Freescale Semiconductor Technical Data

Local Interconnect Network (LIN) Enhanced Physical Interface with Selectable Slew-Rate

Local interconnect network (LIN) is a serial communication protocol designed to support automotive networks in conjunction with controller area network (CAN). As the lowest level of a hierarchical network, LIN enables cost-effective communication with sensors and actuators when all the features of CAN are not required. This device is powered by SMARTMOS technology.

The 33661 is a physical layer component dedicated to automotive LIN sub-bus applications. It offers slew-rate selection for optimized operation at 10 kbps and 20 kbps, fast baud rate (above 100 kbps) for test and programming modes, excellent radiated emission performance, and safe behavior in the event of LIN bus short-to-ground or LIN bus leakage during low power mode.

The 33661 is compatible with LIN Protocol Specification 2.0.

Features

- Operational from V_{SUP} 6.0 V to 18 V DC, functional up to 27 V DC, and handles 40 V during load dump
- Active bus waveshaping offering excellent radiated emission performance
- 5.0 kV ESD on LIN bus pin
- 30 kΩ internal pull-up resistor
- LIN bus short-to-ground or high leakage in Sleep mode
- -18 V to +40 V DC voltage at LIN pin
- 8.0 µA in Sleep mode
- · Local and remote wake-up capability reported by INH and RXD pins
- 5.0 V and 3.3 V compatible digital inputs without any external components required



Document Number: MC33661

33661

LIN PHYSICAL INTERFACE



ORDERING INFORMATION							
Device (For Tape and Reel, add an R2 Suffix)	Temperature Range (T _A)	Package					
MC33661PEF	-40 to 125°C	8 SOICN					



Figure 1. 33661 Simplified Application Diagram

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Figure 2. 33661 Simplified Internal Block Diagram

PIN CONNECTIONS



Figure 3. 33661 8-SOICN Pin Connections

Table 1. 33661 8-SOICN Pin Definitions

A functional description of each pin can be found in the Functional Pin Description section beginning on page page 12.

Pin	Pin Name	Formal Name	Definition
1	RXD	Data Output	MCU interface that reports the state of the LIN bus voltage.
2	EN	Enable Control	Controls the operation mode of the interface.
3	WAKE	Wake Input	High-voltage input used to wake-up the device from Sleep mode.
4	TXD	Data Input	MCU interface to control the state of the LIN output.
5	GND	Ground	Device ground pin.
6	LIN	LIN Bus	Bidirectional pin that represents the single-wire bus transmitter and receiver.
7	VSUP	Power Supply	Device power supply pin.
8	INH	Inhibit Output	This pin can have two main functions: controlling an external switchable voltage regulator having an inhibit input or driving a bus external resistor in the master node application.

ELECTRICAL CHARACTERISTICS

MAXIMUM RATINGS

Table 2. Maximum Ratings

All voltages are with respect to ground, unless otherwise noted. Exceeding these ratings may cause a malfunction or permanent damage to the device.

Ratings	Symbol	Value	Unit
ELECTRICAL RATINGS			
Power Supply Voltage	V _{SUP}		V
Continuous Supply Voltage		27	
Transient Voltage (Load Dump)		40	
WAKE DC and Transient Voltage (Through a 33 k Ω Serial Resistor)	V _{WAKE}	-18 to 40	V
Logic Voltage (RXD, TXD, EN Pins)	V _{LOG}	-0.3 to 5.5	V
LIN Bus Voltage	V _{BUS}		V
DC Voltage		-18 to 40	
Transient (Coupled Through 1.0 nF Capacitor)		-150 to 100	
INH Voltage/Current			
DC Voltage	V _{INH}	-0.3 to V _{SUP} + 0.3	V
DC Current	I _{INH}	40	mA
ESD Voltage ⁽¹⁾	V _{ESD1}		V
Human Body Model			
All Pins		±2000	
LIN Pin with Respect to Ground		±5000	
Machine Model	V _{ESD2}	±200	
THERMAL RATINGS			

Operating Temperature			°C
Ambient	T _A	-40 to 125	
Junction	Τ _J	-40 to 150	
Storage Temperature	T _{STG}	-55 to 150	°C
Thermal Resistance, Junction to Ambient	$R_{ hetaJA}$	150	°C/W
Peak Package Reflow Temperature During Reflow ⁽²⁾ , ⁽³⁾	T _{PPRT}	Note 3	°C
Thermal Shutdown Temperature	T _{SHUT}	150 to 200	°C
Thermal Shutdown Hysteresis Temperature	T _{HYST}	8.0 to 20	°C

Notes

- 1. ESD1 testing is performed in accordance with the Human Body Model (C_{ZAP} = 100 pF, R_{ZAP} = 1500 Ω), ESD2 testing is performed in accordance with the Machine Model (C_{ZAP} = 220 pF, R_{ZAP} = 0 Ω).
- 2. Pin soldering temperature limit is for 10 seconds maximum duration. Not designed for immersion soldering. Exceeding these limits may cause malfunction or permanent damage to the device.
- Freescale's Package Reflow capability meets Pb-free requirements for JEDEC standard J-STD-020C. For Peak Package Reflow Temperature and Moisture Sensitivity Levels (MSL), Go to www.freescale.com, search by part number [e.g. remove prefixes/suffixes and enter the core ID to view all orderable parts. (i.e. MC33xxxD enter 33xxx), and review parametrics.

STATIC ELECTRICAL CHARACTERISTICS

Table 3. Static Electrical Characteristics

Characteristics noted under conditions 7.0 V \leq V_{SUP} \leq 18 V, -40°C \leq T_A \leq 125 °C, GND = 0 V, unless otherwise noted. Typical values noted reflect the approximate parameter means at T_A = 25 °C under nominal conditions, unless otherwise noted.

