

# THVD8000 OOK 変調付き RS-485 電力線通信用トランシーバ

## 1 特長

- 3V~5.5V の電源電圧
- 半二重通信
  - 最大 500kbps のデータ・レート ( $f_0 / \text{bps} = 10$ )
  - $f_0 / \text{bps} < 10$  の場合、より高いデータ・レートも可能
- オン / オフ・キーイング (OOK) 変調による RS-485 電気信号伝達
- ピンで選択可能なキャリア周波数: 125kHz~5MHz
- 拡散スペクトラム・クロック処理による優れた EMI 性能
- 無極性
- スタック・バス条件を回避するための TX タイムアウト
- 動作同相範囲: -7V~12V
- バス I/O 保護
  - $\pm 18\text{V}$  の DC フォルト保護
  - $\pm 16\text{kV}$  HBM ESD
  - $\pm 8\text{kV}$  IEC 61000-4-2 接触放電
  - $\pm 15\text{kV}$  IEC 61000-4-2 エアギャップ放電
  - $\pm 4\text{kV}$  IEC 61000-4-4 高速過渡バースト
- 拡張温度範囲: -40°C~125°C
- スペースに制約のあるアプリケーションに適した 8 ピン SOT-23 パッケージ

## 2 アプリケーション

- HVAC システム
- ビル・オートメーション
- ファクトリ・オートメーション / 制御
- 家電製品
- ライティング
- グリッド・インフラストラクチャ
- PD (パワー・デリバリー)

## 3 概要

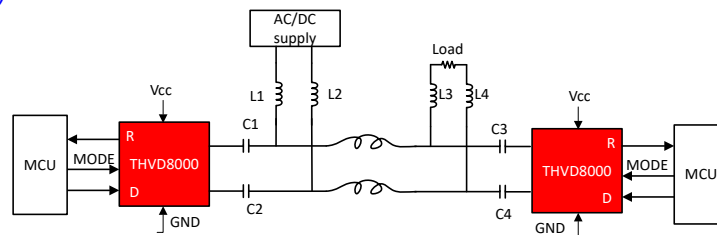
THVD8000 は、オン / オフ・キーイング (OOK) 変調および復調機能を備えた RS-485 電力線通信用トランシーバです。既存の電力線上でデータを変調することで、電力伝送とデータ通信が共通の 1 対の配線を共有できるため、システム・コストを大幅に低減できます。

ピンで設定可能なインターフェイスを採用しているため、システム設計が簡単です。キャリア周波数は、F\_SET ピンの外付け抵抗を変更することで調整できます。キャリア周波数の可変範囲が広いので、システム設計者は外付けのインダクタとコンデンサを柔軟に選択できます。また、OOK 変調はデータの極性に影響されないで動作するため、システムの設置が簡単です。

### 製品情報

部品番号	パッケージ <sup>(1)</sup>	本体サイズ (公称)
THVD8000	SOT-23 (8)	2.90mm × 1.60mm

- (1) 利用可能なすべてのパッケージについては、このデータシートの末尾にある注文情報を参照してください。



概略回路図



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## 4 Revision History

資料番号末尾の英字は改訂を表しています。その改訂履歴は英語版に準じています。

Changes from Revision * (May 2020) to Revision A (March 2021)	Page
• データシートのステータスを次のように変更: 事前情報から量産データ .....	<b>1</b>

## 5 Pin Configuration and Functions

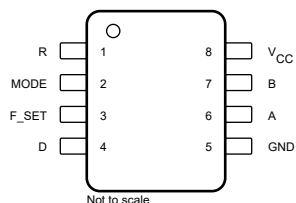


图 5-1. DRL Package, 8-Pin SOT-23, Top View

表 5-1. Pin Functions

PIN		I/O	DESCRIPTION
NAME	NO.		
R	1	Digital output	Receive data output
MODE	2	Digital input	Transmit/receive mode selection. Low = receive mode; High = transmit mode. 2-MΩ pull-down to GND
F_SET	3	Analog input	Carrier frequency selection. Use a resistor to GND to select a frequency.
D	4	Digital input	Driver data input, 2-MΩ pull-up to V <sub>CC</sub>
GND	5	Ground	Device ground
A	6	Bus input/output	Bus I/O port A (complementary to B)
B	7	Bus input/output	Bus I/O port B (complementary to A)
V <sub>CC</sub>	8	Power	3.3-V to 5-V device supply

## 6 Specifications

### 6.1 Absolute Maximum Ratings

See (1)

		MIN	MAX	UNIT
$V_{CC}$	Supply voltage	-0.5	7	V
$V_L$	Input voltage at any logic pin (D, MODE or F_SET)	-0.3	5.7	V
$V_A, V_B$	Voltage at A or B inputs (differential or with respect to GND)	-18	18	V
$I_O$	Receiver output current	-24	24	mA
$T_J$	Junction temperature		170	°C
$T_{STG}$	Storage temperature	-65	150	°C

- (1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions beyond those indicated under [セクション 6.4](#) is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

### 6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001(1)	A and B pins to GND ±16,000	V
			All pins ±4,000	
		Charged-device model (CDM), per JEDEC specification JESD22-C101(2)	All pins ±1,500	

- (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.

### 6.3 ESD Ratings - IEC Specifications

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	IEC 61000-4-2 ESD contact discharge, A and B pins to GND	±8,000	V
		IEC 61000-4-2 ESD air gap discharge, A and B pins to GND	±15,000	
		IEC 61000-4-4 electrical fast transient, A and B pins to GND	±4,000	

### 6.4 Recommended Operating Conditions

			MIN	NOM	MAX	UNIT
$V_{CC}$	Supply voltage		3		5.5	V
$V_{ID}$	Input differential voltage (A and B pins)		-7		12	V
$V_{CM}$	Operational common mode voltage (A and B pins)		-7		12	V
$V_{IH}$	High-level input voltage (D and MODE pins)		2		$V_{CC}$	V
$V_{IL}$	Low-level input voltage (D and MODE pins)		0		0.8	V
$I_O$	Output current	Driver	-60		60	mA
		Receiver	-4		4	
$R_{F\_SET}$	Carrier frequency selection resistor		1.5		80	kΩ
$\Delta R_{F\_SET}$	Carrier frequency selection resistor tolerance		-2		2	%
$1/t_{UI}$	Data rate	Modulation mode(1)			$f_0 / 10$	bps
$C_{F\_SET}$	Recommended load capacitance on F_SET pin				100	pF
$T_A$	Operating ambient temperature		-40		125	°C

- (1)  $f_0$  is the carrier frequency (in Hz) set by the external resistor between F\_SET and GND pins.

## 6.5 Thermal Information

THERMAL METRIC <sup>(1)</sup>		THVD8000	UNIT
		DDF (SOT-23)	
		8 PINS	
R <sub>θJA</sub>	Junction-to-ambient thermal resistance	106.6	°C/W
R <sub>θJC(top)</sub>	Junction-to-case (top) thermal resistance	38.4	°C/W
R <sub>θJB</sub>	Junction-to-board thermal resistance	29.9	°C/W
ψ <sub>JT</sub>	Junction-to-top characterization parameter	29.5	°C/W
ψ <sub>JB</sub>	Junction-to-top characterization parameter	29.5	°C/W

(1) For more information about traditional and new thermalmetrics, see the [Semiconductor and ICPackage Thermal Metrics](#) application report.

## 6.6 Electrical Characteristics

Over operating free-air temperature range (unless otherwise noted). All typical values are measured at 25°C and supply voltage of V<sub>CC</sub> = 5 V.

