

## BLUETOOTH™ and FM TRANSCEIVER SYSTEM on CHIP

The STLC2690 combines Bluetooth and FM transceiver functionality on a single chip and is fully optimized for mobile applications such as mobile phones, smart phones, PDAs and portable media players. The required board space has been minimized, power consumption levels are targeted for battery powered devices and the integration allows a cost effective solution. Amongst others the reduction of external components enables manufacturers to easily and fast integrate the STLC2690 on their product to enable a short time to market. Compared to its successful predecessor, the STLC2593, the STLC2690 is a system on chip device, it adds an FM transmitter, an audio processor and A2DP encapsulation and further optimizes in terms of RF performances and cost.

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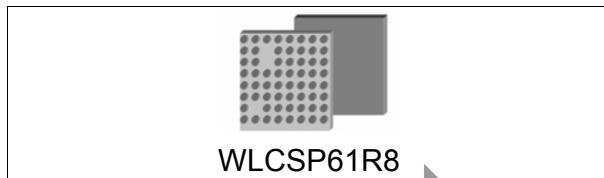
#### Features

- WLCSP 0.6 mm high, 0.4 mm pitch, lead-free/RoHs compliant, 61 pins
- 10 external components: 5 decoupling capacitors on the power supply, 1 B-BPF for Bluetooth, 1 inductor and 3 capacitors for FM RX
- PCB footprint < 36 mm<sup>2</sup>
- Clocks
  - Fast clock input (digital or sine wave) at 13, 16, 16.8, 19.2, 26, 32, 33.6, 38.4, 52 MHz
  - Slow clock input at 32, 32.768 kHz
  - Direct external crystal input
- Power supply
  - Single power supply with internal regulators
- 1.65 V to 1.95 V I/O systems
- Various on-chip auto calibration features (VCO, Filters, ...)

#### Bluetooth Features

- Bluetooth™ specification compliance: V3.0
- Specific BT V3.0 features
  - Enhanced Power Control
  - Read Encryption Key Size
- Adaptive Frequency Hopping (AFH)
- Channel Quality Driven Data Rate (CQDDR)
- Transmit Power
  - Power Class 2 and Power Class 1.5 (above 4 dBm)
  - Programmable output power
- HCI
  - HCI H4 Transport Layer on UART and SPI
  - HCI proprietary commands (e.g. peripherals control)
  - Single HCI command for patch/upgrade download
  - (e)SCO over HCI
- Pitch-Period Error Concealment (PPEC)
- Efficient and flexible support for WLAN coexistence scenarios
- Low power consumption
  - Ultra low power architecture with 3 different low-power levels
  - Deep Sleep modes, including Host-power saving feature
  - Dual Wake-up mechanism
- Communication interfaces

#### Package



WLCSP61R8

#### Order Codes

Part Number	Package	Packing
STLC2690WTR	WLCSP61	Tape on Reel

- UART (up to 4 MHz), SPI (up to 52 MHz), PCM/I2S, I2C
- Up to 22 additional flexibly programmable GPIOs
- External interrupts possible through the GPIOs
- Main processor
  - ARM7TDMI CPU
  - On chip RAM, including provision for patches
  - On chip ROM, preloaded with SW up to HCI and A2DP mediapacket encapsulation
- CoProcessor
  - Audio processor including RAM and ROM
  - ROM preloaded with SBC en-/decoding
  - Ciphering support up to 128 bits key

#### FM Receiver Features

- Worldwide FM band (65.9 - 108 MHz)
- RDS/RBDS
- State of the art receiver sensitivity
- Excellent receiver selectivity for audio and RDS
- DSP-demodulation
- Adaptive signal processing, to provide best audio quality versus received signal quality or in-band blockers.
- Embedded microcontroller to control flexible DSP, to handle and (de)code RDS messages, supporting high-level and low level API
- Ultra fast checking for AF
- Analog and digital audio output
- Dual RF input with embedded FM TX/RX antenna switch to optimize for wire antennas and integrated antennas

#### FM Transmitter Features

- Worldwide FM band (76 - 108 MHz)
- RDS/RBDS
- High output power (120 dB<sub>µ</sub>Vpdiff) linear transmitter
- Dual TX channel mode using AF list, with programmable separation
- SureTune™ to automatically select the optimal transmit frequency
- Embedded filtering for coexistence in mobile handset
- RF output optimized for integrated antennas
- Programmable AGC for optimized frequency deviation
- Programmable limiter to prevent overmodulation
- Highly flexible DSP (shared with FM RX)
- Embedded microcontroller (shared with FM RX)
- Analog and digital audio input

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## 1 INTRODUCTION

The STLC2690 is a system-on-chip Bluetooth V3.0 transceiver and FM radio transceiver. The chip is packed in Wafer Level Chip Scale Package (WLCSP) of 0.6 mm high, 0.4 mm pitch.

The Bluetooth subsystem is the successor of the STLC2500D, a field-proven, single chip ROM-based Bluetooth solution for applications requiring integration up to HCI level. The STLC2690 supports in addition A2DP mediapacket encapsulation and SBC encoding/decoding. This allows to offload those functions from the Host for several use cases. Patch RAM is available, enabling multiple patches/upgrades and fast time to volume. The main interfaces are UART or SPI for HCI transport, PCM or I2S for voice and a WLAN coexistence interface. The radio has been designed specifically for single chip requirements, for low power and minimum BOM count.

The FM radio transceiver contains both a broadcast FM radio tuner and a broadcast FM radio transmitter for portable applications with worldwide FM band support. (De)multiplexing and (de)modulation are performed in a digital data path. A small embedded microcontroller manages the flexibility of the data path and the DSP parameters and takes care of the overall control of the transceiver. This microcontroller is also used for transmission and reception of the European Radio Data System (RDS) and the North American Radio Broadcast Data System (RBDS), including all required symbol decoding, block synchronization, error detection, and error correction functions. The FM can be controlled by the Host via a dedicated I2C interface or via the Bluetooth HCI interface. A Host-level API is offered in order to facilitate integration of the FM driver on the Host. Also a low-level API is supported.

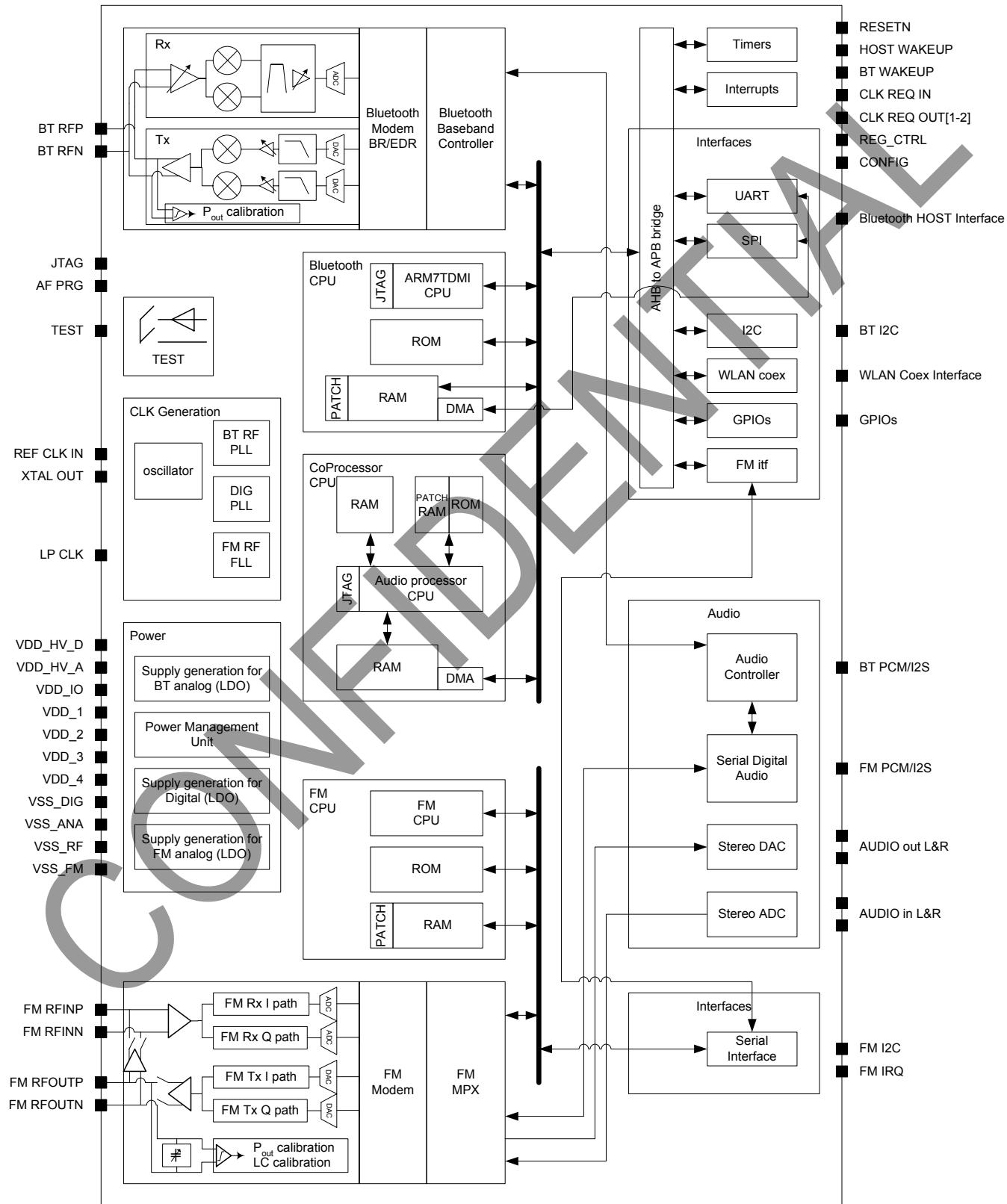
The Bluetooth transceiver and FM transceiver are integrated on the same silicon, and they share at top-level power supplies, clocks and reset control. The chip integrates several regulators to generate the internally needed voltages from the Host platform supply input. The STLC2690 supports several use cases using simultaneous BT and FM and exchanging audio between the two subsystems.

For the Bluetooth transceiver, 5 decoupling capacitors and a band-pass filter are required as external BOM. For the FM transmitter, no external components are required, provided a loop antenna is used. For the FM receiver, 1 inductor and 3 capacitors are required. This results in a required PCB footprint smaller than 36 mm<sup>2</sup> (using 0201 components where possible and with a 0.3 mm spacing rule). The FM antenna matching network, which depends on the specific antenna implementation, is included in this footprint.

## 2 GENERIC DESCRIPTION

### 2.1 Block Diagram

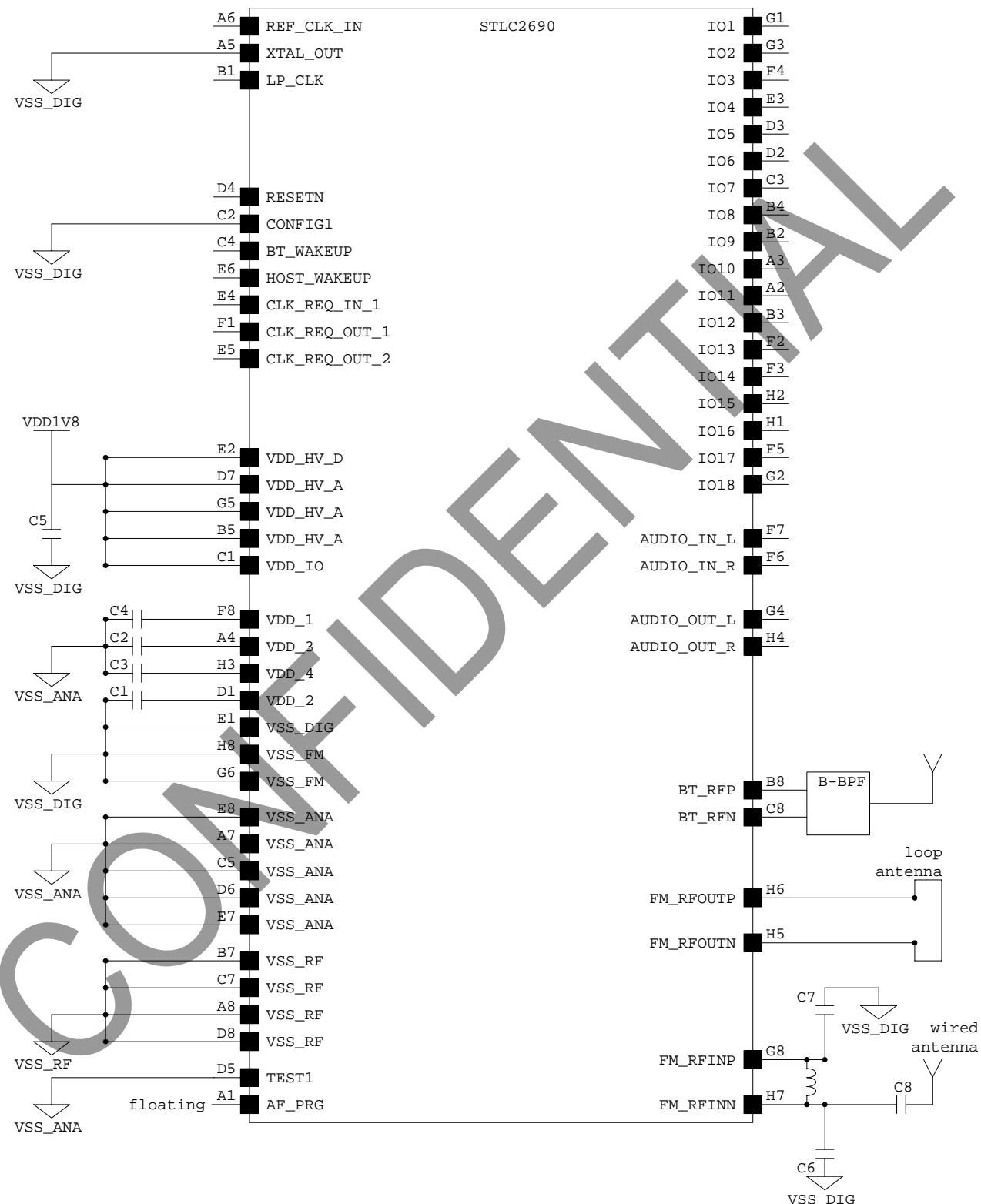
Figure 1. Block diagram



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## 2.2 Application schematic

Figure 2. Typical Application Schematic



For values of the components, refer to the HW Manual.

Note that the application schematic in Figure 2 is for a certain configuration. Other configurations are possible:

- The fast clock is provided from a digital or analog clock signal. This clock can also be generated from an external crystal directly connected to the chip, see section 2.6.
- FM RX is connected to a wired antenna. It can also be connected to the loop antenna, see 4.2.1 for more details.
- VDD\_HV\_D, VDD\_HV\_A and VDD\_IO are connected to the platform supply. Other configurations are possible, see section 2.5.
- The control signals and digital interfaces are not shown in Figure 2, since they depend on which digital interfaces are used in the application. See section 2.4 and 2.5.

## 2.3 Electrical Data

VDD\_HV\_x means VDD\_HV\_A and VDD\_HV\_D.

(See also Table 11)

### 2.3.1 Absolute Maximum Ratings

The Absolute Maximum Rating (AMR) corresponds to the maximum value that can be applied without leading to instantaneous or very short-term unrecoverable hard failure (destructive breakdown).

**Table 1. Absolute Maximum Ratings**

Symbol	Parameter	Min.	Max.	Unit
VDD_HV_x	Core supply voltages (in case of pre-regulated power supply from the platform)	-0.3	2.5	V
VDD_IO	Supply voltage I/O	-0.3	2.5	V
Vin	Input voltage on any digital pin	-0.3	2.5	V
Vssdiff	Maximum voltage difference between different types of Vss pins.	-0.3	0.3	V
Tstg	Storage temperature	-65	+150	°C

### 2.3.2 Operating Ranges

Operating ranges define the limits for functional operation and parametric characteristics of the device. Functionality outside these limits is not guaranteed.

**Table 2. Operating Ranges**

Symbol	Parameter	Min.	Typ.	Max.	Unit
T <sub>amb</sub>	Operating ambient temperature	-40	25	+85	°C
VDD_HV_x	Core supply voltages (in case of pre-regulated power supply from the platform)	1.65	1.8	1.95	V
VDD_IO	I/O supply voltage	1.65	1.8	1.95	V

### 2.3.3 I/O Specifications

The I/Os comply with the EIA/JEDEC standard JESD8-B.

**Table 3. DC Input Specification**

Symbol	Parameter	Min.	Typ.	Max.	Unit
V <sub>IL</sub>	Low level input voltage	-0.2		0.35 * VDD_IO	V
V <sub>IH</sub>	High level input voltage	0.65 * VDD_IO		(VDD_IO + 0.2) and (≤ 2.0)	V
C <sub>in</sub>	Input capacitance, including package <sup>(1)</sup>			5	pF
R <sub>pu</sub>	Pull-up equivalent resistance (with V <sub>in</sub> = 0 V)		50		kΩ
R <sub>pd</sub>	Pull-down equiv. resistance (with V <sub>in</sub> = VDD_IO)		50		kΩ

$V_{\text{hyst}}$	Schmitt trigger hysteresis	150				mV
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1. Typical input capacitance without package is 0.9 pF.

**Table 4. DC Output Specification**

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
$V_{\text{OL}}$	Low level output voltage	$I_d = X^{(1)} \text{ mA}$			0.2	V
$V_{\text{OH}}$	High level output voltage	$I_d = X^{(1)} \text{ mA}$	$V_{\text{DD\_IO}} - 0.2$			V

1. X is the source/sink current under worst-case conditions according to the drive capabilities (see section 2.4).

### 2.3.4 Clock Specifications

For more details on the clocks see section 2.6.

**Table 5. Fast Clock Supported Frequencies**

Symbol	Parameter	Values	Unit
$f_{\text{IN}}$	Clock input frequency list	13, 16, 16.8, 19.2, 26, 32, 33.6, 38.4, 52	MHz

**Table 6. Fast Clock Overall Specifications**

Symbol	Parameter	Min.	Typ.	Max.	Unit
$f_{\text{INTOL}}$	Tolerance on input frequency	-20		20	ppm

**Table 7. Fast Clock, Sine Wave Specifications**

Symbol	Parameter	Min.	Typ.	Max.	Unit
$V_{\text{PP}}$	Peak to peak voltage range	0.2	0.5	1.8	V
$NH$	Total harmonic content of input signal			-25	dBc
$Z_{\text{INRe}}$	Real part of parallel input impedance at pin	30	100		kΩ
$Z_{\text{INIm}}$	Imaginary part of parallel input impedance at pin		2	4.7	pF
$Z_{\text{IDRe}}$	Change in real part of parallel input impedance at pin, when changing mode (expressed in equivalent parallel resistance added or removed)	150			kΩ
$Z_{\text{IDIm}}$	Change in imaginary part of parallel input impedance at pin, when changing mode (expressed in equivalent parallel capacitance added or removed)			500	fF
	Phase noise @ 10 kHz			-130	dBc/Hz
	Phase noise @ 100 kHz			-135	dBc/Hz

**Table 8. Fast Clock, Digital Clock AC Specifications**

Symbol	Parameter	Min.	Typ.	Max.	Unit
$T_{\text{RISE}}$	10% - 90% rise time			70 % of the clock period	ns
$T_{\text{FALL}}$	90% - 10% fall time			70 % of the clock period	ns
$D_{\text{CYCLE}}$	Duty Cycle	35	50	65	%
	Phase noise @ 10 kHz			-130	dBc/Hz
	Phase noise @ 100 kHz			-135	dBc/Hz

Table 9. Slow Clock Specifications

Symbol	Parameter	Min.	Typ.	Max.	Unit
$F_{IN}$	Clock input frequencies	32, 32.768			kHz
	Duty Cycle	30		70	%
	Tolerance on input frequency	~ -250		250 <sup>(3)</sup>	ppm
$V_{IL}$	Low level input voltage			0.35 * VDD_IO	V
$V_{IH}$	High level input voltage	0.65 * VDD_IO			V
$V_{hyst}$	Schmitt trigger hysteresis	150			mV
$C_{IN}$	Input capacitance			5	pF
$T_{RISE}$	10% - 90% rise time <sup>(1)</sup>			500	ns
$T_{FALL}$	90% - 10% fall time <sup>(1)</sup>			500	ns
	Total jitter <sup>(2)</sup>			250 <sup>(3)</sup>	ppm

1. The rise and fall time are not the most important parameters for the slow clock input due to the Schmitt trigger logic. It is more important that the noise on the slow clock line remains substantially below the hysteresis in amplitude.
2. The total jitter is defined as the error that can appear on the actual frequency between two clock edges compared to the perfect frequency. Due to this, the total jitter value must contain the jitter itself and the error due to the accuracy on the clock frequency. The lower the accuracy, the smaller the jitter is allowed to be.
3. For use of the slow clock for FM, in case the accuracy of the externally applied slow clock is not sufficient, the STLC2690 provides a calibration mechanism to calibrate the slow clock versus the fast clock.