Characteristic	Symbol	Min	Тур	Max	Unit		
VSUP PIN (DEVICE POWER SUPPLY)							
Supply Voltage	V _{SUP}				V		
Nominal DC		7.0	13.5	18.0			
Functional DC, $T_A \ge 25 \ ^{\circ}C$		6.0	_	—			
Supply Current in Sleep Mode					μΑ		
$V_{SUP} \le 13.5 \text{ V}$, Recessive State	I _{S1}	—	8.0	12			
13.5 V < V _{SUP} < 1.0 V	I _{S2}	—	—	200			
$V_{\mbox{SUP}} \leq 13.5$ V, Dominant State or Shorted to GND	I _{S3}	—	300	—			
Supply Current in Normal, Slow, or Fast Mode					MA		
Bus Recessive, Excluding INH Output Current	I _{S(REC)}	_	4.0	6.0			
Bus Dominant, Total Bus Load >500 Ω , Excluding INH Output Current	I _{S(DOM)}	_	6.0	8.0			
RXD OUTPUT PIN (LOGIC)							
Low Level Output Voltage	V _{OL}				V		
$I_{IN} \le 1.5 \text{ mA}$		0.0	—	0.9			
High Level Output Voltage	V _{OH}				V		
V_{EN} = 5.0 V, $I_{OUT} \le 250 \ \mu A$		4.25	—	5.25			
V_{EN} = 3.3 V, $I_{OUT} \le 250 \ \mu\text{A}$		3.0	—	3.5			
TXD INPUT PIN (LOGIC)	1				1		
Low Level Input Voltage	V _{IL}	—	_	1.2	V		
High Level Input Voltage	V _{IH}	2.5	_	_	V		
Input Threshold Voltage Hysteresis	V _{INHYST}	100	300	800	mV		
Pull-up Current Source	I _{PU}				μA		
V _{EN} = 5.0 V, 1.0 V < V _{TXD} < 3.5 V		-60	-35	-20			
EN INPUT PIN (LOGIC)							
Low Level Input Voltage	V _{IL}	—	_	1.2	V		
High Level Input Voltage	V _{IH}	2.5	—	—	V		
Input Voltage Threshold Hysteresis	V _{INHYST}	100	300	800	mV		
Low Level Input Current	IIL				μA		
V _{IN} = 1.0 V		5.0	20	30			
High Level Input Current	I _{IH}				μA		
V _{IN} = 4.0 V		—	20	40			

Table 3. Static Electrical Characteristics (continued)

Characteristics noted under conditions 7.0 V \leq V_{SUP} \leq 18 V, -40°C \leq T_A \leq 125 °C, GND = 0 V, unless otherwise noted. Typical values noted reflect the approximate parameter means at T_A = 25 °C under nominal conditions, unless otherwise noted.

Characteristic	Symbol	Min	Тур	Max	Unit
LIN PIN (VOLTAGE EXPRESSED VERSUS V_{SUP} VOLTAGE)					
Low Level Bus Voltage (Dominant State)	V _{DOM}				V
External Bus Pull-up 500 Ω		—	_	1.4	
High Level Bus Voltage (Recessive State)	V _{REC}				V
TXD HIGH, I _{OUT} = 1.0 μA		V _{SUP} - 1.0	—	—	
Internal Pull-up Resistor to VSUP (Normal mode)	R _{PU}	20	30	47	kΩ
Internal Pull-up Current Source (Sleep mode)	I _{PU}	—	20	—	μA
Overcurrent Shutdown Threshold	I _{OV-CUR}	50	75	150	mA
Leakage Current to GND	I _{LEAK}				
Recessive State, 8.0 V \leq V $_{SUP}$ \leq 18 V, 8.0 V \leq V $_{LIN}$ \leq 18 V		0	3.0	20	μΑ
GND Disconnected, V _{GND} = V _{SUP} , V _{LIN} at -18 V		-1.0	—	1.0	mA
VSUP Disconnected, V _{LIN} at +18 V		—	1.0	10	μA
LIN Receiver, Low Level Input Voltage	V _{LINL}				V
TXD HIGH, RXD LOW		0.0 V _{SUP}	—	0.4 V _{SUP}	
LIN Receiver, High Level Input Voltage	V _{LINH}				V
TXD HIGH, RXD HIGH		0.6 V _{SUP}	—	V _{SUP}	
LIN Receiver Threshold Center	V _{LINTH}				V
(V _{LINH -} V _{LINL})/2		0.475 V _{SUP}	0.5 V _{SUP}	0.525 V _{SUP}	
LIN Receiver Input Voltage Hysteresis	V _{LINHYST}				V
V _{LINH -} V _{LINL}		-	—	0.175 V _{SUP}	
LIN Wake-up Threshold Voltage	V _{LINWU}	_	0.5 V _{SUP}	—	V
INH OUTPUT PIN					
Driver ON Resistance (Normal mode)	INH _{ON}	_	35	70	Ω
Leakage Current (Sleep mode)	I _{LEAK}				μA
$0.0 V < V_{INH} < V_{SUP}$		0	—	5.0	
WAKE INPUT PIN					
Typical Wake-up Threshold Voltage (EN = 0 V, 7.0 V \leq V_{SUP} \leq 18 V) $^{(5)}$	V _{WUTH}				V
HIGH-to-LOW Transition		0.3 V _{SUP}	0.43 V _{SUP}	0.55 V _{SUP}	
LOW-to-HIGH Transition		0.4 V _{SUP}	0.55 V _{SUP}	0.65 V _{SUP}	
Wake-up Threshold Voltage Hysteresis	V _{WUHYST}	0.1 V _{SUP}	0.16 V _{SUP}	0.2 V _{SUP}	V
WAKE Input Current	I _{WU}				μA
V _{WAKE} < 27 V		—	1.0	5.0	

Notes

4. This parameter is guaranteed by design; however, it is not production tested.

5. When V_{SUP} > 18 V, the wake-up voltage thresholds remain identical to the wake-up thresholds at 18 V.

DYNAMIC ELECTRICAL CHARACTERISTICS

Table 4. Dynamic Electrical Characteristics

Characteristics noted under conditions 7.0 V \leq V_{SUP} \leq 18 V, -40°C \leq T_A \leq 125°C, GND = 0 V, unless otherwise noted. Typical values noted reflect the approximate parameter means at T_A = 25°C under nominal conditions, unless otherwise noted.

