

# LMX5001

## Dedicated Bluetooth Link Controller

### General Description

The LMX5001 Dedicated Bluetooth™ Link Controller has been designed to interface with the LMX3162, Single Chip Radio Transceiver to provide a rapid design path to a complete Bluetooth physical layer.

The LMX5001 also offers a low power and cost competitive solution to the Bluetooth Link Controller function.

The LMX5001 can be attached to a Link Management Controller, or Host processor performing the Link Management function to implement a complete Bluetooth interface.

Bluetooth is a world-wide recognized wireless communication standard, which operates in the ISM band (2.4 GHz), offering a low cost and convenient wireless replacement for data/voice cable links between fixed and mobile electronic devices.

Utilizing a GFSK modulation scheme, with frequency hopping, Bluetooth is able to offer a low power, low cost, robust and spectrally efficient spread spectrum packet data system.

### Features

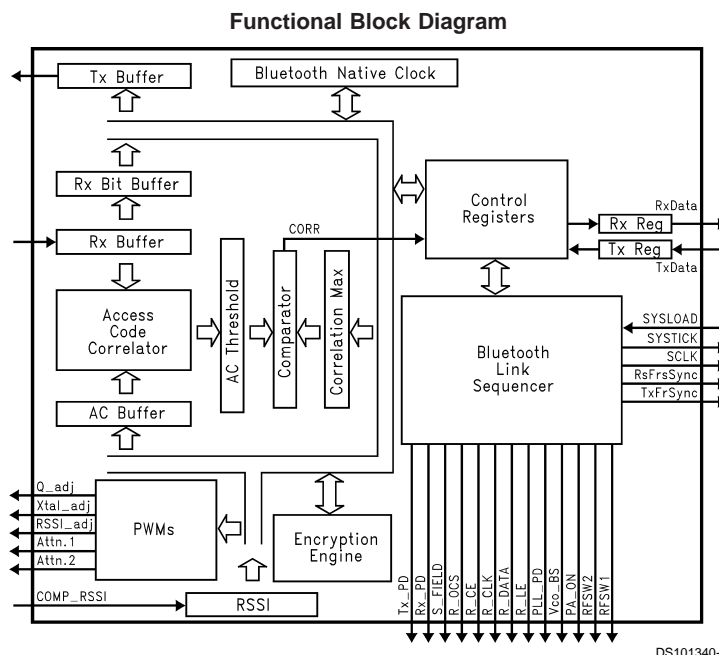
- Bluetooth Specification 1.0B compliant
- Bluetooth physical layer, available today
- Supports Class 1, 2 and 3 Bluetooth (20 dBm, 4 dBm and 0 dBm links)
- 1/8 bit sampling resolution
- Power management for Tx, Rx and PLL

- Piconet and Scatternet communication capable
- Good Bluetooth radio range coverage (when coupled with the LMX3162)
- Support for RSSI channel quality monitoring
- Bluetooth Encryption Engine

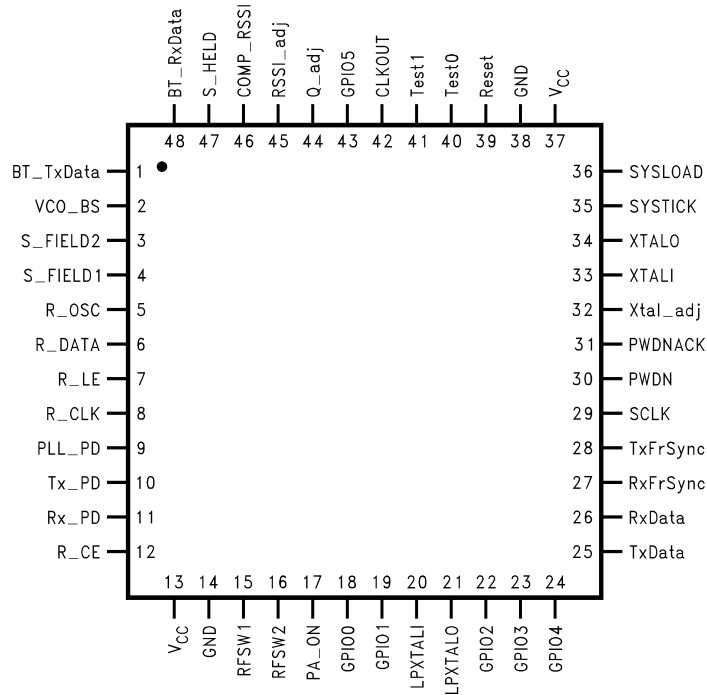
### Applications

- PCMCIA Cards
- Mobile Phones
- Laptop PCs
- Palmtop PCs
- Desktop PCs
- Computer Peripherals
- Wireless Modems
- PDAs
- Palmtops
- P.O.T.S
- Digital Cameras
- Fax
- Printers
- Bar-code Readers
- Notepads
- Cordless Headsets
- In-vehicle Communications

### Block Diagram



## Connection Diagram



DS101340-7

## Pin Descriptions

Pin No.	Pin Name	I/O	Description
1	BT_TxData	O	Transmit data
2	VCO_BS	O	VCO band switch control signal.
3	S_FIELD2	O	LMX3162 DC compensation circuit enable. This signal is enabled (low) throughout the correlation phase.
4	S_FIELD1	O	LMX3162 DC compensation circuit enable. At the beginning of the correlation phase this signal is enabled (low) for 15 $\mu$ s. For the remainder of the correlation phase this signal is PWM by 1/8 (cycle time = 1 $\mu$ s).
5	R_OSC	O	LMX3162 4 MHz oscillator input to the PLL synthesizer. This signal is only enabled when the LMX3162 is active.
6	R_DATA	O	MICROWIRE™ data to LMX3162.
7	R_LE	O	MICROWIRE load enable to LMX3162.
8	R_CLK	O	MICROWIRE clock to LMX3162.
9	PLL_PD	O	LMX3162 PLL power down. This signal is used to open the PLL loop or powering down the PLL. The PLL loop is opened when transmitting to make it possible to FSK modulate the VCO. When receiving it is optional to open the PLL loop (configured by the PLLOpenRX bit in threshold_msb).
10	Tx_PD	O	LMX3162 Transmitter power down. For power conservation, the Transmitter is only powered during Transmit Frames.
11	Rx_PD	O	LMX3162 Receiver power down. For power conservation, the Receiver is only powered during Receive Frames.
12	R_CE	O	LMX3162 chip enable. When the LMX5001 is in Idle Mode the LMX3162 is powered down.
13	V <sub>CC</sub>	Power	+3.3V
14	GND	Power	0V
15	RFSW1	O	Antenna switch control.
16	RFSW2	O	Antenna switch control. This signal is RFSW1 inverted,
17	PA_ON	O	Switches the external PA on/off for 20 dBm/0 dBm transmission, respectively.