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
Driver							
V <sub>OD</sub>	Driver differential output voltage magnitude	R <sub>L</sub> = 60 Ω, -7 V ≤ V <sub>test</sub> ≤ 12 V, Measured at 2nd pulse	See <a href="#">7-1</a>	1.5	3.5	V	
		R <sub>L</sub> = 100 Ω, C <sub>L</sub> = 50 pF, Measured at 2nd pulse	See <a href="#">7-1</a>	2	4		
		R <sub>L</sub> = 54 Ω, C <sub>L</sub> = 50 pF, Measured at 2nd pulse	See <a href="#">7-1</a>	1.5	3.5		
V <sub>OC</sub>	Steady state common-mode output voltage	R <sub>L</sub> = 60 Ω, C <sub>L</sub> = 50 pF	See <a href="#">7-2</a>	1	V <sub>CC</sub> / 2	3	V
ΔV <sub>OC</sub>	Change in differential driver common-mode output voltage	R <sub>L</sub> = 60 Ω, C <sub>L</sub> = 50 pF	See <a href="#">7-2</a>	-160		160	mV
V <sub>OC(PP)</sub>	Peak-to-peak driver common-mode output voltage	R <sub>L</sub> = 60 Ω, C <sub>L</sub> = 50 pF, V <sub>CC</sub> = 3.3 V and V <sub>CC</sub> = 5V	See <a href="#">7-2</a>		425		mV
I <sub>OS</sub>	Driver short-circuit output current	MODE = V <sub>CC</sub> , -7 V ≤ [V <sub>A</sub> or V <sub>B</sub> ] ≤ 12 V		-250		250	mA
f <sub>0</sub>	Minimum carrier frequency <sup>(1)</sup>	R <sub>F_SET</sub> = 77 kΩ	See <a href="#">7-3</a>		125		kHz
	Maximum carrier frequency <sup>(1)</sup>	R <sub>F_SET</sub> = 1.5 kΩ			5		MHz
DCD <sub>f0</sub>	Carrier frequency duty cycle distortion	Measured over the full range of f <sub>0</sub>		-2		2	%
Δf <sub>0</sub>	Carrier frequency tolerance	Measured with a ±2% tolerant R <sub>F_SET</sub>		-25		25	%
Δf <sub>SSC</sub>	Variation of the carrier frequency for spread spectrum clocking	Measured across the full carrier frequency range			±5		%
f <sub>SSC</sub>	Spread spectrum clock rate				30		kHz

Over operating free-air temperature range (unless otherwise noted). All typical values are measured at 25°C and supply voltage of  $V_{CC} = 5\text{ V}$ .

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
Receiver							
I <sub>I</sub>	Bus input current in receive mode	MODE = GND, V <sub>CC</sub> = 0 V or 5.5 V	V <sub>I</sub> = 12 V		75	125	μA
			V <sub>I</sub> = −7 V	−97	−70		
V <sub>MAG_ZERO</sub>	OOK signal differential swing (magnitude) to detect a zero at the R output	MODE = GND, over full common mode range	125 kHz			225	mV
			1 MHz			150	
			5 MHz			115	
V <sub>MAG_ONE</sub>	OOK signal differential swing (magnitude) to detect a one at the R output		125 kHz	20			mV
			1 MHz	10			
			5 MHz	10			
V <sub>MAG_HYS</sub>	Receiver differential input voltage threshold hysteresis		125 kHz	40			mV
			1 MHz	20			
			5 MHz	20			
Logic / Control Pins							
I <sub>IN</sub>	Input current (D, MODE)	V <sub>O</sub> = 0 V or V <sub>CC</sub>		−5		5	μA
I <sub>IN</sub>	Input current (F_SET)	V <sub>O</sub> = V <sub>CC</sub>				55	μA
V <sub>O</sub>	Output voltage (F_SET)	I <sub>O</sub> = 0 mA			1.4		V
		1.5 kΩ ≤ R <sub>PD</sub> ≤ 78 kΩ			785		mV
V <sub>OH</sub>	Receiver high-level output voltage	I <sub>OH</sub> = −4 mA		V <sub>CC</sub> − 0.4	V <sub>CC</sub> − 0.2		V
V <sub>OL</sub>	Receiver low-level output voltage	I <sub>OL</sub> = 4 mA			0.2	0.4	V
I <sub>OZ</sub>	Receiver high-impedance output current	V <sub>O</sub> = 0 V or V <sub>CC</sub> , MODE = 0		−1		1	μA
Device							
I <sub>CC</sub>	Supply current (quiescent)	Transmit mode	D = V <sub>CC</sub> , MODE = V <sub>CC</sub> , resistor between F_SET and GND, no load		3.1	5	mA
		Receive mode	D = V <sub>CC</sub> , MODE = GND, resistor between F_SET and GND, no load		4	6	
T <sub>SD</sub>	Thermal shutdown temperature			160	170	185	°C
T <sub>HYS</sub>	Thermal shutdown hysteresis				11	15	°C

(1) See OOK modulation section for the complete carrier frequency range

## 6.7 Power Dissipation Characteristics

Over operating free-air temperature range (unless otherwise noted). All typical values are measured at 25°C and supply voltage of  $V_{CC} = 5\text{ V}$ .

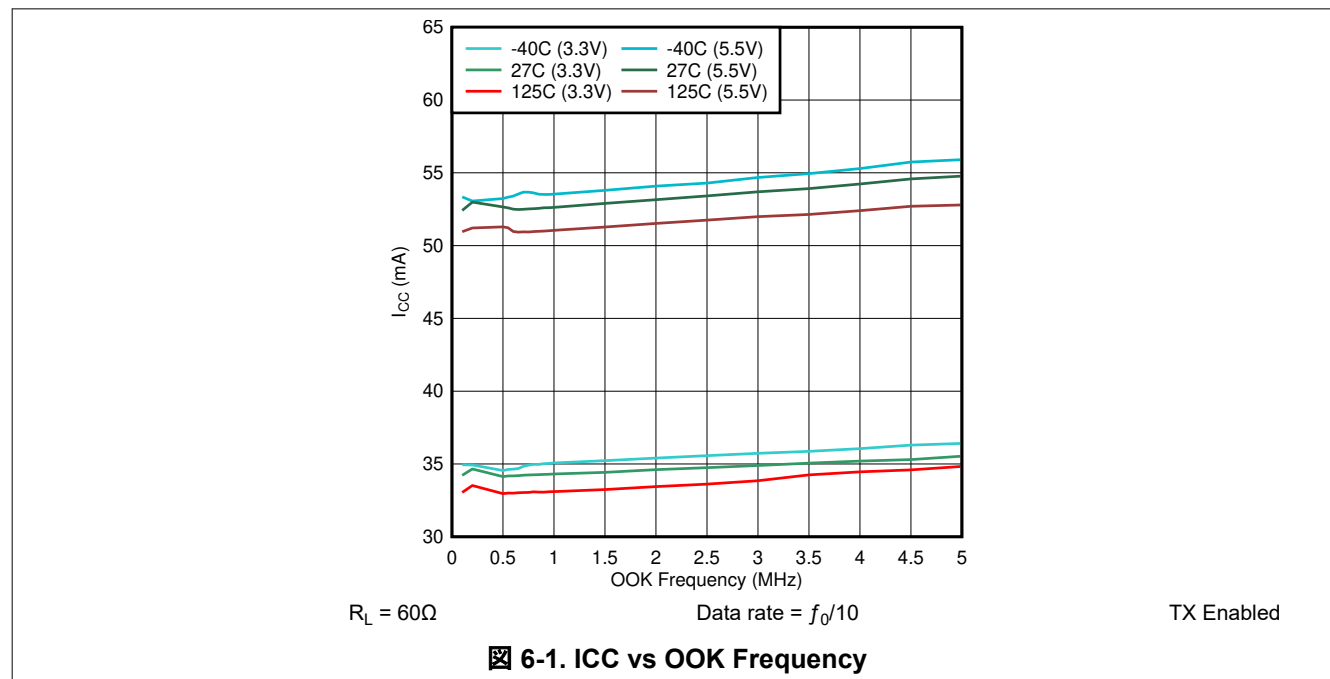
PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
PD <sub>OOK</sub>	Chip power dissipation	MODE = $V_{CC}$ , $R_L = 60\ \Omega$ , no $C_L$ , see Figure 2	$f_0 = 125\text{ kHz}$ , 12.5 kHz (25 kbps) clock pattern as data		60	80	mW
			$f_0 = 5\text{ MHz}$ , 500 kHz (1Mbps) clock pattern as data		90	125	mW

## 6.8 Switching Characteristics

Over operating free-air temperature range (unless otherwise noted). All typical values are measured at 25°C and supply voltage of  $V_{CC} = 5\text{ V}$ .