	Characteristic	Symbol	Min	Тур	Max	Unit
	LIN OUTPUT TIMING CHARACTERISTICS FOR NORMAL MODE	· · · · · ·				
	Dominant Propagation Delay Time TXD to LIN ⁽⁶⁾					μS
$\begin{array}{ c c c c c } \mbox{Measurement Threshold (50% TXD to 28.4% V_{SUP}) & t_{DOM}(MAX) & - & - & 50 \\ \mbox{Measurement Threshold (50% TXD to 42.2% V_{SUP}) & t_{REC}(MIN) & - & - & 50 \\ \mbox{Measurement Threshold (50% TXD to 74.4% V_{SUP}) & t_{REC}(MAX) & - & - & 50 \\ \mbox{Measurement Threshold (50% TXD to 74.4% V_{SUP}) & t_{REC}(MAX) & - & - & 50 \\ \mbox{Measurement Threshold (50% TXD to 74.4% V_{SUP}) & t_{DOM}(MIN) to t_{REC}(MIN) & - & - & 8.12 \\ \mbox{Mom}(MIN) to t_{REC}(MIN) & t_{REC}(MIN) & t_{REC}(MIN) & t_{REC}(MIN) & - & - & 100 \\ \mbox{Measurement Threshold (50% TXD to 81.6% V_{SUP}) & t_{DOM}(MIN) & - & - & 100 \\ \mbox{Measurement Threshold (50% TXD to 16.6% V_{SUP}) & t_{DOM}(MIN) & - & - & 100 \\ \mbox{Measurement Threshold (50% TXD to 81.6% V_{SUP}) & t_{RCC}(MIN) & - & - & 100 \\ \mbox{Measurement Threshold (50% TXD to 81.6% V_{SUP}) & t_{RCC}(MIN) & - & - & 100 \\ \mbox{Measurement Threshold (50% TXD to 10.1% V_{SUP}) & t_{RCC}(MIN) & - & - & 100 \\ \mbox{Measurement Threshold (50% TXD to 81.6% V_{SUP}) & t_{REC}(MIN) & - & - & 100 \\ \mbox{Measurement Threshold (50% TXD to 81.6% V_{SUP}) & t_{REC}(MIN) & - & - & 100 \\ \mbox{Measurement Threshold (50% TXD to 77.8% V_{SUP}) & t_{REC}(MIN) & - & - & 100 \\ \mbox{Measurement Threshold (50% TXD to 77.8% V_{SUP}) & t_{REC}(MIN) & - & - & 100 \\ \mbox{Measurement Threshold (50% TXD to 77.8% V_{SUP}) & t_{REC}(MIN) & - & - & 100 \\ \mbox{Measurement Threshold (50% TXD to 77.8% V_{SUP}) & t_{REC}(MIN) & - & - & 100 \\ \mbox{Measurement Threshold (50% TXD to 77.8% V_{SUP}) & t_{REC}(MIN) & - & - & 100 \\ \mbox{Measurement Threshold (50% TXD to 77.8% V_{SUP}) & t_{REC}(MIN) & - & - & 100 \\ \mbox{Measurement Threshold (50% TXD to 77.8% V_{SUP}) & t_{REC}(MIN) & - & - & 100 \\ \mbox{Measurement Threshold (50% TXD to 77.8% V_{SUP}) & t_{REC}(MIN) & - & - & 100 \\ \mbox{Measurement Threshold (50% TXD to 77.8% V_{SUP}) & t_{RC}(MIN) & t_{RC}$	Measurement Threshold (50% TXD to 58.1% V _{SUP)}	t _{DOM} (MIN)	_	_	50	
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	Measurement Threshold (50% TXD to 28.4% ${\rm V}_{\rm SUP)}$	t _{DOM} (MAX)	—	—	50	
$\begin{array}{ c c c c c } \mbox{Measurement Threshold (50% TXD to 42.2% V_{SUP}) & t_{REC}(MIN) & - & - & 50 \\ \mbox{Measurement Threshold (50% TXD to 74.4% V_{SUP}) & t_{REC}(MAX) & - & - & 50 \\ \mbox{Propagation Delay Time Symmetry & dt_1 & -10.44 & - & 8.12 \\ \mbox{t_DOM}(MIN) to t_{REC}(MAX) & t_{REC}(MIN) & dt_1 & -10.44 & - & 8.12 \\ \mbox{t_DOM}(MAX) to t_{REC}(MIN) & t_{REC}(MIN) & - & - & 100 \\ \mbox{ID UTPUT TIMING CHARACTERISTICS FOR SLOW MODE \\ \mbox{Dominant Propagation Delay Time TXD to LIN (6) & t_{DOM}(MIN) & - & - & 100 \\ \mbox{Measurement Threshold (50% TXD to 61.6% V_{SUP}) & t_{DOM}(MAX) & - & - & 100 \\ \mbox{Measurement Threshold (50% TXD to 53.9% V_{SUP}) & t_{REC}(MIN) & - & - & 100 \\ \mbox{Measurement Threshold (50% TXD to 38.9% V_{SUP}) & t_{REC}(MIX) & - & - & 100 \\ \mbox{Measurement Threshold (50% TXD to 38.9% V_{SUP}) & t_{REC}(MIX) & - & - & 100 \\ \mbox{Measurement Threshold (50% TXD to 38.9% V_{SUP}) & t_{REC}(MIX) & - & - & 100 \\ \mbox{Measurement Threshold (50% TXD to 77.8% V_{SUP}) & t_{REC}(MIX) & - & - & 100 \\ \mbox{Measurement Threshold (50% TXD to 77.8% V_{SUP}) & t_{REC}(MIX) & - & - & 100 \\ \mbox{Measurement Threshold (50% TXD to 77.8% V_{SUP}) & t_{REC}(MIX) & - & - & 100 \\ \mbox{Measurement Threshold (50% TXD to 77.8% V_{SUP}) & t_{REC}(MIX) & - & - & 100 \\ \mbox{Measurement Threshold (50% TXD to 77.8% V_{SUP}) & t_{REC}(MIX) & - & - & 100 \\ \mbox{Measurement Threshold (50% TXD to 77.8% V_{SUP}) & t_{REC}(MIX) & - & - & 