in Comparison (HBM Values in Parenthesis)

10.3.9 Digital Inputs and Outputs

All the devices in this family are single 3.3-V nominal supply devices. The digital logic input and output levels for these devices have TTL threshold levels.

10.4 Device Functional Modes

10.4.1 CAN Bus States

The CAN bus has two logical states during operation: recessive and dominant. See [Figure 31](#) and [Figure 32](#).

Recessive bus state is when the high resistive internal input resistors of each node's receiver bias the bus to a common mode of about 1.85 V across the bus termination resistors. Recessive is equivalent to logic high and is typically a differential voltage on the bus of about 0 V. Recessive state is also the idle state.

Dominant bus state is when the bus is driven differentially by one or more drivers. Current is induced to flow through the termination resistors and generate a differential voltage on the bus. Dominant is equivalent to logic low and is a differential voltage on the bus greater than the minimum threshold for a CAN dominant. A dominant state overwrites the recessive state.

During arbitration, multiple CAN nodes may transmit a dominant bit at the same time. In this case the differential voltage of the bus will be greater than the differential voltage of a single driver.

The host microprocessor of the CAN node will use the TXD terminal to drive the bus and will receive data from the bus on the RXD pin.

Transceivers with low power Standby Mode have a third bus state where the bus terminals are weakly biased to ground via the high resistance internal resistors of the receiver. See [Figure 31](#) and [Figure 32](#).

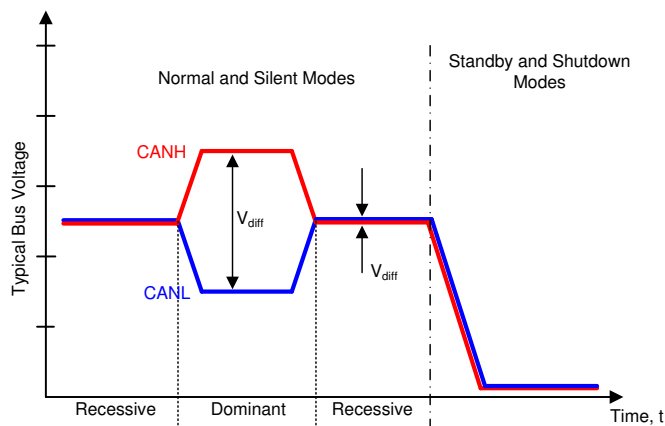


Figure 31. Bus States (Physical Bit Representation)

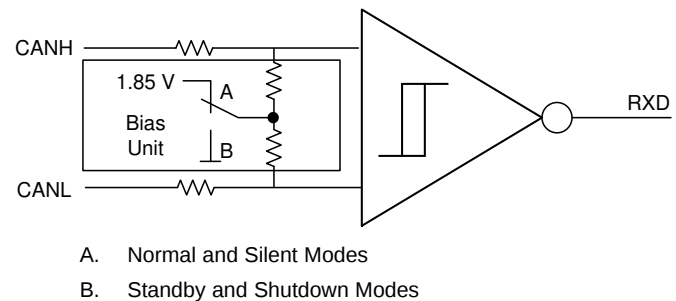


Figure 32. Simplified Recessive Common Mode Bias Unit and Receiver

The devices have four main operating modes:

1. Normal mode (all devices)
2. Silent mode (TCAN330, TCAN337)
3. Standby mode with wake (TCAN334)
4. Shutdown mode (TCAN330, TCAN334)

Table 3. CAN Transceivers with Silent Mode

S	Device MODE	DRIVER	RECEIVER	RXD PIN
HIGH	Reduced Power Silent (Listen) Mode	Disabled (OFF) ⁽¹⁾	Enabled (ON)	Mirrors Bus State ⁽²⁾
LOW/NC	Normal Mode	Enabled (ON)	Enabled (ON)	

(1) See [Figure 31](#) for bus state.

(2) Mirrors bus state: low if CAN bus is dominant, high if CAN bus is recessive.

Table 4. CAN Transceivers with Standby Mode with Wake

STB	Device MODE	DRIVER	RECEIVER	RXD Terminal
HIGH	Ultra Low Current Standby Mode	Disabled (OFF) ⁽¹⁾	Low Power Receiver and Bus Monitor Enabled (ON)	High (Recessive) until WUP, then filtered mirrors of Bus State ⁽²⁾
LOW/NC	Normal Mode	Enabled (ON)	Enabled (ON)	Mirrors Bus State ⁽³⁾

(1) See [Figure 31](#) for bus state.

(2) Standby Mode RXD behavior: See [Figure 33](#).

(3) Mirrors bus state: low if CAN bus is dominant, high if CAN bus is recessive.

Table 5. CAN Transceivers with Shutdown Mode

SHDN	Device MODE	DRIVER	RECEIVER	RXD Terminal
HIGH	Lowest Current	Disabled (OFF) ⁽¹⁾	Disabled (OFF)	High (Recessive)
LOW/NC	Normal Mode	Enabled (ON)	Enabled (ON)	Mirrors Bus State ⁽²⁾

(1) See [Figure 31](#) for bus state.

(2) Mirrors bus state: low if CAN bus is dominant, high if CAN bus is recessive.

10.4.2 Normal Mode

This is the normal operating mode of the device. The CAN driver and receiver are fully operational and CAN communication is bi-directional. The driver is translating a digital input on TXD to a differential output on CANH and CANL. The receiver is translating the differential signal from CANH and CANL to a digital output on RXD.

10.4.3 Silent Mode

This is the silent or receive only mode of the device. The CAN driver is disabled but the receiver is fully operational. CAN communication is unidirectional and only flows from the CAN bus through the receive path of the transceiver to the CAN protocol controller via the RXD output pin. The receiver is translating the differential signal from CANH and CANL to a digital output on RXD.

10.4.4 Standby Mode with Wake

This is the low power mode of the device. The CAN driver and main receiver are turned off and bi-directional CAN communication is not possible. The low power receiver and bus monitor are enabled to allow for RXD Wake Requests via the CAN bus. A wake up request will be output to RXD (driven low) as shown in [Figure 33](#). The local CAN protocol microprocessor should monitor RXD for transitions (high to low) and reactivate the device to normal mode based on the RXD Wake Request. The CAN bus pins are weakly pulled to GND during this mode, see [Figure 32](#).

10.4.5 Bus Wake via RXD Request (BWRR) in Standby Mode

The TCAN334 with low power standby mode, offers a wake up from the CAN bus mechanism called bus wake via RXD Request (BWRR) to indicate to a host microprocessor that the bus is active and it should wake up and return to normal CAN communication.

This device uses the multiple filtered dominant wake-up pattern (WUP) from ISO11898-5 to qualify bus traffic into a request to wake the host microprocessor. The bus wake request is signaled to the microprocessor by a falling edge and low corresponding to a “filtered” bus dominant on the RXD terminal (BWRR).

The wake up pattern (WUP) consists of a filtered dominant bus, then a filtered recessive bus time followed by a second filtered bus time. Once the WUP is detected the device will start issuing wake up requests (BWRR) on the RXD terminal every time a filtered dominant time is received from the bus. The first filtered dominant initiates the WUP and the bus monitor waits on a filtered recessive; other bus traffic does not reset the bus monitor. Once a filtered recessive is received, the bus monitor waits on a filtered dominant and again; other bus traffic does not reset the bus monitor. Immediately upon receiving of the second filtered dominant, the bus monitor recognizes the WUP and transitions to BWRR mode. In this mode, RXD is driven low for all dominant bits lasting for longer than t_{WK_FILTER} . The RXD output during BWRR matches the classical 8-pin CAN devices, such as the TCANA1040A-Q1 device, that used the single filtered dominant on the bus as the wake up request mechanism from ISO11898-5.