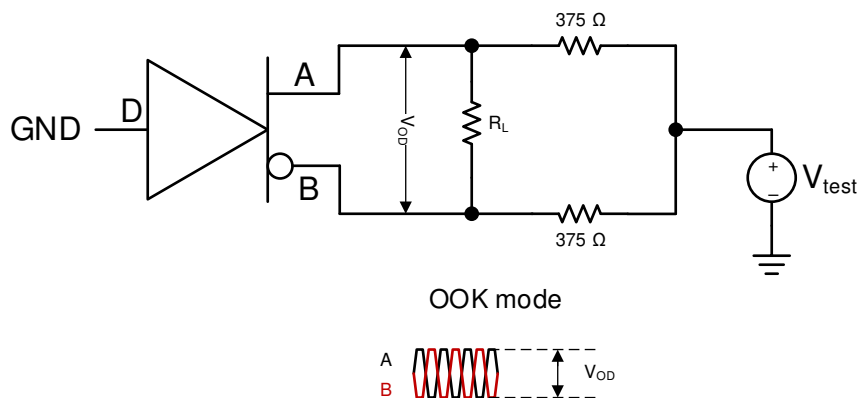
PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
Driver							
t <sub>r</sub> , t <sub>f</sub>	Driver differential output rise and fall times	R <sub>L</sub> = 60 Ω, C <sub>L</sub> = 50 pF, See <a href="#">7-4</a>		10	30	ns	
t <sub>PHL</sub> , t <sub>PLH</sub>	Driver propagation delay			1.2	2.5	Clocks	
t <sub>SK(P)</sub>	Driver pulse skew,  t <sub>PHL</sub> – t <sub>PLH</sub>			0.3	2.5	Clocks	
Receiver							
t <sub>r</sub> , t <sub>f</sub>	Receiver output rise and fall times	C <sub>L</sub> = 15 pF, See <a href="#">7-5</a>		1.5	16	ns	
t <sub>PHL</sub> , t <sub>PLH</sub>	Receiver propagation delay time			4	6.5	Clocks	
t <sub>SK(P)</sub>	Receiver pulse skew,  t <sub>PHL</sub> – t <sub>PLH</sub>			1.1	3		
Device							
t <sub>TX-RX_OOK</sub>	Transmit to receive mode change delay, OOK mode	For all R <sub>FSET</sub>	Worst case of t <sub>TX-RX_OOK_ZERO</sub> and t <sub>TX-RX_OOK_ONE</sub> . See <a href="#">7-6</a> and <a href="#">7-7</a>		14	clocks	
t <sub>RX-TX_OOK</sub>	Receive to transmit mode change delay, OOK mode	For all R <sub>FSET</sub>	See <a href="#">7-8</a>		12	clocks	
t <sub>TX_TIMEOUT</sub>	Transmit timeout delay			60	110	s	

## 6.9 Typical Characteristics

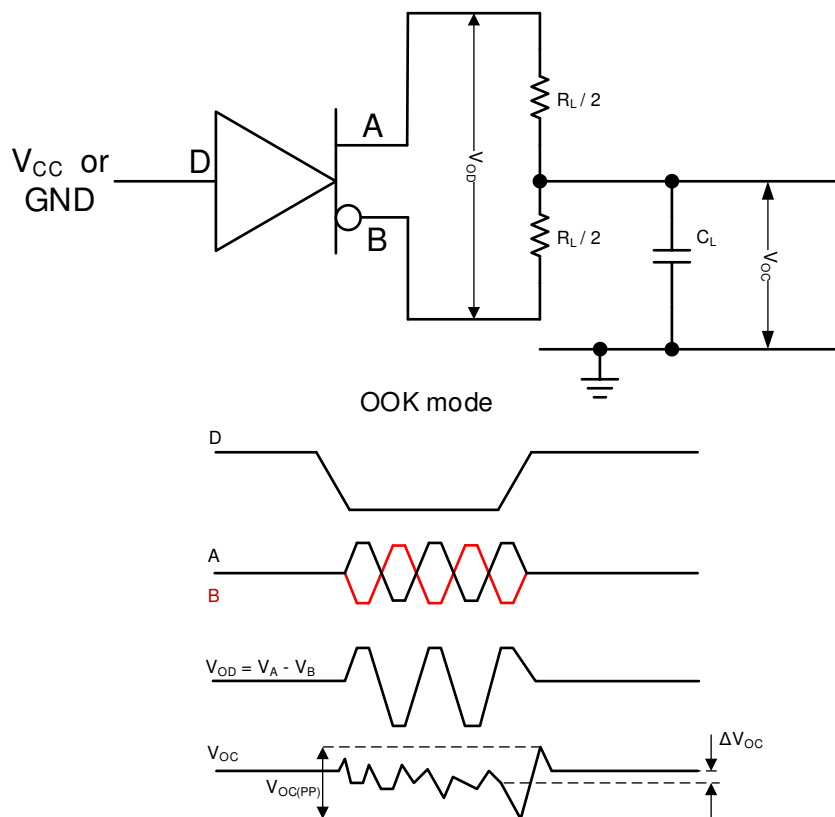




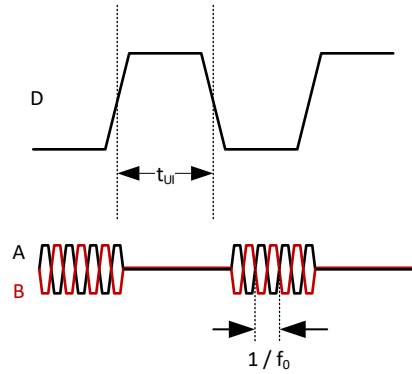
## 7 Parameter Measurement Information



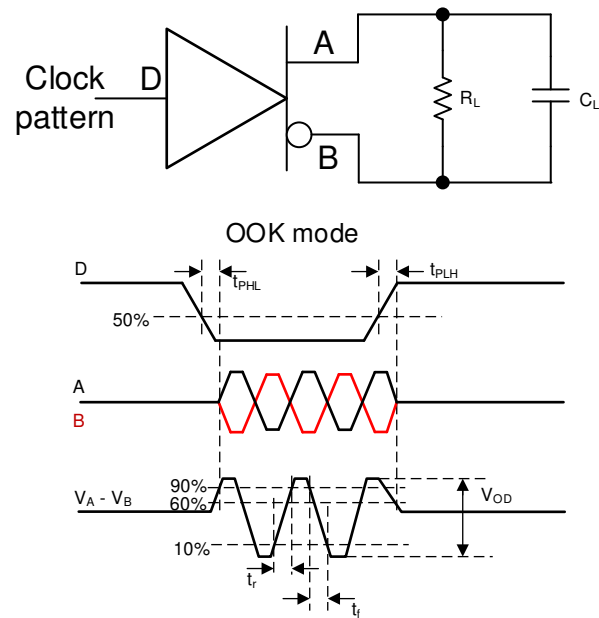
7-1. Measurement of Driver Differential Output Voltage With Common-Mode Load