100 \\ \mbox{Measurement Threshold (50% TXD to 77.8% V_{SUP}) & t_{REC}(MIX) & - & 15 & - & 17.44 \\ \mbox{Measurement Threshold (50% TXD to 77.8% V_{SUP}) & t_{REC}(MIX) & - & 15 & - & 100 \\ \mbox{Measurement Threshold (50% TXD to 77.8% V_{SUP}) & t_{REC}(MIX) & - & 15 & - & 15 \\ \mbox{Measurement Threshold (50% TXD to 77.8% V_{SUP}) & t_{REC}(MIX) & - & 15 & - & 15 \\ \mbox{Measurement Threshold (50% TXD to 77.8% V_{SUP}) & t_{RC}(MIX) & - & 15 & - & 15 \\ Measurement Threshold (MAX) Is REC (MIX) & - & 15 & - & & 15 \\ \mbox{Measurement Threshold (MAX) Is REC $	Recessive Propagation Delay Time TXD to LIN ⁽⁶⁾					μS
$\begin{array}{ c c c c c } \mbox{Measurement Threshold (60\% TXD to 74.4 \% V_{SUP})} & t_{REC}(MAX) & & & 50 \\ \mbox{Propagation Delay Time Symmetry & dt_1 & -10.44 & & 8.12 & 0 \\ t_{DOM}(MIN) to t_{REC}(MAX) & dt_1 & -10.44 & & 8.12 & 0 & 0 \\ Measurement Threshold (S0\% TXD to S1.6 W MODE & $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$	Measurement Threshold (50% TXD to 42.2% $V_{\mbox{SUP})}$	t _{REC} (MIN)	—	_	50	
$\begin{array}{c c c c c c c } Propagation Delay Time Symmetry & t_{DOM}(MIN) to t_{REC}(MAX) & t_{REC}(MAX) & t_{REC}(MIN) & t_{REC}(MIN$	Measurement Threshold (50% TXD to 74.4% $V_{SUP)}$	t _{REC} (MAX)	—	—	50	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Propagation Delay Time Symmetry					μS
$ \frac{t_{DOM}(MAX) to t_{REC}(MIN) }{t_{DOM}(MIN) CHARACTERISTICS FOR SLOW MODE } \\ \begin{tabular}{ c c c c c } IDOM (MIN) IDDA (MIN$	t _{DOM} (MIN) to t _{REC} (MAX)	dt ₁	-10.44	_	8.12	
LIN OUTPUT TIMING CHARACTERISTICS FOR SLOW MODEDominant Propagation Delay Time TXD to LIN (6) Measurement Threshold (50% TXD to 25.1% V _{SUP}) $t_{DOM}(MIN)$ $ 100$ μ SRecessive Propagation Delay Time TXD to LIN (6) Measurement Threshold (50% TXD to 38.9% V _{SUP}) $t_{REC}(MIN)$ $ 100$ μ SMeasurement Threshold (50% TXD to 38.9% V _{SUP}) Measurement Threshold (50% TXD to 77.8% V _{SUP}) $t_{REC}(MAX)$ $ 100$ μ SPropagation Delay Time Symmetry $t_{DOM}(MIN) to t_{REC}(MAX)t_{DOM}(MIN) to t_{REC}(MAX)dt_{1S}-21.88 17.44\muSILN OUTPUT DRIVER FAST MODEdv/dt fastFast Slew Rate (Programming Mode)Fast Slew Ratedv/dt fast 10 \muSLIN Fast Slew Rate (Programming Mode)Fast Slew Ratedv/dt fast 10 \muSLIN PIN 10 \muS\muSCver-current Shutdown Delay Time (7)t_{OV-DELAY} 10 \muSLIN LOW to RXD LOW 3.56.0\muSReceiver Dominant Propagation Delay Time (8)LIN HIGH to RXD HIGH\muS\muS\muSReceiver Propagation Delay Time SymmetryLIN HIGH to RXD HIGHt_{R-1} 3.56.0\muSReceiver Propagation Delay Time SymmetryLIN HIGH to RXD HIGHt_{R-1} 2.0 2.0$	t _{DOM} (MAX) to t _{REC} (MIN)	dt ₂	-10.44	—	8.12	
$\begin{array}{ c c c c c } \hline Dominant Propagation Delay Time TXD to LIN (6) & & & & & & & & & & & & & & & & & & &$	LIN OUTPUT TIMING CHARACTERISTICS FOR SLOW MODE					I
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Dominant Propagation Delay Time TXD to LIN ⁽⁶⁾					μS
$\begin{array}{ c c c c } \mbox{Measurement Threshold (50% TXD to 25.1% V_{SUP})} & t_{DOM}(MAX) & - & - & 100 \\ \hline \mbox{Measurement Threshold (50% TXD to 38.9% V_{SUP})} & t_{REC}(MIN) & - & - & 100 \\ \mbox{Measurement Threshold (50% TXD to 78.8% V_{SUP})} & t_{REC}(MIN) & - & - & 100 \\ \mbox{Measurement Threshold (50% TXD to 77.8% V_{SUP})} & t_{REC}(MAX) & - & - & 100 \\ \mbox{Measurement Threshold (50% TXD to 77.8% V_{SUP})} & t_{REC}(MIN) & - & - & 100 \\ \mbox{Measurement Threshold (50% TXD to 77.8% V_{SUP})} & t_{REC}(MIN) & - & - & 100 \\ \mbox{Topom}(MIN) to t_{REC}(MAX) & t_{REC}(MIN) & t$	Measurement Threshold (50% TXD to 61.6% V _{SUP)}	t _{DOM} (MIN)	—	_	100	
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	Measurement Threshold (50% TXD to 25.1% $V_{\mbox{SUP})}$	t _{DOM} (MAX)	—	—	100	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Recessive Propagation Delay Time TXD to LIN ⁽⁶⁾					μS