For a dominant or recessive to be considered *filtered*, the bus must be in that state for more than t_{WK_FILTER} time. Due to variability in the t_{WK_FILTER} the following scenarios are applicable. Bus state times less than $t_{WK_FILTER(MIN)}$ are never detected as part of a WUP and thus no BWRR is generated. Bus state times between $t_{WK_FILTER(MIN)}$ and $t_{WK_FILTER(MAX)}$ may be detected as part of a WUP and a BWRR may be generated. Bus state times more than $t_{WK_FILTER(MAX)}$ are always detected as part of a WUP and thus a BWRR is always generated.

See Figure 33 for the timing diagram of the WUP. The pattern, t_{WK_FILTER} time used for the WUP and BWRR prevent noise and bus stuck dominant faults from causing false wake requests. If the device is switched to normal mode, or an under voltage event occurs on V_{CC} the BWRR will be lost.

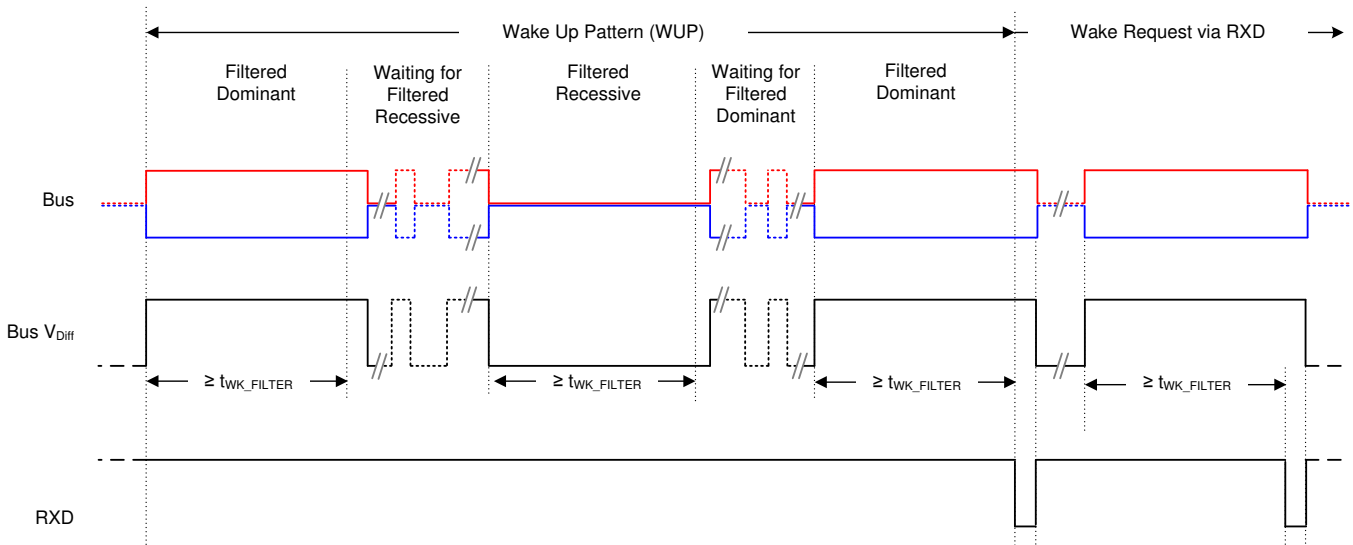


Figure 33. Wake Up Pattern (WUP) and Bus Wake via RXD Request (BWRR)

10.4.6 Shutdown Mode

This is the lowest power mode of all of the devices. The CAN driver and receiver are turned off and bi-directional CAN communication is not possible. It is not possible to receive a remote wake request via the CAN bus in this mode. The CAN bus pins are pulled to GND during this mode as shown in Figure 31.

10.4.7 Driver and Receiver Function Tables

Table 6. Driver Function Table

DEVICE MODE	TXD ⁽¹⁾ INPUT	BUS OUTPUTS ⁽²⁾		DRIVEN BUS STATE ⁽³⁾
		CANH	CANL	
Normal	L	H	L	Dominant
	H or Open	Z	Z	Biased Recessive
Silent	X	Z	Z	Biased Recessive
Standby	X	Z	Z	Weak Pull to GND
Shutdown	X	Z	Z	Weak Pull to GND

(1) H = high level, L = low level, X = irrelevant.

(2) H = high level, L = low level, Z = high Z receiver bias.

(3) For Bus state and bias see [Figure 31](#) and [Figure 32](#).

Table 7. Receiver Function Table Normal and Standby Modes

DEVICE MODE	CAN DIFFERENTIAL INPUTS $V_{(ID)} = V_{(CANH)} - V_{(CANL)}$	BUS STATE	RXD PIN ⁽¹⁾
Normal or Silent	$V_{(ID)} \geq 0.9 \text{ V}$	Dominant	L
	$0.5 \text{ V} < V_{(ID)} < 0.9 \text{ V}$	?	?
	$V_{(ID)} \leq 0.5 \text{ V}$	Recessive	H
Standby	$V_{(ID)} \geq 1.15 \text{ V}$	Dominant	See Figure 33
	$0.4 \text{ V} < V_{(ID)} < 1.15 \text{ V}$	?	
	$V_{(ID)} \leq 0.4 \text{ V}$	Recessive	
Shutdown	Any	Recessive	H
Any	Open ($V_{(ID)} \approx 0 \text{ V}$)	Open	H

(1) I = high level, L = low level, ? = indeterminate.

11 Application and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

11.1 Application Information

11.1.1 Bus Loading, Length and Number of Nodes

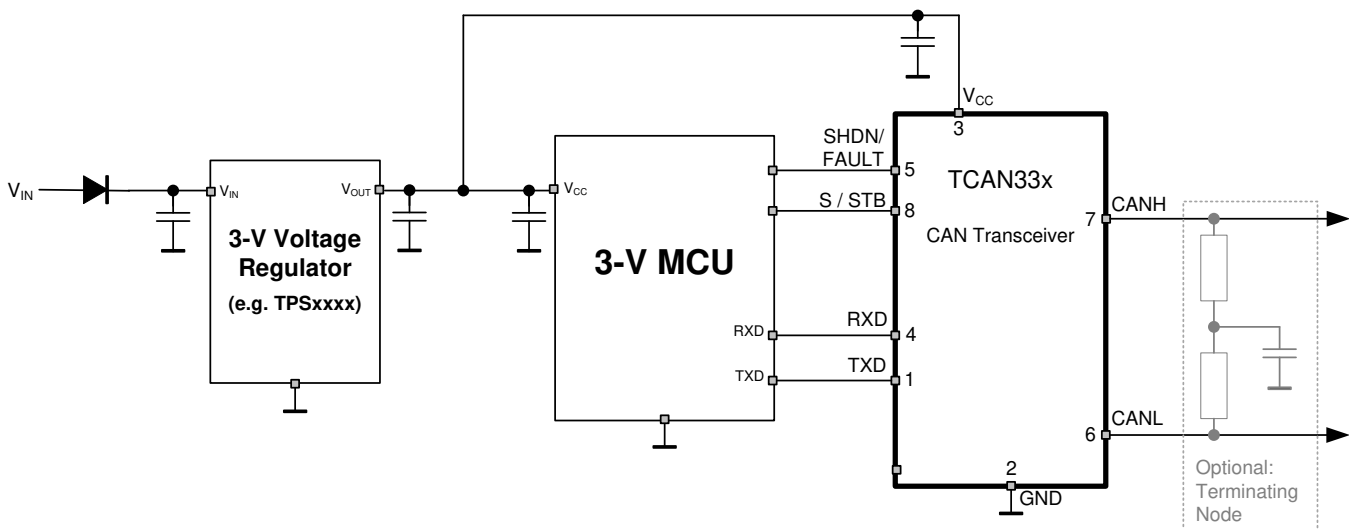
The ISO 11898 standard specifies a data rate up to 1 Mbps, maximum CAN bus cable length of 40 m, maximum drop line (stub) length of 0.3 m and a maximum of 30 nodes. However, with careful network design, the system may have longer cables, longer stub lengths, and many more nodes to a bus. Many CAN organizations and standards have scaled the use of CAN for applications outside the original ISO 11898 standard. They have made system level trade-offs for data rate, cable length, and parasitic loading of the bus. Examples of some of these specifications are ARINC825, CANopen, CAN Kingdom, DeviceNet and NMEA200.