### 2.3.5 Current Consumption

Table 10. Current Consumption<sup>(1)</sup>

Bluetooth subsystem		
(Tamb = 25 °C, 26 MHz digital clock, 4 dBm output power for BR packets, 3 dBm output power for EDR packets, VDD_HV_x = VDD_IO = 1.8 V)		
State	Typ.	Unit
Complete Power Down	1	µA
Deep Sleep mode	18	µA
Functional Sleep mode <sup>(2)</sup>	1.47	mA
HW Inquiry scan (1.28 s period, 11.25 ms window), combined with H4 UART Deep Sleep mode (section 3.3.1.1)	210	µA
HW Page scan (1.28 s period, 11.25 ms window), combined with H4 UART Deep Sleep mode (section 3.3.1.1)	210	µA
HW Inquiry and Page scan (1.28 s period, 11.25 ms window), combined with H4 UART Deep Sleep mode (section 3.3.1.1)	390	µA
Sniff mode (1.28 s, 4 attempts, 0 timeouts), combined with H4 UART Deep Sleep mode (section 3.3.1.1)		
- Master	79	µA
- Slave	105	µA
Idle ACL connection		
- Master	2.9	mA
- Slave	4.9	mA
Active: data: DH1/DH1 symmetrical transfer (172.8 kbps), Master or Slave	21	mA
Active: data: DH5/DH1 asymmetrical transfer (TX 723.2 kbps & RX 57.6 kbps), Master or Slave	30.7	mA
Active: data: DH5/DH5 symmetrical transfer (433.9 kbps), Master or Slave	27.1	mA
Active: data: 2-DH5/2-DH5 symmetrical transfer (869.7 kbps), Master or Slave	28	mA
Active: data: 3-DH5/3-DH5 symmetrical transfer (1306.9 kbps), Master or Slave	28	mA
Active: audio: HV3, Master, not sniffed	8.7	mA
Active: audio: HV3, Slave, Sniff (1.28 s, 2 attempts, 0 timeouts)	8.3	mA

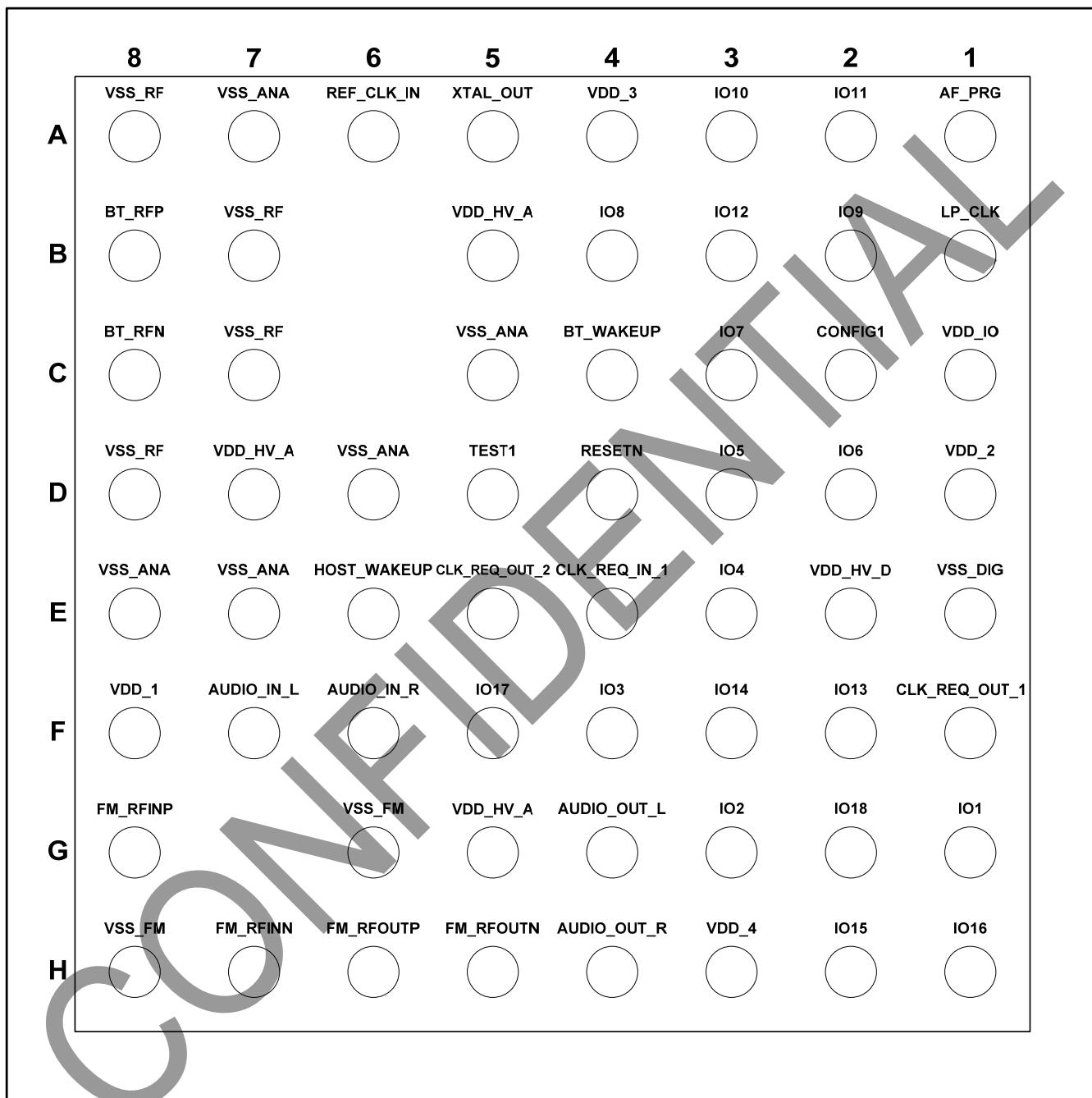
Active: audio: eSCO (EV3), (64 kbps symmetrical, $T_{SCO} = 6$ ) - Master - Slave (1 retransmission)	9 9.4	mA mA
Active: audio: eSCO (2-EV3), (64 kbps symmetrical, $T_{SCO} = 12$ ) - Master - Slave (1 retransmission)	5.9 5.4	mA mA
Active: audio: eSCO (3-EV3), (64 kbps symmetrical, $T_{SCO} = 18$ ) - Master - Slave (1 retransmission)	5 4.3	mA mA
<b>FM subsystem</b> ( $T_{amb} = 25^{\circ}C$ , $VDD_{HV\_x} = VDD_{IO} = 1.8\text{ V}$ ) <sup>(3)</sup>		
<b>State</b>		
Complete power down	1	$\mu\text{A}$
Active RX on slow clock	15	mA
Active TX (at 120 dB $\mu\text{V}$ pdifff output power)	21	mA

1. With HCI interface in sleep mode.
2. In functional Sleep mode, the baseband clock is still running.
3. Using dedicated I2C and I2S interfaces. FM in mono operation. Using the HCI interface for control would add typically the Sleep mode current of the Bluetooth subsystem except if the HCI interface is put in Sleep mode.

## 2.4 Pinout

### 2.4.1 Pinout

Figure 3. Pinout Bottom View



### 2.4.2 Pin List

Table 11 shows the pin list of the STLC2690 during and after reset.

In columns “Reset” and “Default after reset”, the “PD/PU” shows the pads implementing an internal pull-down/up.

The column “Reset” shows the state of the pins during hardware reset; the column “Default after reset” shows the state of the pins after the hardware reset state is left, but before any Host activity on the Host interface and before the SW Parameter File download.

The column “Type” describes the pin directions:

- I for Input (All digital inputs have a Schmitt trigger function.)
- O for Output
- I/O for Input/Output (All digital inputs have a Schmitt trigger function.)
- O/t for tri-state output

For the output pins the default drive capability is 2 mA, except for the pins HOST\_WAKEUP, IO7, IO9 and IO11 where it is 8 mA.

Table 11. The STLC2690 Pin List (Functional and Supply)

Bluetooth subsystem						
Name	Pin #	Type	Description	Function during and after reset	Reset <sup>(1)</sup>	Default <sup>(2)</sup> after reset
<b>Clock Signals</b>						
REF_CLK_IN	A6	I	Fast clock input when XTAL_OUT is strapped to VSS_DIG Otherwise XTAL input		Input	Input
XTAL_OUT	A5	I/O	Strapped to VSS_DIG when fast clock on REF_CLK_IN Otherwise XTAL feedback			
LP_CLK	B1	I	Slow clock input		Input	Input
<b>Digital Control Signals</b>						
RESETN	D4	I	Global reset – active low		Input	Input
CONFIG1	C2	I	Configuration pin, strapped to VSS_DIG		Input = 0	Input = 0
BT_WAKEUP	C4	I	Wake-up signal to Bluetooth (active high), should be strapped to VSS_DIG if not used		Input	Input
HOST_WAKEUP	E6	I/O <sup>(3)</sup>	Programmable pin	HOST_WAKEUP / SPI_INT	Input PD	Output low
CLK_REQ_IN_1	E4	I/O <sup>(3)</sup>	Programmable pin	CLK_REQ_IN	Input PD	Input PD
CLK_REQ_OUT_1	F1	I/O <sup>(3)</sup>	Programmable pin	CLK_REQ_OUT	Input PD	Output high
CLK_REQ_OUT_2	E5	I/O <sup>(3)</sup>	Programmable pin	CLK_REQ_OUT_N	Input PU	Output low
<b>Digital Interfaces</b>						
IO1	G1	I/O <sup>(3)</sup>	Programmable pin	UART_RXD	Input PU	Input PU
IO2	G3	I/O <sup>(3)</sup>		UART_TXD	Input PU	Output high
IO3	F4	I/O <sup>(3)</sup>		UART_CTS	Input PU	Input PU
IO4	E3	I/O <sup>(3)</sup>		UART_RTS	Input PU	Output high
IO5	D3	I/O <sup>(3)</sup>	Programmable pin	SPI_CLK	Input PD	Input PD
IO6	D2	I/O <sup>(3)</sup>		SPI_DI	Input PD	Input PD
IO7	C3	I/O <sup>(3)</sup>		SPI_DO	Input PD	Tristate PD
IO8	B4	I/O <sup>(3)</sup>		SPI_CSN	Input PU	Input PU
IO9	B2	I/O <sup>(3)</sup>	Programmable pin	Not used	Input PD	Input PD
IO10	A3	I/O <sup>(3)</sup>		Not used	Input PD	Input PD
IO11	A2	I/O <sup>(3)</sup>		Not used	Input PD	Input PD
IO12	B3	I/O <sup>(3)</sup>		Not used	Input PD	Input PD
IO13	F2	I/O <sup>(3)</sup>	Programmable pin	FM_I2C_CLK	Input PU	Input PU
IO14	F3	I/O <sup>(3)</sup>		FM_I2C_DATA	Input PU	Input PU
IO15	H2	I/O <sup>(3)</sup>	Programmable pin	Not used	Input PD	Input PD
IO16	H1	I/O <sup>(3)</sup>		Not used	Input PD	Input PD
IO17	F5	I/O <sup>(3)</sup>		Not used	Input PD	Input PD
IO18	G2	I/O <sup>(3)</sup>		Not used	Input PD	Input PD
<b>Bluetooth RF Interface</b>						

BT_RFP	B8	I/O	Differential Bluetooth RF port		
BT_RFN	C8	I/O			
<b>FM RF Interfaces</b>					
FM_RFINP	G8	I	Differential FM RF input		
FM_RFINN	H7	I			
FM_RFOUTP	H6	I/O	Differential FM RF output and input, see section 4.2.1		
FM_RFOUTN	H5	I/O			
<b>Analog audio interfaces</b>					
AUDIO_IN_L	F7	I	Left analog audio input		
AUDIO_IN_R	F6	I	Right analog audio input		
AUDIO_OUT_L	G4	O	Left analog audio output		
AUDIO_OUT_R	H4	O	Right analog audio output		
<b>Power Supply</b>					
VDD_HV_D	E2		Power supply – Connect to platform supply		
VDD_HV_A	D7		Power supply – Connect to platform supply		
	G5				
	B5				
VDD_IO	C1		I/Os supply		
VDD_1	F8		Internal supply decoupling / Regulator output. Need 220 nF decoupling capacitor to VSS_ANA.		
VDD_2	D1		Internal supply decoupling / Regulator output. Need 220 nF decoupling capacitor to VSS_DIG.		
VDD_3	A4		Internal supply decoupling / Regulator output. Need 220 nF decoupling capacitor to VSS_ANA.		
VDD_4	H3		Internal supply decoupling / Regulator output. Need 220 nF decoupling capacitor to VSS_ANA.		
VSS_DIG	E1		Digital ground		
VSS_ANA	A7		Analog ground		
	E8				
	C5				
	E7				
	D6				
VSS_RF	B7		RF ground		
	C7				
	A8				
	D8				
VSS_FM	G6		FM ground		
	H8				
<b>Other pins</b>					
TEST1	D5		Test pin, to be strapped to VSS_ANA		
AF_PRG	A1	I/O	Test pin (leave unconnected) <sup>(4)</sup>	Open	Open

1. Pin behavior during HW reset (RESETN low).
2. Pin behavior immediately after HW reset and internal chip initialization, but before any Host activity on the Host interface and the SW Parameter File download.
3. Reconfigurable I/O pin. The functionality and type of these I/Os can be configured through different procedures (see section 2.4.3).
4. Pin is ST-reserved for test function and it must be soldered to an isolated pad (not connected to anything, just floating).

### 2.4.3 Pin Mapping

Some control signals and the digital interface pins are programmable pins, see Table 11. Different functions and different pull-up/down can be mapped on these pins. The control signals, digital interfaces and GPIOs of section 2.5 can be mapped to these programmable pins.

Following procedure determines the final pin mapping.

- When using SPI as Host interface, the Host has the option to change the default settings of the SPI by writing in the SPI configuration register. One of the configurations is the mapping of the flow control, SPI\_FLOW, to a pin.
- After reset, when the Host starts sending data over UART or SPI, this interface is recognized as being the Host interface. The I/Os are automatically remapped as indicated in [17].
- After the procedures described above are finished, a SW Parameter File can be downloaded to remap some of the pins and to configure pulls, see also section 3.1.7. This can also be done with HCI commands.

A detailed list of which functions map to which pins is available in [17].

## 2.5 Power Supply

The chip runs from one single pre-regulated power supply from the platform for the core functions, VDD\_HV\_D (digital functions) and VDD\_HV\_A (analog functions), and one supply for the I/Os, VDD\_IO. These supplies could be connected to the same platform supply or to different supplies. A decoupling capacitor is needed on these supplies. Also a dedicated regulator can be used, see section 2.5.1.

Internal regulators generate the core voltages. VDD\_1, VDD\_2, VDD\_3, VDD\_4 are the outputs of these internal regulators. Supply decoupling capacitors are needed on these outputs.

The grounds VSS\_DIG, VSS\_ANA, VSS\_RF and VSS\_FM have to be connected to the platform ground.

Specific layout guidelines need to be taken into account to ensure the full chip performance, see [11].

For the absolute maximum ratings and operating conditions, see sections 2.3.1.

### 2.5.1 Dedicated STLC2690 Regulator Operation

The signal REG\_CTRL allows the control of an external battery regulator dedicated to the STLC2690. This regulator is meant to supply the STLC2690 with 1.8 V. It allows to partly decouple the core supply of the STLC2690 from the platform, while keeping the best implementation in terms of power consumption.

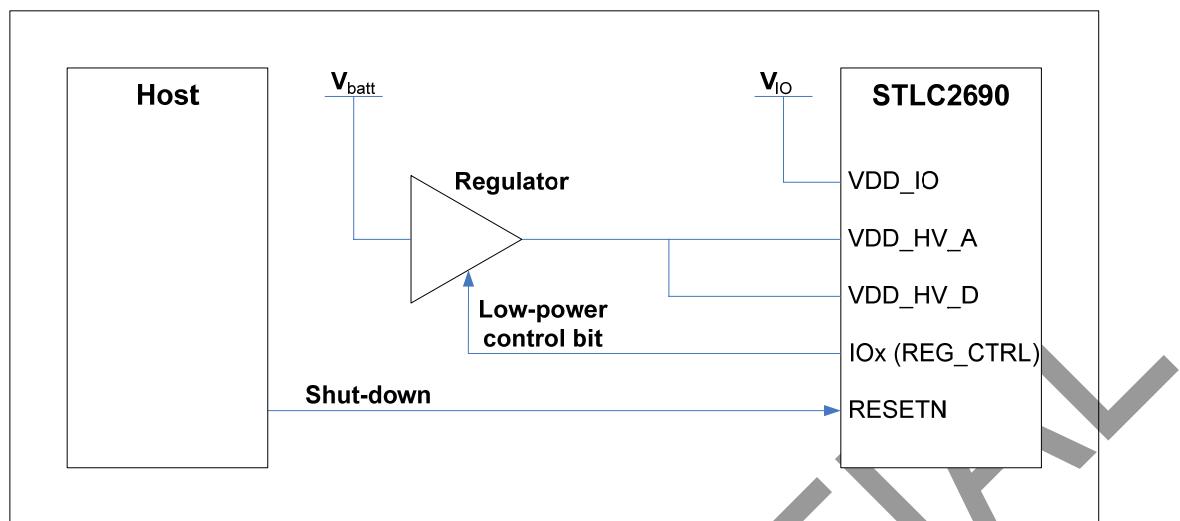
This mode requires a regulator that supports low power mode providing for two modes of operations:

- **Active mode:** High current/accuracy capability;
- **Low power mode:** Small current/lower accuracy, with internal consumption of a few  $\mu$ A.

The low power control bit of this regulator is connected to the REG\_CTRL. When REG\_CTRL = 0, the regulator is in low power mode, when REG\_CTRL = 1, the regulator is in active mode.

The next picture gives an example of the connections. Possible decoupling capacitors are not shown on this drawing.

Figure 4. Dedicated STLC2690 Regulator Operation

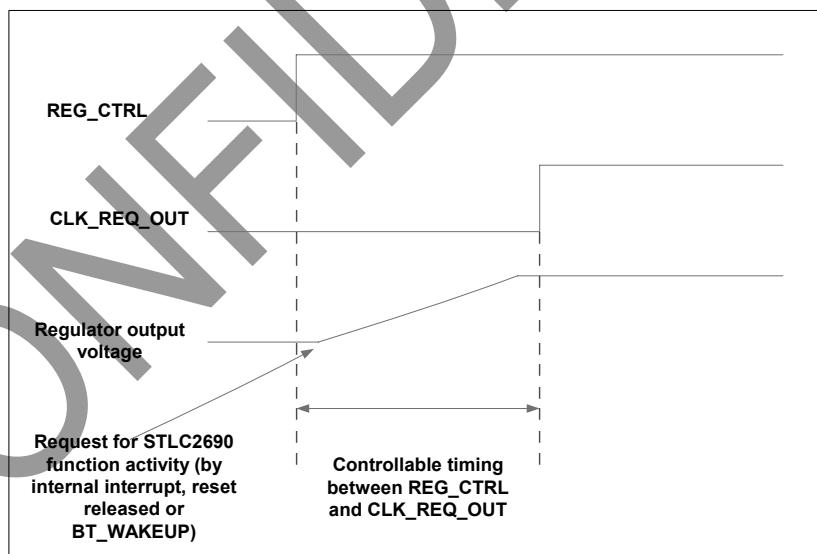


The low power mode usage or active mode of the external regulator is linked with the low power modes of the Bluetooth subsystem (Deep Sleep mode and Complete Power Down) and FM subsystem (Deep Sleep mode and Complete Power Down).