$\begin{tabular}{ c c c c } \label{eq:constraint} $$ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $	Measurement Threshold (50% TXD to 38.9% $V_{SUP)}$	t _{REC} (MIN)	_	_	100	
$\begin{array}{c c c c c c } Propagation Delay Time Symmetry \\ t_{DOM}(MIN) to t_{REC}(MAX) \\ t_{DOM}(MAX) to t_{REC}(MIN) \end{array} & dt_{1S} & -21.88 & - & 17.44 \\ dt_{2S} & -21.88 & - & 17.44 \\ dt_{2S} & -21.88 & - & 17.44 \\ \hline & & & & & & & & & & & & & & & & & &$	Measurement Threshold (50% TXD to 77.8% $V_{\mbox{SUP})}$	t _{REC} (MAX)	—	—	100	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Propagation Delay Time Symmetry					μS
$\begin{tabular}{ c c c c } \hline t_{DOM}(MAX) to t_{REC}(MIN) & dt_{2S} & -21.88 & - & 17.44 \\ \hline l to UTPUT DRIVER FAST MODE & $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$	t _{DOM} (MIN) to t _{REC} (MAX)	dt _{1S}	-21.88	_	17.44	
$\begin{tabular}{ c c c c } \hline LIN OUTPUT DRIVER FAST MODE & & & & & & & & & & & & & & & & & & &$	$t_{DOM}(MAX)$ to $t_{REC}(MIN)$	dt _{2S}	-21.88	—	17.44	
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	LIN OUTPUT DRIVER FAST MODE			1	1	1
Fast Slew Rate $ 15$ $-$ LIN PINOver-current Shutdown Delay Time (7) $t_{OV-DELAY}$ $ 10$ $ \mu$ sLIN RECEIVER CHARACTERISTICSReceiver Dominant Propagation Delay Time (8) t_{RL} $ 3.5$ 6.0 μ sLIN LOW to RXD LOW t_{RH} $ 3.5$ 6.0 μ sReceiver Recessive Propagation Delay Time (8) t_{RH} $ 3.5$ 6.0 μ sReceiver Recessive Propagation Delay Time (8) t_{RH} $ 3.5$ 6.0 μ sReceiver Propagation Delay Time Symmetry t_{R-SYM} -2.0 $ 2.0$ μ s	LIN Fast Slew Rate (Programming Mode)	dv/dt fast				V/µs
LIN PINOver-current Shutdown Delay Time (7) $t_{OV-DELAY}$ $ 10$ $ \mu$ sLIN RECEIVER CHARACTERISTICSReceiver Dominant Propagation Delay Time (8) t_{RL} $ 3.5$ 6.0 μ sLIN LOW to RXD LOW t_{RH} $ 3.5$ 6.0 μ sReceiver Recessive Propagation Delay Time (8) t_{RH} $ 3.5$ 6.0 μ sLIN HIGH to RXD HIGH t_{R-SYM} $ 3.5$ 6.0 μ sReceiver Propagation Delay Time Symmetry t_{R-SYM} -2.0 $ 2.0$ μ s	Fast Slew Rate		_	15	—	
$\begin{array}{c c c c c c } \hline Over-current Shutdown Delay Time (7) & t_{OV-DELAY} & - & 10 & - & \mus \\ \hline LIN RECEIVER CHARACTERISTICS & & & & & & & & & & & & & & & & & & &$	LIN PIN					
$\begin{array}{ c c c c } \mbox{LIN RECEIVER CHARACTERISTICS} \\ \hline Receiver Dominant Propagation Delay Time $$(8)$ & t_{RL} & t_{RL} & 1 &$	Over-current Shutdown Delay Time ⁽⁷⁾	t _{OV-DELAY}		10	—	μS
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	LIN RECEIVER CHARACTERISTICS					
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	Receiver Dominant Propagation Delay Time ⁽⁸⁾	t _{RL}				μS
$ \begin{array}{c c} \mbox{Receiver Recessive Propagation Delay Time } (8) & t_{RH} & t_{RH} & & \mu s & \mu s \\ \mbox{LIN HIGH to RXD HIGH} & & & 3.5 & 6.0 & & \\ \mbox{Receiver Propagation Delay Time Symmetry} & t_{R-SYM} & t_{R-SYM} & & & & \mu s & & \\ \mbox{t}_{RL} \mbox{-} \mbox{t}_{RH} & & & & & & & & \\ \mbox{t}_{RL} \mbox{-} \mbox{t}_{RH} & & & & & & & & & & & \\ \mbox{t}_{RL} \mbox{-} \mbox{t}_{RH} & & & & & & & & & & & & & \\ \mbox{t}_{RL} \mbox{-} \mbox{t}_{RH} & & & & & & & & & & & & & & \\ \mbox{t}_{RL} \mbox{-} \mbox{t}_{RH} & & & & & & & & & & & & & & & & \\ \mbox{t}_{RL} \mbox{-} \mbox{t}_{RH} & & & & & & & & & & & & & & & & & & &$	LIN LOW to RXD LOW		_	3.5	6.0	
LIN HIGH to RXD HIGH-3.56.0Receiver Propagation Delay Time Symmetry $t_{RL} - t_{RH}$ t_{R-SYM} μs -2.0-2.0-2.0	Receiver Recessive Propagation Delay Time ⁽⁸⁾	t _{RH}				μS
Receiver Propagation Delay Time Symmetry t_{R-SYM} t_{R-SYM} μs $t_{RL} - t_{RH}$ -2.0-2.0	LIN HIGH to RXD HIGH			3.5	6.0	
t _{RL} - t _{RH} -2.0 — 2.0	Receiver Propagation Delay Time Symmetry	t _{R-SYM}				μS
	t _{RL} - t _{RH}		-2.0	—	2.0	