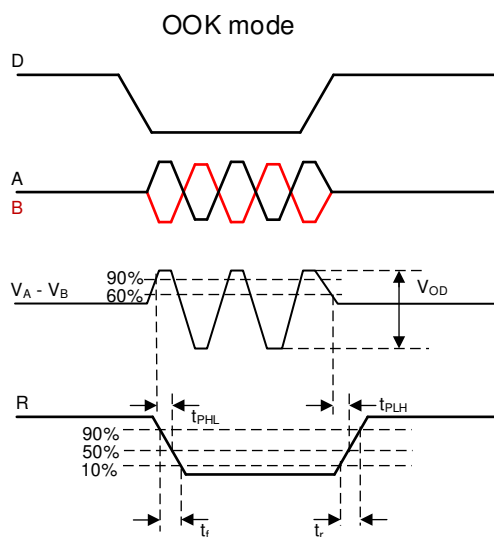
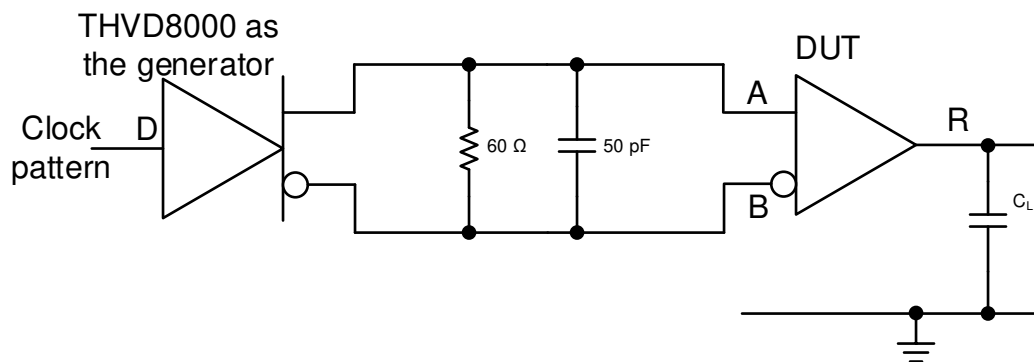
7-2. Measurement of Driver Differential and Common-Mode Outputs



7-3. Measurement of Carrier Frequency



7-4. Measurement of Driver Switching Characteristics



 **7-5. Measurement of Receiver Characteristics**

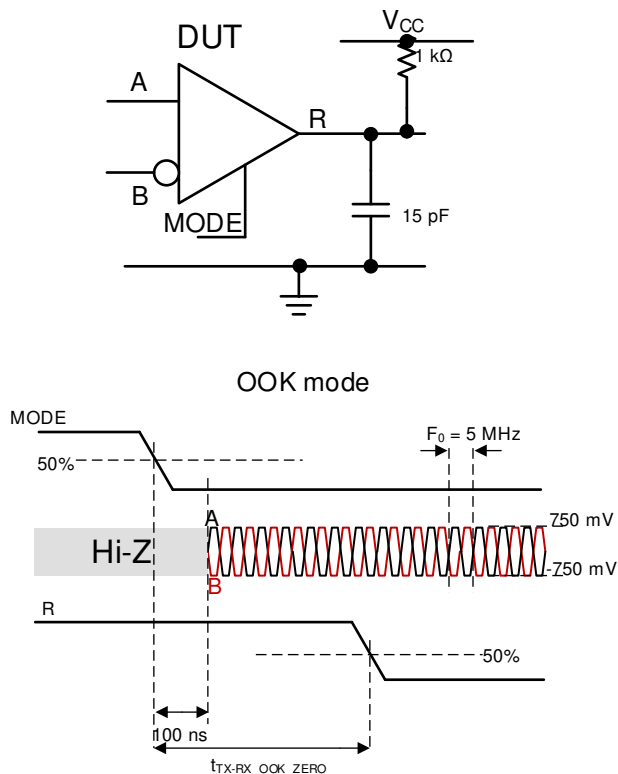


FIG 7-6. Transmit to Receive Mode Change with Low Output

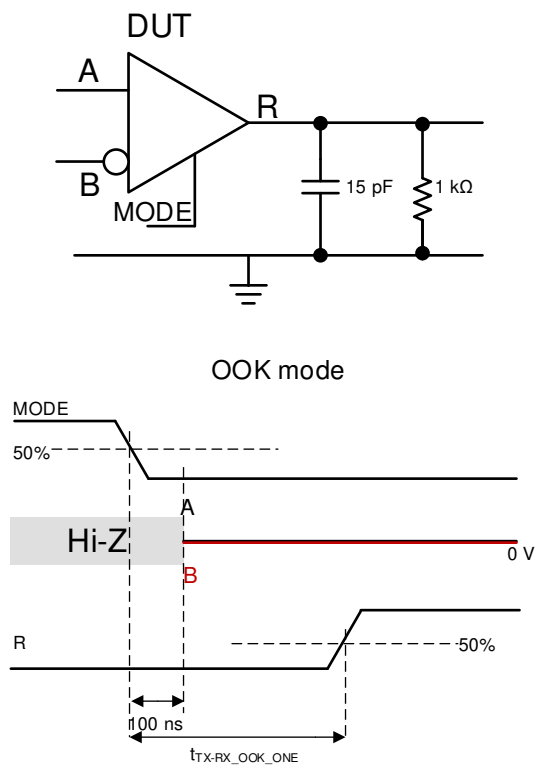
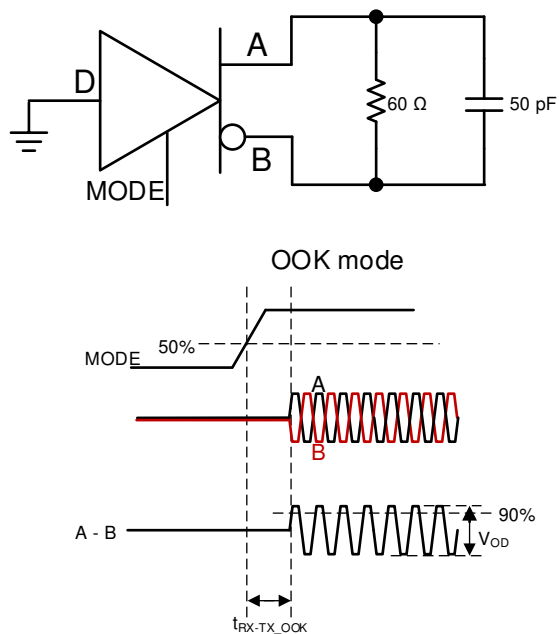


