

# LIN-Transceiver LDO

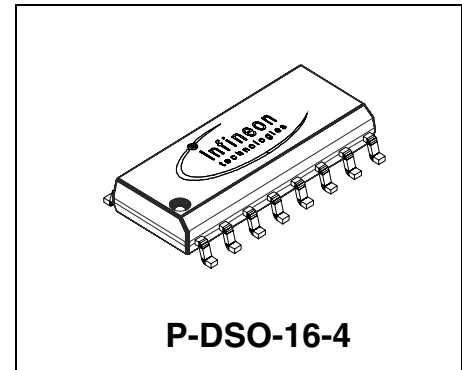
# TLE 6286

## Target Data Sheet

### 1 Overview

#### 1.1 Features

- Single-wire transceiver, suitable for **LIN** protocol
- Transmission rate up to 20 kBaud
- Compatible to LIN specification
- Compatible to ISO 9141 functions
- Very low current consumption in sleep mode
- Control output for voltage regulator
- Short circuit proof to ground and battery
- Overtemperature protection
- Output voltage tolerance  $\leq \pm 2 \%$
- 200 mA output current capability
- Low-drop voltage
- Very low standby current consumption
- Overtemperature protection
- Reverse polarity protection
- Short-circuit proof
- Watchdog
- Wide temperature range
- Suitable for use in automotive electronics



Type	Ordering Code	Package
TLE 6286 G	on request	P-DSO-16-4

#### 1.2 Description

The TLE 6286 is a single-wire transceiver with a LDO. It is chip by chip integrated circuit in a P-DSO-16-4 package. It works as an interface between the protocol controller and the physical bus. The TLE 6286 is especially suitable to drive the bus line in LIN systems in automotive and industrial applications. Further it can be used in standard ISO9141 systems.

In order to reduce the current consumption the TLE 6286 offers a sleep operation mode. In this mode a voltage regulator can be controlled in order to minimize the current consumption of the whole application. The on-chip voltage regulator is designed for this

application but it is also possible to use an external voltage regulator. A wake-up caused by a message on the bus enables the voltage regulator and sets the RxD output low until the device is switched to normal operation mode.

The IC is based on the Smart Power Technology SPT® which allows bipolar and CMOS control circuitry in accordance with DMOS power devices existing on the same monolithic circuit.

The TLE 6286 is designed to withstand the severe conditions of automotive applications.