A high number of nodes requires a transceiver with high input impedance and wide common mode range such as the TCAN33x CAN family. ISO 11898-2 specifies the driver differential output with a 60-Ω load (two 120-Ω termination resistors in parallel) and the differential output must be greater than 1.5 V. The TCAN33x devices are specified to meet the 1.5-V requirement with a 50-Ω load across a common mode range of –12 V to 12 V through a 330-Ω coupling network. This network represents the bus loading of 120 TCAN33x transceivers based on their minimum differential input resistance of 40 kΩ.

For CAN network design, margin must be given for signal loss across the system and cabling, parasitic loadings, network imbalances, ground offsets and signal integrity, thus a practical maximum number of nodes may be lower. Bus length may also be extended beyond the original ISO 11898 standard of 40 m by careful system design and data rate tradeoffs. For example, CANopen network design guidelines allow the network to be up to 1 km with changes in the termination resistance, cabling, number of nodes and data rate.

This flexibility in CAN network design is one of the key strengths of the various extensions and additional standards that have been built on the original ISO 11898 CAN standard.

11.2 Typical Application



Copyright © 2016, Texas Instruments Incorporated

Figure 34. Typical 3.3-V Application

Typical Application (continued)

11.2.1 Design Requirements

11.2.1.1 CAN Termination

The ISO 11898 standard specifies the interconnect to be a twisted-pair cable (shielded or unshielded) with 120-Ω characteristic impedance (Z_0). Resistors equal to the characteristic impedance of the line should be used to terminate both ends of the cable to prevent signal reflections. Unterminated drop lines (stubs) connecting nodes to the bus should be kept as short as possible to minimize signal reflections. The termination may be on the cable or in a node, but if nodes may be removed from the bus the termination must be carefully placed so that it is not removed from the bus.

11.2.2 Detailed Design Procedure

Termination is typically a 120-Ω resistor at each end of the bus. If filtering and stabilization of the common mode voltage of the bus is desired, then split termination may be used (see Figure 8). Split termination uses two 60-Ω resistors with a capacitor in the middle of these resistors to ground. Split termination improves the electromagnetic emissions behavior of the network by eliminating fluctuations in the bus common mode voltages at the start and end of message transmissions.

Care should be taken in the power ratings of the termination resistors used. Typically the worst case condition would be if the system power supply was shorted across the termination resistance to ground. In most cases the current flow through the resistor in this condition would be much higher than the transceiver's current limit.

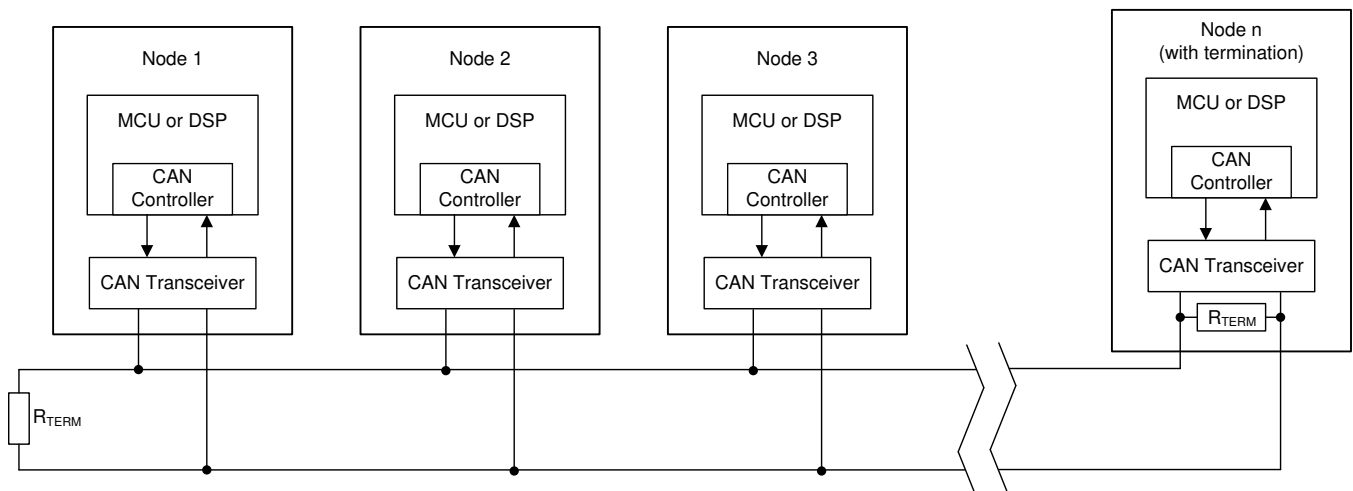


Figure 35. Typical CAN Bus

Typical Application (continued)