This means that REG\_CTRL is low when the Bluetooth and FM subsystem go in low power mode and is high in all other cases.

Based on the time it takes for an external regulator to settle the voltage, the timing of REG\_CTRL can be adjusted to become active before CLK\_REQ\_OUT\_x is active. The picture below shows the behavior for both signals.

Figure 5. Regulator Timing Control



The timing of REG\_CTRL is controllable between 0 and 30 ms in several steps and is set to 30 ms at startup. This parameter is defined via the SW Parameter File download and depends on the regulator and the platform behavior.

## 2.6 Clocks

### 2.6.1 Fast Clock (System Clock)

This clock is the main clock of the chip. It is used for most of the Bluetooth operation like transmission, reception, Host communication, ... The FM transmitter and receiver can work with this clock in all their modes. It is selected

by an FM Parameter, whether the FM works with this clock (and requests it via CLK\_REQ\_OUT\_x) or with the slow clock.

This clock needs only to be present when the STLC2690 is requesting it via CLK\_REQ\_OUT\_x, see section 2.6.4. When the fast clock is generated from an external crystal directly connected to the chip, these clock request signals are not used.

This clock is provided to the chip either as a digital square wave input, a sinusoidal low amplitude signal, or is generated using an external crystal directly connected to the chip.

- When the clock is provided as a digital square wave or as an analog sine wave from the platform, the supported frequencies are 13, 16, 16.8, 19.2, 26, 32, 33.6, 38.4 and 52 MHz. The clock input pin is REF\_CLK\_IN. In this case the XTAL\_OUT should be strapped to ground.
- When the fast clock is generated from an external crystal directly connected to the chip, the supported crystal frequencies are 13, 16, 16.8, 19.2, 26, 32, 33.6 and 38.4 MHz. The integrated oscillator cell supports the crystal characteristics listed in Table 12. The input pin of the crystal is REF\_CLK\_IN, the feedback pin of the crystal is XTAL\_OUT.

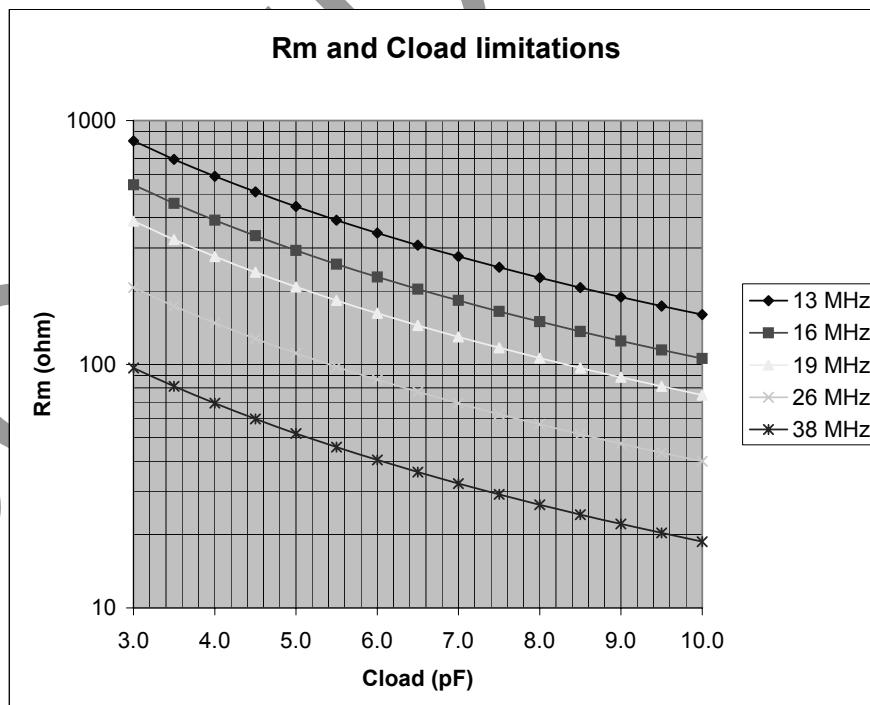
For detailed characteristics, see section 2.3.4.

**Table 12. External crystal characteristics**

Specification	Min.	Typ.	Max.	Unit
Initial crystal frequency accuracy			$\pm 25$	ppm
Crystal pullability	10		150	ppm/pF
Crystal drift (aging & temperature drift)			$\pm 15$	ppm

The maximally tolerated motional resistance ( $R_m$ ) of the crystal depends both on the frequency and load capacitance seen by the crystal, as shown in Figure 6.

**Figure 6. The maximally tolerated motional resistance ( $R_m$ ) of the external crystal**



## 2.6.2 Slow Clock (Low Power Clock)

This clock is used for the low power modes support of BT. The FM transmitter and receiver can work with this clock in all their modes. It is selected by an FM Parameter, whether the FM works with this clock or with the fast clock.

After power-up, the slow clock must be available before the reset is released. It must remain active all the time until the chip is powered off.

This clock is provided to the chip through a standard digital input, LP\_CLK, with default characteristics. The input contains a Schmitt trigger and does not contain any pull, see also Table 11.

The slow clock can be 32 kHz or 32.768 kHz with an accuracy of  $\pm 250$  ppm. For detailed characteristics, see section 2.3.4.

For use of the slow clock for FM, in case the accuracy of the externally applied slow clock is not sufficient, the STLC2690 provides a calibration mechanism to calibrate the slow clock versus the fast clock.

### 2.6.3 Clock Detection

An integrated automatic detection algorithm detects the system and slow clock frequencies after a hardware reset. The steps in the clock detection routine are:

- Identification of the fast clock frequency (13 MHz, 16 MHz, 16.8 MHz, 19.2 MHz, 26 MHz, 32 MHz, 33.6 MHz, 38.4 MHz, 52 MHz)
- Identification of the slow clock (32.768 kHz or 32 kHz)
- The slow clock frequency can be confirmed during parameter download and is mandatory if 32 kHz frequency is used

### 2.6.4 Clock Request Signals

To allow minimum power consumption, a clock request feature is available so that the fast clock (REF\_CLK\_IN) can be stopped when not needed by the Bluetooth or FM system. The clock request signal can be active high or active low, and the STLC2690 supports internal propagation of clock request signal coming from another device in the system. When the fast clock is generated from an external crystal directly connected to the chip, these clock request signals are not used.

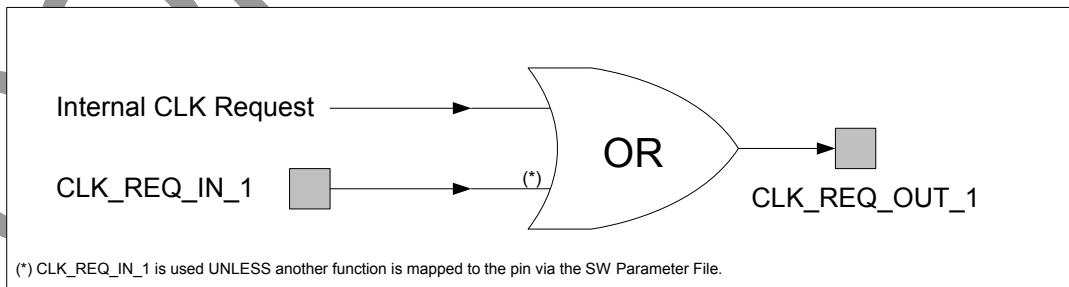
Different configurations as described below are supported during reset and in all operation modes, provided that VDD\_IO is available. For the propagation of the external request signal, both VDD\_HV\_D and VDD\_IO need to be present.

The clock request functionality is based on three different signals: CLK\_REQ\_OUT\_1, CLK\_REQ\_OUT\_2 and CLK\_REQ\_IN\_1, with the following function. The signals are available depending on the pin mapping, see section 2.4.3.

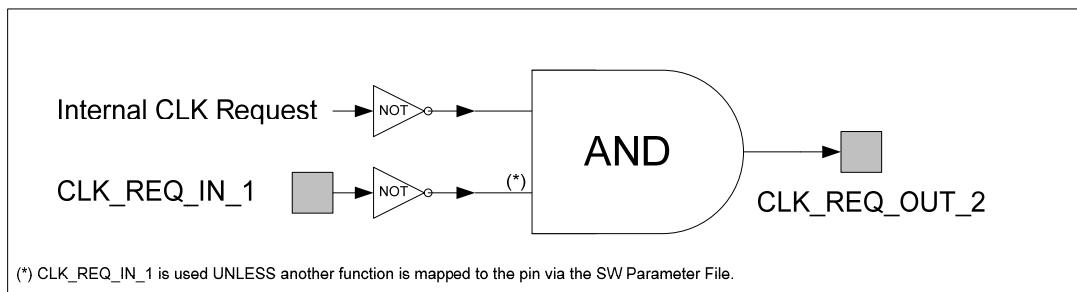
- CLK\_REQ\_OUT\_1: active high clock request output. Support for either push-pull or open drain output.
- CLK\_REQ\_OUT\_2: active low clock request output. Support for either push-pull or open drain output.
- CLK\_REQ\_IN\_1: active high clock request input from another device.

The following modes are supported:

- Active high clock request input and active high clock request output:



- Active high clock request input and active low clock request output:



## 2.7 Reset and Power-up

The behavior of the chip is independent of the power supplies (VDD\_HV\_x and VDD\_IO) activation sequence.

In case of pre-regulated power supply from the platform, the RESETN pin should be active while powering up VDD\_HV\_x and should stay active at least two cycles of the slow clock (LP\_CLK) after power-up is completed.

The chip is able to start without the fast clock being present. It requests it through CLK\_REQ\_OUT\_x before using it.

The time between the Bluetooth subsystem making CLK\_REQ\_OUT\_x active and the platform providing a stable clock should maximally be 15 ms. If the clock is starting faster on the platform, this timing can be reduced through parameter download.

As the FM radio and the Bluetooth are sharing the same reset pin in STLC2690, the start-up sequences of both functions are not completely independent. Hence, a typical start-up should be compliant with the sequence below:

- Supplies are powered-up
- LP\_CLK (slow clock) is running and stable
- RESETN pin is released after at least two LP\_CLK cycles.
- After around 30 ms, CLK\_REQ\_OUT\_x is set to request the fast clock (REF\_CLK\_IN).
- After 15 ms, REF\_CLK\_IN should be stable and the system can start using it. The SW is starting, doing clock recognition, internal configuration, and the HCI interface becomes operational.
- The Host performs the SW Parameter File download of the Bluetooth subsystem. This allows the Bluetooth subsystem to correctly operate, but this allows also and mainly to set the device in the optimal power mode for the application in which it resides.
- From this point on, the Host can either decide to use Bluetooth only, or it can also start configuring or using the FM radio, either through the FM I2C interface, or through the BT HCI interface. The signals REG\_CTRL and CLK\_REQ\_OUT\_x indicate which supply is needed and whether the fast clock is needed or can be shut down.

However, it is possible to use the FM radio through the FM I2C interface without doing the Bluetooth SW Parameter File download.

## 2.8 Power down

The power down of the chip does not contain any constraints. It is possible to power-off VDD\_IO and VDD\_HV\_x independently and in whatever order without resulting in increased static current consumption. If any of the two supplies is removed, the chip goes back to reset state. It is however recommended that the platform activates the RESETN at least 2 LP\_CLK cycles before powering-off of the supplies.

## 2.9 Low Power Modes

### 2.9.1 Overview

The STLC2690 is designed for lowest power operation in all modes. To achieve this, several power modes are supported. Due to their different ways of operating (in bursts for Bluetooth, constant for FM), different low power modes are defined both for Bluetooth and FM as listed below.

On top of these internal power modes, and linked to them, the HCI interface also has the capability to be put in a low power mode (called Sleep mode). This is the only way for the Bluetooth subsystem of the system to go in Deep Sleep mode or Complete Power Down. When no data have to be transferred on the HCI interface for some time, the Host should place it in Sleep mode so that the power consumption is always minimized for the system.

**Table 13. Bluetooth Low Power Modes**

Low Power Mode	Description
Sleep mode	<p>The Bluetooth subsystem:</p> <ul style="list-style-type: none"> <li>- Accepts HCI commands from the Host.</li> <li>- Supports all types of Bluetooth links.</li> <li>- Can transfer data over Bluetooth links.</li> <li>- Dynamically switches between sleep and active mode when needed.</li> <li>- The fast clock is still active in part of the design.</li> <li>- Parts of the chip are dynamically powered off depending on the Bluetooth activity.</li> </ul>
Deep Sleep mode	<p>The Bluetooth subsystem:</p> <ul style="list-style-type: none"> <li>- Does not accept HCI commands from the Host.</li> <li>- Supports Page and Inquiry scans.</li> <li>- Supports Bluetooth links that are in Sniff or Sniff Subrating.</li> <li>- Dynamically switches between Deep Sleep and active mode during Bluetooth activity. The Deep Sleep mode entry is initiated by the Host, the Bluetooth subsystem acknowledges or not. The wake-up mechanism must be enabled by the SW Parameter File download before it can be used.</li> <li>- The fast clock is not active in any part of the design.</li> <li>- Parts of the chip are dynamically powered off depending on the Bluetooth activity.</li> </ul>
Complete Power Down	<p>The Bluetooth subsystem is effectively powered down:</p> <ul style="list-style-type: none"> <li>- No Bluetooth activity is supported.</li> <li>- The HCI interface is shut down.</li> <li>- The fast clock is not active in any part of the design.</li> <li>- Most parts of the chip are completely powered off.</li> <li>- RAM content is not maintained (initialization is required at wake-up).</li> <li>- Some pins (4 UART, CLKREQIN) keep their previous configuration (input or output, pull behavior) during Complete Power Down.</li> <li>- The Host needs to send once an HCI command to allow the Bluetooth subsystem to go in Complete Power Down. The Bluetooth subsystem then goes into Complete Power Down each time the Host sends a Deep Sleep command and there is no activity anymore on the Bluetooth subsystem, this in order to ensure a smooth transition from active to Complete Power Down state. In order to go out of this mode, either a HW reset or BT_WAKEUP = '1' is needed.</li> </ul>

**Table 14. FM Low Power Modes**

Low Power Mode	Description
Active mode	<p>The FM radio is running and is either receiving or transmitting FM signal. The necessary logic for operation is powered and clocked. The user can define what operation mode is selected and can transfer audio or RDS data through I2C, I2S or analog audio interfaces.</p>
Complete Power Down	<p>The FM radio is not operating. FM radio restart is done either through a dedicated command through the FM I2C interface or through the BT HCI interface. Most parts of the FM radio are powered off to reduce leakage to the minimum. If SW download is necessary for FM operation, the SW needs to be downloaded again when going out of Complete Power Down mode. The switch between Active and Complete Power Down mode for FM is done on request of the Host.</p>

## 2.9.2 Examples for the Usage of the Bluetooth Low Power Modes

### Sniff or Sniff Subrating

The Bluetooth subsystem is in active mode with a Bluetooth connection. Once the transmission is concluded, Sniff or Sniff Subrating is programmed. When one of these two states is entered, the Bluetooth subsystem goes into Sleep mode. After that, the Host may decide to place the Bluetooth subsystem in Deep Sleep mode. The

Deep Sleep mode allows for lower power consumption. When the Bluetooth subsystem needs to send or receive a packet (e.g. at  $T_{\text{sniff}}$  or at the beacon instant), the Bluetooth subsystem requests the fast clock and enters active mode for the needed transmission/reception. Immediately afterwards, the Bluetooth subsystem goes back to Deep Sleep mode. If some HCI transmission is needed, the UART or SPI link is reactivated and the Bluetooth subsystem moves from Deep Sleep mode to Sleep mode.

### Inquiry/Page scan

When only Inquiry scan or Page scan is enabled, the Bluetooth subsystem goes in Sleep mode or Deep Sleep mode outside the receiver activity. The selection between Sleep mode and Deep Sleep mode depends on the UART/SPI activity as in Sniff or Sniff Subrating.

### No Connection

If the Host allows Deep Sleep mode and there is no activity, then the Bluetooth subsystem puts itself in Deep Sleep mode. The Host can decide to exit the Deep Sleep mode by the wake-up mechanisms described in section 3.3.1. In this Deep Sleep mode (no connection), the Host can also decide to put the Bluetooth subsystem in Complete Power Down to further reduce the power consumption. In this case some part of the Bluetooth subsystem is completely powered off. The request to quit the Complete Power Down is done either by putting the BT\_WAKEUP signal to '1' or with an HW reset.

### Active Link

When there is an active link ((e)SCO or ACL), the Bluetooth Controller does not go in Deep Sleep mode and not in Complete Power Down. But the Bluetooth Controller is made in such a way that whenever it is possible, depending on the scheduled activity (number of link, type of link, amount of data exchanged), it goes in Sleep mode.

### 2.9.3 Bluetooth and FM Operation Modes

The different low power modes of BT and FM are combined for the different mode of operation, especially when FM is controlled through the HCI interface. The table below summarizes these different operation modes and the related used power modes for the two functions.

**Table 15. Bluetooth and FM Operation Modes**

Operation mode	BT Power Mode	FM Power Mode	HCI Mode
System startup, reset released, fast clock available	Active/Sleep	Complete power down	Active
<ul style="list-style-type: none"> <li>- BT SW Parameter File download done</li> <li>- no Bluetooth activity</li> <li>- no FM activity</li> <li>- HCI interface active</li> </ul>	Sleep	Complete power down	Active
<ul style="list-style-type: none"> <li>- BT SW Parameter File download done</li> <li>- no Bluetooth activity</li> <li>- no FM activity</li> <li>- HCI interface in sleep</li> </ul>	Deep sleep	Complete power down	Sleep
<ul style="list-style-type: none"> <li>- Bluetooth active (ACL or SCO)</li> <li>- FM not active</li> <li>- HCI interface active</li> </ul>	Active/Sleep	Complete power down/Sleep	Active
<ul style="list-style-type: none"> <li>- Bluetooth in low power mode (sniff or scan)</li> <li>- FM not active</li> <li>- HCI in sleep</li> </ul>	Deep sleep (with regular switch to sleep/active for BT activity)	Complete power down/Sleep	Sleep
<ul style="list-style-type: none"> <li>- Bluetooth active (ACL or SCO)</li> <li>- FM active</li> <li>- HCI interface active</li> </ul>	Active/Sleep	Active	Active
<ul style="list-style-type: none"> <li>- Bluetooth in low power mode (sniff or scan)</li> <li>- FM active, using dedicated I2C and I2S or analog audio output</li> <li>- HCI in sleep</li> </ul>	Deep sleep (with regular switch to sleep/active for BT activity)	Active	Sleep

– Bluetooth not active	Deep sleep	Active	Sleep
– FM active, using dedicated I2C and I2S or analog audio output	Deep sleep (can not go in real CPD until FM radio is off)	Active	Sleep
– HCI in sleep			
– Bluetooth in complete power down (set by HCI command)	Deep sleep (can not go in real CPD until FM radio is off)	Active	Sleep
– FM active, using dedicated I2C and I2S or analog audio output	Deep sleep (can not go in real CPD until FM radio is off)	Active	Sleep
– Bluetooth in virtual reset	Complete power down	Complete power down	Sleep
– FM not active			
– Bluetooth not active	Sleep/Active	Active	Active/Sleep
– FM active, using HCI for control			
– HCI mode under control of the Host			
– Bluetooth not active	Deep sleep	Active	Active/Sleep
– FM active, using dedicated I2C for control and PCM/I2S of Bluetooth for audio	Deep sleep	Active	Active/Sleep
– HCI mode under control of the Host			

## 2.10 Multimedia features

Thanks to its ultra low power audio DSP, the STLC2690 offers efficient offloading to reduce the Host computation needs and to optimize overall platform power.

### 2.10.1 Direct loopback of FM Rx to BT A2DP link

The STLC2690 implements the streaming of FM radio over a BT A2DP link without any involvement of the Host during the streaming. This leads to a drastic reduction of the power consumptions as the Host can stay continuously in Sleep mode.

All the necessary processing that is normally done in the Host is handled inside the STLC2690. This includes SBC encoding and A2DP/L2CAP framing.