### 1.3 Pin Configuration (top view)

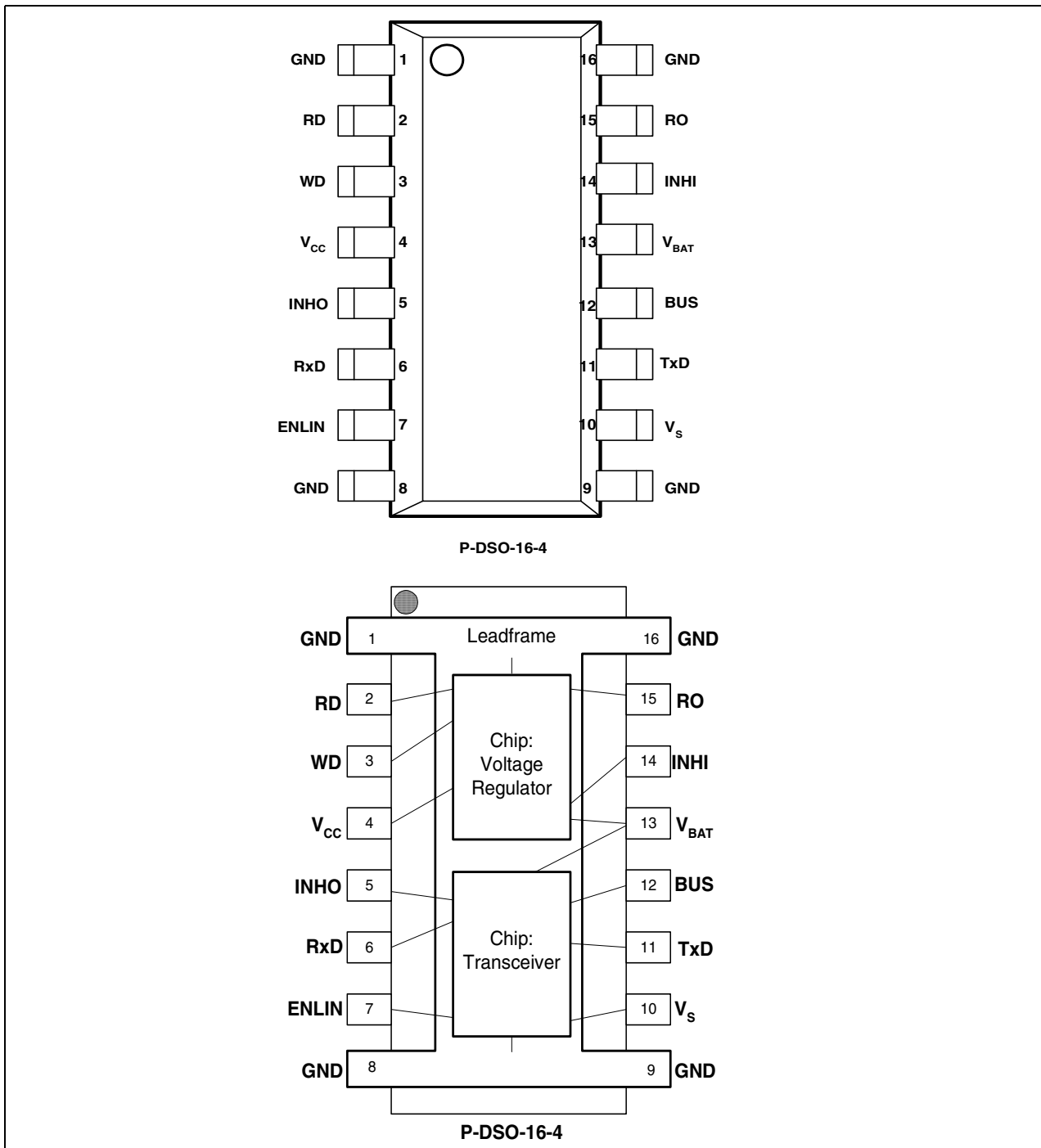


Figure 1 Pinout

#### 1.4 Pin Definitions and Functions:

Pin No.	Symbol	Function
1,8,9,16	GND	<b>Ground</b> ; place to cooling tabs to improve thermal behavior
2	RD	<b>Reset delay</b> ; connected to ground with capacitor
3	WD	<b>Window Watchdog</b> ; rising-edge triggered, for monitoring a microcontroller
4	V <sub>CC</sub>	<b>5V Output</b> ; connected to GND with 22μF capacitor, ESC<3Ω
5	INH0	<b>Inhibit LIN Output</b> ; to control a voltage regulator
6	RxD	<b>Receive Data Output</b> ; internal 30kΩ pull up to V <sub>s</sub> , LOW in dominant state
7	ENLIN	<b>Enable LIN Input</b> ; integrated 30kΩ pull down, transceiver in normal operation mode when HIGH
10	V <sub>s</sub>	<b>5V Supply Input</b> ; V <sub>CC</sub> input to supply the LIN transceiver
11	TxD	<b>Transmit Data Input</b> ; internal 30kΩ pull up to V <sub>s</sub> , LOW in dominant state
12	BUS	<b>LIN BUS Output/Input</b> ; internal 30kΩ pull up to V <sub>s</sub> , LOW in dominant state
13	V <sub>BAT</sub>	<b>Battery Supply Input</b> ; a reverse current protection diode is required, block GND with 100nF ceramic capacitor and 22μF capacitor
14	INH1	<b>Inhibit Voltage Regulator Input</b> ; TTL compatible, low active input
15	RO	<b>Reset Output</b> ; open collector output connected to the output via a resistor of 30kΩ

### 1.5 Functional Block Diagram

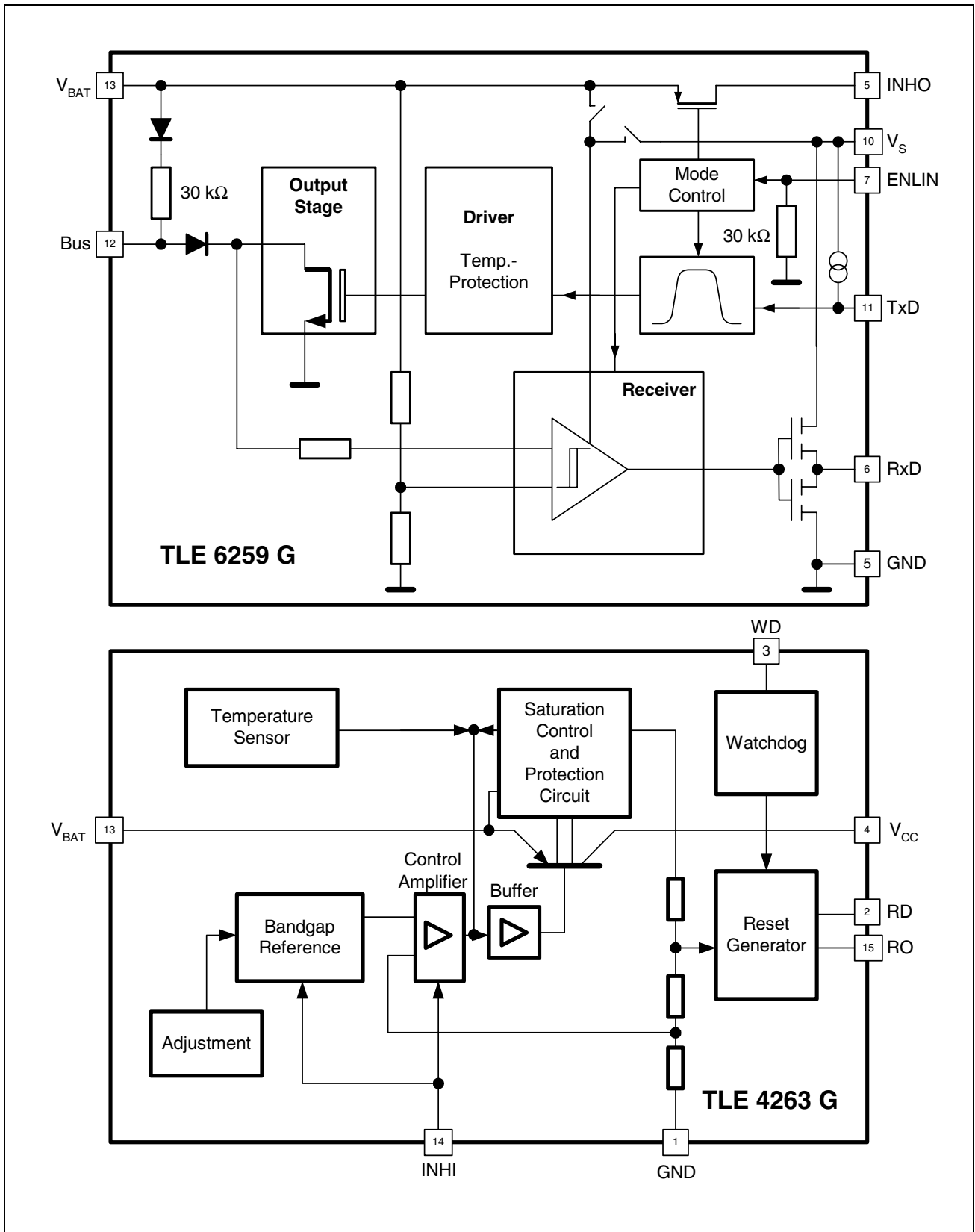


Figure 2 Block Diagram

## 2 Circuit Description

The TLE 6286 is a single-wire transceiver combined with a LDO. It is a chip by chip integrated circuit in a P-DSO-16-4 package. It works as an interface between the protocol controller and the physical bus. The TLE 6286 is especially suitable to drive the bus line in LIN systems in automotive and industrial applications. Further it can be used in standard ISO9141 systems. The on-chip voltage regulator with watchdog is designed for sleep mode applications but it is also possible to use an external voltage regulator.