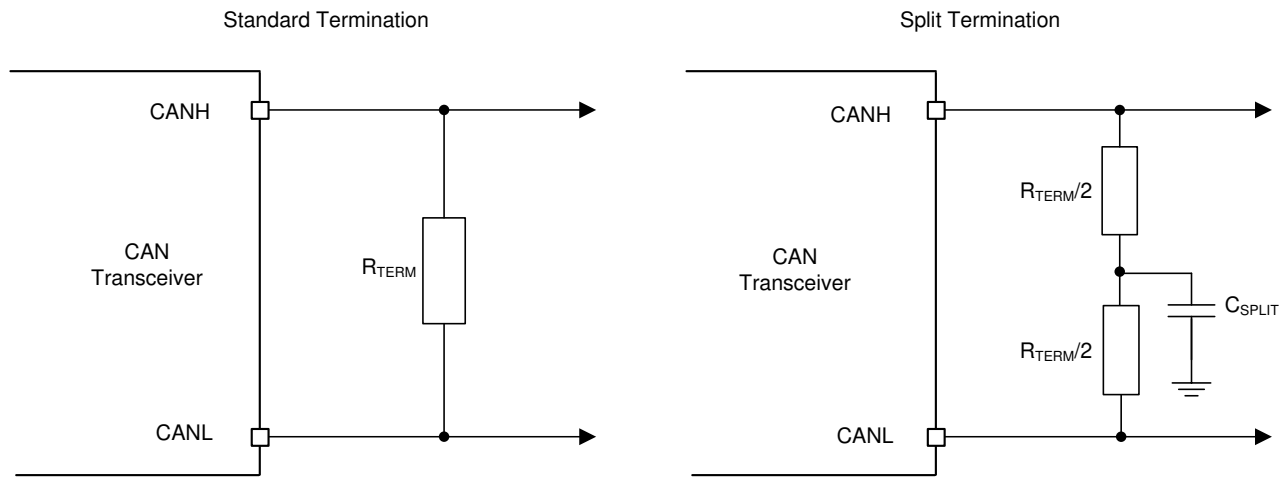
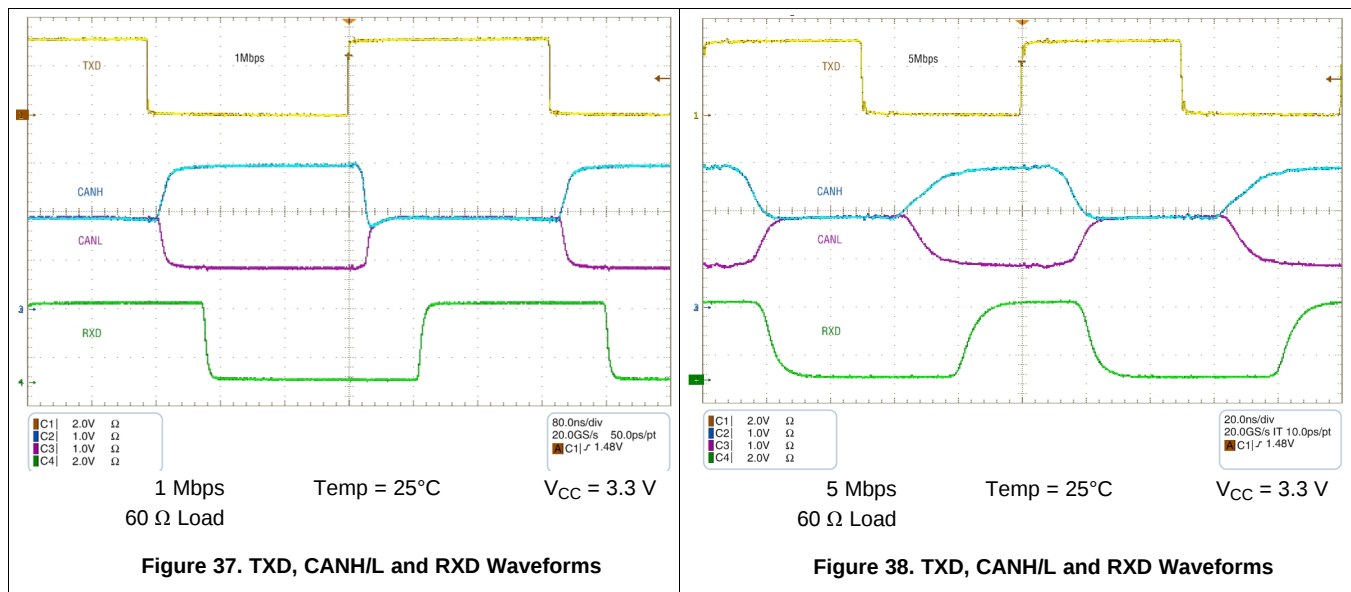


Figure 36. CAN Bus Termination Concepts

11.2.3 Application Curves



11.3 System Examples

11.3.1 ISO11898 Compliance of TCAN33x Family of 3.3-V CAN Transceivers Introduction

Many users value the low power consumption of operating their CAN transceivers from a 3.3-V supply. However, some are concerned about the interoperability with 5 V supplied transceivers on the same bus. This report analyzes this situation to address those concerns.

System Examples (continued)

11.3.2 Differential Signal

CAN is a differential bus where complementary signals are sent over two wires and the voltage difference between the two wires defines the logical state of the bus. The differential CAN receiver monitors this voltage difference and outputs the bus state with a single ended logic level output signal.

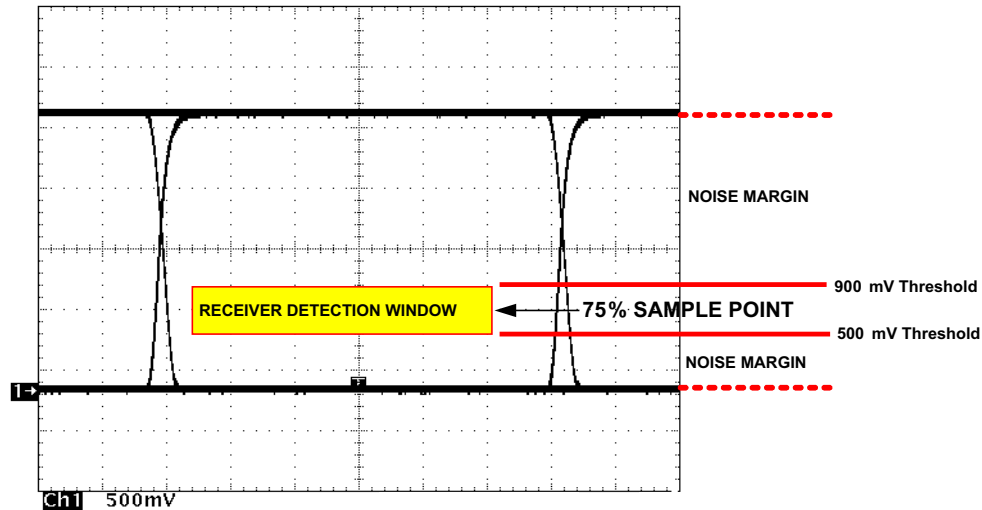


Figure 39. Typical Differential Output Waveform

The CAN driver creates the differential voltage between CANH and CANL in the dominant state. The dominant differential output of the TCAN33x is greater than 1.5 V and less than 3 V across a 60-Ω load as defined by the ISO11898 standard. These are the same limiting values for 5 V supplied CAN transceivers. The bus termination resistors drive the recessive bus state and not the CAN driver.

A CAN receiver is required to output a recessive state when less than 500 mV of differential voltage exists on the bus, and a dominant state when more than 900 mV of differential voltage exists on the bus. The CAN receiver must do this with common-mode input voltages from –2 V to 7 V. The TCAN33x family receivers meet these same input specifications as 5 V supplied receivers.

11.3.3 Common-Mode Signal and EMC Performance

A common-mode signal is an average voltage of the two signal wires that the differential receiver rejects. The common-mode signal comes from the CAN driver, ground noise, and coupled bus noise. Since the bias voltage of the recessive state of the device is dependent on V_{CC} , any noise present or variation of V_{CC} has an effect on this bias voltage seen by the bus. The TCAN33x family has the recessive bias voltage set higher than $0.5 \times V_{CC}$ to match common mode in recessive mode to dominant mode. This results in superior EMC performance.

12 Power Supply Recommendations

To ensure reliable operation at all data rates and supply voltages, each supply should be decoupled with a 100-nF ceramic capacitor located as close to the V_{CC} supply pins as possible. The TPS76333 is a linear voltage regulator suitable for the 3.3 V supply.

13 Layout

13.1 Layout Guidelines

TCAN33x family of devices incorporates integrated IEC 61000-4-2 ESD protection. Should the system requires additional protection against ESD, EFT or surge, additional external protection and filtering circuitry may be needed.

In order for the PCB design to be successful, start with design of the protection and filtering circuitry. Because ESD and EFT transients have a wide frequency bandwidth from approximately 3 MHz to 3 GHz, high frequency layout techniques must be applied during PCB design.

Design the bus protection components in the direction of the signal path. Do not force the transient current to divert from the signal path to reach the protection device. Below is a list of layout recommendations when designing a CAN transceiver into an application.