## Pin Descriptions (Continued)

Pin No.	Pin Name	I/O	Description
18	GPIO0 (XTAL Config)	I/O	XTAL configuration during reset (Note 1).
19	GPIO1 (XTAL Config)	I/O	XTAL configuration during reset (Note 1).
20	LPXTALI	I	128 kHz XTAL connection for low power mode. This is used in low power mode. If the low power mode is not used it is not necessary with at XTAL here. External 128 kHz clock can also be feed in here.
21	LPXTALO	O	128 kHz XTAL connection.
22	GPIO2	I/O	General Purpose I/O
23	GPIO3	I/O	General Purpose I/O
24	GPIO4	I/O	General Purpose I/O
25	TxDData	I	LCI Data Transmit
26	RxDData	O	LCI Data Receive
27	RxFrSync	O	LCI Receive Frame Sync.
28	TrFrSync	O	LCI Transmit Frame Sync.
29	SCLK	O	LCI Serial Clock.
30	PWDN	O	Power Down to Link Management Controller
31	PWDNACK	I	Power Down Acknowledge from Link Management Controller
32	Xtal_adj	O	PWM signal to make adjustments to the XTAL.
33	XTALI	I	16 MHz XTAL connection. (External clock input).
34	XTALO	O	16 MHz XTAL connection.
35	SYSTICK	O	Systick generated from the internal LMX5001 Master/Slave Counter.
36	SYSLOAD	I	When low holds the LMX5001 in Idle Mode. A rising edge causes a system load. After a rising edge the LMX5001 will start to load control data from and store status information to the LMC via the LCI.
37	V <sub>CC</sub>	Power	
38	GND	Power	
39	Reset	I	Reset. After Reset is released the LMX5001 will be in Idle Mode, awaiting a SYSLOAD.
40	Test0	I	Should be tied low. This signal is used in production test.
41	Test1	I	Should be tied low. This signal is used in production test.
42	CLKOUT	O	Xtal clock output to Link Management Controller. This signal can be disabled using the Sysload Command (for power saving).
43	GPIO5	I/O	General Purpose I/O
44	Q_adj	O	PWM signal to make it possible to adjust the quadrature tank circuit to the LMX3162.
45	RSSI_adj	O	PWM signal for use in creating an RSSI AD converter.
46	COMP_RSSI	I	Output from the external comparator in the RSSI AD converter.
47	S_Field3	O	DC Compensation circuit enable. At the beginning of the correlation phase, this signal is enabled (low) for 15 $\mu$ s.
48	BT_RxDData	I	Receive data.

**Note 1:** During Reset GPIO0 and GPIO1 are sampled to setup the Xtal division ratio. The assumed external Xtal frequency is derived using the following relationship:

GPIO1	GPIO0	Xtal Division Ratio
Low	Low	Divide by 2 (i.e., 16 MHz XTAL or clock input).
Low	High	Divide by 3 (i.e., 24 MHz XTAL or clock input).
High	Low	Divide by 4 (i.e., 32 MHz XTAL or clock input).
High	High	Not used.

After Reset is completed, GPIO0 and GPIO1 can be used as normal general purpose I/Os.

### Absolute Maximum Ratings (Note 2)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Operating Ambient Temperature 0°C to +70°C  
 Storage Temperature -65°C to +150°C

Maximum Input Voltage:

Inputs  $V_{DD} + 0.5V$   
 5V Tolerant  $V_{DD5} + 0.5V$

Maximum Operating Voltage 3.6V

**Note 2:** Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

### DC Electrical Characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Units
$T_A$	Ambient Temperature		0		70	°C
$V_{DD}$	Supply Voltage		3.0	3.3	3.6	V
$I_{IH}$	High-Level Input Current	$V_{IN} = V_{DD}; V_{DD} = V_{DDmax}$			10	µA
$I_{IL}$	Low-Level Input Current	$V_{IN} = V_{SS}; V_{DD} = V_{DDmax}$	-10			µA
$I_{OZ}$	High-Impedance State Output Current	$V_{IN} = V_{DD} \text{ or } V_{SS}; V_{DD} = V_{DDmax}$	-10		10	µA
$I_{OC}$	Output Short-Circuit Current This is true for all outputs except crystal outputs XTALO and LPXTALO.	$V_{OUT} = V_{DD}; V_{DD} = V_{DDmax}$		70		mA
		$V_{OUT} = V_{SS}; V_{DD} = V_{DDmax}$		-45		
$V_{IH}$	High-Level Input Voltage		2.0	1.7		V
$V_{IL}$	Low-Level Input Voltage			1.1	0.8	V
$V_{OH}$	High-Level Output Voltage	$I_{OH} = \text{As rated}; V_{DD} = V_{DDmin}$ all outputs except XTALO and LPXTALO are rated with $I_{OH} = 10\text{ma}$ and $I_{OL} = -10\text{mA}$ . XTALO is rated +/-8mA and LPXTALO is rated +/-2mA.	0.7 $V_{DD}$			V
$V_{OL}$	Low-Level Output Voltage	$I_{OL} = \text{As rated}; V_{DD} = V_{DDmin}$ all outputs except XTALO and LPXTALO are rated with $I_{OH} = 10\text{ma}$ and $I_{OL} = -10\text{mA}$ . XTALO is rated +/-8mA and LPXTALO is rated +/-2mA.			0.4	V

### Functional Description

#### BLUETOOTH COMMUNICATION

The following illustrates a Bluetooth, Frequency Hopping, TDD, Packet based communication link:

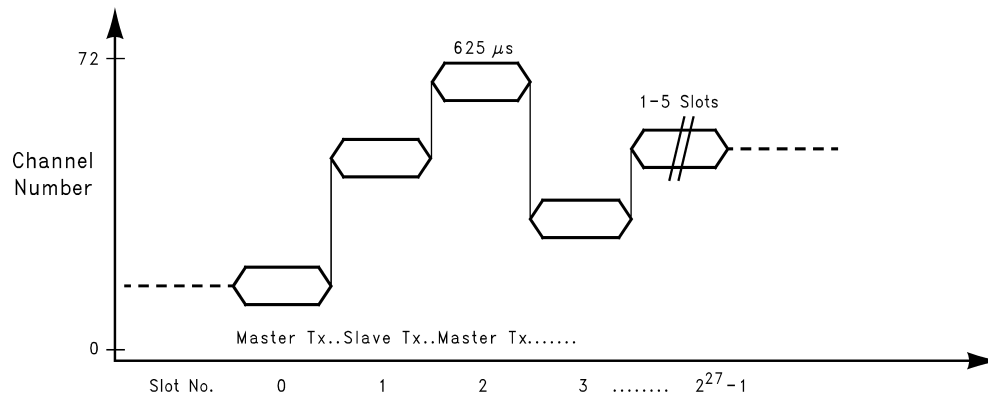


FIGURE 1. Bluetooth Frequency Hopping TDD

The LMX5001 performs all the necessary functions and interconnect to permit the LMX3162 to be operated as a Blue-

## Functional Description (Continued)

tooth radio. It also provides the following functions (under the control of either a Link Management Controller, or a Host processor performing Link Management Control functions):

- Receive Data and Clock recovery
- Access Code correlation
- Frame/Slot Counters
- Radio control (LMX3162)
- Radio Signal Strength Indication (RSSI)
- DC Offset compensation
- Data transmission and receiving
- Link Management Controller communication (LCI)
- Power management
- Encryption

### LMX5001 COMMAND SET

In order to support the range of Bluetooth communication modes, the LMX5001 has the ability to implement the following commands from the Link Management Controller:

- Slave Receive with Continuous Correlation
- Slave Receive with Windowed Correlation
- Slave Transmit
- Master Receive
- Master Transmit
- Change to Master Clock
- Change to Slave Clock
- Power Down
- Slave Receive with Windowed Correlation, Encryption Enabled
- Slave Transmit, Encryption Enabled
- Master Receive, Encryption Enabled
- Master Transmit, Encryption Enabled

The LMX5001 can also be placed into an Idle State by the Link Management Controller asserting SYSLOAD. SYSLOAD also start the system load process. During this process, the transfer of information between LMX5001 Link Controller and the Link Management Controller takes place. The interface between the two is Link Controller Interface (LCI). The formatting of the Command Set, along with Configuration and Status data, sent via the LCI is further detailed in the LCI sections of this Datasheet.

### RECEIVE DATA AND CLOCK RECOVERY

Since Bluetooth is based on a packetized, wireless communications protocol, it is necessary to frame timing from the received packets, before the data itself can be recovered. Also, since Bluetooth supports both point-to-point and point-to-multipoint connection, it is also necessary to establish whether the received packet is addressed to the unit in question.

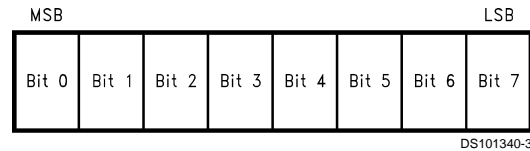
In receive mode, the LMX5001 receives samples from the LMX3162 at 8 times the Bluetooth Symbol rate (i.e., 8 Mbps). This ensures a +/- 1/8 bit accuracy for receive data and frame/slot clocking. If the unit in question is operating as a Slave, then the Slave (Frame/Slot) Counter is updated using the recovered frame/slot clock upon successful Access Code correlation.

The received samples are shifted into a 512 sample Buffer in the correlator. The length of this buffer is fixed to enable the correlation of a 64-bit Sync Word (8x oversampled) of the Access Code.

### DATA TRANSMISSION AND RECEIVING

Bluetooth data is transferred via a serial interface (LCI) with the Link Management Controller. The transferred data is broken down to 8-bit packets. The LCI then uses a 10-bit package to send each of these 8-bit packets using a big-endian mode.

The big-endian mode is illustrated in the *Figure 2* below:



**FIGURE 2. Big-endian Data Convention**

### ACCESS CODE CORRELATION

Access Code Correlation is performed to establish whether a packet's payload is intended for the unit in question.

The Access Code to be correlated against the incoming Receive Data is passed to the LMX5001 from the Link Management Controller via the LCI. It is then stored in a 64-bit AC Buffer in the LMX5001.

The AC Buffer is then correlated with the incoming Receive Data (stored in the RX Buffer) and the maximum correlation achieved is transferred to the Correlation Max Buffer.

The Correlation Max is then compared with the contents of the AC (Access Code) Threshold Buffer, to determine whether the incoming Access Code sufficiently matches the unit in question. If the Correlation Max exceeds the AC Threshold, then the Control Registers "CORR" flag is cleared, to indicate a correlation.

### EXTERNAL CRYSTALS

There are two external crystals, one running at 16 MHz ( $\pm 10$  ppm) and the other at 128 kHz ( $\pm 125$  ppm). The higher rate crystal is used to drive the Bluetooth native clock in normal mode. This clock is also used as the Link Management Controller clock input. The lower rate crystal is used when the Bluetooth unit is in low power mode. In this mode, the higher rate crystal is shut down so is the Link Management Controller. Leaving only the lower rate crystal running to update the internal Bluetooth native clock.

### FRAME/SLOT COUNTERS

The LMX5001 maintains an internal counter. It is 28 bits in length, to support the Bluetooth requirement for  $2^{27}-1$  slots. The Bluetooth slot number is generated based on this counter. It is also the basis for the Link Management firmware to update its implementation of the Bluetooth Master and Slave Counters. This clock is in half Bluetooth slot intervals (312.5  $\mu$ s).