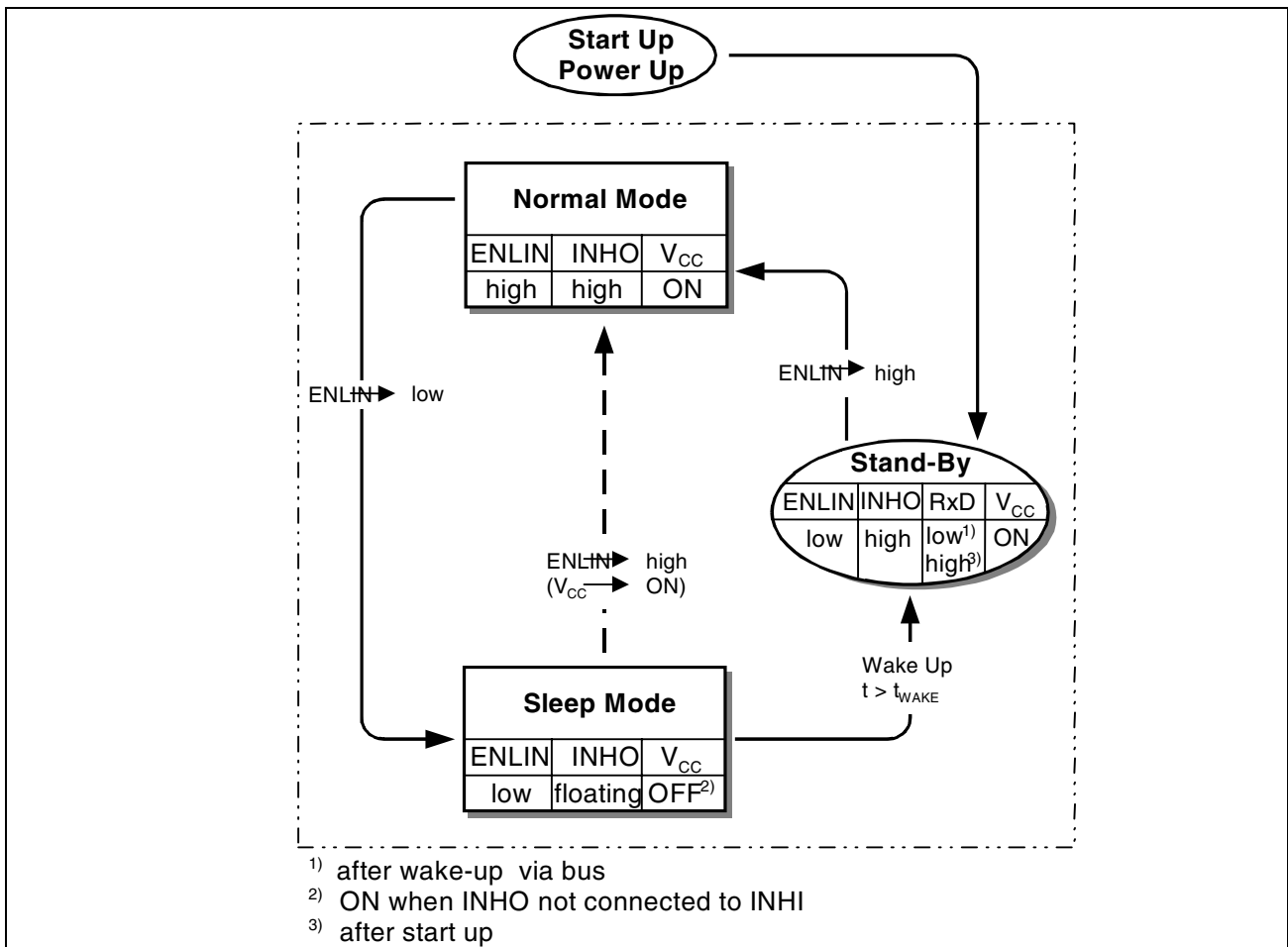


Figure 3 Operation Mode State Diagram

### 2.1 Operation Modes

In order to reduce the current consumption the TLE 6286 offers a sleep operation mode. This mode is selected by switching the enable input EN low (see figure 3, state diagram). In the sleep mode a voltage regulator can be controlled via the INH output in order to minimize the current consumption of the whole application. A wake-up caused by a message on the communication bus automatically enables the voltage regulator by switching the INH output high. In parallel the wake-up is indicated by setting the RxD output low. When entering the normal mode this wake-up flag is reset and the RxD output is released to transmit the bus data.

In case the voltage regulator control input is not connected to INH output or the microcontroller is active respectively, the TLE6286 can be set in normal operation mode without a wake-up via the communication bus.

## 2.2 LIN Transceiver

The LIN Transceiver has already a pull up resistor of 30k $\Omega$  as termination implemented. There is also a diode in this path, to protect the circuit from feedback of voltages from the bus line to the power supply. To configure the TLE 6286 as a master node, an additional external termination resistor of 1k $\Omega$  is required. To avoid reverse currents from the bus line into the battery supply line in case of an unpowered node, it is also recommended to place a diode in series to the external pull up. For small systems (low bus capacitance) the EMC performance of the system is supported by an additional capacitor of at least 1nF in the master node (see figure 6, application circuit).