Notes

 $6. \quad 7.0 \ V \leq V_{SUP} \leq 18 \ V. \ \text{Bus load} \ \text{R}_0 \ \text{and} \ \text{C}_0\text{:} \ 1.0 \ \text{nF}/1.0 \ \text{k}\Omega, \ 6.8 \ \text{nF}/660 \ \Omega, \ 10 \ \text{nF}/500 \ \Omega.$

7. This parameter is guaranteed by design; however, it is not production tested.

8. Measured between LIN signal threshold $\rm V_{LINL}$ or $\rm V_{LINH}$ and 50% of RXD signal.

Table 4. Dynamic Electrical Characteristics (continued)

Characteristics noted under conditions 7.0 V \leq V_{SUP} \leq 18 V, -40°C \leq T_A \leq 125°C, GND = 0 V, unless otherwise noted. Typical values noted reflect the approximate parameter means at T_A = 25°C under nominal conditions, unless otherwise noted.

Characteristic	Symbol	Min	Тур	Max	Unit
SLEEP MODE AND WAKE-UP TIMINGS					
EN Pin Wake-up Time ⁽⁹⁾	t _{LWUE}	—	5.0	15	μS
WAKE Pin Filter Time ⁽¹⁰⁾	t _{WF}	10	—	70	μS
LIN Pin Wake-up Filter Time (LIN Bus Wake-Up) ⁽¹¹⁾	t _{WUF}	40	70	120	μS
Sleep Mode Delay Time ⁽¹²⁾	t _{SD}				μS
EN HIGH-to-LOW		50	—	—	
Delay for INH Turning off When Device Enters in Sleep Mode ^{(16), (17)}	t _{SD INH}				μS
EN HIGH-to-LOW and INH HIGH-to-LOW	_	—	—	50	
Delay Time Between EN and TXD for Mode Selection ^{(13), (14)}	t _{D_MS}	5.0	_	—	μS
Delay Time Between First TXD after Device Mode Selection ^{(13), (14)}	t _{D_COM}	50	—	—	μS
FAST BAUD RATE TIMING					

Delay Entering Fast Baud Rate Using Toggle Function ⁽¹⁵⁾	t ₁				μS
EN LOW to EN HIGH		—	—	35	
Delay on EN Pin Resetting Fast Baud Rate to Previous Baud Rate (15)	t ₂				μS
EN LOW to EN HIGH		—	—	5.0	

Notes

9. See <u>Figures 7</u> and <u>8</u>, <u>10</u>.

10. See Figures 9 and 10, 10.

11. See Figures 11 and 12, 11.

12. See Figure 14a, 11.

13. See Figures 7 through <u>12</u>, pp. <u>10–11</u>.

14. This parameter is guaranteed by design; however, it is not production tested.

15. See Figure 13, 11.

16. No capacitor is connected to the INH pin. Measurement is done between the EN HIGH-to-LOW transition at 80% of INH voltage.

17. See Figure 14b, 11.

TIMING DIAGRAMS



Figure 4. Normal Mode Bus Timing Characteristics



Figure 5. Slow Mode Bus Timing Characteristics



Note R₀ and C₀: 1.0 k Ω /1.0 nF, 660 Ω /6.8 nF, and 500 Ω /10 nF.

Figure 6. Test Circuit for Timing Measurements

FUNCTIONAL DIAGRAMS



Figure 7. EN Pin Wake-up and Normal Baud Rate Selection (1.0 kbps to 20 kbps)



Figure 8. EN Pin Wake-up and Slow Baud Rate Selection (1.0 kbps to 10 kbps)



Figure 9. WAKE Pin Wake-up and Normal Baud Rate Selection (1.0 kbps to 20 kbps)



Figure 10. WAKE Pin Wake-up and Slow Baud Rate Selection (1.0 kbps to 10 kbps)



Figure 11. LIN Bus Wake-up and Normal Baud Rate Selection (1.0 kbps to 20 kbps)



Figure 12. LIN Bus Wake-up and Slow Baud Rate Selection (1.0 kbps to 10 kbps)



Figure 13. Fast Baud Rate Selection (Toggle Function)







Figure 14. Sleep Mode Enter

FUNCTIONAL DESCRIPTION

INTRODUCTION

The 33661 is a Physical Layer component dedicated to automotive LIN sub-bus applications.

The 33661 features include slew rate selection for optimized operation at 10 kbps and 20 kbps, fast baud rate for test and programming modes, excellent radiated emission

POWER SUPPLY PIN (VSUP)

The VSUP supply pin is the power supply pin for the 33661. The pin is connected to a battery through a serial diode for reverse battery protection. The DC operating voltage is from 7.0 V to 27 V. This pin sustains standard automotive voltage conditions such as 27 V DC during jump-start conditions and 40 V during load dump. Supply current in the Sleep mode is typically 8.0 μ A.

GROUND PIN (GND)

In case of a ground disconnection at the module level, the 33661 does not have significant current consumption on the LIN bus pin when in the recessive state. (Less than 100 μ A is sourced from LIN bus pin, which creates 100 mV drop voltage from the 1.0 k Ω LIN bus pull-up resistor.)

LIN BUS PIN (LIN)

This I/O pin represents the single-wire bus transmitter and receiver.

Transmitter Characteristics

The LIN driver is a low-side MOSFET with internal overcurrent thermal shutdown. An internal pullup resistor with a serial diode structure is integrated so no external pullup components are required for the application in a slave node. An additional pullup resistor of 1.0 k Ω must be added when the device is used in the master node.

Voltage can go from -18 V to 40 V without current other than the pull-up resistance. The LIN pin exhibits no reverse current from the LIN bus line to VSUP, even in the event of GND shift or V_{PWR} disconnection.