### LMX5001 LINK CONTROLLER INTERFACE (LCI)

All Host/Link Management Control of the LMX5001 (and LMX3162) takes place via the serial LCI.

The signals associated with this port are:

- SYSLOAD
- SYSTICK

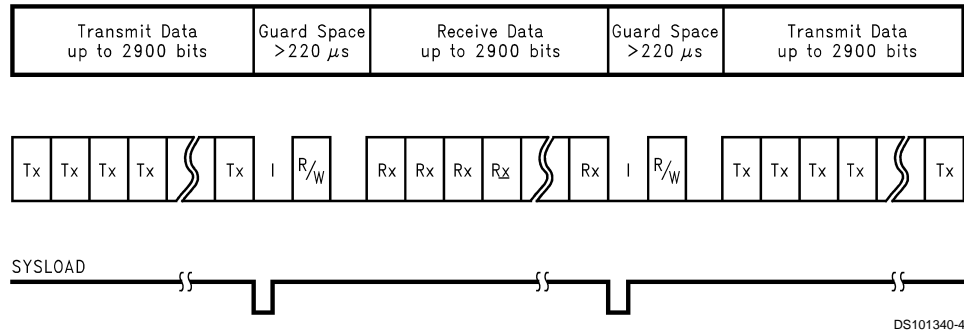
## Functional Description (Continued)

- SCLK
- TxDATA
- RxDATA
- RxFrSync
- TxFrSync

The LMX5001 functions as a master when communicating with the Bluetooth Link Management Controller/Host processor. It achieves this by providing LCI Frame (TxFrSync and RxFrSync) and Data (SCLK) synchronization signals to the Link Management Controller.

SYSTICK provides the Link Management Controller with Bluetooth Frame/Slot boundary information. The SYSTICK pauses needs a minimum width of 100 ns and are spaced at half Bluetooth slot. Two of those SYSTICK pauses make one Bluetooth Frame/Slot. SYSTICK is also an indication of the beginning of Bluetooth packets.

System Load on this LCI port occurs during Bluetooth “Guard Space” intervals (i.e., during Frequency Hopping transitions between two transmit/receive transactions) Reference *Figure 3* below:



Tx = Bluetooth transmit data  
 Rx = Bluetooth receive data  
 I = Idle mode  
 R = Read command and register information from Link Management Controller (26 Bytes)  
 W = Write status information to Link Management Controller (12 Bytes)  
 SYSLOAD = Input pin on Link Controller

**FIGURE 3. LCI Communication Scheduling**

### IDLE MODE

When SYSLOAD is asserted by the Link Manager Controller, the LMX5001 internal BT Link is reset and the LMX5001 is placed in “Idle” Mode. In order to guarantee this state is achieved SYSLOAD pause must be held for a minimum period of 2 μs.

In Idle Mode the LMX5001 will place the LMX3162 in a low power state, and will cease processing Bluetooth Transmit and Receive data. It will remain in this state for approximately 2 μs before “System Load” takes place.

### SYSTEM LOAD

System load (Sysload) takes place between the LMX5001 and the Link Management Controller on the LCI.

Sysload will cause the LMX5001 to read commands/ configuration information and write status information from/to

the Link Management Controller via the LCI. Sysload is performed in fully duplex, synchronous mode. The complete command and status information is sent in one synchronous packet.

### LMX5001/LMX3162 Configuration Data Transfer

LMX5001/LMX3162 Configuration Data is transmitted by the Link Management Controller via TxData (under the control of SCLK and TxFrameSync) on the LCI.

Configuration Data is sent as a series of bytes where Bytes 0, 10 through 17 contain LMX5001 configuration information, Bytes 1 through 9 contain LMX3162 programming information (reference LMX3162 Datasheet for further details) and Bytes 18 through 25 contain the Bluetooth Access Code (employed by the LMX5001).

The data transfer relative to each Byte is detailed in *Table 1*.

**TABLE 1. Configuration Data Bytes**

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Byte 0	Command Code							
Byte 1	PW1(19)	PW1(18)	PW1(17)	PW1(16)	PW1(15)	PW1(14)	PW1(13)	PW1(12)
Byte 2	PW1(11)	PW1(10)	PW1(9)	PW1(8)	PW1(7)	PW1(6)	PW1(5)	PW1(4)
Byte 3	PW1(3)	PW1(2)	PW1(1)	PW1(0)	0	0	0	0
Byte 4	PW2(19)	PW2(18)	PW2(17)	PW2(16)	PW2(15)	PW2(14)	PW2(13)	PW2(12)
Byte 5	PW2(11)	PW2(10)	PW2(9)	PW2(8)	PW2(7)	PW2(6)	PW2(5)	PW2(4)
Byte 6	PW2(3)	PW2(2)	PW2(1)	PW2(0)	0	0	0	0
Byte 7	PW3(19)	PW3(18)	PW3(17)	PW3(16)	PW3(15)	PW3(14)	PW3(13)	PW3(12)

## Functional Description (Continued)

**TABLE 1. Configuration Data Bytes (Continued)**

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Byte 8	PW3(11)	PW3(10)	PW3(9)	PW3(8)	PW3(7)	PW3(6)	PW3(5)	PW3(4)
Byte 9	PW3(3)	PW3(2)	PW3(1)	PW3(0)	0	0	0	0
Byte 10	LSB of Transmit Bits							
Byte 11	MSB of Transmit Bits							
Byte 12	LSB of Correlation Threshold							
Byte 13	RXattn	RXpol	TXpol	PLLOpenRX	RSSI_PH	0	MSB Corr. Thres.	
Byte 14	Xtaladj PWM Value							
Byte 15	Quad. PWM Value							
Byte 16	GPIO5	GPIO4	GPIO3	GPIO2	CLKDIV		GPIO1	GPIO0
Byte 17	_EN	_EN	_EN	_EN	0	0	_EN	_EN
Byte 18	AC(63)	AC(62)	AC(61)	AC(60)	AC(59)	AC(58)	AC(57)	AC(56)
Byte 19	AC(55)	through to						AC(48)
Byte 20	AC(47)	through to						AC(40)
Byte 21	AC(39)	through to						AC(32)
Byte 22	AC(31)	through to						AC(24)
Byte 23	AC(23)	through to						AC(16)
Byte 24	AC(15)	through to						AC(8)
Byte 25	AC(7)	through to						AC(0)