FIG 7-7. Transmit to Receive Mode Change with High Output



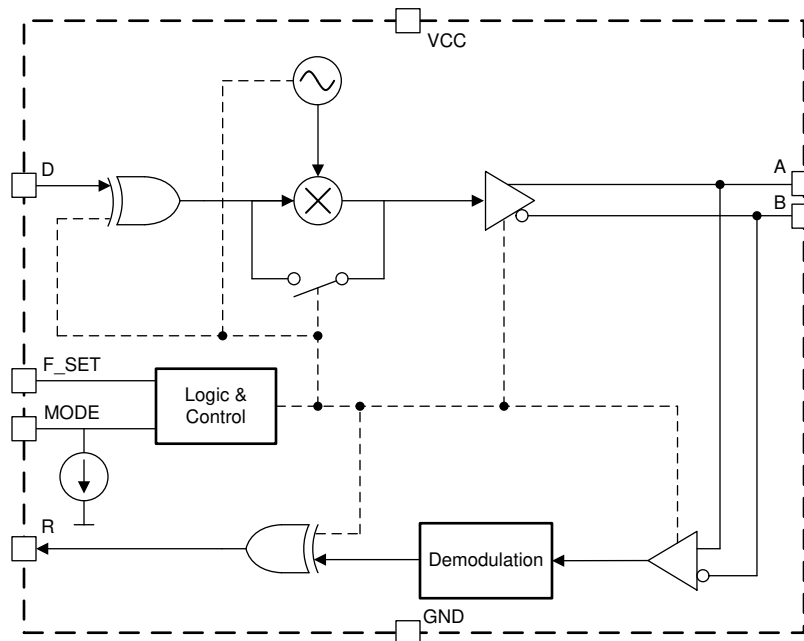
7-8. Receive to Transmit Mode Change

## 8 Detailed Description

### 8.1 Overview

THVD8000 enables power line communication using RS-485 physical layer signaling. An integrated OOK modulator enables RS-485 data to be directly coupled onto existing power cables via series capacitors without any updates to the MCU or the controller. The THVD8000 receiver extracts the data from the power cables through series capacitors by using a precise bandpass filter and a demodulator.

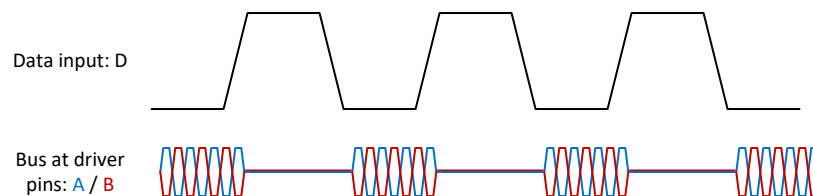
### 8.2 Functional Block Diagrams



### 8.3 Feature Description

#### 8.3.1 OOK Modulation with F\_SET pin

Data at the D input is modulated with the carrier frequency ( $f_0$ ) via the F\_SET pin. [Figure 8-1](#) illustrates the modulation scheme. A high level at the D input is driven to the mid-level with zero differential voltage ( $V_{OD}$ ). A low level at the D input is modulated at the carrier frequency. It is recommended to use a carrier frequency that is 10x higher than the data rate. Higher data rates are possible at the expense of increased pulse width distortion with the use of lower ratios.



**Figure 8-1. OOK Modulation Scheme**

$f_0$  is programmable by changing the external resistor ( $R_{F\_SET}$ ) value connected to ground. [Table 8-1](#) shows the carrier frequency for the each recommended resistor value.

**Table 8-1. OOK  $f_0$  versus  $R_{F\_SET}$**

$R_{F\_SET}$ (k $\Omega$ )	OOK $f_0$ (kHz)
77	125
50	187.5
19	500

表 8-1. OOK  $f_0$  versus  $R_{F\_SET}$  (continued)

$R_{F\_SET}$ (k $\Omega$ )	OOK $f_0$ (kHz)
12.5	750
9.3	1000
4.4	2000
1.5	5000

The oscillator used to generate the carrier frequency features spread spectrum clocking to reduce emissions.

### 8.3.2 OOK Demodulation

The OOK signal received at the A and B inputs go through a bandpass filter and a peak detector to regenerate the original data stream. 8-2 shows the OOK input and the R output waveforms. The bandpass filter characteristics will adapt to optimal settings automatically based on the carrier frequency, set via  $R_{F\_SET}$ .

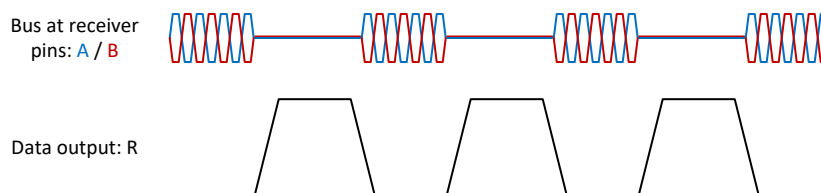


图 8-2. OOK Demodulation

### 8.3.3 Transmitter Timeout

The driver path incorporates a timeout feature to prevent a faulty node from occupying the bus indefinitely in a multi-drop application.

The driver stops transmitting and the outputs will go high impedance if the D input doesn't detect an edge (either rising or falling) for longer than  $t_{TX\_TIMEOUT}$ . One of the following events brings the device back to normal operation.

- Any edge at D input
- Toggle MODE pin

The transmit path resumes operation within  $t_{MODE}$ .

### 8.3.4 Polarity Free Operation

THVD8000 is immune to A and B polarity at the receiver input in OOK mode. The receiver data comparator only checks for the receive input signal magnitude, ignoring the polarity, to determine its logic level. Note that reversing the polarity does result in degraded pulse width distortion.

### 8.3.5 Glitch Free Mode Change

The device incorporates a delay of up to  $t_{MODE}$  when changing the state of the MODE pin. This feature ensures that there are no glitches at the A, B and R outputs when transitioning between transmit and receive modes.

### 8.3.6 Integrated IEC ESD and EFT Protection

Internal ESD protection circuits protect the transceiver against electrostatic discharges (ESD) according to IEC 61000-4-2 of up to  $\pm 8$  kV contact and against electrical fast transients (EFT) according to IEC 61000-4-4 of up to  $\pm 4$  kV. This integrated protection eliminates the need of external components reducing the system BOM.

## 8.4 Device Functional Modes

表 8-2. THVD8000 Functional Modes

F_SET Configuration	Device Functional Mode
R <sub>F_SET</sub> between F_SET and GND	OOK mode, f <sub>0</sub> set by the R <sub>F_SET</sub> value
F_SET at high impedance	Invalid, not recommended for normal operation
F_SET at V <sub>CC</sub>	
F_SET short to GND	

### 8.4.1 OOK Mode

Data at the D input is modulated with the carrier frequency set by the R<sub>F\_SET</sub> value when the device is transmitting (MODE = V<sub>CC</sub>). See [セクション 8.3.1](#) section for more details. In receiving (MODE = GND), the device expects an OOK modulated signal at the A and B inputs. The data is demodulated and sent out via R pin. See [セクション 8.3.2](#) section for more details.

表 8-3. Driver function table for OOK mode

INPUTS			OUTPUTS		FUNCTION
F_SET	MODE	D	A	B	
R <sub>F_SET</sub> (See <a href="#">表 8-1</a> )	H	H or Z	Bias to V <sub>CM</sub>	Bias to V <sub>CM</sub>	Driver is actively biased to V <sub>CM</sub> on the bus
	H	L	Oscillating	Oscillating	Bus actively driven at carrier frequency
	L or Z	X	Z	Z	Driver disabled, device in receive mode

表 8-4. Receiver function table for OOK mode

INPUTS			OUTPUT	FUNCTION
F_SET	MODE	Input	R	
R <sub>F_SET</sub> (See <a href="#">表 8-1</a> )	L or Z	Oscillating at F_SET and V <sub>ID</sub> > V <sub>MAG_ZERO</sub>	L	Receive valid bus low
	L or Z	Oscillating at F_SET and V <sub>MAG_ONE</sub> < V <sub>ID</sub> < V <sub>MAG_ZERO</sub>	?	Receive invalid bus, output indeterminate
	L or Z	Oscillating at F_SET and V <sub>ID</sub> < V <sub>MAG_ONE</sub>	H	Receive valid bus high
	L or Z	Z / not oscillating	H	Receive valid bus high
	L or Z	OPEN, SHORT, IDLE (V <sub>ID</sub> = 0 V)	H	Failsafe high output
	H	X	Z	Receiver disabled, device in transmit mode

### 8.4.2 Thermal shutdown (TSD)

The THVD8000 has a protection feature called thermal shutdown. When the junction temperature reaches T<sub>SD</sub>, the device enters thermal shutdown protection mode. This mode disables the driver and receiver outputs, which will halt all communication through the device. Normal operation resume once the junction temperature drops out of thermal shutdown, which is typically T<sub>SD</sub> - T<sub>HYS</sub>.