- Transient Protection on CANH and CANL: Transient Voltage Suppression (TVS) and capacitors (D1, C5 and C7 shown in [Figure 40](#)) can be used for additional system level protection. These devices must be placed as close to the connector as possible. This prevents the transient energy and noise from penetrating into other nets on the board.
- Bus Termination on CANH and CANL: [Figure 40](#) shows split termination where the termination is split into two resistors, R5 and R6, with the center or split tap of the termination connected to ground through capacitor C6. Split termination provides common mode filtering for the bus. When termination is placed on the board instead of directly on the bus, care must be taken to ensure the terminating node is not removed from the bus, as this causes signal integrity issues if the bus is not properly terminated on both ends.
- Decoupling Capacitors on V_{CC} : Bypass and bulk capacitors must be placed as close as possible to the supply pins of transceiver (examples are C2 and C3).
- Ground and power connections: Use at least two vias for V_{CC} and ground connections of bypass capacitors and protection devices to minimize trace and via inductance.
- Digital inputs and outputs: To limit current of digital lines, serial resistors may be used. Examples are R1, R2, R3 and R4.
- Filtering noise on digital inputs and outputs: To filter noise on the digital I/O lines, a capacitor may be used close to the input side of the I/O as shown by C1, C8 and C4.
- Fault Output Pin (TCAN337 only): Because the FAULT output pin is an open drain output, an external pullup resistor is required to pull the pin voltage high for normal operation (R7).
- TXD input pin: If an open-drain host processor is used to drive the TXD pin of the device, an external pullup resistor between 1 k Ω and 10 k Ω must be used to help drive the recessive input state of the device (weak internal pullup resistor).

13.2 Layout Example

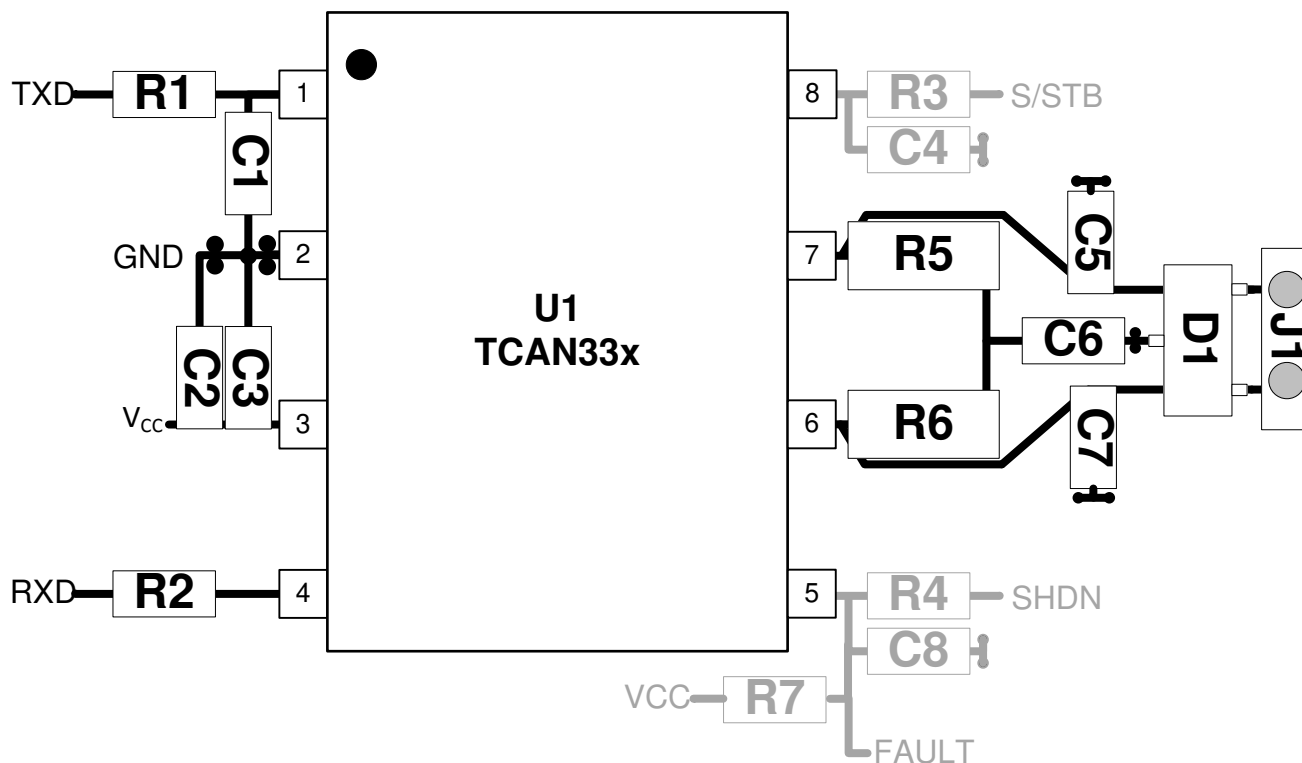


Figure 40. Layout Example

14 Device and Documentation Support

14.1 Related Links

The table below lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to sample or buy.

Table 8. Related Links

PARTS	PRODUCT FOLDER	SAMPLE & BUY	TECHNICAL DOCUMENTS	TOOLS & SOFTWARE	SUPPORT & COMMUNITY
TCAN330	Click here	Click here	Click here	Click here	Click here
TCAN332	Click here	Click here	Click here	Click here	Click here
TCAN334	Click here	Click here	Click here	Click here	Click here
TCAN337	Click here	Click here	Click here	Click here	Click here
TCAN330G	Click here	Click here	Click here	Click here	Click here
TCAN332G	Click here	Click here	Click here	Click here	Click here
TCAN334G	Click here	Click here	Click here	Click here	Click here
TCAN337G	Click here	Click here	Click here	Click here	Click here

14.2 Support Resources

TI E2E™ support forums are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

Linked content is provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's [Terms of Use](#).

14.3 Trademarks

E2E is a trademark of Texas Instruments.

All other trademarks are the property of their respective owners.

14.4 Electrostatic Discharge Caution



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

14.5 Glossary

SLYZ022 — TI Glossary.

This glossary lists and explains terms, acronyms, and definitions.

15 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
TCAN330D	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TC330	Samples
TCAN330DCNR	ACTIVE	SOT-23	DCN	8	3000	Green (RoHS & no Sb/Br)	NIPDAU	Level-1-260C-UNLIM	-40 to 125	330	Samples
TCAN330DCNT	ACTIVE	SOT-23	DCN	8	250	Green (RoHS & no Sb/Br)	NIPDAU	Level-1-260C-UNLIM	-40 to 125	330	Samples
TCAN330DR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TC330	Samples
TCAN330GD	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TC330	Samples
TCAN330GDCNR	ACTIVE	SOT-23	DCN	8	3000	Green (RoHS & no Sb/Br)	NIPDAU	Level-1-260C-UNLIM	-40 to 125	330	Samples
TCAN330GDCNT	ACTIVE	SOT-23	DCN	8	250	Green (RoHS & no Sb/Br)	NIPDAU	Level-1-260C-UNLIM	-40 to 125	330	Samples
TCAN330GDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TC330	Samples
TCAN332D	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TC332	Samples
TCAN332DCNR	ACTIVE	SOT-23	DCN	8	3000	Green (RoHS & no Sb/Br)	NIPDAU	Level-1-260C-UNLIM	-40 to 125	332	Samples
TCAN332DCNT	ACTIVE	SOT-23	DCN	8	250	Green (RoHS & no Sb/Br)	NIPDAU	Level-1-260C-UNLIM	-40 to 125	332	Samples
TCAN332DR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TC332	Samples
TCAN332GD	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TC332	Samples
TCAN332GDCNR	ACTIVE	SOT-23	DCN	8	3000	Green (RoHS & no Sb/Br)	NIPDAU	Level-1-260C-UNLIM	-40 to 125	332	Samples
TCAN332GDCNT	ACTIVE	SOT-23	DCN	8	250	Green (RoHS & no Sb/Br)	NIPDAU	Level-1-260C-UNLIM	-40 to 125	332	Samples
TCAN332GDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TC332	Samples
TCAN334D	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TC334	Samples