### LMX5001 CONTROL DATA—Byte 0

Byte 0 contains control data (reference *Table 1*) to support Bluetooth HCI Commands by instructing the Bluetooth Link Sequencer to perform one of the tasks listed in *Table 2* below:

**TABLE 2. Bluetooth Link Sequencer—Command Codes**

Command	Command Code
Slave Receive with Continuous Correlation Upon successful correlation, native clock is updated.	0x01
Slave Receive with Windowed Correlation Same as command Code 0x01 except that correlation window falls within 10 $\mu$ s before and 78 $\mu$ s after the next SYSTICK.	0x02
Slave Transmit	0x03
Change to Master Clock Master clock in effect the next SYSTICK.	0x04
Master Receive	0x05
Master Transmit	0x06
Change to Slave Clock Same as Command Code 0x04 except that the Link Management Controller may update the native clock with bits set via the “transmit bits” field.	0x07
Power Down During power down mode, the high crystal, CLKOUT, as well as RFFE are turned off. Native clock is updated using the low crystal. It wake at “mark” time given via the “transmit bits” field.	0x08
Slave Receive with Windowed Correlation with Encryption	0x12
Slave transmit with Encryption	0x13
Master Receive with Encryption	0x15
Master transmit with Encryption	0x16

## Functional Description (Continued)

### CONFIGURATION DATA—Bytes 1 through 9

Bytes 1 through 9 are used to transport LMX3162 Program Words (PW), via the LMX5001. The LMX3162 is controlled using 3 Program Words (PW1–PW3), each word being 20 bits long. Detailed information on the content and application of these Programming Words is provided in the LMX3162 Datasheet.

### CONFIGURATION DATA—Bytes 10 and 11

Bytes 10 and 11 contain “transmit bits”. It indicates number of bits to be transferred when the command in Byte 0 signal a transmission. This value is 12-bit in length with Byte 10 containing the least significant byte and the lower 4 bits of Byte 11 containing the remaining 4 most significant bits (reference *Table 1*). In the “power down” command, the “transmit bits” field contains wake up point. When the lower 12 bits of the native clock reaches this point, the Bluetooth unit comes out of the “power down” mode and wakes up to full power mode. The LMX5001 and LMX3162 take 3 SYSTICKS to complete a full power up sequence.

Bit 4 of Byte 11 is used as “loadclk”. It is valid only for “Change to Slave Clock” command. When this bit is set to 1, the lower 12 bits of the native clock is updated with the value in the “transmit bits” field. When this bit is 0, the native clock remains unchanged.

### CONFIGURATION DATA—Bytes 12 and 13

Bytes 12 and 13 contain a “Threshold” value. This value is used by the LMX5001 to test for an acceptable level of correlation between the internal Bluetooth Access Code (reference Bluetooth Specification) and the Access Code from the incoming packet. If the resulting maximum correlation exceeds this “Threshold” value then the LMX5001 achieves a correlation. The “Correlation” Flag is set in the packet’s payload, and subsequently transferred to the Link Management Controller (reference **section on LCI Rx Data**).

The Access Code Correlation Threshold is 10 bits in length with Byte 12 containing the least significant byte of the correlation threshold and the lower 2 bits of Byte 13 containing the remaining 2 most significant bits (reference *Table 1*).

Bits 7, 6, and 5 of Byte 13 are used for Receive Attenuation and Receive/Transmit Polarity (reference *Table 1*). When Bit 7 is set, the RX/TX switch in Radio Frequency Front End (RFFE) is set in the TX direction when receiving, which gives

~20 db attenuation in the receiver to help resolving the inter-modulation problem. When Bit 6 is set, the polarity of RX data is inverted. When Bit 5 is set, the polarity of TX data is inverted.

Bit 4 of Byte 13 is PLLOpenRX. It controls PLL loop when receiving. The loop is opened if this bit set to 1.

Bit 3 of Byte 13 is RSSI\_PH. It controls RSSI value A/D conversion scheme. If it is set to 1 the conversion uses peak-hold and the conversion is running throughout the entire receive phase. If it is set to 0 the conversion is running only during the correlation phase.

### CONFIGURATION DATA—Bytes 14 and 15

Bytes 14 and 15 are assigned to the control of external modulation components (reference *Table 1*).

### CONFIGURATION DATA—Bytes 16 and 17

Bytes 16 and 17 are assigned GPIO operation (reference *Table 1*). Byte 16 is used for GPIO output and Byte 17 is used for enable and disable. When the corresponding bit in Byte 17 is set to 0, the GPIO is input, otherwise, it is output. Bit 3 of Byte 16 has a special meaning. When it is 1, GPIO2 (Bit 4 of Byte 16) outputs a 4 MHz clock. When it is 0, GPIO2 performs regular GPIO function.

### CONFIGURATION DATA—Bytes 18 through 25

Bytes 18 through 25 contain the appropriate Sync Word part of the access code. The Sync Word is a 64-bit value (reference *Table 1*).

### LMX5001/LMX3162 STATUS DATA TRANSFER

LMX5001 (and LMX3162) status is communicated to the Link Management Controller by use of the RxData line on the LCI (supported by RxFrSync and SCLK signals). This transfer is under the control of the LMX5001, and occurs at a specific interval (reference *Figure 3—LCI Communication Scheduling*).

Note that the Status information which is presented to the Link Management Controller (via the LCI) details the Status of the LMX5001 and LMX3162 for the Frame/Slot immediately prior to the current one - there is a one frame delay in the transfer of Status information.

The data transfer relative to each Byte is detailed in *Table 3* below.