### 2.10.2 SBC host offloading for BT A2DP

BT A2DP offloading can also be performed with audio data transferred from the Host over the BT PCM or BT I2S interface. This slightly reduces the processing needs at the Host side for BT A2DP streaming (becomes similar to playback with wired headset).

In that mode, the Host sends stereo audio data samples (44.1 or 48 kHz) to the STLC2690. This data is encoded internally on the STLC2690 using SBC and encapsulated in A2DP and L2CAP frames for sending over the air.

## 2.11 Examples of Bluetooth and FM Use Cases

This paragraph lists the most common use cases that are supported. Each use case defines the mode of operation of the Bluetooth and the FM subsystem, and the active voice or audio interfaces. The HCI and FM I2C interfaces are not listed because in all use cases, HCI can be active or in sleep and FM I2C can be used or not, depending if FM is controlled through I2C or through BT HCI. This list does not include BT only or FM only use cases.

**Table 16. Bluetooth and FM Use Cases**

ID	Use case details	FM mode	BT mode	BT PCM	FM I2S
1	Transfer Bluetooth data while listening to radio.	Active Rx	Active ACL	No	Yes
2	Listening to radio with BT stereo headset using A2DP. The audio data are SBC encoded in the application processor or cellular baseband.	Active Rx	Active ACL	No	Yes
3	Listening to radio with BT stereo headset using A2DP. Audio is transferred from FM to BT inside the chip. The audio data are SBC encoded on the STLC2690.	Active Rx	Active ACL	No	No

4	Listening to radio (low quality) with BT voice headset. Audio is transferred from FM to BT at 8 kHz inside the chip.	Active Rx	Active SCO	No	No
5	Listening to radio (low quality) with BT voice headset. Audio is transferred from FM to BT outside the chip.	Active Rx	Active SCO	Yes (8 kHz)	Yes
6	Background RDS (RDS info retrieval) with tones over BT to headset.	Active Rx	Active SCO	Yes	No
7	Listening to radio (low quality) with BT voice headset, while streaming RDS data to laptop/PDA/...	Active Rx	Active ACL + SCO	Yes	Yes
8	Listening to radio (low quality) with BT voice headset, while transferring data over Bluetooth. Audio is transferred from FM to BT inside the chip.	Active Rx	Active ACL + SCO	No	No
9	Listening to radio (low quality) with BT voice headset, while transferring ACL data (for example DUN).	Active Rx	Active ACL + (e)SCO	Yes	Yes
10	Listening to radio with BT stereo headset using A2DP while transferring other data over Bluetooth. The audio data are SBC encoded in the application processor or cellular baseband.	Active Rx	Active ACL (A2DP) + ACL (other data)	No	Yes
11	Car radio hands free: voice call on GSM with BT headset connected. The received voice is sent to the car radio through FM Tx in place of the headset speaker.	Active Tx	Active (e)SCO	Yes	No (the FM transmit signal goes through BT PCM interface)
12	Audio FM transmit while doing gaming on Bluetooth (piconet with low latency).	Active Tx	Active ACLs	No	Yes

## 2.12 Digital Interfaces

Some of these interfaces are available by default on the pins during and after reset, others become available by default as soon as the STLC2690 has detected which Host interface is used, others can be mapped to the programmable pins according to section 2.4.3.

### 2.12.1 General Control Signals

The STLC2690 supports several control signals that have impact on the operation of the full chip (not dedicated to a specific function). Some of these signals are available by default on a pin, others can be mapped to a pin according to section 2.4.3.

**Table 17. Control signals**

Signal	Direction	Function
RESETN	input	Overall RESET of the chip, active low. If the chip is in reset, its power consumption is reduced to the minimum. More info on the timing and behavior on the reset can be found in section 2.7. The pin RESETN is used by default as input for this signal RESETN.
REG_CTRL	output	Signal allowing the control of an external regulator dedicated to core voltage supply. This signal can be used to switch a regulator between low current and high current mode. This signal is active high. For more info on this signal behavior, see section 2.5.1. This signal is not available by default on a pin, but can be mapped to a pin according to section 2.4.3.
CLK_REQ_OUT	Output/Open drain output	Signal that requests the fast clock only when needed to allow power saving. An active high and an active low version of this signal are available, CLK_REQ_OUT and CLK_REQ_OUT_N respectively. For more info on this

		signal behavior, see sections 2.6.4, 2.7 and 2.9. These signals are available by default on the pins CLK_REQ_OUT_1 and CLK_REQ_OUT_2. If this function is not used, these pins may be reused for other functions after reset.
CLK_REQ_IN	input	Signal that allows the sharing of the fast clock between several devices on a board without the need of external components for the control of the enable of this clock. The pin CLK_REQ_IN_1 is used by default as input for this signal. If this function is not used, the pin may be reused for other functions after reset. For more info on this signal behavior, see sections 2.6.4, 2.7 and 2.9.
BT_WAKEUP	input	Wakeup of Bluetooth subsystem of the chip when in low power mode. For more info on this signal behavior, see sections 2.7 and 2.9. The pin BT_WAKEUP is used by default as input for this signal.
HOST_WAKEUP	output	Wakeup of the Host by the chip when in low power mode. For more info on this signal behavior, see sections 2.7 and 2.9. This signal is available by default on the pin HOST_WAKEUP. If this function is not used, the pin may be reused for other functions after reset.
CONFIG1	input	Configuration signal. The pin CONFIG1 is used by default as input for this signal. Should be strapped to VSS_DIG.
FM_IRQ	output	Signal that indicates a state change in the FM subsystem of the chip. E.g. RDS data received, FM channel found, ... For more info on this signal behavior, see section 4.1.2. This signal is not available by default on a pin, but can be mapped to a pin according to section 2.4.3.

### 2.12.2 UART Interface

The UART interface is a 4-wire data interface (UART\_RXD, UART\_TXD, UART\_RTS, and UART\_CTS). The UART interface is compatible with the 16450, 16550 and 16750 standards.

The 4 signals of the UART interface are the following:

- UART\_RXD: Data transfer from the Host to the STLC2690. To be connected to the Host TXD.
- UART\_TXD: Data transfer from the STLC2690 to the Host. To be connected to the Host RXD.
- UART\_RTS: Flow control. To be connected to the Host CTS. If the STLC2690 UART\_RTS output is low, then the Host is allowed to send. If the STLC2690 UART\_RTS output is high, then the Host is not allowed to send.
- UART\_CTS: Flow control. To be connected to the Host RTS. If the STLC2690 CTS input is low, then the STLC2690 is allowed to send. If the STLC2690 CTS input is high, then the STLC2690 is not allowed to send.

The UART interface has following characteristics:

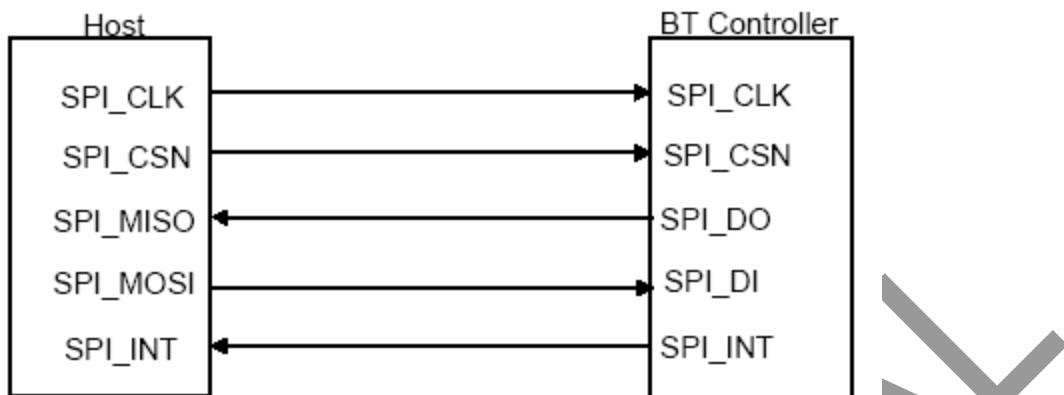
- It is running up to 4000 kbps (+1.5% / -1%). At startup, the UART baud rate is fixed at 115200 bps independently of the REF\_CLK\_IN frequency. A specific HCI command is provided to change the UART baud rate when necessary within the range 56 kbps to 4000 kbps. All standard baud rates and many other ones are supported.
- The configuration is 8 data bits, 1 start bit, 1 stop bit, and no parity bit.
- The transmit and receive paths contain a DMA function for low CPU load and high throughput. Auto RTS/CTS is implemented in HW, controllable by SW. RTS/CTS flow control is used to prevent temporary UART buffer overrun between the STLC2690 and the Host.
- Flow-off response time is 500  $\mu$ s. The flow-off response time defines the maximum time that the STLC2690 can still receive data after setting RTS high.

The UART interface is available on the pins by default during and after reset. When the STLC2690 has detected that the UART is not used as the Host interface, these pins are remapped with different functions. See section 2.4.3.

### 2.12.3 SPI Interface

The SPI interface is a 5-wire data interface (SPI\_CS<sub>N</sub>, SPI\_CLK, SPI\_DO, SPI\_DI and SPI\_INT).

Figure 7. SPI Interface



The 5 signals of the SPI interface are the following:

- SPI\_CSN: chip select allows the use of multiple Slaves (1 chip select per Slave). This signal is active low. This signal is mandatory, even with only 1 Slave, because the Host must drive this signal to indicate SPI frames.
- SPI\_CLK: clock signal, active for a multiple of data length cycles during an SPI transfer (SPI\_CSN active). The clock is allowed to be active when SPI\_CSN is not active, in order to serve other Slaves.
- SPI\_DO: data transfer from Slave to Master. Data is generated on the negative edge of SPI\_CLK by the Slave and sampled on the positive edge of SPI\_CLK. When SPI\_CSN is inactive, this STLC2690 output is in tristate mode.
- SPI\_DI: data transfer from Master to Slave. Data is generated on the negative edge of SPI\_CLK by the Master and sampled on the positive edge of SPI\_CLK.
- SPI\_INT: interrupt from the Slave, used to request an SPI transfer by the Slave to the Master. The signal is active high (Host input must be level sensitive).

The SPI interface has following characteristics:

- The maximum operating frequency is 52 MHz. The SPI interface in STLC2690 supports the timings defined below.
- The SPI interface is operating in half duplex mode.
- The SPI interface is Master at the Host side, and Slave at the STLC2690 side.
- The SPI data length, endianness and flow control are configurable. The Host can change the configuration by writing in the SPI configuration register.
- The flow control consists of an indication from the STLC2690 whether its receive buffers are ready to receive data. This indication is available in three ways:
  - On the SPI\_DO during  $T_{SCS}$  (time between SPI\_CSN becoming active and SPI\_CLK becoming high).
  - In a register that can be read by the Host.
  - Optionally on one of the programmable pins. This is enabled by writing the SPI configuration register, see section 2.4.3.
- The default SPI configuration is:
  - 16 bit data length
  - Most significant byte first
  - Most significant bit first
  - Flow control on SPI\_DO and in a register

The SPI interface is available on the pins by default during and after reset, except for the SPI\_INT. When the STLC2690 has detected that the SPI is used as Host interface, the SPI\_INT is mapped to one of the other programmable pins. When the STLC2690 has detected that the SPI is not used as the Host interface, these pins are remapped with different functions. See section 2.4.3.

For more detailed information on the SPI interface refer to [14].

Figure 8. SPI Data Transfer from the Host (Master) to the STLC2690 (Slave)

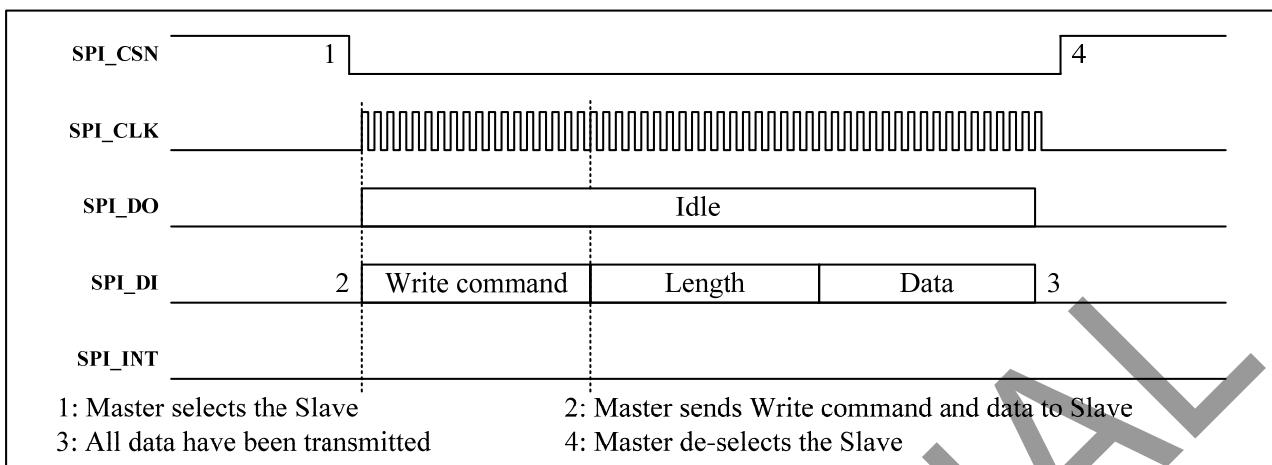


Figure 9. SPI Data Transfer from the STLC2690 (Slave) to the Host (Master)

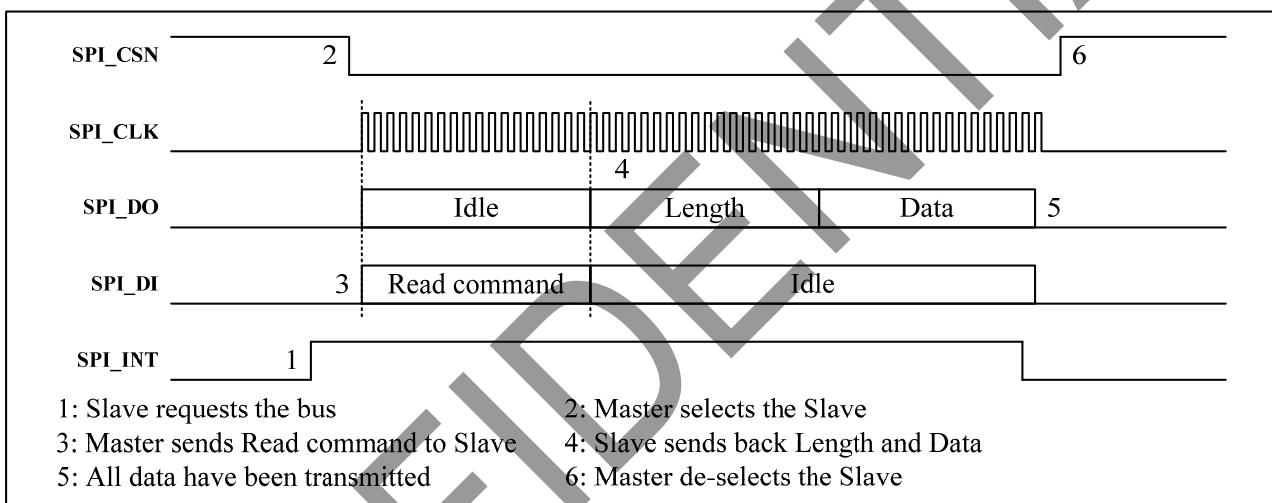


Figure 10. SPI Setup and Hold Timing

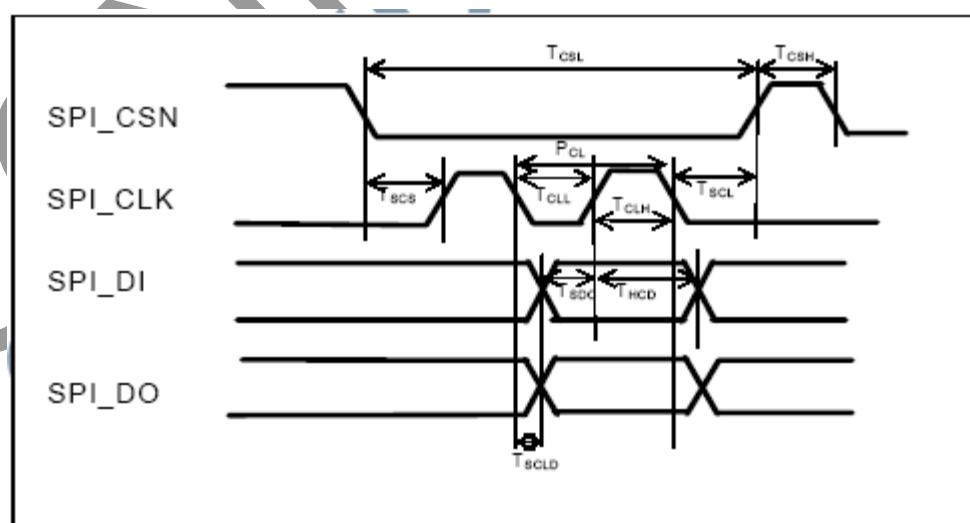


Table 18. SPI Timing Parameters

Symbol	Description	Min.	Typ.	Max.	Unit
--------	-------------	------	------	------	------

$P_{CL}$	SPI_CLK full period	19.23			ns
$T_{CLH}$	High period of SPI_CLK	9			ns
$T_{CLL}$	Low period of SPI_CLK	9			ns
$T_{CSH}$	High period of SPI_CSN	$1 * P_{CL}$			ns
$T_{CSL}$	Low period of SPI_CSN	$9 * P_{CL}$			ns
$T_{SCS}$	Setup time, SPI_CSN low to SPI_CLK high	$1 * P_{CL}$			ns
$T_{SCL}$	Setup time, SPI_CLK low to SPI_CSN high	$1/2 * P_{CL}$			ns
$T_{SDC}$	Setup time, SPI_DI valid to SPI_CLK high	5			ns
$T_{HCD}$	Hold time, SPI_DI valid after SPI_CLK high	1			ns
$T_{SCLD}$	Setup time, SPI_CLK low to SPI_DO valid		9		ns

#### 2.12.4 FM I2C Interface

The FM I2C interface is a 2-wire low speed data interface (I2C\_SCL and I2C\_SDA) to access I2C peripherals. It is compatible with the I2C specification version 2.1, see [9].

The 2 signals of the I2C interface are the following:

- I2C\_SCL: clock signal.
- I2C\_SDA: bidirectional data.

The FM I2C interface has following characteristics:

- The FM I2C interface is Slave at the STLC2690 side.
- It supports the fast mode operation, meaning 400 kHz I2C\_SCL clock frequency. The I2C interface supports the timings below.
- It supports the 7-bits addressing mode and is able to coexists with the 10-bits addressing mode.

The FM I2C interface is present on chip pins in reset and default after reset, however all I2C traffic on these pins is not considered until the FM I2C address has been programmed by the Host via a vendor-specific HCI command on the Bluetooth HCI interface. The Host can decide to remap these pins with other functions. See section 2.4.3.