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
TCAN334DCNR	ACTIVE	SOT-23	DCN	8	3000	Green (RoHS & no Sb/Br)	NIPDAU	Level-1-260C-UNLIM	-40 to 125	334	Samples
TCAN334DCNT	ACTIVE	SOT-23	DCN	8	250	Green (RoHS & no Sb/Br)	NIPDAU	Level-1-260C-UNLIM	-40 to 125	334	Samples
TCAN334DR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TC334	Samples
TCAN334GD	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TC334	Samples
TCAN334GDCNR	ACTIVE	SOT-23	DCN	8	3000	Green (RoHS & no Sb/Br)	NIPDAU	Level-1-260C-UNLIM	-40 to 125	334	Samples
TCAN334GDCNT	ACTIVE	SOT-23	DCN	8	250	Green (RoHS & no Sb/Br)	NIPDAU	Level-1-260C-UNLIM	-40 to 125	334	Samples
TCAN334GDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TC334	Samples
TCAN337D	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TC337	Samples
TCAN337DCNR	ACTIVE	SOT-23	DCN	8	3000	Green (RoHS & no Sb/Br)	NIPDAU	Level-1-260C-UNLIM	-40 to 125	337	Samples
TCAN337DCNT	ACTIVE	SOT-23	DCN	8	250	Green (RoHS & no Sb/Br)	NIPDAU	Level-1-260C-UNLIM	-40 to 125	337	Samples
TCAN337DR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TC337	Samples
TCAN337GD	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TC337	Samples
TCAN337GDCNR	ACTIVE	SOT-23	DCN	8	3000	Green (RoHS & no Sb/Br)	NIPDAU	Level-1-260C-UNLIM	-40 to 125	337	Samples
TCAN337GDCNT	ACTIVE	SOT-23	DCN	8	250	Green (RoHS & no Sb/Br)	NIPDAU	Level-1-260C-UNLIM	-40 to 125	337	Samples
TCAN337GDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TC337	Samples

(1) The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

OBSOLETE: TI has discontinued the production of the device.

⁽²⁾ **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of ≤ 1000 ppm threshold. Antimony trioxide based flame retardants must also meet the ≤ 1000 ppm threshold requirement.

⁽³⁾ **MSL, Peak Temp.** - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

⁽⁴⁾ There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

⁽⁵⁾ Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "-" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

⁽⁶⁾ **Lead/Ball Finish** - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

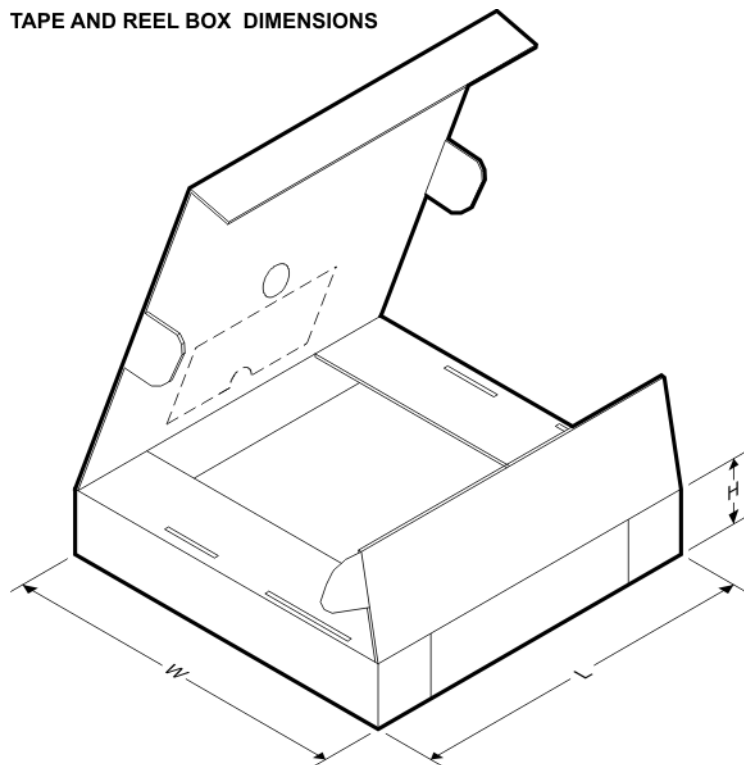
TAPE AND REEL INFORMATION


*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TCAN330DCNR	SOT-23	DCN	8	3000	180.0	8.4	3.23	3.17	1.37	4.0	8.0	Q3
TCAN330DCNT	SOT-23	DCN	8	250	180.0	8.4	3.23	3.17	1.37	4.0	8.0	Q3
TCAN330DR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
TCAN330GDCNR	SOT-23	DCN	8	3000	180.0	8.4	3.23	3.17	1.37	4.0	8.0	Q3
TCAN330GDCNT	SOT-23	DCN	8	250	180.0	8.4	3.23	3.17	1.37	4.0	8.0	Q3
TCAN330GDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
TCAN332DCNR	SOT-23	DCN	8	3000	180.0	8.4	3.23	3.17	1.37	4.0	8.0	Q3
TCAN332DCNT	SOT-23	DCN	8	250	180.0	8.4	3.23	3.17	1.37	4.0	8.0	Q3
TCAN332DR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
TCAN332GDCNR	SOT-23	DCN	8	3000	180.0	8.4	3.23	3.17	1.37	4.0	8.0	Q3
TCAN332GDCNT	SOT-23	DCN	8	250	180.0	8.4	3.23	3.17	1.37	4.0	8.0	Q3
TCAN332GDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
TCAN334DCNR	SOT-23	DCN	8	3000	180.0	8.4	3.23	3.17	1.37	4.0	8.0	Q3
TCAN334DCNT	SOT-23	DCN	8	250	180.0	8.4	3.23	3.17	1.37	4.0	8.0	Q3
TCAN334DR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
TCAN334GDCNR	SOT-23	DCN	8	3000	180.0	8.4	3.23	3.17	1.37	4.0	8.0	Q3
TCAN334GDCNT	SOT-23	DCN	8	250	180.0	8.4	3.23	3.17	1.37	4.0	8.0	Q3
TCAN334GDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TCAN337DCNR	SOT-23	DCN	8	3000	180.0	8.4	3.23	3.17	1.37	4.0	8.0	Q3
TCAN337DCNT	SOT-23	DCN	8	250	180.0	8.4	3.23	3.17	1.37	4.0	8.0	Q3
TCAN337DR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
TCAN337GDCNR	SOT-23	DCN	8	3000	180.0	8.4	3.23	3.17	1.37	4.0	8.0	Q3
TCAN337GDCNT	SOT-23	DCN	8	250	180.0	8.4	3.23	3.17	1.37	4.0	8.0	Q3
TCAN337GDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1