The transmitter has two slew rate selections: 20 kbps (normal slew rate) and 10 kbps (slow slew rate). The slow slew rate can be used to improve radiated emissions.

Receiver Characteristics

The receiver thresholds are ratiometric with the device supply pin.

performance, and safe behavior in case of LIN bus short-toground or LIN bus leakage during low power mode.

Digital inputs are 5.0 V and 3.3 V compatible without any external component required.

The INH output may be used to control an external voltage regulator or to drive a LIN bus pull-up resistor.

FUNCTIONAL PIN DESCRIPTION

DATA INPUT PIN (TXD)

The TXD input pin is the MCU interface to control the state of the LIN output. When TXD is LOW, LIN output is LOW; when TXD is HIGH, the LIN output transistor is turned OFF. The threshold is 3.3 V and 5.0 V compatible. The baud rate selection (normal or Slow mode) is done at device wake-up by the state of the TXD pin prior to a HIGH level at the EN pin (see Figures 7 through 12).

DATA OUTPUT PIN (RXD)

The RXD output pin is the MCU interface, which reports the state of the LIN bus voltage. LIN HIGH (recessive) is reported by a high-voltage on RXD; LIN LOW (dominant) is reported by a low-voltage on RXD. The RXD output structure is a CMOS-type push-pull output stage.

The low level is fixed. The high level is dependant on the EN voltage. If EN is set at 3.3 V, RXD V_{OH} is 3.3 V. If EN is set at 5.0 V, RXD V_{OH} is 5.0 V.

In the Sleep mode, RXD is high impedance. When a wakeup event is recognized from WAKE pin or from the LIN bus pin, RXD is pulled LOW to report the wake-up event. An external pull-up resistor may be needed.

ENABLE INPUT PIN (EN)

The EN input pin controls the operation mode of the interface. If EN = 1, the interface is in Normal mode, with transmission path from TXD to LIN and from LIN to RXD both active. The threshold is 3.3 V and 5.0 V compatible. The high level at EN defines the V_{OH} at RXD. The Sleep mode is entered by setting EN LOW while TXD is HIGH. Sleep mode is active after the t_{SD} filter time (see Figure 14).

INHIBIT OUTPUT PIN (INH)

The INH output pin may have two main functions. It may be used to control an external switchable voltage regulator having an inhibit input. The high drive capability also allows it to drive the bus external resistor in the master node application. This is illustrated in <u>Figures 18</u> and <u>19</u>.

In Sleep mode, INH is turned OFF. If a voltage regulator inhibit input is connected to INH, the regulator will be disabled. If the master node pull-up resistor is connected to INH, the pull-up resistor will be disabled from the LIN bus.

FUNCTIONAL DESCRIPTION FUNCTIONAL PIN DESCRIPTION

WAKE INPUT PIN (WAKE)

The WAKE pin is a high-voltage input used to wake-up the device from the Sleep mode. WAKE is usually connected to an external switch in the application. The typical wake thresholds are $V_{SUP}/2$.

The WAKE pin has a special design structure and allows wake-up from both High-to-Low or Low-to-High transitions. When entering into Sleep mode, the LIN monitors the state of the WAKE pin and stores it as a reference state. The opposite state of this reference state will be the wake-up event used by the device to enter again into Normal mode.

An internal filter is implemented (40 μ s typical filtering time delay). WAKE pin input structure exhibits a high-impedance, with extremely low input current when voltage at this pin is below 14 V. When voltage at the WAKE pin exceeds 14 V, input current starts to sink into the device. A serial resistor should be inserted in order to limit the input current mainly during transient pulses. Recommended resistor value is 33 k Ω .

Important The WAKE pin should *not* be left open. If the wake-up function is not used, WAKE should be connected to ground to avoid false wake-up.

FUNCTIONAL DEVICE OPERATION

OPERATIONAL MODES

As described in the following, and as depicted in Figure 15 and Table 5, the 33661 has two operational modes, Normal and Sleep. Normal mode may be adjusted to improve radiated emissions by changing the slew rate of the LIN bus output to Fast or Slow mode. In addition, there are two transitional modes: Awake mode, which allows the device to go in Normal or Slow mode, and Wait Slow mode, which is a temporary state before the device enters the Slow mode.

NORMAL MODE

In the Normal mode, the 33661 has slew rate and timing compatible with the LIN protocol specification, and operates from 1.0 kbps to 20 kbps. This mode is selected after Sleep mode by setting the TXD pin High prior to setting EN from Low to High. Once Normal mode is selected, it is impossible to select the Slow mode unless the 33661 is set into Sleep mode.

Slow Mode

In the Slow mode, the slew rate is around half the normal slew rate, and bus speed operation ranges from 1.0 kbps to 10 kbps. The radiated emission is significantly reduced compared to the already excellent emission level of the Normal mode. Slow mode is entered after Sleep mode by setting the TXD pin Low prior to setting EN from Low to High. Once the Slow mode is selected, it is impossible to select the Normal mode unless the device is set to Sleep mode.

Fast Mode

In the Fast mode, the slew rate is around 10 times faster than the Normal mode. This allows very fast data transmission (>100 kbps)—for instance, for electronic control unit (ECU) tests and microcontroller program download. The bus pull-up resistor might be reduced to ensure a correct RC time constant in line with the high baud rate used.

Fast mode can be selected from either Normal or Slow mode. Fast mode is entered via a special sequence (called toggle function) as follows: TXD and EN pins set Low, then TXD pulled High, and at the EN pin Low-to-High transition, the device enters into the Fast Baud rate. The duration of this sequence must be less than 35 μ s. The toggle function is described in Figure 13. Once in the Fast mode, two different procedures will bring the device back to the previously selected mode (Normal or Slow):

- The toggle function already described.
- A glitch on EN where t₂ < 5.0 µs also resets the device to the previously selected mode (Normal or Slow) (Figure 13).