Figure 11. I2C Interface Timing

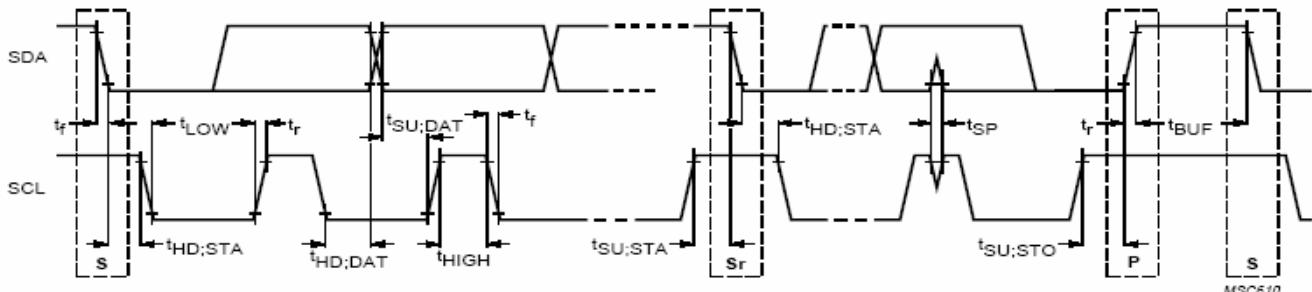


Table 19. I2C Interface Timing

Symbol	Parameter	Min.	Typ.	Max.	Unit
$f_{SCL}$	SCL clock frequency	0		400	kHz
$t_{HD;STA}$	Hold time (repeated) START condition. After this period, the first clock pulse is generated	0.6		-	$\mu$ s
$t_{LOW}$	Low period of the SCL clock	1.3		-	$\mu$ s
$t_{HIGH}$	High period of the SCL clock	0.6		-	$\mu$ s
$t_{SU;STA}$	Setup time for repeated START condition	0.6		-	$\mu$ s
$t_{HD;DAT}$	Data hold time for I2C-bus devices	0		0.9	$\mu$ s
$t_{SU;DAT}$	Data setup time	100		-	ns

$t_r$	Rise time of both SDA and SCL signals ( $C_b$ is bus line capacitance)	$20 + 0.1 * C_b$		300	ns
$t_f$	Fall time of both SDA and SCL signals ( $C_b$ is bus line capacitance)	$20 + 0.1 * C_b$		300	ns
$t_{SU,STO}$	Setup time for stop condition	0.6			μs
$t_{BUF}$	Bus free time between a STOP and a START condition	1.3			μs
$t_{SP}$	Pulse width of spikes which must be suppressed by input filter	0		50	ns

## 2.12.5 Generic I2C Interface

This I2C interface has the same specification as the FM I2C interface. Except that it is Master at the STLC2690 side.

The Generic I2C interface can be used for any purpose, e.g. control of peripherals, and is controllable from HCI.

The Generic I2C interface is not present on chip pins in reset or default after reset, and does not become default available once the STLC2690 has detected which interface is used as the Host interface. The Generic I2C interface can be mapped to the programmable pins by the SW Parameter File download or an HCI command. See section 2.4.3.

## 2.12.6 BT PCM Interface

The BT PCM interface is a 4 wire voice/audio interface (PCM\_CLK, PCM\_SYNC, PCM\_A and PCM\_B) that allows direct voice/audio sample transfer between chips or to a standard codec.

The 4 signals of the PCM interface are the following:

- PCM\_CLK : PCM clock
- PCM\_SYNC : PCM synchronization signal, typically 8 kHz
- PCM\_A : PCM data
- PCM\_B : PCM data

The BT PCM interface has following characteristics (configurable through the SW Parameter File download or through HCI commands):

- By default PCM\_A is the STLC2690 TX data and PCM\_B is the STLC2690 RX data. This can be swapped.
- The following external PCM data formats are supported: linear (13 up to 16 bits), μ-law (8 bits) and A-law (8 bits).
- The air data format can be chosen independently from the external format and can be one of the following: CVSD, μ-law, A-law. Another possible air data format is “transparent data”, meaning that no coding or conversion is done on the data. In that case the external format has to be 8 bits wide.
- The interface can be programmed to act as a PCM Master or as a PCM Slave. By default the interface is in Slave mode, i.e. the 4 pins are in input mode, with pull-down active.
- In Master mode the PCM clock can be configured to be on only during the active PCM slots, or it can be on all the time there is an (e)SCO link.
- As a Master the interface by default generates a PCM clock rate of 2048 kHz, it can be configured to rates from 128 kHz up to 2048 kHz. As a Slave, it can automatically handle external PCM clock rates from 128 kHz up to 4000 kHz.
- When configured as a Master, the number of PCM clock cycles in one PCM\_SYNC period can be reconfigured. In this way, the PCM\_SYNC rate can be set to 8 kHz for narrow-band speech
- When configured as a Master, by default the PCM\_SYNC signal is locked to the PCM clock. Alternatively, in order to address clock drift between the local and the remote PCM clock, the PCM\_SYNC signal can be locked to the Bluetooth piconet clock. In that case the number of PCM clock cycles in one PCM\_SYNC period is adjusted from time to time by 1 clock cycle at most. E.g. in the default configuration there may be some periods of 255 or 257 PCM clock cycles.
- In Master mode the PCM\_SYNC length is configurable to 1 (short frame), 8 or 16 (long frame) PCM\_CLK clock periods. In Slave mode all possible PCM\_SYNC lengths are automatically supported, including

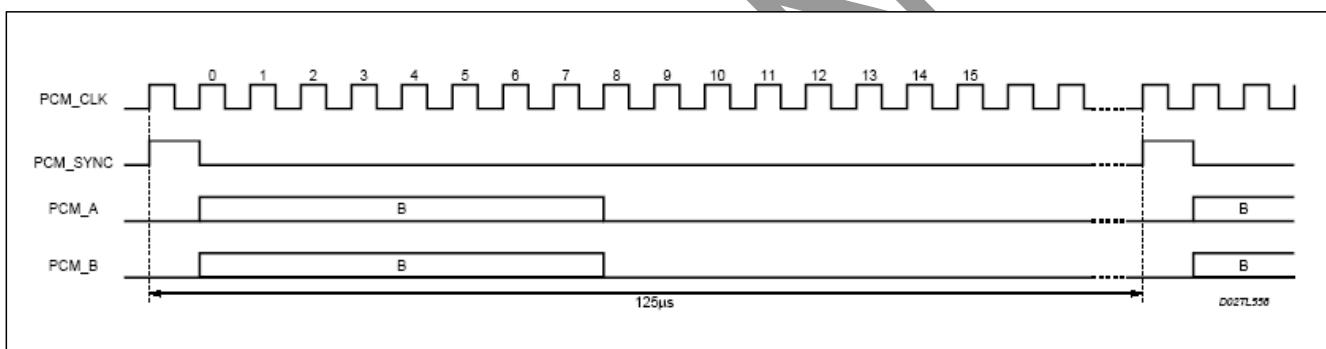
“short frame” (taking 1 PCM\_CLK clock period) and “long frame” PCM\_SYNC signals (taking more than 1 PCM\_CLK clock period).

- The interface also supports multi-port PCM operations: up to 3 different voice streams are supported by using up to 3 slots per PCM frame. This can also be used to generate stereo traffic in PCM interface.
- The start of the PCM data is configurable in the following ways:
  - The PCM\_SYNC pulse (or pulses, see below) can be delayed with respect to the internal reference. The delay is expressed as a number of PCM clock cycles and is programmable between 0 and 255.
  - Alternatively, the start of each PCM slot can be delayed with respect to the rising edge of the PCM\_SYNC signal. The delay is expressed as a number of PCM clock cycles and is programmable between 0 and 255.
- TX data are by default generated on the rising edge of PCM\_CLK and expected to be latched by the external device on the falling edge, while RX data are latched on the falling edge of PCM\_CLK. The inverted clock mode is also supported, whereby the generation of TX data is on the falling edge and the latching of TX and RX data is on the rising edge.
- When the STLC2690 is Master, one additional PCM\_SYNC signal can be provided via the GPIO pins.
- Outside the active PCM slot(s) the PCM TX signal (PCM\_A or PCM\_B) can be configured in tristate or as output driving ‘0’.

The BT PCM interface is not present on chip pins in reset or default after reset, but becomes available once the STLC2690 has detected which interface is used as the Host interface. See section 2.4.3.

## Restricted Distribution

**Figure 12. PCM (A-law,  $\mu$ -law) Standard Mode**



**Figure 13. Linear Mode**

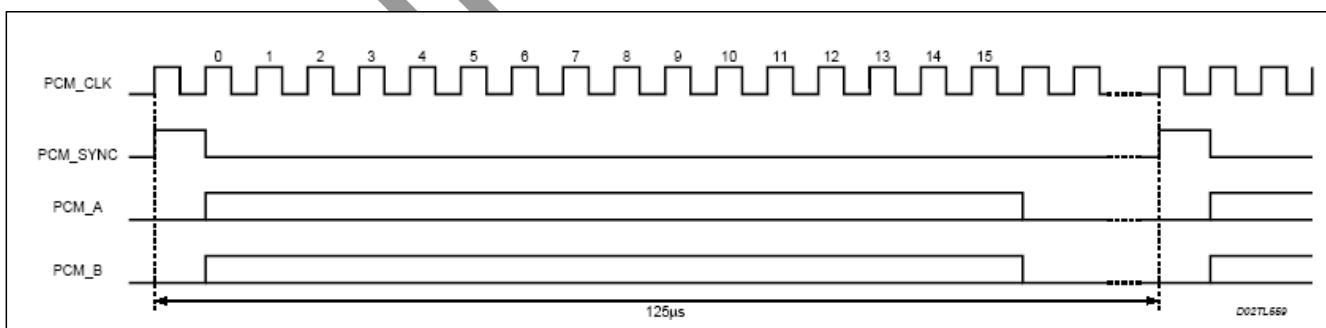


Figure 14. Multi-Slot Operation

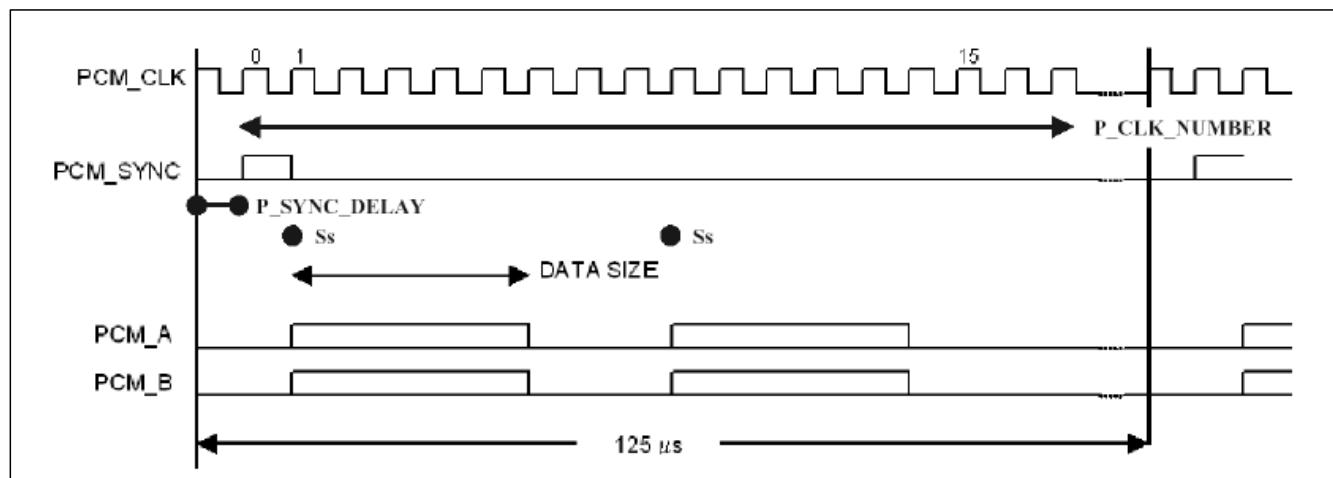


Table 20. PCM Interface Parameters

Symbol	Description	Min.	Typ.	Max.	Unit
<b>PCM Interface</b>					
$f_{PCM\_CLK}$	Frequency of PCM_CLK	128 <sup>(1)</sup>	2048	4000 <sup>(2)</sup>	kHz
$f_{PCM\_SYNC}$	Frequency of PCM_SYNC		8		kHz
$P_{sync\_delay}$	Delay of the starting of the first slot	0		255	cycles
$S_s$	Slot start (programmable for every slot)	0		255	cycles
D	Data size	8		16	bits
N	Number of slots per frame	1		3	

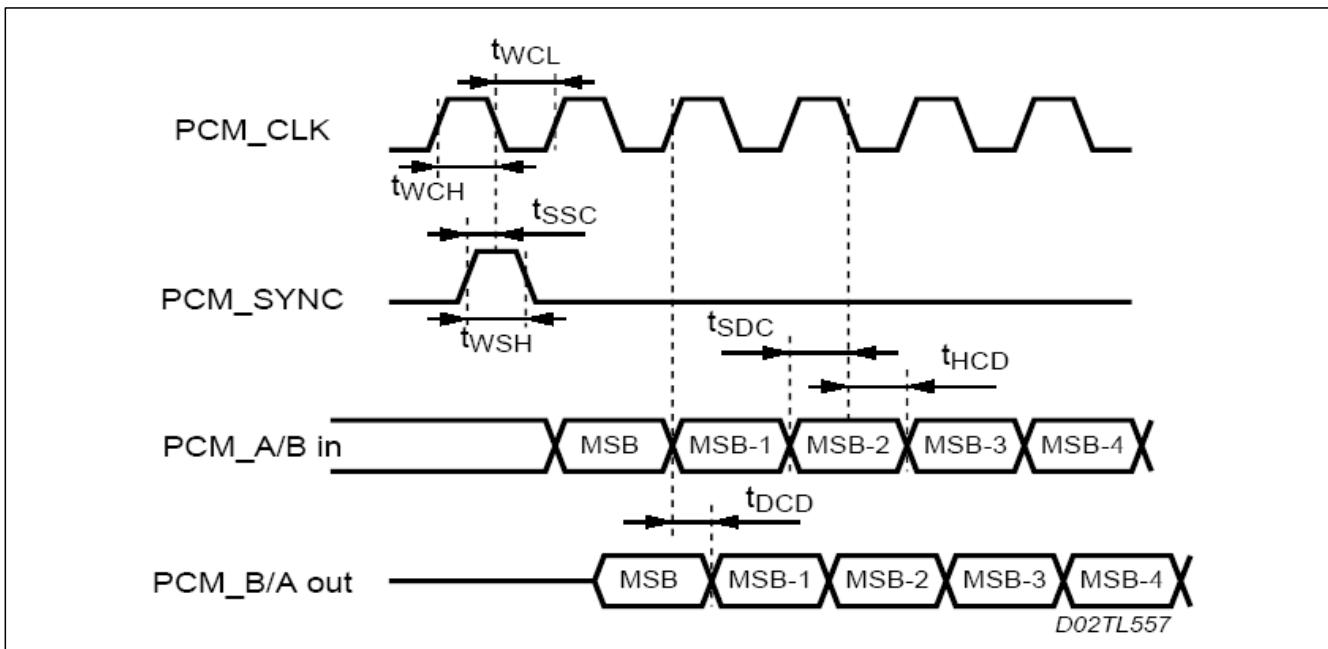
1. Note that it is not possible to use 16 bits in Slave case if PCM\_CLK is 128 kHz. This is the only exception.

2. In Master case, the maximum PCM\_CLK frequency is limited to 2048 kHz.

Table 21. PCM Interface Timing (at  $PCM\_CLK = 2048$  kHz)

Symbol	Description	Min.	Typ.	Max.	Unit
$t_{WCH}$	High period of PCM_CLK	200			ns
$t_{WCL}$	Low period of PCM_CLK	200			ns
$t_{WSH}$	High period of PCM_SYNC	200			ns
$t_{SSC}$	Setup time, PCM_SYNC high to PCM_CLK low	100			ns
$t_{SDC}$	Setup time, PCM_A/B input valid to PCM_CLK low	100			ns
$t_{HCD}$	Hold time, PCM_CLK low to PCM_A/B input valid	100			ns
$t_{DCD}$	Delay time, PCM_CLK high to PCM_A/B output valid			150	ns

Figure 15. PCM Interface Timing



### 2.12.7 FM PCM interface

The FM PCM interface is a 4 wire voice/audio interface (PCM\_CLK, PCM\_SYNC, PCM\_A and PCM\_B) that allows direct voice/audio sample transfer between chips or to a standard codec.

The 4 signals of the PCM interface are the following:

- PCM\_CLK : PCM clock
- PCM\_SYNC : PCM synchronization signal, typically 8 kHz
- PCM\_DIN : STLC2690 PCM input data
- PCM\_DOUT : STLC2690 PCM output data

The FM PCM interface has the following characteristics (configurable by FM commands) :

- The external PCM data format is linear (up to 16 bits).
- The interface can be programmed to act as a PCM Master or as a PCM Slave. By default the interface is in Slave mode, i.e. the 4 pins are in input mode, with pull-down active.
- In Master mode the PCM clock can be configured to be on only during the active PCM slots, or it can be on all the time when the interface is enabled.
- Supported PCM\_SYNC rates range from 8 kHz to 48 kHz.
- When configured as a Master, the number of PCM clock cycles in one PCM\_SYNC period can be configured, with a maximum number of 512.
- In Master mode the PCM\_SYNC length is configurable to 1 PCM\_CLK clock period (short frame) or to the entire length of the transfer (long frame). In Slave mode all possible PCM\_SYNC lengths are automatically supported, including “short frame” (taking 1 PCM\_CLK clock period) and “long frame” PCM\_SYNC signals (taking more than 1 PCM\_CLK clock period).
- Both the early PCM\_SYNC case (PCM\_SYNC preceding the data transfer by one PCM\_CLK period) and the non-early PCM\_SYNC case (PCM\_SYNC starting simultaneously with the data transfer) are supported.
- TX data are by default generated on the rising edge of PCM\_CLK and expected to be latched by the external device on the falling edge, while RX data are latched on the falling edge of PCM\_CLK. The inverted clock mode is also supported, whereby the generation of TX data is on the falling edge and the latching of TX and RX data is on the rising edge.
- Outside the active PCM slot(s) the PCM DOUT signal can be configured in tristate or as output driving ‘0’.

- Similarly, when the PCM interface is disabled the PCM DOUT signal can be configured in tristate or as output driving '0'.

The FM PCM interface is not present on chip pins in reset or default after reset, and does not become default available once the STLC2690 has detected which interface is used as the Host interface. The FM PCM interface can be mapped to the programmable FM I2S pins by FM commands. See section 2.4.3.

### 2.12.8 FM I2S Interface

The I2S interface is a 4-wire voice/audio interface (I2S\_CLK, I2S\_WS, I2S\_DIN and I2S\_DOUT). It is compatible with the I2S specification, see [10].

The 4 signals of the I2S interface are the following:

- I2S\_CLK : I2S clock
- I2S\_WS: I2S word select signal at sampling frequency
- I2S\_DIN : I2S STLC2690 input data
- I2S\_DOUT : I2S STLC2690 output data

The interface has following characteristics (configurable through the SW Parameter File download or through HCI commands):

- The external data format is linear with 16 bits. Data are transferred with the most significant bit first and are left aligned.
- Both mono and stereo modes are supported. In mono mode the same data are sent in the two slots. In stereo mode the left data are sent when the I2S\_WS signal is low while the right data are sent when the I2\_WS signal is high.
- The FM I2S interface is operating in half-duplex.
- The interface can be programmed to act as a Master or as a Slave.
- Both as a Master and as a Slave the interface supports I2S clock rates from 192 kHz up to 6144 kHz in steps of 8 kHz.
- Both as a Master and as a Slave the interface supports I2S sample rates from 8 kHz up to 192 kHz.
- When configured as a Master, the STLC2690 generates and outputs I2S\_CLK and I2S\_WS; in this mode, the clock rate is fixed to 32 times the I2S\_WS rate.
- By default, data is shifted out on I2S\_DOUT on the falling edge of I2S\_CLK and expected to be latched by the external device on the rising edge, while data shifted in through I2S\_DIN is latched on the rising edge of I2S\_CLK.
- The polarity of I2S\_CLK, I2S\_WS, I2S\_DIN and I2S\_DOUT is, however, programmable.
- By default, the MSB bits are transmitted in the I2S clock cycle following the transition of the I2S\_WS signal, but the interface can also be configured to have the MSB bits coincide with the transitions of the I2S\_WS signal, to connect to CODECs that are not compliant with I2S but use a left aligned or 16-bit right aligned data format instead.
- When more than 16 bits per channel are transferred, i.e. the clock rate is higher than 32 times the I2S\_WS rate, the data output on I2S\_DOUT is padded with zeros as LSBs, and the LSBs of incoming data on I2S\_DIN are ignored.

The FM I2S interface is not present on chip pins in reset or default after reset, but becomes available once the STLC2690 has detected which interface is used as the Host interface. See section 2.4.3.

### 2.12.9 BT I2S Interface

This I2S interface has the same specification as the FM I2S interface, except for the following:

- Both as a Master and as a Slave the interface supports I2S clock rates from 256 kHz up to 4000 kHz in steps of 8 kHz.
- Both half-duplex and full-duplex are supported.
- The position of the rising edge of the I2S\_WS signal can be configured for the case where the clock rate is faster than 32 times the I2S\_WS rate.
- When the clock rate is faster than 32 times the I2S\_WS rate, during the non-active clock cycles the I2S\_DOUT signal can be configured in tristate or as output driving '0'. The I2S clock can be configured to remain on during these non-active clock-cycles, or it can be configured to be off.