An capacitor of 10 $\mu$ F at the supply voltage input  $V_S$  buffers the input voltage. In combination with the required reverse polarity diode this prevents the device from detecting power down conditions in case of negative transients on the supply line.

## 2.3 Voltage Regulator

The control amplifier compares a reference voltage, which is kept highly accurate by resistance adjustment, to a voltage that is proportional to the output voltage and drives the base of the series transistor via a buffer. Saturation control as a function of the load current prevents any over-saturation of the power element. If the externally scaled down output voltage at the reset threshold input drops below 1.35 V, the external reset delay capacitor is discharged by the reset generator. When the voltage of the capacitor reaches the lower threshold  $V_{DRL}$ , a reset signal occurs at the reset output and is held until the upper threshold  $V_{DU}$  is exceeded. If the reset threshold input is connected to GND, reset is triggered at an output voltage of typ. 4.65 V. A connected microcontroller will be monitored through the watchdog logic. In case of missing pulses at pin W, the reset output is set to low. The pulse sequence time can be set in a wide range with the reset delay capacitor. The IC can be switched at the TTL-compatible, low-active inhibit input. The IC also incorporates a number of internal circuits for protection against overload, overtemperature, reverse polarity

## 2.4 Input Capacitor

The input capacitor  $C_I$  is necessary for compensation of line influences. Using a resistor of approx. 1  $\Omega$  in series with  $C_I$ , the oscillating circuit consisting of input inductivity and input capacitance can be damped. The output capacitor is necessary for the stability of the regulating circuit. Stability is guaranteed at values  $\geq 22 \mu$ F and an ESR of  $\leq 3 \Omega$  within the operating temperature range. For small tolerances of the reset delay the spread of the capacitance of the delay capacitor and its temperature coefficient should be noted.

## 2.5 Reset Timing

The power-on reset delay time is defined by the charging time of an external capacitor  $C_D$  which can be calculated as follows:

$$C_D = (t_{rd} \times I_{D,ch}) / \Delta V$$

Definitions:  $C_D$  = delay capacitor

$t_{rd}$  = reset delay time

$I_{D,ch}$  = charge current, typical 60  $\mu A$

$\Delta V$  =  $V_{DU}$ , typical 1.70 V

$V_{DU}$  = upper delay switching threshold at  $C_D$  for reset delay time

## 2.6 Watchdog Timing

The frequency of the watchdog pulses has to be higher than the minimum pulse sequence which is set by the external reset delay capacitor  $C_D$ . Calculation can be done according to the formulas given in **Figure 5**.



### 3 Electrical Characteristics

#### 3.1 Absolute Maximum Ratings

Parameter	Symbol	Limit Values		Unit	Remarks
		min.	max.		

#### Voltages

Supply voltage	$V_{CC}$	-0.3	6	V	
Battery supply voltage	$V_S$	-0.3	40	V	
Bus input voltage	$V_{bus}$	-20	32	V	
Bus input voltage	$V_{bus}$	-20	40	V	$t < 1 \text{ s}$
Logic voltages at EN, TxD, RxD	$V_I$	-0.3	$V_{CC} + 0.3$	V	$0 \text{ V} < V_{CC} < 5.5 \text{ V}$
Input voltages at INH	$V_{INH}$	-0.3	$V_S + 0.3$	V	
Output current at INH	$I_{INH}$		1	mA	
Reset output voltage	$V_R$	- 0.3	42	V	-
Reset delay voltage	$V_D$	- 0.3	42	V	
Output voltage Vcc	$V_Q$	- 0.3	7	V	-
INHIBIT voltage	$V_{INH}$	- 42	45	V	-
Watchdog voltage	$V_W$	- 0.3	6	V	-
Electrostatic discharge voltage at Vs, Bus	$V_{ESD}$	-4	4	kV	human body model (100 pF via 1.5 k $\Omega$ )
Electrostatic discharge voltage	$V_{ESD}$	-2	2	kV	human body model (100 pF via 1.5 k $\Omega$ )
<b>Temperatures</b>					
Junction temperature	$T_j$	-40	150	$^{\circ}\text{C}$	-

*Note: Maximum ratings are absolute ratings; exceeding any one of these values may cause irreversible damage to the integrated circuit.*

### 3.2 Operating Range

Parameter	Symbol	Limit Values		Unit	Remarks
		min.	max.		
Supply voltage	$V_{CC}$	4.5	5.5	V	
Battery Supply Voltage	$V_S$	6	20	V	
Junction temperature	$T_j$	- 40	150	°C	-

#### Thermal Shutdown (junction temperature)

Thermal shutdown temp.	$T_{jSD}$	150	170	190	°C
Thermal shutdown hyst.	$\Delta T$	-	10	-	K

#### Thermal Resistances

Junction ambient	$R_{thj-a}$	-	115	K/W	-
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### 3.3 Electrical Characteristics

4.5 V <  $V_{CC}$  < 5.5 V; 6.0 V <  $V_S$  < 20 V;  $R_L = 1\text{ k}\Omega$ ;  $V_{EN} > V_{EN,ON}$ ;  $-40\text{ }^\circ\text{C} < T_j < 125\text{ }^\circ\text{C}$ ; all voltages with respect to ground; positive current flowing into pin; unless otherwise specified.

Parameter	Symbol	Limit Values			Unit	Remarks
		min.	typ.	max.		