SLEEP MODE

In the Sleep mode, the transmission path is disabled and the 33661 is in Low Power mode. Supply current from VSUP is very low. Wake-up can occur from LIN bus activity from node internal wake-up through the EN pin and from the WAKE input pin.

In the Sleep mode, the 33661 has an internal 20 μ A pullup source to VSUP. This avoids the high current path from the battery to ground in the event the bus is shorted to ground. (Refer to succeeding paragraphs describing wakeup behavior.)

DEVICE POWER-UP (AWAKE TRANSITIONAL MODE)

At power-up (V_{SUP} rises from zero), the 33661 automatically switches to the Awake transitional mode. It switches the INH pin to High state and RXD to Low state. The MCU of the application will then confirm Normal or Slow mode by setting the TXD and EN pins appropriately.

DEVICE WAKE-UP EVENTS

The 33661 can be awakened from Sleep mode by three wake-up events:

- · Remote wake-up via LIN bus activity
- Internal node wake-up via the EN pin
- Toggling the WAKE pin

Remote Wake from LIN Bus (Awake Transitional Mode)

The LIN bus wake-up is recognized by a recessive-todominant transition, followed by a dominant level with a duration greater than 70 μ s, followed by a dominant-torecessive transition. This is illustrated in Figures 11 and 12. Once the wake-up is detected, the 33661 enters the Awake Transitional mode, with INH High and RXD pulled Low.

Wake-up from Internal Node Activity (Normal or Wait Slow Mode)

The 33661 can wake-up by internal node activity through a Low-to-High transition of the EN pin. When EN is switched from Low-to-High, the device is awakened and enters either the Normal or the Wait Slow transitional mode depending on the level of TXD input. The MCU must set the TXD pin LOW or HIGH prior to waking up the device through the EN pin.

Wake-up from WAKE Pin (Awake Transitional Mode)

If the WAKE input pin is toggled, the 33661 enters the Awake transitional mode, with INH High and RXD pulled Low.



Note Refer to Table 5 for explanation.



Table 5.	Explanation of O	perational and	Transitional Modes	State Diagram
	Explanation of O	perational ana	Transitional modes	Oluce Diagram

Operational/ Transitional	LIN	INH	EN	ТХД	RXD
Sleep Mode	Recessive state, driver off. 20 μ A pull-up current source.	Low	Low	X	High-impedance. High if external pull-up to V _{DD.}
Awake	Recessive state, driver off. 30 k Ω pull-up active.	High	Low	Х	Low. If external pull-up, High-to- Low transition reports wake-up.
Normal Mode	Driver active. 30 kΩ pull-up active. Slew rate normal (20 kbps).	High	High	High to enter Normal mode. Once in Normal mode: Low to drive LIN bus in dominant, High to drive LIN bus in recessive.	Report LIN bus level: • Low LIN bus dominant • High LIN bus recessive
Wait Slow	Recessive state. Driver off. 30 k Ω pull-up active.	High	High	Low	High
Slow	Driver active. 30 k Ω pull-up active. Slew rate slow (10 kbps).	High	High	Low to enter Slow mode. Once in Slow mode: Low to drive LIN bus in dominant, High to drive LIN bus in recessive.	Report LIN bus level: • Low LIN bus dominant • High LIN bus recessive
Fast	Driver active. 30 k Ω pull-up active. Slew rate fast (>100 kbps).	High	High	Low to drive LIN bus in dominant, High to drive LIN bus in recessive.	Report LIN bus level: • Low LIN bus dominant • High LIN bus recessive

X = Don't care.

ELECTROMAGNETIC COMPATIBILITY

RADIATED EMISSION IN NORMAL AND SLOW MODES

The 33661 has been tested for radiated emission performances. <u>Figures 16</u> and <u>17</u> show the results in the frequency range 100 kHz to 2.0 MHz. Test conditions are in accordance with CISPR25 recommendations, bus length of

1.5 meters, device loaded with 10 nF and 500 Ω bus impedance.

Figure 16 displays the results when the device is set in the Normal mode, optimized for baud rate up to 20 kbps. Figure 17 displays the results when the device is set in the Slow mode, optimized for baud rate up to 10 kbps. The level of emissions is significantly reduced compared to the already excellent level of the Normal mode.









TYPICAL APPLICATIONS

The 33661 can be configured in several applications. <u>Figures 18</u> and <u>19</u> show master and slave node applications. An additional pull-up resistor of 1.0 k Ω in series with a diode must be added when the device is used in the master node.



Figure 18. Master Node Typical Application



Figure 19. Slave Node Typical Application

PACKAGING

PACKAGE DIMENSIONS

Important For the most current revision of the package, visit <u>www.freescale.com</u> and do a keyword search on the 98ASB42564B drawing number below.Dimensions shown are provided for reference ONLY.





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- 1. DIMENSIONS ARE IN MILLIMETERS.
- 2. DIMENSIONING AND TOLERANCING PER ASME Y14.5M-1994.
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REFERENCE DOCUMENTS

Table 6. Reference Documents

Title	Literature Number
Local Interconnect Network (LIN) Physical Interface: Difference Between MC33399 and MC33661	EB215

REVISION HISTORY

REVISION	DATE	DESCRIPTION OF CHANGES
5.0	10/2006	 Implemented Revision History page Updated the Freescale format and style Added MCZ33661EF/R2 to the part number Ordering Information
6.0	11/2006	 Removed Peak Package Reflow Temperature During Reflow (solder reflow) parameter from MAXIMUM RATINGS 4. Added note with instructions from www.freescale.com.
7.0	2/2012	 Updated Freescale format and package drawing. No content was altered. Updated ordering information. Removed MC33661D/R2 and MCZ33662EF/R2, and replaced with MC33661PEF/R2.
	4/2012	 Corrected the definition of LIN Updated Freescale form and style
8.0	4/2013	 Change T_{STG} to -55 to 150 Revised back page. Updated document properties. Added SMARTMOS sentence to first paragraph.

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