The BT I2S interface is not present on chip pins in reset or default after reset, and does not become default available once the STLC2690 has detected which interface is used as the Host interface. The BT I2S interface can be mapped to the programmable PCM pins by the SW Parameter File download or an HCI command. See section 2.4.3.

### 2.12.10 WLAN/WiMAX coexistence interface

The WLAN/WiMAX coexistence interface is a 1 to 4-wire interface (WLAN1, WLAN2, WLAN3 and WLAN4) to a WLAN and/or WiMAX chip that allows optimal coexistence between Bluetooth and WLAN and/or WiMAX, when both functions are collocated.

The 4 signals of the WLAN/WiMAX coexistence interface and the characteristics are defined in section 3.1.9.

The WLAN/WiMAX coexistence interface is not present on chip pins in reset or default after reset, but becomes available once the STLC2690 has detected which interface is used as the Host interface. See section 2.4.3.

### 2.12.11 JTAG Interface

The JTAG interface is a 5-wire interface (TCK, TMS, TDI, TDO, nTRST) that allows both the boundary scan of the digital pins and the debug of the ARM7TDMI application when connected with the standard ARM7 developments tools. It is also used for the industrial test of the device. It is compliant with the JTAG IEEE Standard 1149.1.

## 2.13 RF/Analog Interfaces

### 2.13.1 BT RF port

The BT RF port is a differential port. In order to ensure the performances, typically a balanced band-pass filter needs to be connected to this port. A list of recommended filters is available on request. For RF performances and modem features, see section 3.

### 2.13.2 FM RF in and out

The FM RF input port and output port are differential ports. For RF performances and modem features, see section 4. Both FM\_RFINx and FM\_RFOUTx can be used as FM RX input ports. The STLC2690 includes an internal switch to connect the FM\_RFOUTx to the FM TX or FM RX path. For more details see section 4.2.1.

When using a loop antenna for FM TX, no external components are required.

For the FM receiver using the FM\_RFINx as input port an external matching and blocking circuit is needed. For the FM receiver using the FM\_RFOUTx as input port an external blocking circuit is needed, connected to the FM\_RFINx pins.

### 2.13.3 FM Analog Audio in

A left and right analog audio input is available.

For audio performances and features, see section 4.

### 2.13.4 FM Analog Audio out

A left and right analog audio output is available.

For audio performances and features, see section 4.

## 2.14 GPIOs

Up to 22 GPIOs can be mapped to the programmable pins. These GPIOs can be used as generic output or input (interrupt) signals.

## 3 BLUETOOTH

### 3.1 Bluetooth Functional Description

#### 3.1.1 Modem Receiver

The Bluetooth subsystem implements a low-IF receiver for Bluetooth modulated input signals. The radio signal is taken from a balanced RF input and amplified by an LNA. The mixers are driven by two quadrature LO signals, which are locally generated from a VCO signal running at twice the frequency. The I and Q mixer output signals are band pass filtered by a poly-phase filter for channel filtering and image rejection. The band pass filter amplifies the signals to the optimal input range for the ADC. Further channel filtering is done in the digital part. The digital part demodulates the GFSK,  $\pi/4$ -DQPSK or 8-DPSK coded bit stream by evaluating the phase information. RSSI data is extracted. Overall automatic gain amplification in the receive path is controlled digitally. The RC time constants for the analog filters are automatically calibrated on chip.

#### 3.1.2 Modem Transmitter

The transmitter uses the serial transmit data from the Bluetooth Controller. The transmitter modulator converts this data into GFSK,  $\pi/4$ -DQPSK or 8-DPSK modulated I and Q digital signals for respectively 1, 2 and 3 Mbps transmission speed. These signals are then converted to analog signals that are low pass filtered before up-conversion. The carrier frequency drift is limited by a closed loop PLL.

#### 3.1.3 RF PLL

The on-chip VCO is part of a PLL. The tank resonator circuitry for the VCO is completely integrated without need of external components. Variations in the VCO center frequency are calibrated out automatically.

#### 3.1.4 Bluetooth Controller

##### 3.1.4.1 V1.2 and V2.0 + EDR Features

The Bluetooth Controller is backward compatible with the Bluetooth specification V1.2 [4] and V2.0 + EDR [3]. Here below is a list with the main features of those specifications:

- Adaptive Frequency Hopping (AFH)
- Fast Connection: Interlaced scan for Page and Inquiry scan, answer FHS at first reception, RSSI used to limit range
- Extended SCO (eSCO) links: supports EV3, EV4 and EV5 packets
- Channel Quality Driven Data Rate change (CQDDR)
- QoS Flush
- Synchronization: BT clocks are available at HCI level for synchronization of parallel applications on different Slaves
- L2CAP Flow & Error control
- LMP SCO handling
- Scatternet support
- 2 Mbps packet types
  - ACL: 2-DH1, 2-DH3, 2-DH5
  - eSCO: 2-EV3, 2-EV5
- 3 Mbps packet types
  - ACL: 3-DH1, 3-DH3, 3-DH5
  - eSCO: 3-EV3, 3-EV5

##### 3.1.4.2 Bluetooth Controller V2.1 + EDR Features

- Encryption Pause/Resume (EPR)
- Extended Inquiry Response (EIR)

- Link Supervision Time Out (LSTO)
- Secure Simple Pairing (SSP)
- Sniff Subrating (SSR)
- Quality of Service (QoS)
  - Packet Boundary Flag (PBF)
  - Erroneous Data Delivery (ED)

### 3.1.4.3 Bluetooth Controller V3.0 Features

- Enhanced Power Control
- Read Encryption Key Size

### 3.1.4.4 TX Output Power Control

The Bluetooth subsystem supports output power control:

- With the standard TX power control algorithm enabled, the Bluetooth subsystem adapts its output power when a remote BT device supports the RSSI feature; this allows the remote device to measure the link strength and to request the Bluetooth subsystem to decrease/increase its output power. In case the remote device does not support the RSSI feature, the Bluetooth subsystem uses its 'default' output power level

The Bluetooth subsystem supports operation at Class 1 output power levels up to 10 dBm.

### 3.1.5 Main Processor and Memory

- ARM7TDMI
- On chip RAM, including provision for patches
- On chip ROM preloaded with
  - SW up to HCI
  - A2DP mediapacket encapsulation
- Patch RAM
  - The Bluetooth subsystem includes a HW block that allows patching of the ROM code.
  - Additionally, a SW patch mechanism allows replacing complete SW functions without changing the ROM image.
  - A part of the RAM memory is used for HW and SW patches.

### 3.1.6 CoProcessor

- Audio processor
- RAM, including provision for patches
- ROM, preloaded with
  - SBC encoding/decoding
- Patch RAM
  - a SW patch mechanism allows replacing complete SW functions without changing the ROM image.
  - A part of the RAM memory is used for SW patches.

### 3.1.7 Download of the SW Parameter File

To change the device configuration a set of customizable parameters have been defined and put together in one file, the SW Parameter File. This SW Parameter File is downloaded at start-up into the Bluetooth subsystem.

Examples of parameters are: radio configuration, PCM settings etc.

The same HCI command is used to download the file containing the patches (both those for the SW and HW mechanism).

For a more detailed description of the SW Parameter File refer to [16].

### 3.1.8 Pitch Period Error Concealment (PPEC)

PPEC stands for Pitch Period Error Concealment. It is an algorithm and associated hardware used in the STLC2690 chip to improve the quality of voice transfer over the Bluetooth air channel. It provides for increased speech quality in the vicinity of interference, and improves the coexistence with WLAN. The algorithm works at the receiver side and has no implications at all on the implementation of the Bluetooth specification.

PPEC works as follows: whenever a received packet is completely lost, instead of muting the output some previously received CVSD samples are inserted. These inserted samples are retrieved from a buffer. The PPEC algorithm continuously analyzes the samples that were previously received, and it uses fundamental speech properties to determine which samples from the buffer need to be inserted. As samples are just replaced, the PPEC algorithm does not add any latency to the voice transfer.

### 3.1.9 Bluetooth – WLAN/WiMAX Coexistence in Collocated Scenario

The coexistence interface uses up to 4 WLAN control signal pins, which can be mapped via the SW Parameter File download on different pins of the Bluetooth subsystem (see section 3.1.7).

The functionality of the 4 WLAN control signal pins depends on the selected algorithm, as explained below and summarized in Table 22.

Bluetooth and WLAN 802.11 technologies occupy the same 2.4 GHz ISM band. The Bluetooth subsystem implements a set of mechanisms to avoid interference in a collocated scenario.

The Bluetooth subsystem supports 5 different algorithms in order to provide efficient and flexible simultaneous functionality between the two technologies in collocated scenarios:

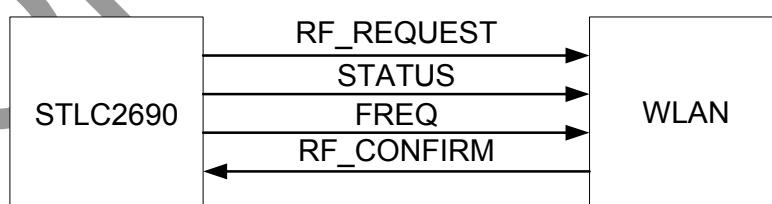
- **Algorithm 1:** PTA (Packet Traffic Arbitration) based coexistence algorithm defined in accordance with the IEEE 802.15.2 recommended practice [7].
- **Algorithm 2:** the WLAN is the Master and it indicates to the Bluetooth subsystem when not to operate in case of simultaneous use of the air interface.
- **Algorithm 3:** the Bluetooth subsystem is the Master and it indicates to the WLAN chip when not to operate in case of simultaneous use of the air interface.
- **Algorithm 4:** Two-wire mechanism
- **Algorithm 5:** Alternating Wireless Medium Access (AWMA), defined in accordance with the WLAN 802.11 technologies.

The algorithm is selected via an HCI command. The default algorithm is algorithm 1.

#### 3.1.9.1 Algorithm 1: PTA (Packet Traffic Arbitration)

The algorithm is based on a bus connection between the Bluetooth subsystem and the WLAN chip:

**Figure 16. PTA**



By using this coexistence interface it is possible to dynamically allocate bandwidth to the two devices when simultaneous operations are required while the full bandwidth can be allocated to one of them in case the other one does not require activity.

The algorithm involves

- a priority mechanism, which allows preserving the quality of certain types of link.
- a mechanism to indicate that a periodic communication is ongoing.

A typical application would be to guarantee optimal quality to the Bluetooth voice communication while an intensive WLAN communication is ongoing.

Several algorithms have been implemented in order to provide a maximum of flexibility and efficiency for the priority handling. ST specific HCI commands are implemented to select the algorithm and to tune the priority handling.

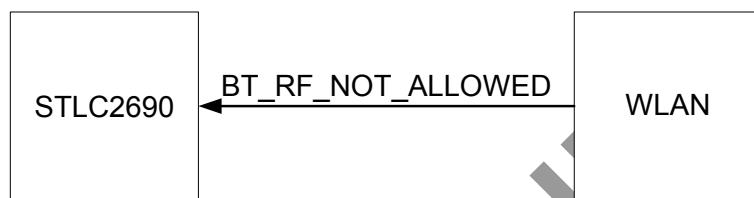
The combination of time division multiplexing and the priority mechanism avoids the interference due to packet collision. It also allows the maximization of the 2.4 GHz ISM bandwidth usage for both devices while preserving the quality of some critical types of link.

### 3.1.9.2 Algorithm 2: WLAN Master

In case the Bluetooth subsystem has to cooperate, in a collocated scenario, with a WLAN chip not supporting a PTA based algorithm, it is possible to put in place a simpler mechanism.

The interface is reduced to 1 line:

**Figure 17. WLAN Master**



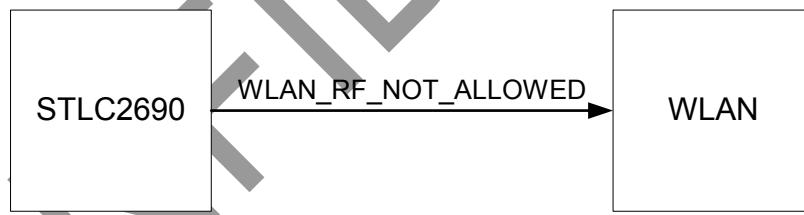
When the WLAN has to operate, it alerts high the BT\_RF\_NOT\_ALLOWED signal and the Bluetooth subsystem does not operate while this signal stays high.

This mechanism permits to avoid packet collision in order to make an efficient use of the bandwidth but cannot provide guaranteed quality over the Bluetooth links.

### 3.1.9.3 Algorithm 3: Bluetooth Master

This algorithm represents the symmetrical case of algorithm 2. Also in this case the interface is reduced to 1 line:

**Figure 18. Bluetooth Master**



When the Bluetooth subsystem has to operate it alerts high the WLAN\_RF\_NOT\_ALLOWED signal and the WLAN does not operate while this signal stays high.

This mechanism permits to avoid packet collision in order to make an efficient use of the bandwidth, it provides high quality for all Bluetooth links but cannot provide guaranteed quality over the WLAN links.

### 3.1.9.4 Algorithm 4: Two-wire Mechanism

Based on algorithm 2 and 3, the Host decides, on a case-by-case basis, whether WLAN or Bluetooth is Master. The Master role can be checked and changed at run-time by the Host via an HCI command.

### 3.1.9.5 Algorithm 5: Alternating Wireless Medium Access (AWMA)

AWMA utilizes a portion of the WLAN beacon interval for Bluetooth operations. From a timing perspective, the medium assignment alternates between usage following WLAN procedures and usage following Bluetooth procedures.

The timing synchronization between the WLAN and the Bluetooth subsystem is done by the HW signal MEDIUM\_FREE.

### 3.1.9.6 WiMax co-existence interface

The WiMax co-existence interface connects a single wire between the STLC2690 and the WiMax controllers. The goal of the WiMax PTA implementation is to protect the traffic in the WiMax licensed bands adjacent to both ends of the 2.4 GHz ISM band used by Bluetooth. The WiMax disable pin is interpreted as a request to immediately shut down any ongoing or scheduled RF activity on the Bluetooth side. The WiMax system should assert this pin each time the Wimax RX activity takes place. The disable pin is directly connected to the BT radio control and BT shutdown can happen in less than 20  $\mu$ s.

### 3.1.9.7 WLAN HW Signal Assignment

**Table 22. WLAN HW Signal Assignment**

WLAN Control Signal	Scenario 1: PTA	Scenario 2: WLAN Master	Scenario 3: BT Master	Scenario 4: 2-wire	Scenario 5: AWMA
WLAN 1	RF_CONFIRM	BT_RF_NOT_ALLOWED	Not used	BT_RF_NOT_ALLOWED	MEDIUM_FREE
WLAN 2	RF_REQUEST	Not used	WLAN_RF_NOT_ALLOWED	WLAN_RF_NOT_ALLOWED	Not used
WLAN 3	STATUS	Not used	Not used	Not used	Not used
WLAN 4	FREQ (optional)	Not used	Not used	Not used	Not used

## 3.2 Bluetooth RF Performances

All the values are provided according to the Bluetooth specification V3.0 unless otherwise specified.

### 3.2.1 Receiver

All specifications below are given at device pin level and with the conditions as specified. Parameters are given for each of the 3 modulation types supported.

**Table 23. 1 Mbps Receiver Parameters - GFSK**

(Typical is defined at  $T_{amb} = 25$  °C,  $VDD\_HV\_x = 1.8$  V. Minimum and Maximum are worst cases over corner lots and temperature. Parameters are given at device pin, except for receiver interferers measured at antenna with a filter having a typical attenuation of 2.3 dB, for filter details see [12]. Measured with an impedance of 26+j32 at the IC pins (this impedance is at 25degree, at low/high temp the impedance is changing with temperature).)

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
RFin	Input frequency range		2402		2480	MHz
RXsensC	Receiver sensitivity (Clean transmitter)	@ BER 0.1%	-92.5	-91	-86.5	dBm
RXsensD	Receiver sensitivity (Dirty transmitter <sup>(1)</sup> )	@ BER 0.1%	-91.5	-90	-86	dBm
RXmax	Maximum useable input signal level	@ BER 0.1%	10		10	dBm

#### Receiver Blocking Performance @ BER 0.1% on Channel 58 (without Filter)

	CW signal in GSM band 900 MHz (824 MHz to 960 MHz)	@ Input signal strength = -67 dBm		-7		dBm
	CW signal in GSM band 1800 MHz (1805 MHz to 1990 MHz)	@ Input signal strength = -67 dBm		-3		dBm
	CW signal in WCDMA band (2010 MHz to 2170 MHz)	@ Input signal strength = -67 dBm		-1		dBm

#### Receiver Interferer Performance @ BER 0.1%

C/I <sub>co-channel</sub>	Co-channel interference	@ Input signal strength = -60 dBm		8.5	10	dB
C/I <sub>1MHz</sub>	Adjacent ( $\pm 1$ MHz) interference	@ Input signal strength = -60 dBm		-9	0	dB
C/I <sub>+2MHz</sub>	Adjacent (+2 MHz) interference	@ Input signal strength = -60 dBm		-39	-30	dB

C/I <sub>-2MHz</sub>	Adjacent (-2 MHz) interference	@ Input signal strength = -67 dBm		-25	-9	dB
C/I <sub>+3MHz</sub>	Adjacent (+3 MHz) interference	@ Input signal strength = -67 dBm		-46.5	-40	dB
C/I <sub>-3MHz</sub>	Adjacent (-3 MHz) interference	@ Input signal strength = -67 dBm		-43	-20	dB
C/I <sub>≥4MHz</sub>	Adjacent ( $\geq \pm 4$ MHz) interference	@ Input signal strength = -67 dBm		-45	-40	dB
<b>Receiver Inter-Modulation</b>						
IMD	Inter-modulation	Measured as defined in BT test specification [6].	-39	-32.3		dBm

1. Dirty transmitter including carrier frequency drift, as defined in the BT SIG spec [6].

**Table 24. 2 Mbps Receiver Parameters - π/4-DQPSK**

(Typical is defined at  $T_{amb} = 25$  °C,  $VDD_{HV\_x} = 1.8$  V. Minimum and Maximum are worst cases over corner lots and temperature. Parameters are given at device pin, except for receiver interferers measured at antenna with a filter having a typical attenuation of 2.3 dB, for filter details see [12]. Measured with an impedance of 26+j32 at the IC pins (this impedance is at 25degree, at low/high temp the impedance is changing with temperature).)

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
RFin	Input frequency range		2402		2480	MHz
RXsensC	Receiver sensitivity (Clean transmitter)	@ BER 0.01%	-91.5	-90	-86	dBm
RXsensD	Receiver sensitivity (Dirty transmitter <sup>(1)</sup> )	@ BER 0.01%	-91	-89.5	-85.5	dBm
RXmax	Maximum useable input signal level	@ BER 0.1%		6		dBm

**Receiver Blocking Performance @ BER 0.1% on Channel 58 (without Filter)**

	CW signal in GSM band 900 MHz (824 MHz to 960 MHz)	@ Input signal strength = -67 dBm		-6		dBm
	CW signal in GSM band 1800 MHz (1805 MHz to 1990 MHz)	@ Input signal strength = -67 dBm		-1		dBm
	CW signal in WCDMA band (2010 MHz to 2170 MHz)	@ Input signal strength = -67 dBm		1		dBm

**Receiver Interferer Performance @ BER 0.1%**

C/I <sub>co-channel</sub>	Co-channel interference	@ Input signal strength = -60 dBm		11.8	13	dB
C/I <sub>1MHz</sub>	Adjacent ( $\pm 1$ MHz) interference	@ Input signal strength = -60 dBm		-15	0	dB
C/I <sub>+2MHz</sub>	Adjacent (+2 MHz) interference	@ Input signal strength = -60 dBm		-40	-30	dB
C/I <sub>-2MHz</sub>	Adjacent (-2 MHz) interference	@ Input signal strength = -67 dBm		-20	-7	dB
C/I <sub>+3MHz</sub>	Adjacent (+3 MHz) interference	@ Input signal strength = -67 dBm		-48.5	-40	dB
C/I <sub>-3MHz</sub>	Adjacent (-3 MHz) interference	@ Input signal strength = -67 dBm		-47	-20	dB
C/I <sub>≥4MHz</sub>	Adjacent ( $\geq \pm 4$ MHz) interference	@ Input signal strength = -67 dBm		-47	-40	dB

1. Dirty transmitter including carrier frequency drift, as defined in the BT SIG spec [6].

**Table 25. 3 Mbps Receiver Parameters - 8-DPSK**

(Typical is defined at  $T_{amb} = 25^{\circ}C$ ,  $VDD\_HV\_x = 1.8$  V. Minimum and Maximum are worst cases over corner lots and temperature. Parameters are given at device pin, except for receiver interferers measured at antenna with a filter having a typical attenuation of 2.3 dB, for filter details see [12]. Measured with an impedance of  $26+j32$  at the IC pins (this impedance is at 25degree, at low/high temp the impedance is changing with temperature).)