## 9 Application Information Disclaimer

### 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, as well as validating and testing their design implementation to confirm system functionality.

### 9.1 Application information

The THVD8000 is able to transmit data over an AC coupled power line pair using On-Off Keying (OOK).

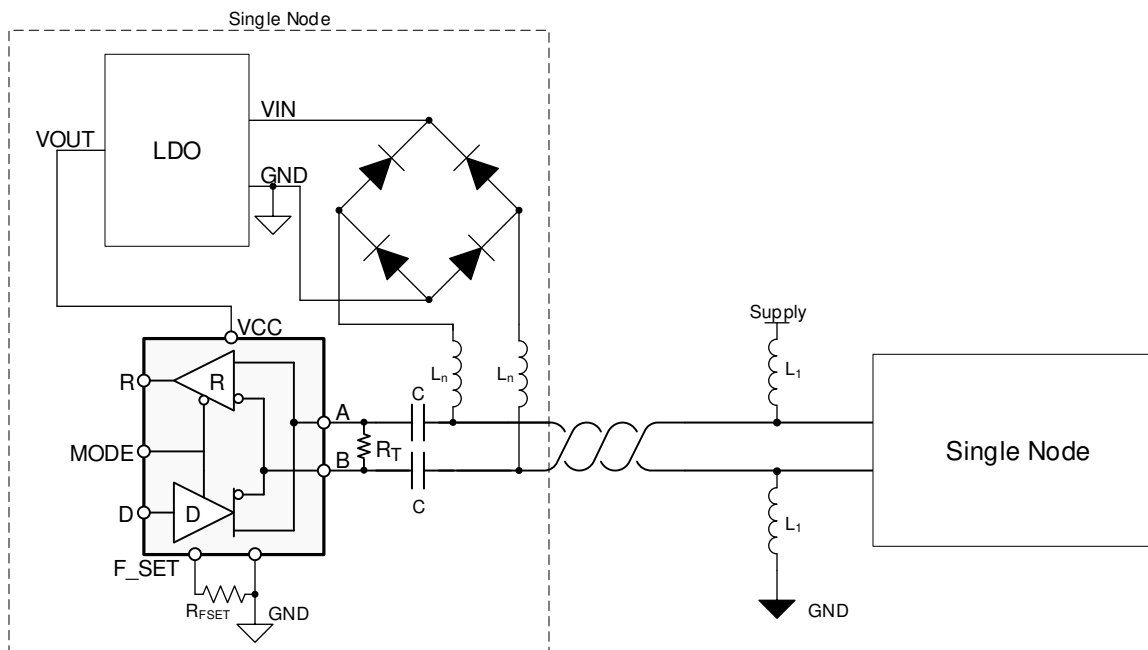
### 9.2 Typical application (OOK mode)

In order to combine data and power over a single pair of wires, capacitors and inductors are used in a bias-tee configuration. High-frequency differential data is AC-coupled onto the bus lines via series capacitances while power is DC-coupled via series inductances. The values of these components will depend on the carrier frequency, number of nodes on the bus, and the power delivery requirements (i.e., voltage and total current sourced or consumed by a given node).

The transmitted differential communication signal is AC-coupled onto the power bus as shown below. This configuration provides the advantage that the power transmitted on the bus has little impact on the differential data, allowing for a wide range of voltage and current scenarios. Typical applications are realized with the THVD8000 transmitting over a power bus of 24VDC or 24VAC with currents from 100mA to 1A, but due to the AC-coupling the THVD8000 does not directly see these voltages. For more information, please refer for the [THVD8000 design guide](#).

In [Figure 9-1](#), there is an optional rectifier network pictured on the bus lines. This network of diodes can ensure that the node receives power correctly from the bus wires, even if the lines get swapped.

A termination resistance,  $R_T$ , is not required for device functionality but can be useful in improving signal integrity in some applications by reducing reflections that can occur at cable ends.



**Figure 9-1. Typical power line network with 2 nodes**

## 9.2.1 Design requirements

The main requirements are the values of the bus capacitors and the power inductors. Both of these values are dependant upon the carrier frequency selected.

### 9.2.1.1 Carrier frequency

This device uses on-off-keying to transmit binary data on the bus. Please read [セクション 8.3.1](#) for detailed information. The modulation and demodulation of the data can result in pulse width distortion due to asymmetries in low-to-high and high-to-low transition times. These asymmetries are due to factors like synchronization of the data to the internal carrier oscillator in the transmit path and the response time of the band-pass filter in the receive path. The impact of these factors can be minimized by choosing a carrier frequency much higher than the data rate required. A frequency ratio of at least 10:1 is recommended.

## 9.2.2 Detailed design procedure

### 9.2.2.1 Inductor value selection

It is important to note that the inductor selected must also take power consumption into consideration. The inductor should be sized to handle the maximum anticipated current in addition to the inductance value.

The parallel aggregate impedance should be selected so that the total equivalent impedance at the carrier frequency is  $Z \geq 375 \Omega$ . This assumes RS-485 loading with  $60 \Omega$  termination. If no termination is used in the application, then the total equivalent impedance at the carrier frequency could be reduced to  $Z \geq 60 \Omega$ . These examples assume that termination is used. [式 1](#) shows the parallel aggregate impedance equation for inductors  $L_1$  to  $L_n$ . Since the inductance value for each node should be the same, it's simple to determine that each node's impedance should be  $n$  times the total equivalent impedance. For example, if there are 4 nodes connected to the bus and the equivalent impedance is  $375 \Omega$ , then each node impedance should be  $1,500 \Omega$ .

$$Z = Z_1 || Z_2 || \dots || Z_n \quad (1)$$

To determine the suggested inductance value, [式 2](#) can be rearranged to determine  $L_n$ , as shown in [式 3](#).

$$Z_n = 2\pi f_0 L_n \quad (2)$$

$$L_n = \frac{Z_n}{2\pi f_0} \quad (3)$$

$f_0$  is the carrier frequency (OOK frequency) used. If the previous  $1.5 \text{ k}\Omega$  impedance per node is assumed with a carrier frequency of  $1 \text{ MHz}$ , the resulting inductance limit is  $\sim 240 \mu\text{H}$  per node. Be aware that this is the minimum suggested value per node. Refer to [図 9-2](#) as a quick reference on the minimum inductance value to achieve  $375 \Omega$  of total aggregate impedance. This value can be multiplied by the number of nodes on the bus to get the minimum inductance per node. Referring to the previous example, if there are 4 nodes and a carrier frequency of  $1 \text{ MHz}$ , then the minimum aggregate inductance is about  $60 \mu\text{H}$ , which is  $240 \mu\text{H}$  when multiplied by 4.

### 9.2.2.2 Capacitor value selection

Capacitor selection is easier than inductor selection, primarily because capacitance impedance is important to allow higher frequency signals through. However, the capacitor ratings for voltage must be carefully selected to meet the application requirements. Special considerations for hot plug nodes should be made to ensure that voltage transients during hot plugging do not exceed the absolute maximum values. See [セクション 6.1](#).