#### Current Consumption

Current consumption	$I_{CC}$		0.5	1.5	mA	recessive state; $V_{TxD} = V_{CC}$
Current consumption	$I_S$		0.5	1.0	mA	recessive state; $V_{TxD} = V_{CC}$
Current consumption	$I_{CC}$		0.7	2.0	mA	dominant state; $V_{TxD} = 0\text{ V}$
Current consumption	$I_S$		0.7	1.5	mA	dominant state; $V_{TxD} = 0\text{ V}$
Current consumption	$I_S$		20	30	$\mu\text{A}$	sleep mode; $T_j = 25\text{ }^\circ\text{C}$
Current consumption	$I_S$		20	40	$\mu\text{A}$	sleep mode

#### Receiver Output RxD

HIGH level output current	$I_{RD,H}$		-0.7	-0.4	mA	$V_{RD} = 0.8 \times V_{CC}$ ,
LOW level output current	$I_{RD,L}$	0.4	0.7		mA	$V_{RD} = 0.2 \times V_{CC}$ ,

#### Bus receiver

Receiver threshold voltage, recessive to dominant edge	$V_{bus,rd}$	0.44 $\times V_S$	0.48 $\times V_S$		V	$-8\text{ V} < V_{bus} < V_{bus,dom}$
Receiver threshold voltage, dominant to recessive edge	$V_{bus,dr}$		0.52 $\times V_S$	0.56 $\times V_S$	V	$V_{bus,rec} < V_{bus} < 20\text{ V}$
Receiver hysteresis	$V_{bus,hys}$	0.02 $\times V_S$	0.04 $\times V_S$	0.06 $\times V_S$	mV	$V_{bus,hys} = V_{bus,rec} - V_{bus,dom}$
wake-up threshold voltage	$V_{wake}$	0.40 $\times V_S$	0.55 $\times V_S$	0.70 $\times V_S$	V	

#### Transmission Input TxD

HIGH level input voltage threshold	$V_{TD,H}$		2.9	0.7 $\times$ $V_{CC}$	V	recessive state
TxD input hysteresis	$V_{TD,hys}$	300	600		mV	

### 3.3 Electrical Characteristics (cont'd)

4.5 V <  $V_{CC}$  < 5.5 V; 6.0 V <  $V_S$  < 20 V;  $R_L = 1\text{ k}\Omega$ ;  $V_{EN} > V_{EN,ON}$ ;  $-40\text{ }^\circ\text{C} < T_j < 125\text{ }^\circ\text{C}$ ; all voltages with respect to ground; positive current flowing into pin; unless otherwise specified.

Parameter	Symbol	Limit Values			Unit	Remarks
		min.	typ.	max.		
LOW level input voltage threshold	$V_{TD,L}$	0.3 x $V_{CC}$	2.1		V	dominant state
TxD pull up current	$I_{TD}$	-150	-110	-80	$\mu\text{A}$	$V_{TxD} < 0.3 V_{CC}$

#### Bus transmitter

Bus recessive output voltage	$V_{bus,rec}$	0.9 x $V_S$		$V_S$	V	$V_{TxD} = V_{CC}$
Bus dominant output voltage	$V_{bus,dom}$	0		1.5	V	$V_{TxD} = 0\text{ V}$ ;
Bus short circuit current	$I_{bus,sc}$	40	85	125	mA	$V_{bus,short} = 13.5\text{ V}$
Leakage current	$I_{bus,lk}$	-350	-100		$\mu\text{A}$	$V_{CC} = 0\text{ V}$ , $V_S = 0\text{ V}$ , $V_{bus} = -8\text{ V}$ , $T_j < 85\text{ }^\circ\text{C}$
			5	20	$\mu\text{A}$	$V_{CC} = 0\text{ V}$ , $V_S = 0\text{ V}$ , $V_{bus} = 20\text{ V}$ , $T_j < 85\text{ }^\circ\text{C}$
Bus pull up resistance	$R_{bus}$	20	30	47	k $\Omega$	

#### Enable input (pin ENLIN)

HIGH level input voltage threshold	$V_{EN,on}$		2.8	0.7 x $V_{CC}$	V	normal mode
LOW level input voltage threshold	$V_{EN,off}$	0.3 x $V_{CC}$	2.2		V	low power mode
EN input hysteresis	$V_{EN,hys}$	300	600		mV	
EN pull down resistance	$R_{EN}$	15	30	60	k $\Omega$	

#### Inhibit output (pin INHO)

HIGH level drop voltage $\Delta V_{INH} = V_S - V_{INH}$	$\Delta V_{INH}$		0.5	1.0	V	$I_{INH} = -0.15\text{ mA}$
Leakage current	$I_{INH,lk}$	- 5.0		5.0	$\mu\text{A}$	sleep mode; $V_{INHO} = 0\text{ V}$

### 3.3 Electrical Characteristics (cont'd)

4.5 V < V<sub>CC</sub> < 5.5 V; 6.0 V < V<sub>S</sub> < 20 V; R<sub>L</sub> = 1 kΩ; V<sub>EN</sub> > V<sub>EN,ON</sub>; -40 °C < T<sub>j</sub> < 125 °C; all voltages with respect to ground; positive current flowing into pin; unless otherwise specified.

Parameter	Symbol	Limit Values			Unit	Remarks
		min.	typ.	max.		

#### Vcc Output (pin Vcc)

Output voltage	V <sub>Q</sub>	4.90	5.00	5.10	V	5 mA ≤ I <sub>Q</sub> ≤ 150 mA; 6 V ≤ V <sub>I</sub> ≤ 28 V
Output voltage	V <sub>Q</sub>	4.90	5.00	5.10	V	6 V ≤ V <sub>I</sub> ≤ 32 V; I <sub>Q</sub> = 100 mA; T <sub>j</sub> = 100 °C
Output current	I <sub>Q</sub>	200	250	–	mA	1)
Current consumption; I <sub>q</sub> = I <sub>I</sub> – I <sub>Q</sub>	I <sub>q</sub>	–	0	50	μA	V <sub>INH</sub> = 0
	I <sub>q</sub>	–	900	1300	μA	I <sub>Q</sub> = 0 mA
	I <sub>q</sub>	–	10	18	mA	I <sub>Q</sub> = 150 mA
	I <sub>q</sub>	–	15	23	mA	I <sub>Q</sub> = 150 mA; V <sub>I</sub> = 4.5 V
Drop voltage	V <sub>dr</sub>	–	0.35	0.50	V	I <sub>Q</sub> = 150 mA <sup>1)</sup>
Load regulation	ΔV <sub>Q,lo</sub>	–	–	25	mV	I <sub>Q</sub> = 5 mA to 150 mA
Line regulation	ΔV <sub>Q,li</sub>	–	3	25	mV	V <sub>I</sub> = 6 V to 28 V; I <sub>Q</sub> = 150 mA
Power Supply Ripple Rejection	PSRR	–	54	–	dB	f <sub>r</sub> = 100 Hz; V <sub>r</sub> = 0.5 V <sub>PP</sub>