TAPE AND REEL BOX DIMENSIONS



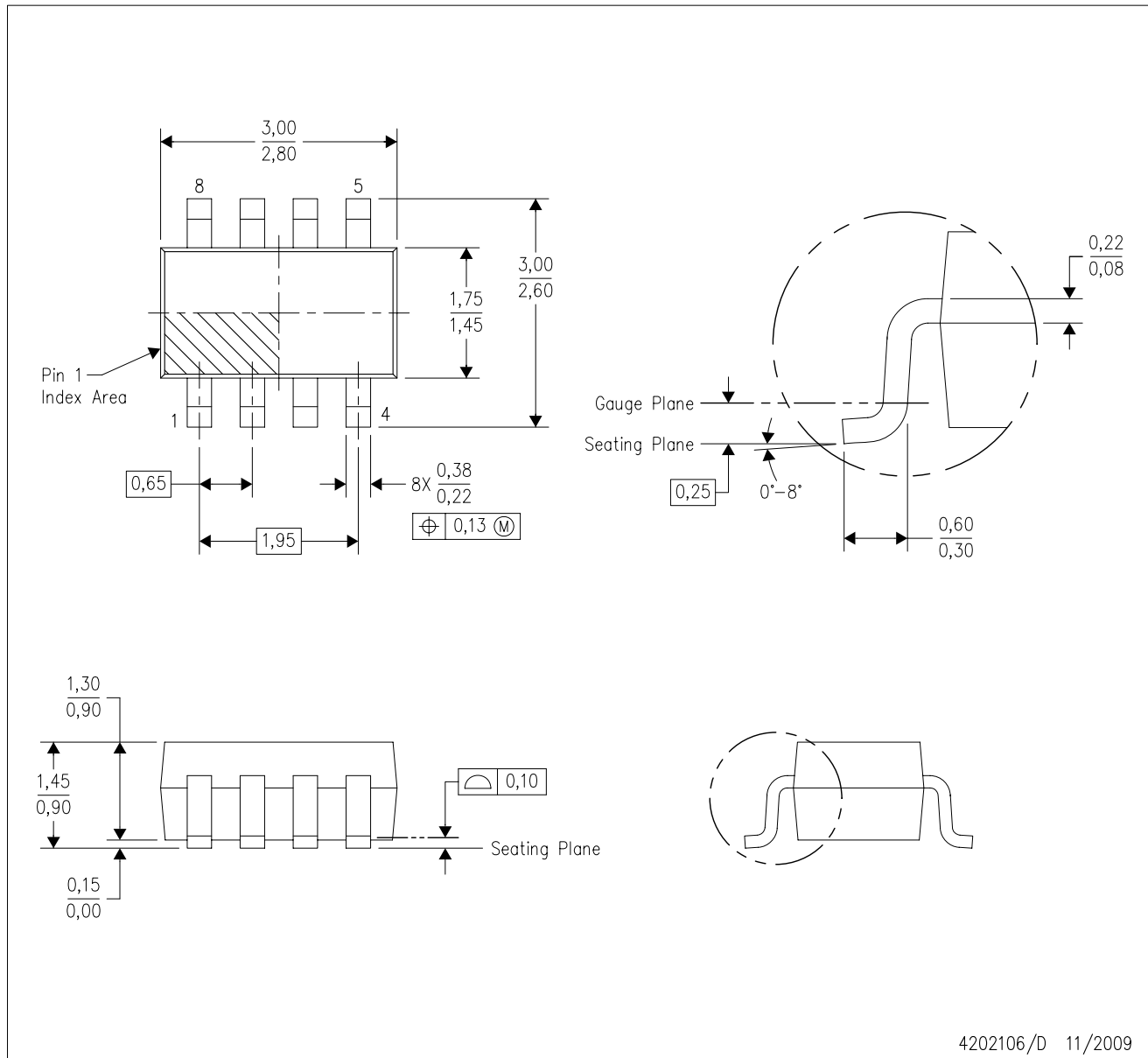
*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TCAN330DCNR	SOT-23	DCN	8	3000	202.0	201.0	28.0
TCAN330DCNT	SOT-23	DCN	8	250	202.0	201.0	28.0
TCAN330DR	SOIC	D	8	2500	340.5	338.1	20.6
TCAN330GDCNR	SOT-23	DCN	8	3000	202.0	201.0	28.0
TCAN330GDCNT	SOT-23	DCN	8	250	202.0	201.0	28.0
TCAN330GDR	SOIC	D	8	2500	340.5	338.1	20.6
TCAN332DCNR	SOT-23	DCN	8	3000	202.0	201.0	28.0
TCAN332DCNT	SOT-23	DCN	8	250	202.0	201.0	28.0
TCAN332DR	SOIC	D	8	2500	340.5	338.1	20.6
TCAN332GDCNR	SOT-23	DCN	8	3000	202.0	201.0	28.0
TCAN332GDCNT	SOT-23	DCN	8	250	202.0	201.0	28.0

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TCAN332GDR	SOIC	D	8	2500	340.5	338.1	20.6
TCAN334DCNR	SOT-23	DCN	8	3000	202.0	201.0	28.0
TCAN334DCNT	SOT-23	DCN	8	250	202.0	201.0	28.0
TCAN334DR	SOIC	D	8	2500	340.5	338.1	20.6
TCAN334GDCNR	SOT-23	DCN	8	3000	202.0	201.0	28.0
TCAN334GDCNT	SOT-23	DCN	8	250	202.0	201.0	28.0
TCAN334GDR	SOIC	D	8	2500	340.5	338.1	20.6
TCAN337DCNR	SOT-23	DCN	8	3000	202.0	201.0	28.0
TCAN337DCNT	SOT-23	DCN	8	250	202.0	201.0	28.0
TCAN337DR	SOIC	D	8	2500	340.5	338.1	20.6
TCAN337GDCNR	SOT-23	DCN	8	3000	202.0	201.0	28.0
TCAN337GDCNT	SOT-23	DCN	8	250	202.0	201.0	28.0
TCAN337GDR	SOIC	D	8	2500	340.5	338.1	20.6

DCN (R-PDSO-G8)