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
RFin	Input frequency range		2402		2480	MHz
RXsensC	Receiver sensitivity (Clean transmitter)	@ BER 0.01%	-85	-83	-78.5	dBm
RXsensD	Receiver sensitivity (Dirty transmitter) <sup>(1)</sup>	@ BER 0.01%	-84	-82	-77.5	dBm
RXmax	Maximum useable input signal level	@ BER 0.1%		-3		dBm
<b>Receiver Blocking Performance @ BER 0.1% on Channel 58 (without Filter)</b>						
	CW signal in GSM band 900 MHz (824 MHz to 960 MHz)	@ Input signal strength = -67 dBm		-11		dBm
	CW signal in GSM band 1800 MHz (1805 MHz to 1990 MHz)	@ Input signal strength = -67 dBm		-7		dBm
	CW signal in WCDMA band (2010 MHz to 2170 MHz)	@ Input signal strength = -67 dBm		-9		dBm
<b>Receiver Interferer Performance @ BER 0.1%</b>						
C/I <sub>co-channel</sub>	Co-channel interference	@ Input signal strength = -60 dBm		19	21	dB
C/I <sub>1MHz</sub>	Adjacent ( $\pm 1$ MHz) interference	@ Input signal strength = -60 dBm		-5	5	dB
C/I <sub>+2MHz</sub>	Adjacent ( $+2$ MHz) interference	@ Input signal strength = -60 dBm		-37	-25	dB
C/I <sub>-2MHz</sub>	Adjacent ( $-2$ MHz) interference	@ Input signal strength = -67 dBm		-12	0	dB
C/I <sub>+3MHz</sub>	Adjacent ( $+3$ MHz) interference	@ Input signal strength = -67 dBm		-46	-33	dB
C/I <sub>-3MHz</sub>	Adjacent ( $-3$ MHz) interference	@ Input signal strength = -67 dBm		-40	-13	dB
C/I <sub><math>\geq 4</math>MHz</sub>	Adjacent ( $\geq \pm 4$ MHz) interference	@ Input signal strength = -67 dBm		-42	-33	dB

1. Dirty transmitter including carrier frequency drift, as defined in the BT SIG spec [6].

### 3.2.2 Transmitter

**Table 26. Transmitter Parameters**

(Unless otherwise stated, typical is defined at  $T_{amb} = 25^{\circ}C$ ,  $VDD\_HV\_x = 1.8$  V. Minimum and Maximum are worst cases over corner lots and temperature. Parameters are given at device pin, except for in-band spurious measured at antenna with a filter having a typical attenuation of 2.3 dB, for filter details see [12]. Measured with an impedance of  $26+j32$  at the IC pins (this impedance is at 25degree, at low/high temp the impedance is changing with temperature).)

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
RFout	Output frequency range		2400		2483.5	MHz
<b>RF Transmit Power</b>						
TXpout (GFSK)	Maximum output power <sup>(1)</sup>	@ 2402 - 2480 MHz @ 25 °C	8	10	12	dBm

TXpout (GFSK)	Maximum output power <sup>(1)</sup>	@ 2402 - 2480 MHz @ worst cases over corner lots and temperature	7	10	13	dBm	
TXprange (GFSK, $\pi/4$ -DQPSK, 8-DPSK)	Power control range	@ 2402 - 2480 MHz		40		dB	
	Resolution of power control <sup>(10)</sup>			0.25		dB	
TXpout ( $\pi/4$ -DQPSK)	Maximum output power <sup>(1) (2)</sup>	@ 2402 - 2480 MHz @ 25 °C	5	7	9	dBm	
TXpoutrel ( $\pi/4$ -DQPSK)	Relative transmit power <sup>(3)</sup>	@ 2402 - 2480 MHz	0	-0.5	-1	dB	
TXpout (8-DPSK)	Maximum output power <sup>(1) (2)</sup>	@ 2402 - 2480 MHz @ 25 °C	5	7	9	dBm	
TXpoutrel (8-DPSK)	Relative transmit power <sup>(3)</sup>	@ 2402 - 2480 MHz	0	-0.5	-1	dB	
<b>In-Band Spurious Emission<sup>(4)</sup></b>							
FCC	FCC's 20 dB BW			935	970	kHz	
ACP_2	Channel offset = $\pm 2$ MHz			-39	-20	dBm	
ACP_3	Channel offset = $\pm 3$ MHz			-47	-40	dBm	
ACP_4	Channel offset $\geq \pm 4$ MHz			-50	-40	dBm	
EDR_IBS_1	Channel offset = $\pm 1$ MHz (2 and 3 Mbps)			-27	-26	dBc	
EDR_IBS_2	Channel offset = $\pm 2$ MHz (2 and 3 Mbps)			-28	-20	dBm	
EDR_IBS_3	Channel offset = $\pm 3$ MHz (2 and 3 Mbps)			-44	-40	dBm	
EDR_IBS_4	Channel offset = $\pm 4$ MHz (2 and 3 Mbps)			-47	-40	dBm	
<b>Initial Carrier Frequency Tolerance (for an exact reference)</b>							
$ \Delta f $	$ f_{TX-f0} $			-75	$0^{(5)}$	75	kHz
Carrier Frequency Stability <sup>(6)</sup>							
$ \Delta f_s $	Carrier frequency stability			3.2	10	kHz	
Carrier Frequency Drift <sup>(7)</sup>							
$ \Delta f_{p1} $	One slot packet			12 <sup>(5)</sup>	25	kHz	
$ \Delta f_{p3} $	Three slots packet			14 <sup>(5)</sup>	40	kHz	
$ \Delta f_{p5} $	Five slots packet			14 <sup>(5)</sup>	40	kHz	
Carrier Frequency Drift Rate <sup>(7)</sup>							
$ \Delta f/50\mu s $	Frequency drift rate			8	20	kHz/50 $\mu s$	
Modulation Accuracy <sup>(6)(7)(8)</sup>							
$\Delta f_{1avg}$	Maximum modulation			140	163	175	kHz
$\Delta f_{2avg}$	Minimum modulation			115	140		kHz
$\Delta f_{2avg}/\Delta f_{1avg}$				0.8	0.9		
	2-DH5 RMS DEVM			7.2	20	%	
	2-DH5 99% DEVM				30	%	
	2-DH5 Peak DEVM			17.5	35	%	
	3-DH5 RMS DEVM			7.2	13	%	
	3-DH5 99% DEVM				20	%	

	3-DH5 Peak DEVM			15	25	%
<b>TX Out of Band Emission</b>						
E100	Emission in FM band (76-108 MHz)	(7)(9)		-123		dBm/Hz
E700	Emission in CDMA2000 band (776-794 MHz)	(7)(9)		-135		dBm/Hz
E850	Emission in GSM band (869-960 MHz)	(7)(9)		-134		dBm/Hz
E900	Emission in GSM band (925-960 MHz)	(7)(9)		-134		dBm/Hz
E1500	Emission in GPS band (1570-1580 MHz)	(7)(9)		-140		dBm/Hz
E1800	Emission in GSM band (1805-1880 MHz)	(7)(9)		-136		dBm/Hz
E1900	Emission in GSM band (1930-1990 MHz)	(7)(9)		-136		dBm/Hz
E2100	Emission in WCDMA band (2110-2170 MHz)	(7)(9)		-136		dBm/Hz
E2600	Emission in WCDMA band (2620-2690 MHz)	(7)(9)		-135		dBm/Hz
E5000	Emission in WLAN band (5150-5825 MHz)	(7)(9)		-130		dBm/Hz

1. Lower transmit power (i.e. Class 2) can be obtained by programming the radio init power table via the SW Parameter File download or an HCI command.
2. Power of GFSK part.
3. Relative power of EDR part compared to the GFSK part.
4. At antenna with maximum output power, filter attenuation of 2.3 dB.
5. Phase noise adds maximum [-10 kHz;10 kHz] for worst case clock 200 mVpp at 13 MHz.
6. Worst case clock 200 mVpp at 13 MHz. Measurement according to EDR RF test spec V2.0.E.3 [6].
7. With maximum output power.
8. Measured on reference schematic following layout recommendations.
9. Transmitting DH5 packets.
10. The step size can be controlled via the SW Parameter File.

### 3.3 Bluetooth Interfaces

#### 3.3.1 HCI Transport Layer

##### 3.3.1.1 H4 UART Transport Layer

The HCI transport layer supported on the UART is the H4 transport layer defined by the SIG [5]. The HCI UART transport layer assumes that the UART communication is free from line errors.

The UART interface is defined in section 2.12.2.

Two ways to enter and exit the low power modes are supported (For more details, refer to [15]):

- H4 UART: using CLK\_REQ\_OUT\_x, UART\_RXD and UART\_RTS.
- H4 UART with handshake: using CLK\_REQ\_OUT\_1, BT\_WAKEUP and HOST\_WAKEUP.

##### 3.3.1.2 Enhanced H4 SPI Transport Layer

The HCI transport layer supported on the SPI is the H4 transport layer defined by the SIG [5]. The HCI SPI transport layer assumes that the SPI communication is free from line errors.

In addition a messaging protocol is defined for controlling the Deep Sleep mode entry and wake-up. Three messages are defined: SLEEP, WAKEUP and WOKEN. For more details, refer to [14].

The SPI interface is defined in section 2.12.3.

One way to enter and exit the low power modes is supported (For more details, refer to [14]):

- Enhanced H4 SPI: using CLK\_REQ\_OUT\_x and the SPI in band signaling.

### 3.3.1.3 (e)SCO over HCI

The STLC2690 supports synchronous data packet transfer ((e)SCO) over HCI.

### 3.3.2 BT audio interface

The Bluetooth subsystem of STLC2690 supports one audio interface which can be used for (e)SCO voice transmission and reception or for A2DP. This interface can be either the BT PCM or the BT I2S as defined in 2.12.6 and 2.12.9.

The interface is fully configurable by the Host via the SW Parameter File download and when a SCO connection or A2DP connection is started-up (in order to allow different configuration based on use case). It is possible to configure 2 SCO connections on the PCM interface taking advantage of the multi-port PCM support. The configuration of the PCM for the second SCO is not disturbing the first SCO connection.

For Bluetooth voice operation (PCM/I2S and (e)SCO), the interface always works at 8 kHz. However, it is possible to configure the interface to other frame rates like 16 or 32 kHz, and link it to an eSCO link operating at the same rate. In I2S mode, it is possible to exchange voice on the left or on the right channel only. When two (e)SCO are active, each SCO uses one of the channels. The channel which is not used is padded with '0' on data out.

For A2DP operation, the I2S sample rate is configurable e.g. 44.1 or 48 kHz. The audio is SBC encoded and A2DP encapsulated in the STLC2690, before being transmitted over the BT link.

### 3.3.3 WLAN/WiMAX Coexistence Interface

The WLAN/WiMAX coexistence interface to a WLAN and/or WiMAX chip allows optimal coexistence between the two functions when collocated. This interface can contain 1 to 4 wires (WLAN1, WLAN2, WLAN3 and WLAN4). For more details refer to section 3.1.9. The 4 control signals are mapped on the pins as indicated in section 2.4.3.

### 3.3.4 GPIOs

Up to 22 GPIOs can be mapped to the pins. These GPIOs can be used as a generic output or input (interrupt) signals.

## 4 FM TRANSCEIVER

### 4.1 FM Functional Description

The FM subsystem of the chip contains a full receiver function and a full transmitter function. The Host selects which function is performed. Note that the two functions cannot be active at the same time.

The FM subsystem is compliant with all relevant international and regional standards and regulations, e.g.

- ITU BS.450-3
- ETSI 301 357
- FCC part 15 and 73

For the transmitter function, depending on the platform in which the STLC2690 is integrated, the maximum radiated output power can be adjusted by the Host to be in line with the local regulations.

Both the receiver and the transmitter fully support RDS/RBDS. The RDS/RBDS is compliant with all relevant international and regional standards, e.g.

- CENELEC EN50067 (1992), CENELEC EN62106 (2001)
- NRSC RBDS (04/1998), NRSC 4 A (04/2005) and Annexes

The FM transceiver uses a low-IF receiver and a quadrature up-conversion transmitter.

The RF frequency is generated by an on-chip Frequency Locked Loop (FLL).

A small embedded microcontroller manages the flexibility of the data path and the DSP parameters. It reduces the load on the Host by taking care of the encapsulation (for the transmitter) and extraction (for the receiver) of RDS/RBDS messages. It also takes care of the overall control of the transceiver.

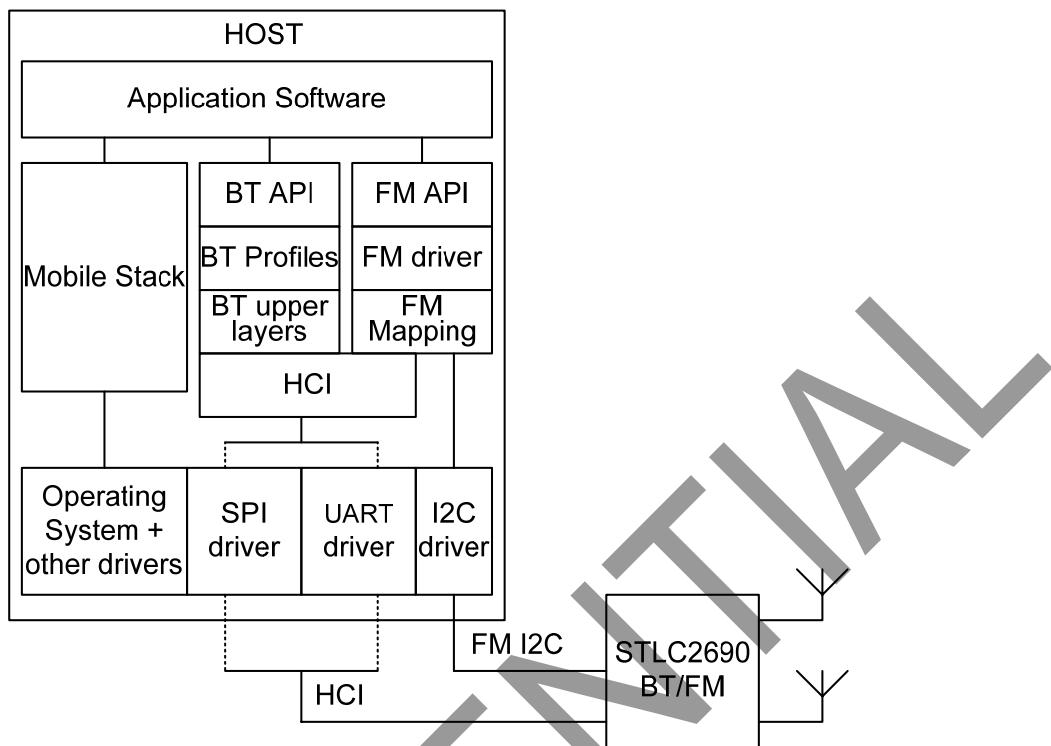
An integrated switch to connect either the FM transmitter or the FM receiver to an integrated FM antenna is available in the STLC2690.

#### 4.1.1 FM external control

There are two alternatives to control the FM subsystem from the Host side.

- The first way is to use the FM I2C interface.
- The second way is to control the FM subsystem over the Bluetooth HCI interface. Vendor-specific HCI commands and events have been defined for this purpose.

Figure 19. FM external control through FM I2C or BT HCI interface



The command encoding is exactly the same when using I2C or BT HCI such that the Host driver can be the same for both.

As shown in Figure 19 a Host-level API layer is offered in order to facilitate integration of the FM driver on the Host. This API consists of a limited set of primitives, hiding the details of the FM device. It also avoids polling, thereby reducing the load on the Host. Source codes are provided for an example application as well as for the driver primitives itself.

As an example, the following primitives are offered:

- RadioBoot(<list of parameters>): to perform power-on of the FM subsystem and to perform platform dependent initialization
- RadioRxConfig(<list of parameters>): to configure different aspects of the receiver function
- RadioRxSetFreq(dwRxFrequency): to set the tuning frequency.

#### 4.1.2 Interrupt to the Host

In case the FM subsystem is controlled via I2C a dedicated signal on the chip, FM\_IRQ, can be used as an interrupt line to the Host. In order to map this signal to a pin of the chip a download of the Bluetooth parameter file is required. The interrupt line can be configured as an active high or active low signal.

In case the FM subsystem is controlled via HCI no hardware interrupt line needs to be used. Instead, the Host is notified via a vendor-specific HCI event.

The interrupt (or event) can be generated for many functions in the FM subsystem, e.g. to signal the availability of information in the RDS data buffers. The Host is able to configure when to generate an interrupt (or event) and for which function.

#### 4.2 FM radio receiver

The receiver offers worldwide band support (65.9 MHz up to 108 MHz).

The receiver uses a low-IF architecture. The RF signal is down-converted, after which anti-aliasing filtering and coarse channel filtering is performed. An automatic gain control (AGC) circuit controls the gain of the input amplifier. A high resolution ADC then digitizes the baseband-analog signal for further digital signal processing.

Digital signal processing (DSP) involves channel selection, FM demodulation, stereo separation and RDS/RDBS processing. The DSP extracts additional information such as the RSSI level of the incoming signal and other quality characteristics. This information is used by the embedded microprocessor for circumstantial control in order to optimize the user's audio experience on-the-fly.

As a reference clock the FM subsystem can either use the externally supplied slow clock or the fast clock supplied by the Bluetooth subsystem. The FM subsystem is in a handshaking process with the BT subsystem to exchange information on each other's power state and on the availability of reference clock sources. Optionally the FM subsystem can from time to time calibrate the slow clock using the fast clock, allowing for a larger inaccuracy of the slow clock.

#### 4.2.1 Dual RF input with RX/TX antenna switch

The STLC2690 supports two alternative RF inputs for the FM receiver:

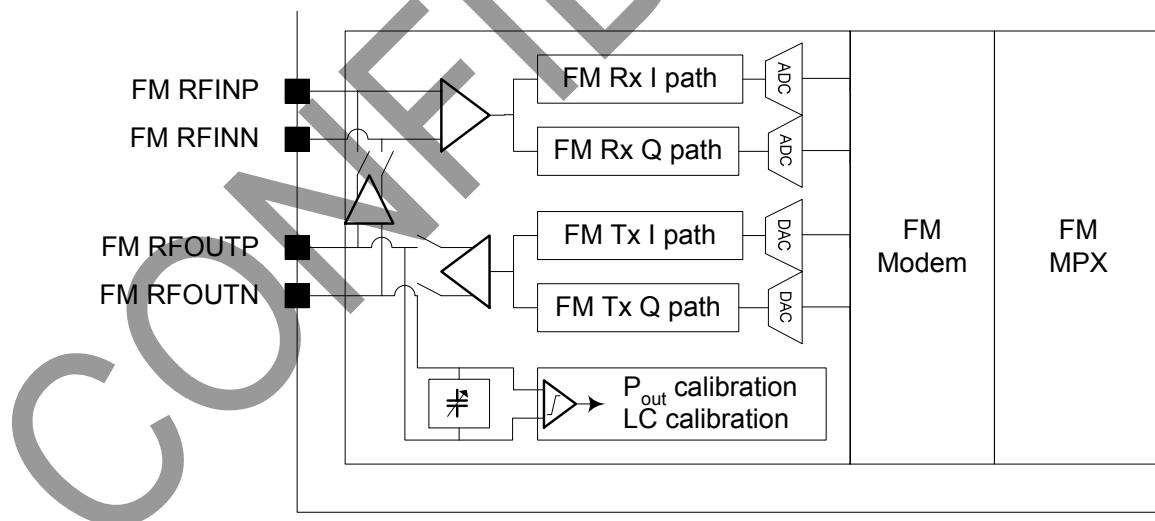
- One RF input dedicated to the FM receiver, at pins FM\_RFINP/FM\_RFINN. This is a low-resistive input. This input is suited for external headset wire antennas. An external matching network is recommended to match to a typical headset wire antenna impedance and to fulfill blocking requirements, see [13].
- One RF input shared with the FM transmitter, at pins FM\_RFOUTP/FM\_RFOUTN. This is a high-resistive and capacitive input. This input is suited for antennas integrated on the PCB. An internal switch inside the STLC2690 connects the pins FM\_RFOUTP/FM\_RFOUTN to the FM TX path or to the FM RX path. The STLC2690 integrates a tunable capacitor bank to perform an automatic calibration of the output power and the RF load including the antenna. An external matching network connected to FM\_RFINP/FM\_RFINN is recommended to fulfill blocking requirements, see [13].