**TABLE 3. Status Data Bytes**

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Byte 0	Version Major				Version Minor			
Byte 1	GPIO5	GPIO4	GPIO3	GPIO2	0	0	GPIO1	GPIO0
Byte 2	LSB Maximum Correlation							
Byte 3	0	0	0	0	0	0	MSB Max Corr.	
Byte 4	LSB Timescew							
Byte 5	0	0	0	0	MSB Timescew			
Byte 6	NC(7)	NC(6)	NC(5)	NC(4)	NC(3)	NC(2)	NC(1)	NC(0)
Byte 7	NC(15)	NC(14)	NC(13)	NC(12)	NC(11)	NC(10)	NC(9)	NC(8)
Byte 8	NC(23)	NC(22)	NC(21)	NC(20)	NC(19)	NC(18)	NC(17)	NC(16)
Byte 9	0	0	0	0	NC(27)	NC(26)	NC(25)	NC(24)
Byte 10	0	0	0	AD value				
Byte 11	reserved				0	1	0	0



## Functional Description (Continued)

### STATUS DATA—Byte 0

Bytes 0 contains LMX5001 version number. It is in <Major>.<Minor> format.

### STATUS DATA—Byte 1

Bytes 1 contains GPIO input value. There are no corresponding enable bits for these GPIOs.

### STATUS DATA—Byte 2 and 3

Bytes 2 and 3 contain maximum correlation value of the receiving package. This value is 10-bit in length with Byte 2 containing the least significant byte and the lower 2 bits of Byte 3 containing the remaining 2 most significant bits (reference *Table 3*).

### STATUS DATA—Byte 4 and 5

Bytes 4 and 5 contain timeskew value. A timeskew is the phase difference between master and slave clock. The following formula is used to calculate timeskew: timeskew = slave clock - master clock.

Timeskew is within the range of -2499 to 2499. Its value is in 125 ns. That represents a clock value ranging -312.5 μs to 312.5 μs.

Timeskew is 13-bit in length with Byte 4 containing the least significant byte and the lower 5 bits of Byte 5 containing the remaining 5 most significant bits (reference *Table 3*).

### STATUS DATA—Byte 6 through 9

Bytes 6 through 9 contain the value of the native clock in half Bluetooth slot, 312.5 μs. This value is 28-bit in length with Byte 6 through 8 containing the least significant 3 bytes and the lower 4 bits of Byte 9 containing the 4 most significant bits (reference *Table 3*).

### STATUS DATA—Byte 10

Bytes 10 contains RSSI AD value from the LMX3162 Radio Controller. This value is 5 bits in length occupying the lower 5 bits.

### BLUETOOTH RECEIVE DATA

Bluetooth Receive Data is passed to the Link Management Controller via the LCI, using RxData in conjunction with RxFrSync and SCLK. Receive Data is formatted into 3, 8-bit Bytes (reference *Table 4*).

**TABLE 4. LCI—Bluetooth Receive Data**

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Byte 0	0	CORR	0	0	0	0	trail(0)	trail(1)
Byte 1	trail(2)	trail(3)	head(0)	head(1)	head(2)	head(3)	head(4)	head(5)
Byte 2	head(6)	head(7)	head(8)	head(9)	head(10)	head(11)	head(12)	head(13)

Note from *Table 4*, that bit 6 of Byte 0 (CORR) contains an Access Code correlation status bit. When this bit is logic “0” this indicates to the Link Management Controller that a satisfactory level of correlation exists between the incoming data packet’s Access Code and the Bluetooth Access Code present in the LMX5001. It follows that a logic “1” indicates that the received data packet’s Access Code did not sufficiently match that contained in the LMX5001.

The 4 Trailer bits (in Byte 0 and 1 above) are the Trailer bit which immediately follow the Sync Word on which an Access Code correlation has just been done. Note that the bit “Trail(0)” is disregarded in most situations, due to the fact that the bit timing is also being obtained from the correlation task (this being updated in most cases).

Bluetooth Receive Data will continuously be presented to the LCI whenever the LMX5001 is executing “Slave Receive with Windowed Correlation” or “Master Receive” (reference LMX5001 Command Set). However, when a “Slave Receive with Continuous Correlation” is executed, Receive Data will only be present on the LCI when its Access Code correlation exceeds the AC Threshold (reference “Access Code Correlation” section of this Datasheet).

### BLUETOOTH TRANSMIT DATA

Bluetooth Transmit Data is received by the LMX5001, from the Link Management Controller via the LCI, using TxData in conjunction with TxFrSync and SCLK. Transmit Data is formatted as follows (reference *Table 5*):

**TABLE 5. LCI—Bluetooth Transmit Data**

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Byte 0	X	X	Extpre(0)	Extpre(1)	Extpre(2)	Extpre(3)	Extpre(4)	Extpre(5)
Byte 1	Extpre(6)	Extpre(7)	Extpre(8)	Extpre(9)	Extpre(10)	Extpre(11)	Extpre(12)	Extpre(13)
Byte 2	Extpre(14)	Extpre(1'5)	Pre(0)	Pre(1)	Pre(2)	Pre(0)	Sync(0)	Sync(1)

Note from *Table 5*, that, following the first two bits (which are ignored by the LMX5001), the subsequent 16 bits contain an “Extended Preamble”. While this is not a requirement of the Bluetooth Specification, they are included to improve Radio performance.

Following Byte 2, subsequent Bytes presented to the LMX5001 LCI should contain the data which is to be transmitted over the Bluetooth link. The format for this data should

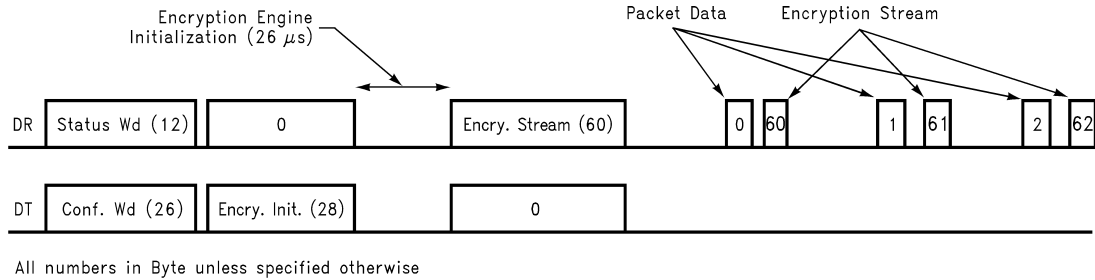
follow the convention laid out above. Once the data has been forwarded to the LMX5001, the Transmit mode is exited by the Link Management Controller asserting a SYS-LOAD on the LCI.