The number of nodes on the bus does not play into the capacitance calculation. The impedance of a capacitor is shown in [式 4](#).

$$Z = \frac{1}{2\pi f_0 C} \quad (4)$$

Maintaining  $Z \leq 5 \Omega$  keeps the impedance low enough at the carrier frequency to allow data to pass through. If the equation is rearranged to calculate C, the result is shown in 式 5.

$$C = \frac{1}{2\pi f_0 Z} \quad (5)$$

If the previous example of a 1 MHz carrier frequency is used, then a minimum capacitance value of about 32 nF. For a quick reference, refer to 図 9-3.

### 9.2.3 Application Curves

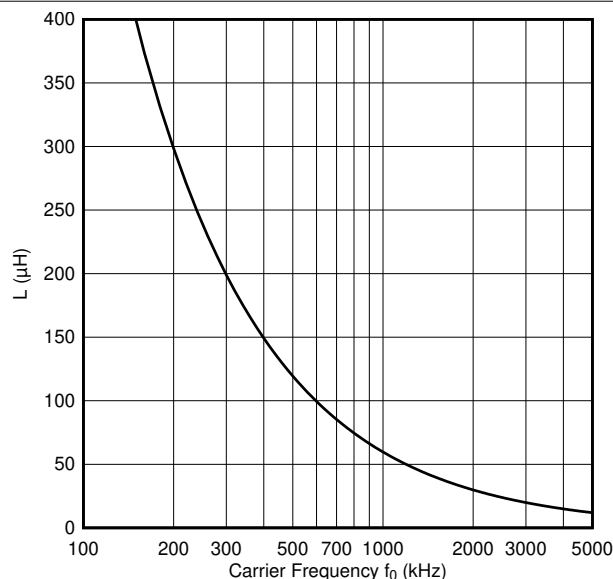


図 9-2. Inductor selection (select values above the line)

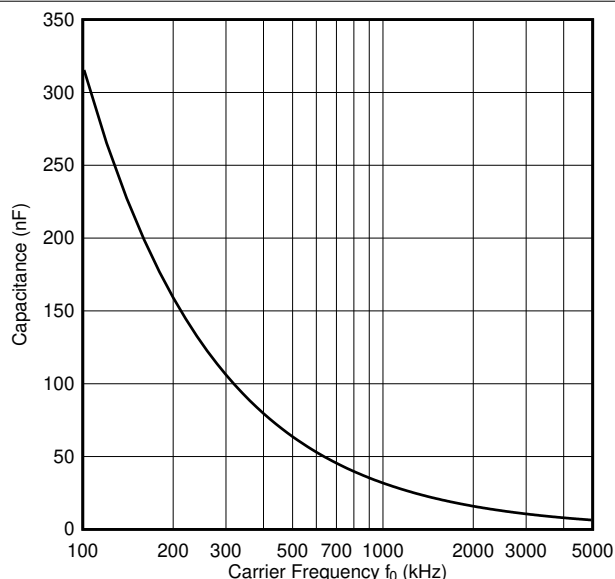


図 9-3. Capacitor selection (select values above the line)

## 10 Power supply recommendations

To ensure reliable operation at all data rates and supply voltages, the supply should be decoupled with a 100 nF to 220 nF ceramic capacitor and a 1 μF capacitor (for ESD sensitive designs) located as close to the supply pins as possible. This helps to reduce supply voltage ripple present on the outputs of switched-mode power supplies and also helps to compensate for the resistance and inductance of the PCB power planes.

## 11 Layout

### 11.1 Layout guidelines

Robust and reliable bus node design often requires the use of external transient protection devices in order to protect against surge transients that may occur in industrial environments. Since these transients have a wide frequency bandwidth (from approximately 3 MHz to 300 MHz), high-frequency layout techniques should be applied during PCB design.

1. Place the protection circuitry close to the bus connector to prevent noise transients from propagating across the board.
2. Use  $V_{CC}$  and ground planes to provide low inductance. Note that high-frequency currents tend to follow the path of least impedance and not the path of least resistance.
3. Place F\_SET components near the pin to keep capacitance load below recommended value
4. Use a pull up or down resistor on mode to set a default state
5. Apply 100-nF to 220-nF decoupling capacitors as close as possible to the  $V_{CC}$  pins of transceiver, UART and/or controller ICs on the board.
6. Use at least two vias for  $V_{CC}$  and ground connections of decoupling capacitors and protection devices to minimize effective via inductance.
7. Use 1-k $\Omega$  to 10-k $\Omega$  pull-up and pull-down resistors for enable lines to limit noise currents in these lines during transient events.
8. Insert pulse-proof resistors into the A and B bus lines if the TVS clamping voltage is higher than the specified maximum voltage of the transceiver bus pins. These resistors limit the residual clamping current into the transceiver and prevent it from latching up.
9. While pure TVS protection is sufficient for surge transients up to 1 kV, higher transients require metal-oxide varistors (MOVs) which reduce the transients to a few hundred volts of clamping voltage, and transient blocking units (TBUs) that limit transient current to less than 1 mA.

### 11.2 Layout Example

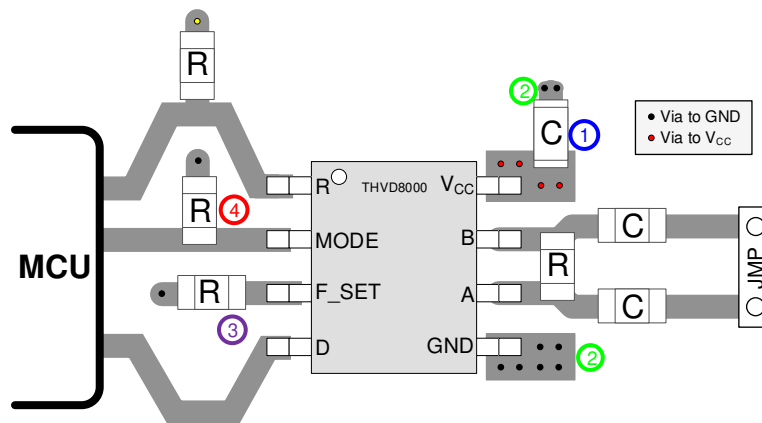


FIG 11-1. Layout Example (OOK)

## 12 Device and Documentation Support

### 12.1 Device Support

### 12.2 ドキュメントの更新通知を受け取る方法

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### 12.3 サポート・リソース

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### 12.6 用語集

[TI 用語集](#) この用語集には、用語や略語の一覧および定義が記載されています。

## 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 part number	Status (1)	Material type (2)	Package   Pins	Package qty   Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
<a href="#">THVD8000DDFR</a>	Active	Production	SOT-23-THIN (DDF)   8	3000   LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	8000
THVD8000DDFR.A	Active	Production	SOT-23-THIN (DDF)   8	3000   LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	8000

- <sup>(1)</sup> **Status:** For more details on status, see our [product life cycle](#).
- <sup>(2)</sup> **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.
- <sup>(3)</sup> **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.
- <sup>(4)</sup> **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.
- <sup>(5)</sup> **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.
- <sup>(6)</sup> **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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## 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
THVD8000DDFR	SOT-23-THIN	DDF	8	3000	180.0	9.5	3.17	3.1	1.1	4.0	8.0	Q3