#### Reset Generator (pin RD)

Switching threshold	V <sub>Q,rt</sub>	4.5	4.65	4.8	V	
Reset adjust threshold	V <sub>RADJ,th</sub>	1.26	1.35	1.44	V	V <sub>Q</sub> > 3.5 V
Reset low voltage	V <sub>RO,l</sub>	–	0.10	0.40	V	I <sub>RO</sub> = 1 mA
Saturation voltage	V <sub>D,sat</sub>	–	50	100	mV	V <sub>Q</sub> < V <sub>R,th</sub>
Upper timing threshold	V <sub>DU</sub>	1.45	1.70	2.05	V	–
Lower reset timing threshold	V <sub>DRL</sub>	0.20	0.35	0.55	V	–
Charge current	I <sub>D,ch</sub>	40	60	85	μA	–
Reset delay time	t <sub>rd</sub>	1.3	2.8	4.1	ms	C <sub>D</sub> = 100 nF
Reset reaction time	t <sub>rr</sub>	0.5	1.2	4	μs	C <sub>D</sub> = 100 nF

### 3.3 Electrical Characteristics (cont'd)

4.5 V <  $V_{CC}$  < 5.5 V; 6.0 V <  $V_S$  < 20 V;  $R_L = 1\text{ k}\Omega$ ;  $V_{EN} > V_{EN,ON}$ ;  $-40\text{ }^\circ\text{C} < T_j < 125\text{ }^\circ\text{C}$ ; all voltages with respect to ground; positive current flowing into pin; unless otherwise specified.

Parameter	Symbol	Limit Values			Unit	Remarks
		min.	typ.	max.		

#### Watchdog (pin WD)

Discharge current	$I_{D,wd}$	4.40	6.25	9.10	$\mu\text{A}$	$V_D = 1.0\text{ V}$
Upper timing threshold	$V_{DU}$	1.45	1.70	2.05	V	–
Lower timing threshold	$V_{DWL}$	0.20	0.35	0.55	V	–
Watchdog trigger time	$T_{WI,tr}$	16	22.5	27	ms	$C_D = 100\text{ nF}$

#### Inhibit Input (INH)

Switching voltage	$V_{INH,ON}$	3.6	–	–	V	IC turned on
Turn-OFF voltage	$V_{INH,OFF}$	–	–	0.8	V	IC turned off
Input current	$I_{INH}$	5	10	25	$\mu\text{A}$	$V_{INH} = 5\text{ V}$

**Note:** The reset output is low within the range  $V_Q = 1\text{ V}$  to  $V_{Q,rt}$   
<sup>1)</sup>Drop voltage =  $V_i - V_Q$  (measured when the output voltage has dropped 100 mV from the nominal value obtained at 6 V input)

### 3.3 Electrical Characteristics (cont'd)

4.5 V < V<sub>CC</sub> < 5.5 V; 6.0 V < V<sub>S</sub> < 20 V; R<sub>L</sub> = 1 kΩ; V<sub>EN</sub> > V<sub>EN,ON</sub>; -40 °C < T<sub>j</sub> < 125 °C; all voltages with respect to ground; positive current flowing into pin; unless otherwise specified.

Parameter	Symbol	Limit Values			Unit	Remarks
		min.	typ.	max.		

#### Dynamic Transceiver Characteristics

falling edge slew rate	S <sub>bus(L)</sub>	-3	-2.0	-1	V/μs	80% > V <sub>bus</sub> > 20% C <sub>bus</sub> = 3.3 nF; T <sub>ambient</sub> < 85 °C; V <sub>CC</sub> = 5 V; V <sub>S</sub> = 13.5 V
rising edge slew rate	S <sub>bus(H)</sub>	1	1.5	3	V/μs	20% < V <sub>bus</sub> < 80% C <sub>bus</sub> = 3.3 nF; V <sub>CC</sub> = 5 V; V <sub>S</sub> = 13.5 V
Propagation delay TxD-to-RxD LOW (recessive to dominant)	t <sub>d(L),TR</sub>	2	5	10	μs	C <sub>bus</sub> = 3.3nF; V <sub>CC</sub> = 5 V; V <sub>S</sub> = 13.5 V C <sub>RxD</sub> = 20 pF
Propagation delay TxD-to-RxD HIGH (dominant to recessive)	t <sub>d(H),TR</sub>	2	5	10	μs	C <sub>bus</sub> = 3.3 nF; V <sub>CC</sub> = 5 V; V <sub>S</sub> = 13.5 V C <sub>RxD</sub> = 20 nF
Propagation delay TxD LOW to bus	t <sub>d(L),T</sub>		1	4	μs	V <sub>CC</sub> = 5 V
Propagation delay TxD HIGH to bus	t <sub>d(H),T</sub>		1	4	μs	V <sub>CC</sub> = 5 V
Propagation delay bus dominant to RxD LOW	t <sub>d(L),R</sub>		1	4	μs	V <sub>CC</sub> = 5V; C <sub>RxD</sub> = 20pF
Propagation delay bus recessive to RxD HIGH	t <sub>d(H),R</sub>		1	4	μs	V <sub>CC</sub> = 5 V; C <sub>RxD</sub> = 20 pF
Receiver delay symmetry	t <sub>sym,R</sub>	-2		2	μs	t <sub>sym,R</sub> = t <sub>d(L),R</sub> - t <sub>d(H),R</sub>
Transmitter delay symmetry	t <sub>sym,T</sub>	-2		2	μs	t <sub>sym,T</sub> = t <sub>d(L),T</sub> - t <sub>d(H),T</sub>
Wake-up delay time	t <sub>wake</sub>	30	100	200	μs	