## Functional Description (Continued)

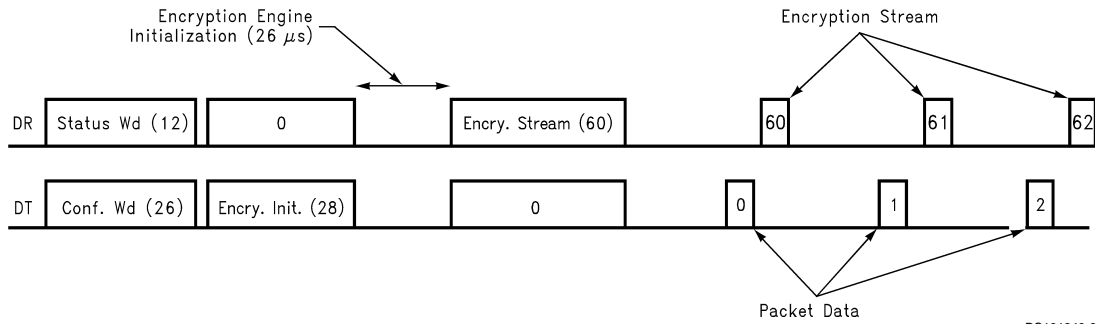
### ENCRYPTION ENGINE

A Bluetooth encryption engine is implemented in the LMX5001. The algorithm of the engine follows figure 14.6 and Steps 2, 3 and 4 in section 14.3.5 of the Bluetooth Specification 1.0A. The encryption engine initialization is carried out over the LCI. It occurs after system load and before the actual data transmission/receiving. 208 initialization bits are loaded to LMX5001 after the system load. The LMX5001

then runs the encryption initialization for 26  $\mu$ s. After encryption initialization the first 60 bytes of the “encryption stream  $Z_t$ ” is sent back to the LMC to allow firmware enough time to get the encrypted transmit data ready. The 60 byte lead time is needed only for transmit, but it is sent regardless the type of transaction to reduce the firmware complexity. The consequent bytes in the encryption stream are piggy-backed with the packet data once the transition starts. The encryption enabled data transfer activity on LCI is illustrated in the figures below:



**FIGURE 4. Receive with encryption enabled (command code 0x12 or 0x15)**



**FIGURE 5. Transmit with encryption enabled (command code 0x13 or 0x16)**

The 28 Encryption Initialization bytes are detailed in *Table 6* below:

**TABLE 6. Encryption Initialization Bytes**

Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Byte 0				$Kc'[0]_6 \dots Kc'[0]_0$				$CL_{24}$
Byte 1	$Kc'[1]_0$			$CL[0]_L$		0	0	1
Byte 2				$Kc'[2]_6 \dots Kc'[2]_0$				$CL_{25}$
Byte 3	$Kc'[3]_0$			$CL[0]_U$		1	1	1
Byte 4				$Kc'[4]_6 \dots Kc'[4]_0$				$Kc'[0]_7$
Byte 5	$Kc'[5]_0$				$Kc'[1]_7 \dots Kc'[1]_1$			
Byte 6				$Kc'[6]_6 \dots Kc'[6]_0$				$Kc'[2]_7$
Byte 7	$Kc'[7]_0$				$Kc'[3]_7 \dots Kc'[3]_1$			
Byte 8				$Kc'[8]_6 \dots Kc'[8]_0$				$Kc'[4]_7$
Byte 9	$Kc'[9]_0$				$Kc'[5]_7 \dots Kc'[5]_1$			
Byte 10				$Kc'[10]_6 \dots Kc'[10]_0$				$Kc'[6]_7$
Byte 11	$Kc'[11]_0$				$Kc'[7]_7 \dots Kc'[7]_1$			
Byte 12				$Kc'[12]_6 \dots Kc'[12]_0$				$Kc'[8]_7$
Byte 13	$Kc'[13]_0$				$Kc'[9]_7 \dots Kc'[9]_1$			
Byte 14				$Kc'[14]_6 \dots Kc'[14]_0$				$Kc'[10]_7$
Byte 15	$Kc'[15]_0$				$Kc'[11]_7 \dots Kc'[11]_1$			

## Functional Description (Continued)

**TABLE 6. Encryption Initialization Bytes (Continued)**

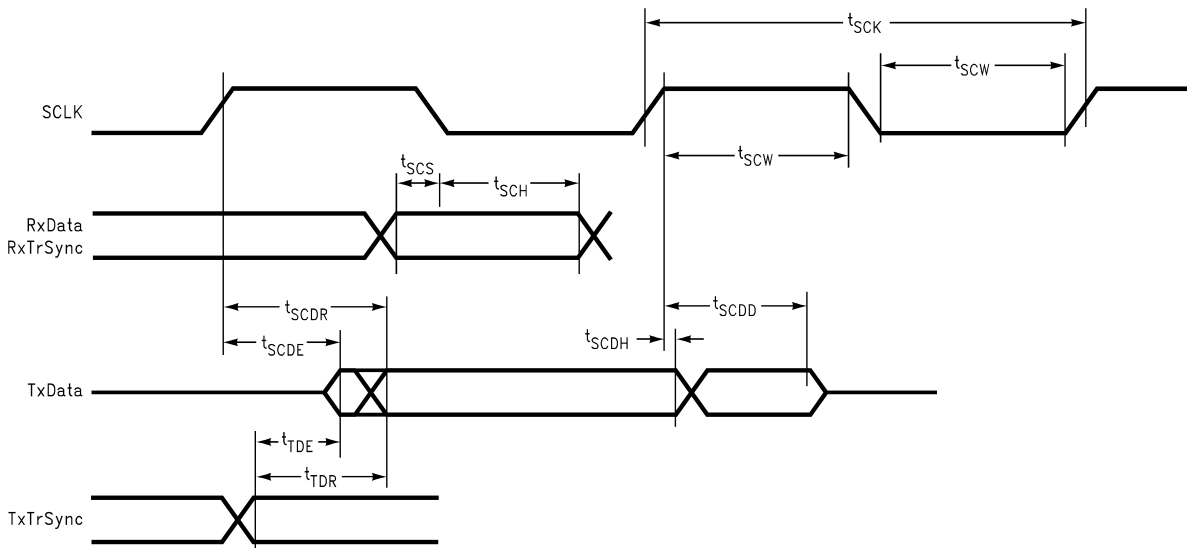
Byte No.	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Byte 16	CL[1] <sub>6</sub> ...CL[1] <sub>0</sub>							Kc'[12] <sub>7</sub>
Byte 17	ADR[0] <sub>0</sub>	Kc'[13] <sub>7</sub> ...Kc'[13] <sub>1</sub>						
Byte 18	CL[2] <sub>6</sub> ...CL[2] <sub>0</sub>							Kc'[14] <sub>7</sub>
Byte 19	ADR[1] <sub>0</sub>	Kc'[15] <sub>7</sub> ...Kc'[15] <sub>1</sub>						
Byte 20	ADR[2] <sub>6</sub> ...ADR[2] <sub>0</sub>							CL[1] <sub>7</sub>
Byte 21	ADR[3] <sub>0</sub>	ADR[0] <sub>7</sub> ...ADR[0] <sub>1</sub>						
Byte 22	ADR[4] <sub>6</sub> ...ADR[4] <sub>0</sub>							CL[2] <sub>7</sub>
Byte 23	ADR[5] <sub>0</sub>	ADR[1] <sub>7</sub> ...ADR[1] <sub>1</sub>						
Byte 24	0-fill							ADR[2] <sub>7</sub>
Byte 25	0-fill	ADR[3] <sub>7</sub> ...ADR[3] <sub>1</sub>						
Byte 26	0-fill							ADR[4] <sub>7</sub>
Byte 27	0-fill	ADR[5] <sub>7</sub> ...ADR[5] <sub>1</sub>						