## TAPE AND REEL BOX DIMENSIONS



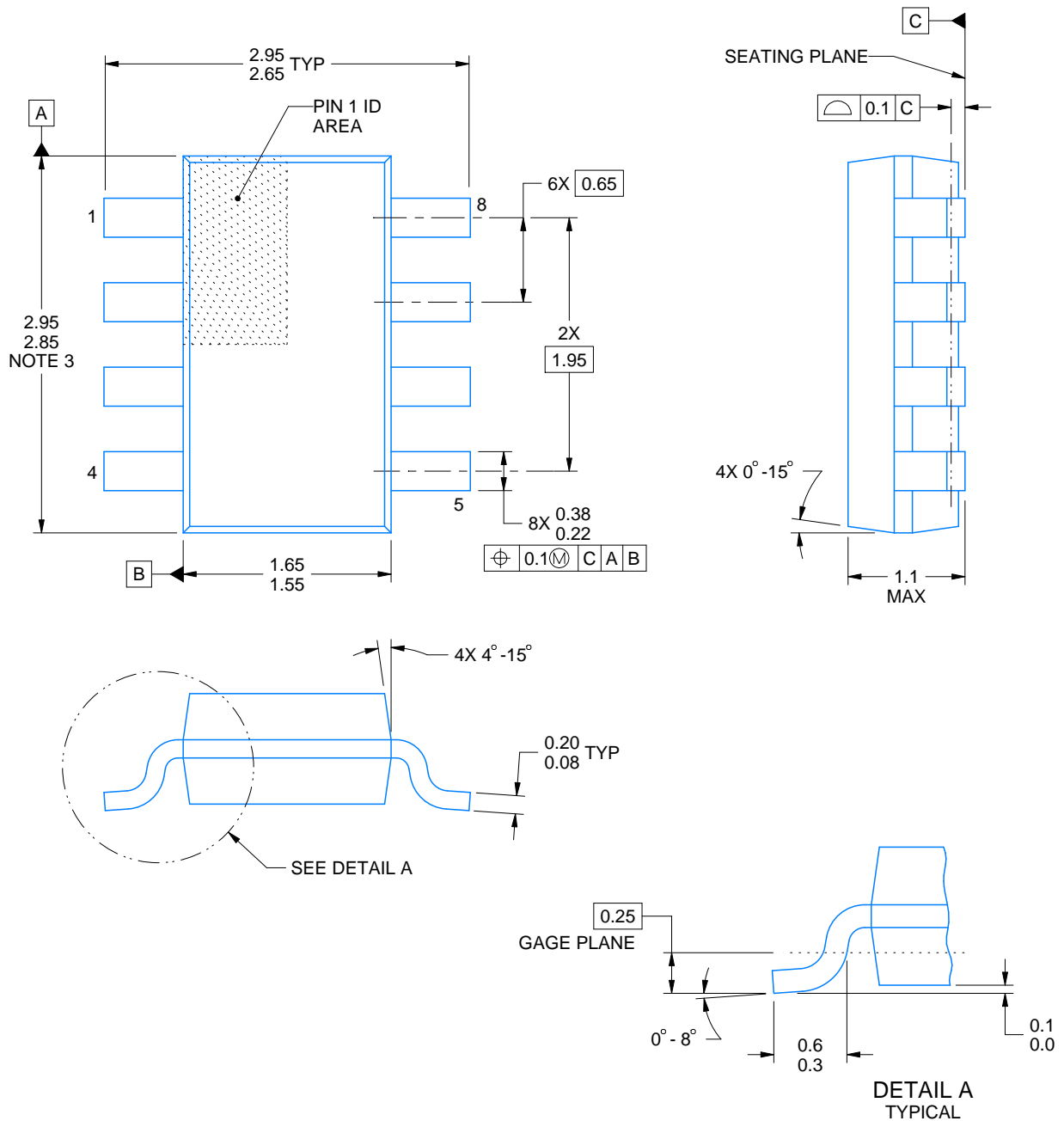
\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
THVD8000DDFR	SOT-23-THIN	DDF	8	3000	205.0	200.0	30.0



**DDF0008A****PACKAGE OUTLINE****SOT-23-THIN - 1.1 mm max height**

PLASTIC SMALL OUTLINE



4222047/E 07/2024

**NOTES:**

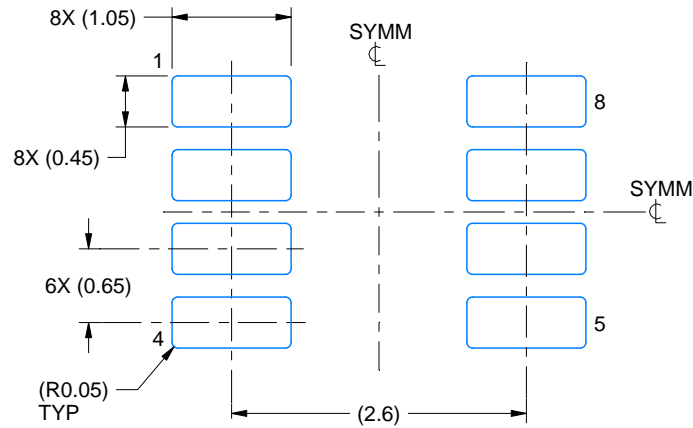
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.

# EXAMPLE BOARD LAYOUT

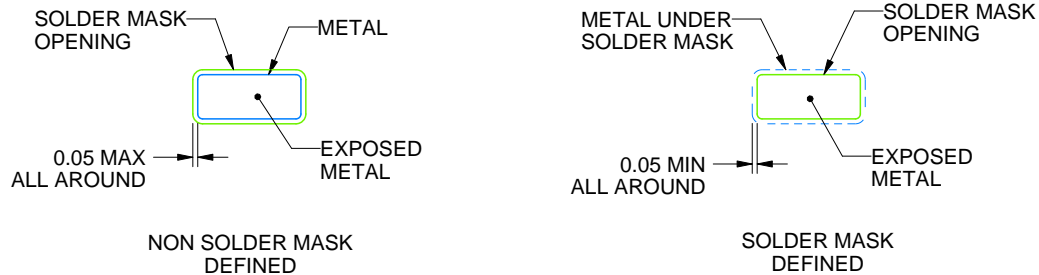
DDF0008A

SOT-23-THIN - 1.1 mm max height

PLASTIC SMALL OUTLINE



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:15X



SOLDER MASK DETAILS

4222047/E 07/2024

NOTES: (continued)

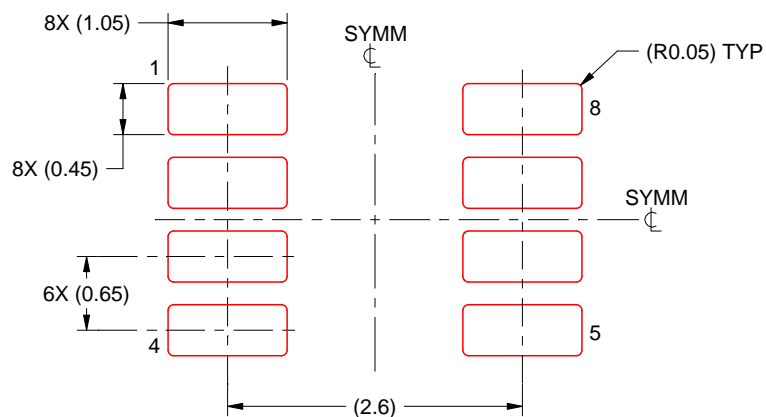
4. Publication IPC-7351 may have alternate designs.
5. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

## EXAMPLE STENCIL DESIGN

DDF0008A

SOT-23-THIN - 1.1 mm max height

PLASTIC SMALL OUTLINE



SOLDER PASTE EXAMPLE  
BASED ON 0.125 mm THICK STENCIL  
SCALE:15X

4222047/E 07/2024

NOTES: (continued)

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

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