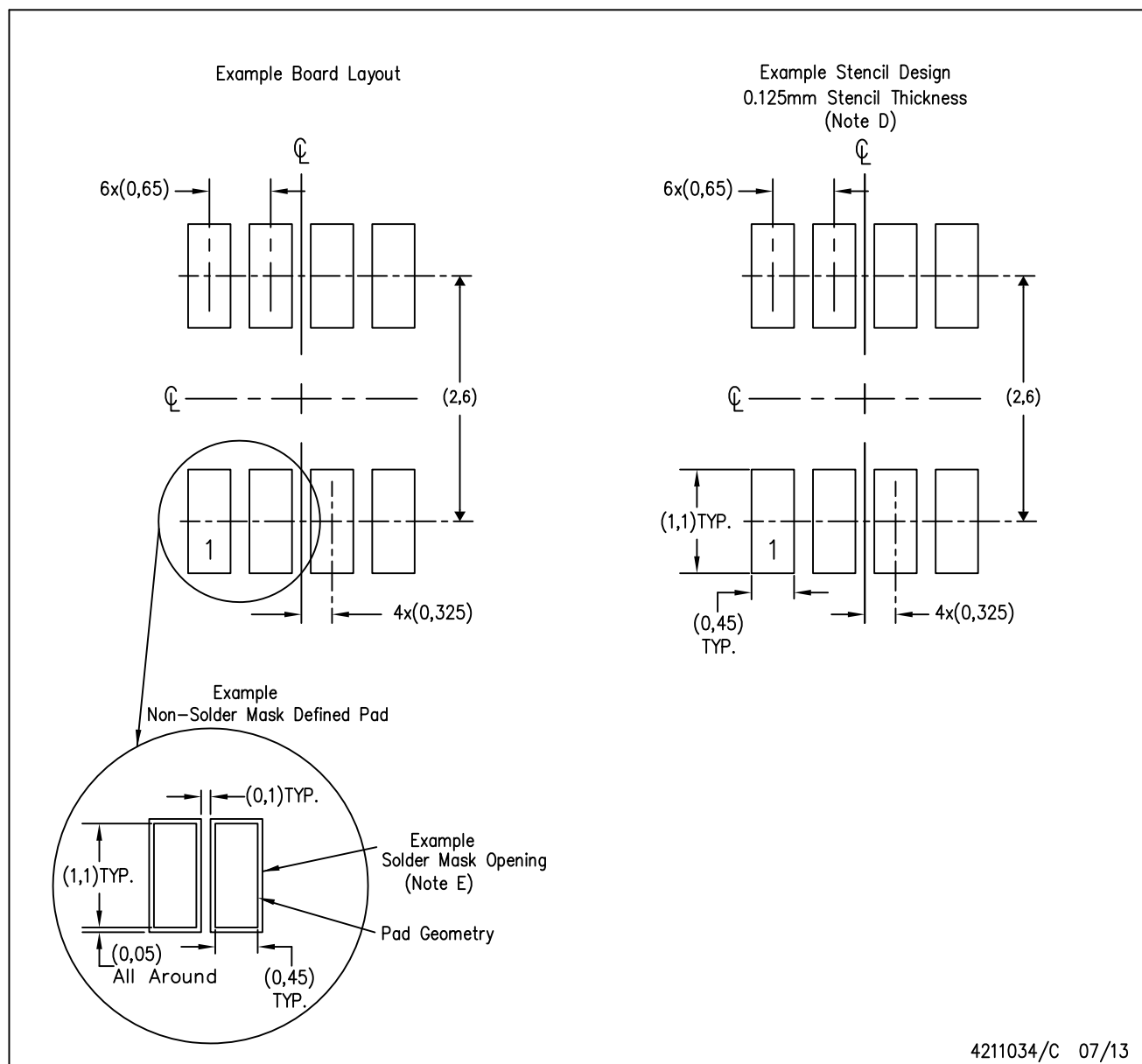
PLASTIC SMALL-OUTLINE PACKAGE (DIE DOWN)



- NOTES:
- A. All linear dimensions are in millimeters.
 - B. This drawing is subject to change without notice.
 - C. Package outline exclusive of metal burr & dambar protrusion/intrusion.
 - D. Package outline inclusive of solder plating.
 - E. A visual index feature must be located within the Pin 1 index area.
 - F. Falls within JEDEC MO-178 Variation BA.
 - G. Body dimensions do not include flash or protrusion. Mold flash and protrusion shall not exceed 0.25 per side.

DCN (R-PDSO-G8)

PLASTIC SMALL-OUTLINE PACKAGE (DIE DOWN)



- NOTES:
- All linear dimensions are in millimeters.
 - This drawing is subject to change without notice.
 - Publication IPC-7351 is recommended for alternate designs.
 - Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525.
 - Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

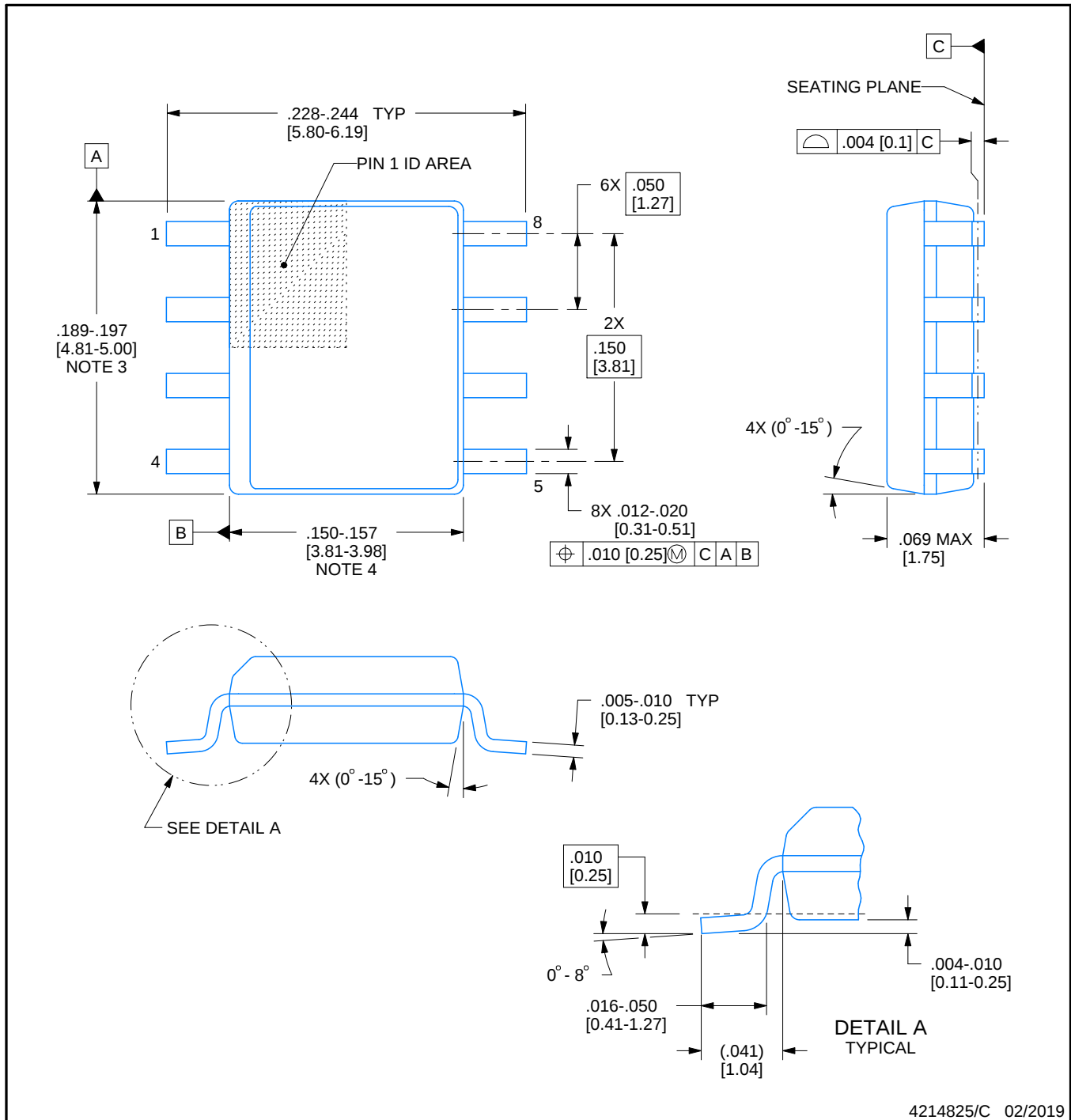


D0008A

PACKAGE OUTLINE

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



4214825/C 02/2019

NOTES:

1. Linear dimensions are in inches [millimeters]. Dimensions in parenthesis are for reference only. Controlling dimensions are in inches. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed .006 [0.15] per side.
4. This dimension does not include interlead flash.
5. Reference JEDEC registration MS-012, variation AA.

D0008A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:8X



SOLDER MASK DETAILS

4214825/C 02/2019

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

EXAMPLE STENCIL DESIGN

D0008A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



SOLDER PASTE EXAMPLE
BASED ON .005 INCH [0.125 MM] THICK STENCIL
SCALE:8X

4214825/C 02/2019

NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, or other requirements. These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to TI's Terms of Sale (www.ti.com/legal/termsofsale.html) or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2020, Texas Instruments Incorporated