Byte 0 is corresponding to the rightmost 8-bit of the upper initialization in figure 14.8 of the Bluetooth Specification 1.0A, i.e. CL<sub>24</sub> and 7-bit of Kc'[0]. Byte 1 is the rightmost 8-bit of the 2nd initialization and so on. The names in *Table 6* follow those in the Bluetooth Specification 1.0A.

### LMX3162 MICROWIRE Interface

The functionality of this interface is detailed in the LMX3162 Datasheet.

## Link Controller Interface AC Timing Characteristics



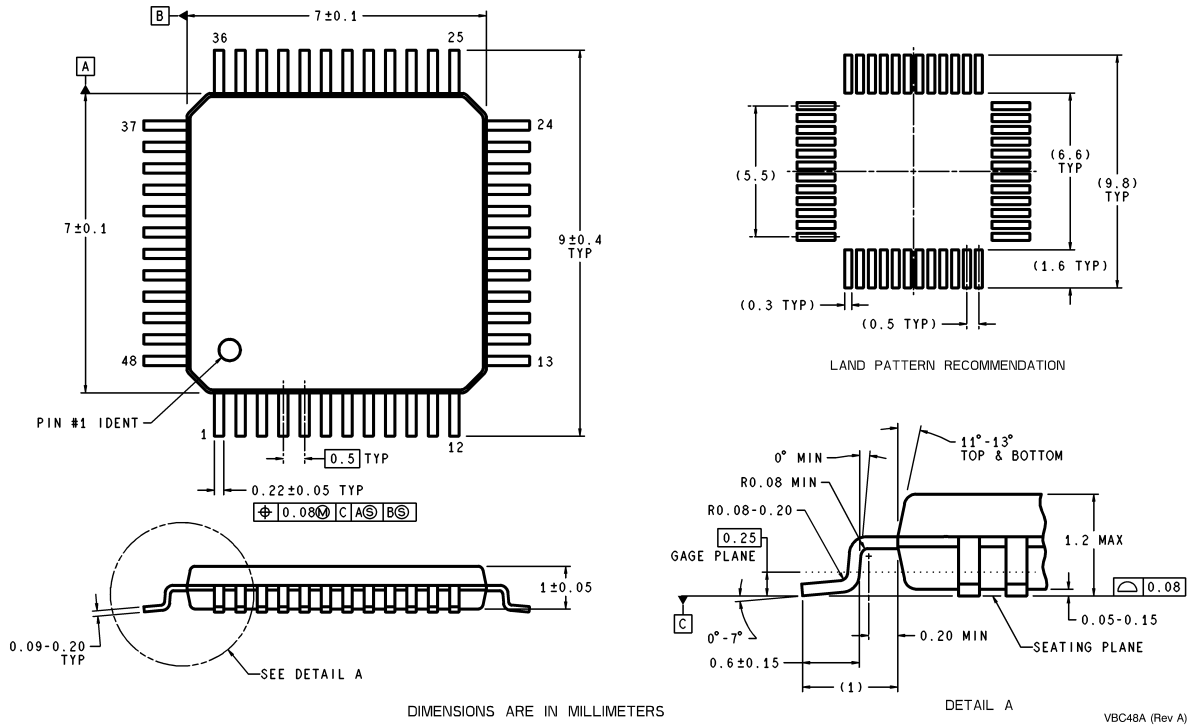
DS101340-8

Parameter	Min	Max	Units
SCLK Period, $t_{sck}$	80		ns
RxData/RxTrSync Setup before SCLK low, $t_{scs}$	8		ns
RxData/RxTrSync Hold after SCLK low, $t_{sch}$	10		ns
SCLK Width, $t_{scw}$	30		ns
SCLK High to TxData Enable, $t_{scdR}$	0		ns
SCLK High to TxData Ready, $t_{scdR}$		20	ns
TxData Hold after SCLK, $t_{scdH}$	0		ns
TxTrSync to TxData Enable, $t_{tde}$	0		ns
TxTrSync to TxData Ready, $t_{tdr}$		18	ns
SCLK High to TxData Disable, $t_{scdD}$		25	ns

## LMX3162 MICROWIRE AC Timing Characteristics

The timing characteristics for this port are detailed in the LMX3162 Datasheet.

**Physical Dimensions** inches (millimeters) unless otherwise noted



DIMENSIONS ARE IN MILLIMETERS

**48-Pin Thin Quad Flatpak**  
**Order Number LMX5001VBC**  
**NS Package Number VBC48A**

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