#### 4 Diagrams

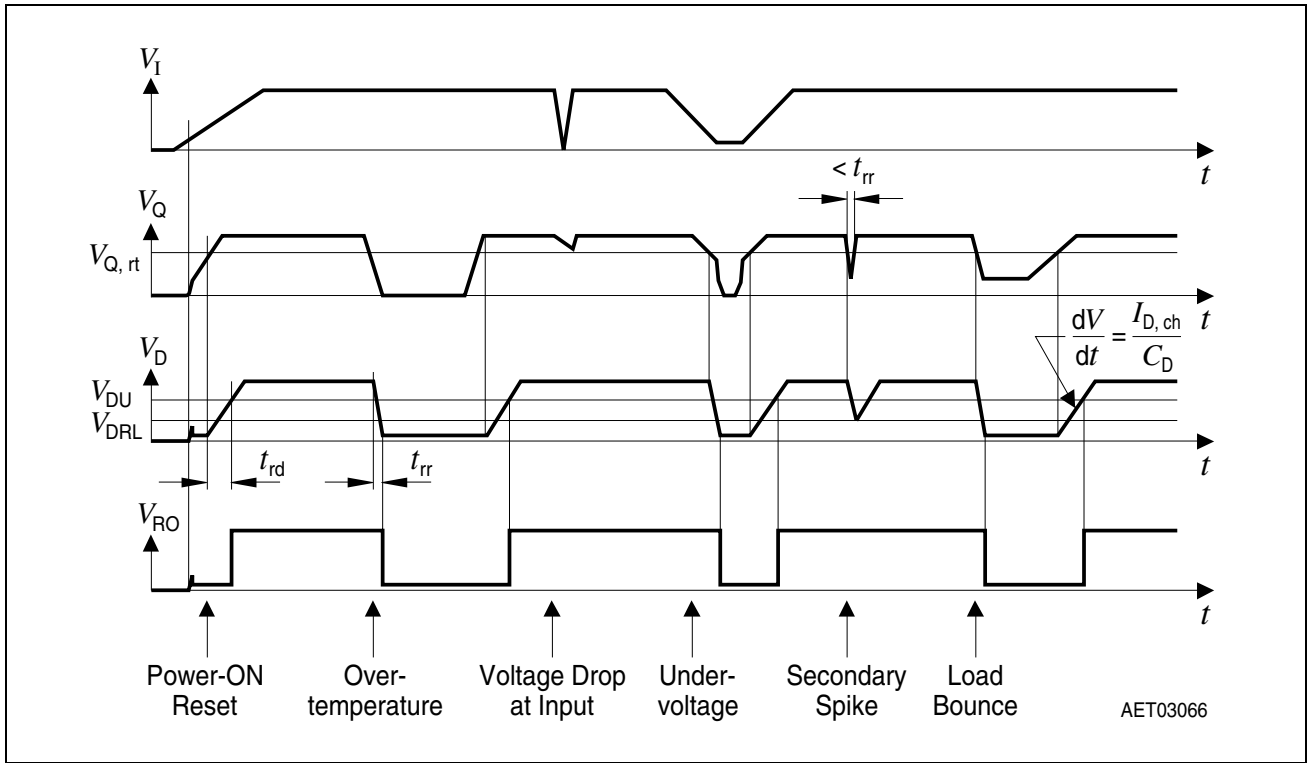


Figure 4 Time Response, Watchdog with High-Frequency Clock

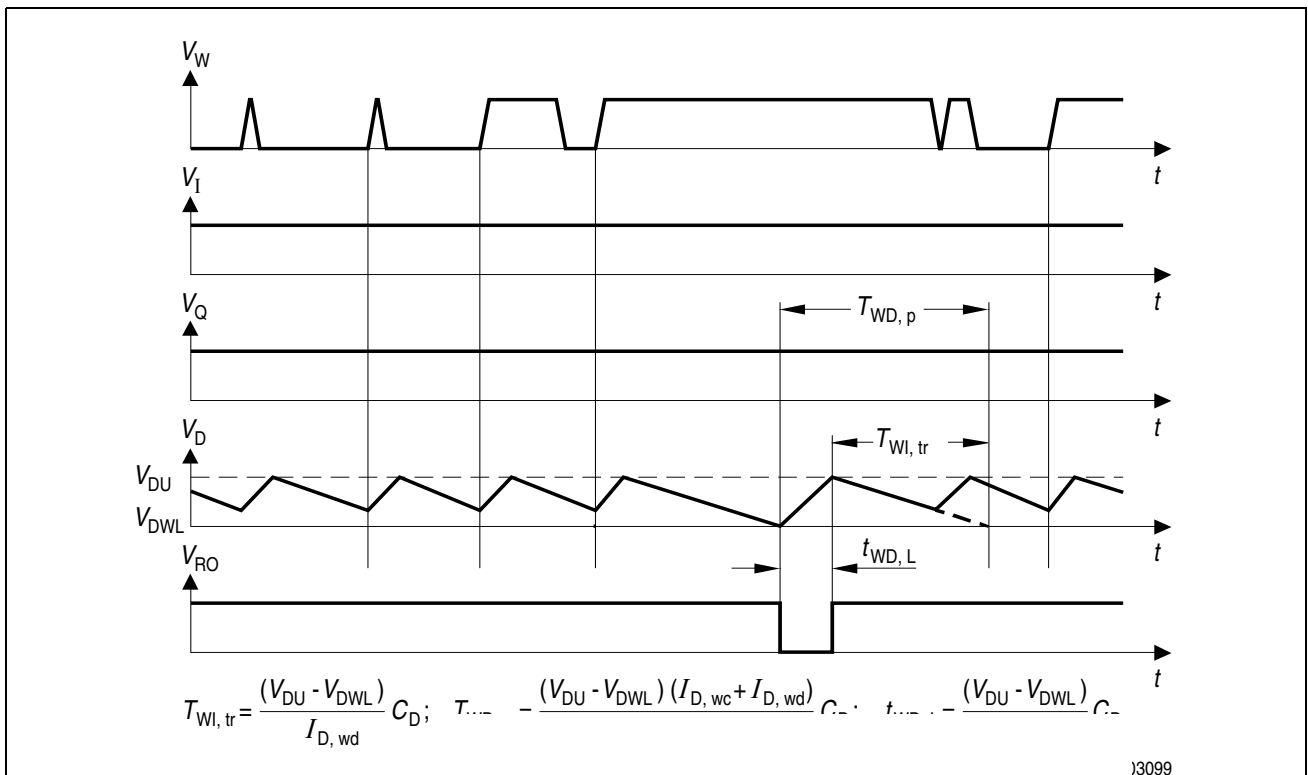


Figure 5 Timing of the Watchdog Function Reset



## 5 Application

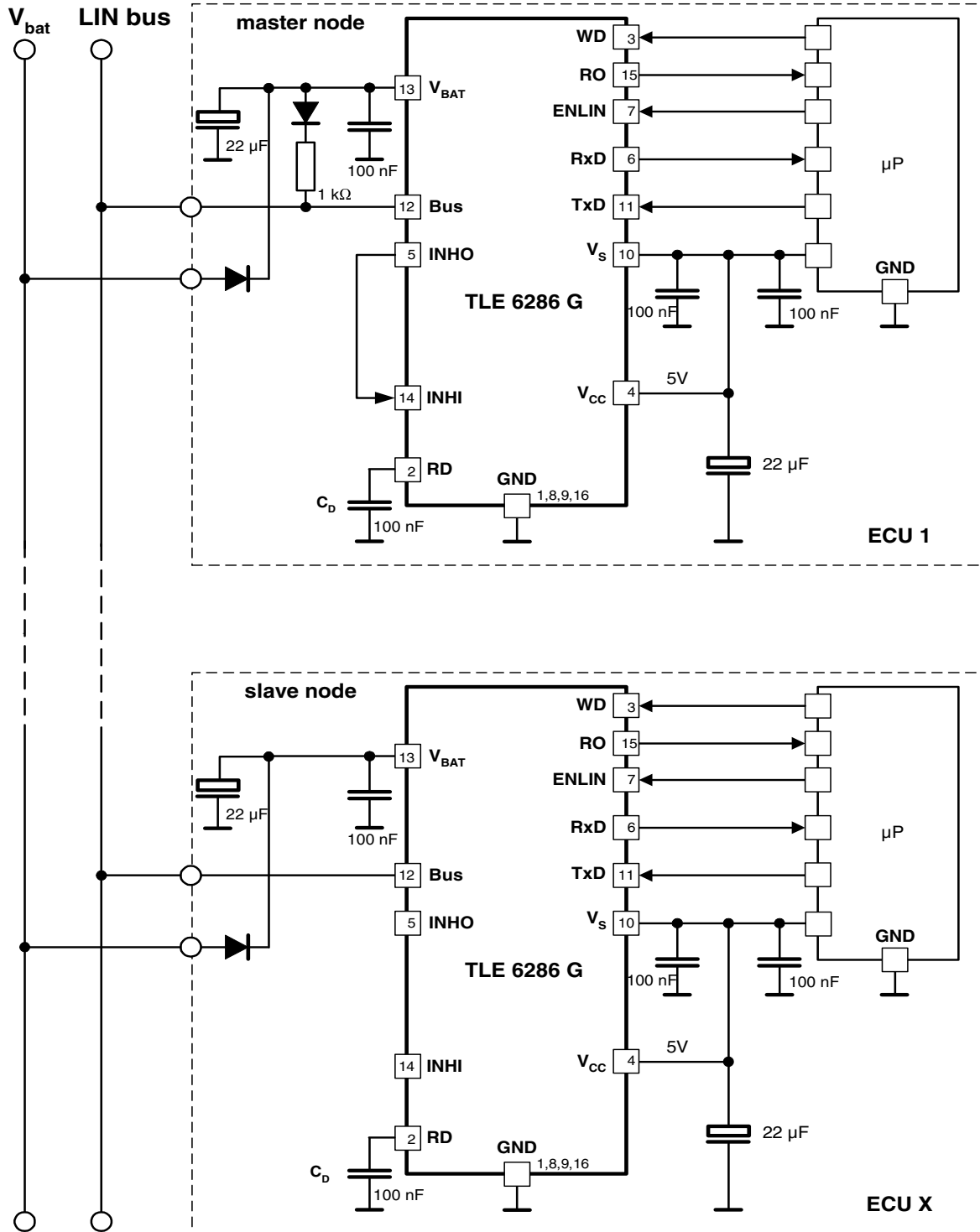


Figure 6 Application Circuit

## 6 Package Outlines

**P-DSO-16-4**  
(Plastic Dual Small Outline Package)

**Pictures of the housing will be added in near future!**

### **Sorts of Packing**

Package outlines for tubes, trays etc. are contained in our Data Book "Package Information".

SMD = Surface Mounted Device

Dimensions in mm

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