Impedances and performances of the two RF inputs are listed in section 4.4.1.

The implementation in STLC2690 (as depicted below) offers the following advantages:

- Isolation of the FM transmit path using a handset antenna towards the headset wire which can still be connected.
- Unchanged RF input impedance return loss in case of regular reception via a headset wire.
- High impedant RF input in case of reception via FM transmit antenna.

**Figure 20. Dual RF input with FM RX/TX antenna switch**



#### 4.2.2 Receiver RF functions

##### Band selection

The chip can be configured either to the OIRT band (65.9 – 74 MHz), the Chinese band (70 – 108 MHz), the Japanese FM band (76 - 90 MHz), the Japanese FM wide band, the USA/Europe FM band (87.5 - 108 MHz) or to the worldwide band (70 - 108 MHz).

##### Scan up / scan down

An autonomous frequency scan can be requested. The scan stops when a station is found that exceeds the currently configured RSSI level. On top of the RSSI level the Host can also impose a CNR value (Carrier-to-Noise Ratio) to be met.

Alternatively the PTY information can be used to stop the scan when a specified value is found. This value is configurable by the Host.

The frequency step for the scan is programmable either to 30 kHz, 50 kHz, 100 kHz or 200 kHz.

#### RF AGC

The RF AGC prevents saturation and limits the amount of intermodulation products created by strong adjacent channels. The RF AGC is on by default but it can be turned off.

In addition there is an in-band AGC to prevent overloading by the wanted channel. The in-band AGC is always turned on.

#### Pre-demodulation RF bandwidth reduction

When the stereo blending function is activated and the signal level is close to sensitivity, the RF bandwidth is automatically, seamlessly reduced and the receiver is set in mono mode to improve the sensitivity by about 3 dB. The RF bandwidth reduction is on by default but it can be turned off.

#### RSSI level

The RSSI level can be retrieved by the Host. It is also used internally for the Mute, Scan, Blend and Alternative Frequency functions. The information is low-pass filtered and the refresh cycle time can be configured.

#### Image detection

The image detector determines whether a received signal is from a true station, or is the image of a station after mixing.

The process is automatically enabled when the auto scan is running, but it can be switched off.

When an image is detected, an interrupt is generated if the FM frequency had been requested by the Host. In autonomous mode (during a Scan or an Alternative Frequency), the interrupt is not generated.

### 4.2.3 Receiver audio functions

#### Volume control

The output level is adjustable by a simultaneous control of the left and right channel. The level can be set to 32 different levels in steps of 1.5 dB.

The volume control can be configured to apply to both analog and digital output simultaneously, or only to the analog output (providing a line-out function to the digital output).

#### Boost and audio equalizer

The equalizer can be configured either as a 3-band equalizer, by genre or according to the RDS PTY information. The genres are pre-defined and the following genres can be chosen: Normal (Speech), Classic, Rock and Pop.

When configured as a 3-band equalizer each band can be set at 15 different levels in steps of 1.5 dB, between -10.5 and +10.5 dB. The corner frequency for the low band is 300 Hz, the corner frequency for the high band is 3 kHz.

#### Soft mute

In case of low RF input levels the RSSI information, after being integrated and low-pass filtered, drives the soft mute attenuator. The audio output is faded when soft mute is being applied. The soft mute function can be switched off.

The RSSI level at which soft muting starts can be shifted up or down by 3 dB. See the following table for some parameters of the soft mute function.

**Table 27. Soft mute parameters**

Parameter	Conditions	Typical	Unit
-----------	------------	---------	------

## STLC2690

Soft mute start level	Default mode (programmable +/- 3 dB)	10	dB $\mu$ V
Soft mute attenuation	$V_{in} = 0 \text{ dB}\mu\text{V}$ , $\Delta f_{\text{audio}} = 22.5 \text{ kHz}$ , $f_{\text{mod}} = 1 \text{ kHz}$ , $L = R$	14	dB

### Audio mute

The left and right audio outputs can be muted completely. This can be done simultaneously but it can also be done for each channel individually.

Note that the audio output is automatically muted during an Alternative Frequency update.

### Mono/Stereo configuration

The receiver can be set either to mono or to stereo.

The STLC2690 supports the pilot-tone system stereo decoding, it does not support polar-modulation stereo decoding.

### Mono/Stereo indication

The receiver offers a mono/stereo indicator to the Host. The indicator can be based either upon the measured pilot deviation or upon the degree of mono/stereo blending (see below). In either case some hysteresis is used to avoid too frequent toggling of the indicator:

- in case the Host configures the indicator to be based upon the pilot deviation, the indicator will toggle typically at 4.5 kHz (for increasing pilot deviation) or at 3 kHz (for decreasing pilot deviation).
- in case the Host configures the indicator to be based upon the mono/stereo blending, the indicator will toggle when reaching 25% of stereo (for decreasing RSSI) or when reaching 75% of stereo (for increasing RSSI).

An interrupt can be configured to trigger when the indicator toggles.

### Automatic audio bandwidth (high cut) control

An automatic audio bandwidth limitation can be set. This is used in case of low RSSI levels.

### Signal dependent mono/stereo blending

As the RF input level drops the decoder makes a transition from stereo to mono in order to limit the output noise. This process is called blending. The transition can be smooth (in case gliding blending is configured) or fast (in case hard blending is configured).

Blending starts at a programmable threshold on the RF level (see the table below). The blending can also be switched off by the Host.

**Table 28. Mono/stereo blending parameters**

Parameter	Conditions	Typical	Unit
Mono/stereo blend start level	Default mode (programmable +/- 3 dB)	42	dB $\mu$ V

### Adjacent channel detection

When a strong adjacent channel is about to interfere with the wanted signal, the RF bandwidth is seamlessly reduced. This option is enabled by default, but can be switched off.

#### 4.2.4 Receiver RDS/RBDS support

##### RDS/RBDS decoder

In order to minimize the load on the Host RDS/RBDS synchronization, error correction (whenever possible) and block identification are performed locally. The same is done for some specific RDS/RBDS information.

The Host is able to set some parameters for acquisition, maintenance and loss of synchronization.

Up to a maximum of 85 blocks can be stored locally, including an extra 8 bits per block for status signaling: block identification (3 bits), error status (3 bits), FIFO status (1 bit) and a spare bit.

When the FIFO capacity reaches a certain configurable level an interrupt is generated to notify the Host, so when the interrupt is received on a regular basis the Host can download the complete RDS memory.

Table 29 shows the processing that is embedded inside the chip so as to avoid frequent access to the Host.

All RDS data, including the data that are not present in Table 29, are still stored inside the chip and can be sent to the Host upon request.

**Table 29. RDS/RBDS data processed inside the chip**

Acronym	Name	Note
AF	Alternative Frequency	(1)
EON	Enhanced Other Network	(3) (4)
MS	Music Speech	(3)
PI	Program Identification	(1)
PTY	Program Type	(3)
PTYN	Program Type Name	
TA	Traffic Announcement	(2)
TP	Traffic Program	(2)
CT	Clock Time and Date	
DI	Decoder Identification	
ECC	Extended Country Code	
PIN	Program Item Number	
PS	Program Service	
RT	Radio Text	
RT+	Radio Text Plus as defined in [8]	

1. This is used in AF processing
2. Specifically used during automatic scan
3. Equalizer can be programmed to automatically adapt to the music genre
4. Used for TA/TP switching, for temporary switching to another RF channel when it broadcasts a traffic announcement

### Alternative Frequency (AF)

The receiver can autonomously change the tuning frequency to the Alternative Frequency which provides the same or an equivalent program of the same radio network with a better quality.

In this autonomous mode the receiver performs AF list acquisition, checks the quality of the station(s) at the alternative frequency(ies), performs image detection and checks the PI code. All these actions, including switching back to the original frequency in case the alternative frequency(ies) do not prove to be adequate, are completed within a time of 15 ms except for the PI check.

The AF feature can be switched off. The RSSI threshold level below which the process is started, can be configured. In order to avoid continuous switching the minimum RSSI level expected at the Alternative Frequency can also be configured.

### Audio pause detector

The pause detection is used to perform inaudible frequency jumps during silences. The detection is based on the sum of left and right channels with a programmable threshold on the audio level, specified in terms of corresponding FM deviation.

The pause time, being the minimum duration of an audio silence for the receiver to accept it as a valid pause, can be programmed.

The pause detector can be disabled. In that case the AF switch is triggered immediately when the RSSI drops below the configured threshold.

### 4.3 FM radio transmitter

The transmitter offers worldwide band support (76 MHz up to 108 MHz).

The transmitter circuit uses digital signal processing (DSP) to generate a stereo MPX signal, perform FM modulation and quadrature signal generation. After converting both quadrature signals to an analog signal, an up-converting mixer followed by a power amplifier produces the RF signal. The transmitter has extra filtering as to ensure coexistence with existing wireless applications in a handset. It has calibration circuits and variable gain in the transmit path to establish the correct output power. A tunable capacitor array is used to tune the antenna circuit.

The transmitter supports RDS/RDBS message handling.

The transmitter may run from the externally applied low power reference clock (in this case the embedded microprocessor should receive information on the clock inaccuracy to compensate for). It can also be configured to run from the fast clock supplied from the Bluetooth subsystem. Optionally the FM subsystem can from time to time calibrate the slow clock using the fast clock, allowing for a larger inaccuracy of the slow clock.

#### 4.3.1 SureTune™

The STLC2690 supports SureTune™ technology. This technology features a microprocessor controlled, fast auto search algorithm to identify suitable transmit frequencies at a 50, 100 or 200 kHz grid. The tuner in the transceiver scans the FM band in a few seconds. Based on the acquired information, the embedded microcontroller then determines the best transmit frequency, after which transmission can start. Several TX channel presets can be stored in memory. The frequency scan on FM RX can be done either on FM\_RFINx or FM\_RFOUTx, depending on the configuration, see section 4.2.1.

#### 4.3.2 Transmitter audio functions

##### Programmable analog input range

Three different analog input ranges are supported: 92 mVpeak, 147 mVpeak and 234 mVpeak.

##### MPX multiplexing

The following independent configurations to the MPX signal are possible:

- mono or stereo
- audio present or not
- pilot present or not
- RDS/RBDS present or not.

##### Pre-emphasis

The pre-emphasis can be set to either 50 or 75  $\mu$ s.

##### Digital AGC/limiter

The digital part contains an AGC and a limiter to prevent overmodulation. The AGC has a peak detector with a programmable threshold and time constant. The limiter implements saturation at a programmable level.

##### Programmable maximum FM deviation

The maximum FM deviation can be programmed to a value of up to 100 kHz.

##### Programmable gains

The gains can be set separately for the audio signal and the RDS/RBDS component.

#### 4.3.3 Transmitter RF functions

##### Programmable transmit level

The default transmit level is 120 dB $\mu$ V peak in differential mode. A gain range of -30 to 0 dB is available.

##### Simultaneous transmission on two FM channels

The same MPX signal can be transmitted on two different RF frequencies. This allows an FM receiver to switch to an alternative frequency with better reception of the same broadcast source. The spacing between both FM

channels is programmable, with a typical setting of 1.6 MHz. In this case the peak output power is equal to the one of a single FM channel, however divided over the two channels.

### Automatic calibration

The transmitter performs an automatic calibration of the output power and the RF load including the antenna, by tuning a programmable capacitor bank at the RF output.

This tuning can be done periodically during operation, without audible effects.

### 4.3.4 Transmitter RDS/RBDS support

The programmable RDS/RBDS is compliant with international and regional standards:

- CENELEC EN50067 (1992), CENELEC EN62106 (2001)
- NRSC RBDS (04/1998), NRSC 4 A (04/2005) and Annexes

The transmitter supports RDS/RBDS message handling in a versatile way. It takes care of block framing and error coding, but also the scheduling and repeated transmission of a large series of blocks can be left to its embedded microcontroller if desired. In that case the same types of RDS/RBDS data are supported as for the receiver, including RT+, see Table 29, except for TA/TP.

## 4.4 FM Radio Performance

### 4.4.1 FM radio receiver performance

**Table 30. FM Radio receiver performance**

(Typical is defined at  $T_{amb} = 25^{\circ}C$ ,  $VDD\_HV\_x = 1.8\text{ V}$ . Minimum and Maximum are worst cases over corner lots and temperature.)

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
<b>FM General Parameters</b> <sup>(4)(5)(6)</sup>						
$F_{RF}$	Operating Frequency	At FM_RFINx	65.9		108	MHz
$F_{RF}$	Operating Frequency	At FM_RFOUTx	76		108	MHz
S/Nmax	Maximum (S+N)/N	Mono <sup>(1)(3)</sup>		63		dB
S/Nmax	Maximum (S+N)/N	Stereo <sup>(2)(3)</sup>		58		dB
US	Useable Max Sensitivity	50 $\Omega$ matching network, @FM_RFINx, see section 4.2.1 <sup>(1)</sup> (S+N)/N = 26 dB, $T_{amb} = 25^{\circ}C$		-2	1 <sup>(7)</sup>	dB $\mu$ V
US	Useable Max Sensitivity	50 $\Omega$ matching network, @FM_RFINx, see section 4.2.1 <sup>(1)</sup> (S+N)/N = 26 dB, full temperature range		-2	5 <sup>(7)</sup>	dB $\mu$ V
US intermediate	Useable Intermediate Sensitivity	50 $\Omega$ matching network, @FM_RFINx, see section 4.2.1 <sup>(1)</sup> (S+N)/N = 45 dB		11		dB $\mu$ V
Sel@200k	Selectivity	Interferer at $\pm 200$ kHz, measured as per EN55020	43			dB
Sel@400k	Selectivity	Interferer at $\pm 400$ kHz, measured as per EN55020	52			dB
IIP3	Overall Input	Interferers at $\pm 200$ kHz, $\pm 400$ kHz,	85	90		dB $\mu$ V

## Restricted Distribution

	third Order Intercept Point	AGC OFF, Gain set at GMAX, at S+N)/N = 26 dB				
IIP3	Overall Input third Order Intercept Point	Interferers at $\pm 1, \pm 2$ MHz, AGC OFF Gain set at GMIN, at S+N)/N = 26 dB	130	135		dB $\mu$ V
IIP3	Overall Input third Order Intercept Point	Interferers at $\pm 1, \pm 2$ MHz, AGC OFF Gain set at GMAX, at S+N)/N = 26 dB	85	88		dB $\mu$ V
AM suppr	AM suppression	<sup>(1)(3)</sup>	58	67		dB
RDS S @1.2kHz	RDS sensitivity	50 $\Omega$ matching network, @FM_RFINx, see section 4.2.1 $\Delta f_{RDS} = 1.2$ kHz, L = -R 95% of blocks decoded with no errors, taken over 5000 blocks <sup>(2)</sup>		21	22	dB $\mu$ V
RDS S @2kHz	RDS sensitivity	50 $\Omega$ matching network, @FM_RFINx, see section 4.2.1 $\Delta f_{RDS} = 2$ kHz, L = -R 95% of blocks decoded with no errors, taken over 5000 blocks <sup>(2)</sup>		16	18	dB $\mu$ V
RDS Sel@200k	RDS Selectivity at $\pm 200$ kHz	Wanted RF level = RDS sensitivity (S) + 3 dB, conditions as for RDS S @ 2 kHz Interferer: $\Delta f = 40$ kHz, fmod = 1 kHz	S + 20			dB $\mu$ V
RDS Sel@400k	RDS Selectivity at $\pm 400$ kHz	Wanted RF level = RDS sensitivity (S) + 3 dB, conditions as for RDS S @ 2 kHz Interferer: $\Delta f = 40$ kHz, fmod = 1 kHz	S + 40			dB $\mu$ V
<b>RF <sup>(4)(5)(6)</sup></b>						
$R_{FM\_RFIN}$	RF input resistance	Differential at pins, @FM_RFINx, see section 4.2.1		200		$\Omega$
$V_{RF,max}$	RF maximum input level	Maximum input level, audio parameters are met.			105	dB $\mu$ V
	RF blocking levels (at antenna input)	FM sensitivity degraded with 1 dB. With 5 component 50 $\Omega$ matching network, @FM_RFINx, see section 4.2.1. 824 – 915 MHz (modulations: EDGE, CDMA)		10		dBm
	RF blocking levels (at antenna input)	FM sensitivity degraded with 1 dB. With 5 component 50 $\Omega$ matching network, @FM_RFINx, see section 4.2.1. 1710 – 1980 MHz (modulations: EDGE, CDMA, WCDMA)		10		dBm
	RF blocking levels (at antenna input)	FM sensitivity degraded with 1 dB. With 5 component 50 $\Omega$ matching network, @FM_RFINx, see section 4.2.1. 2400 – 2483.5 MHz (modulations: BT, WLAN)		8		dBm
<b>Stereo decoder and Base band when in digital or analog output mode <sup>(4)(5)(6)</sup></b>						
THD	Total Harmonic Distortion	Mono, $\Delta f_{audio} = 75$ kHz, not A-weighted <sup>(1)(3)</sup>		0.08	0.1	%

THD	Total Harmonic Distortion	Stereo, $\Delta f_{\text{audio}} = 67.5 \text{ kHz}$ , not A-weighted <sup>(2)(3)</sup>		0.07	0.13	%
THD	Total Harmonic Distortion	Mono, $\Delta f_{\text{audio}} = 100 \text{ kHz}$ , not A-weighted <sup>(2)(3)</sup>		0.07	0.15	%
AudSpur	Audio Spurious Products	<sup>(1)(3)</sup>			-60	dBc
StereoSep	Stereo Separation	Stereo blending OFF, 32 dB $\mu$ V input level, $\Delta f_{\text{audio}} = 67.5 \text{ kHz}$ , R = 0, L = 1 <sup>(2)</sup>	43	44		dB
PilotSup	Pilot suppression	Stereo, $\Delta f_{\text{audio}} = 67.5 \text{ kHz}$ , without 15 kHz LP filter in the audio analyzer, absolute value (i.e. difference between 1kHz <sup>(3)</sup> tone and pilot tone after filtering) <sup>(2)</sup>	80			dB
$T_{\text{deemphasis}}$	De-emphasis time constant		73	75	77	$\mu\text{s}$
$T_{\text{deemphasis}}$	De-emphasis time constant		49	50	51	$\mu\text{s}$
AudioMute	Audio soft muting attenuation	When FM function enabled and in auto-search or when soft mute active	60			dB
<b>Analog Audio outputs only</b> <sup>(4)(5)(6)</sup>						
VAF	Audio output level	Rload > 30 k $\Omega$ , $\Delta f_{\text{audio}} = 22.5 \text{ kHz}$ Mono <sup>(1)</sup> and Stereo <sup>(2)</sup> <sup>(3)</sup>	61	69	71	mVrms
VAFmax	Maximum audio output level	Rload > 30 k $\Omega$ , $\Delta f_{\text{audio}} = 100 \text{ kHz}$ Mono <sup>(1)</sup> <sup>(3)</sup>	293	307	315	mVrms
VAFL/VAFR	Audio Left/Right Channel imbalance	<sup>(2)(3)</sup> at high volume levels	-0.1		0.1	dB
BW	Upper Audio Bandwidth (-3 dB point)	for both $T_{\text{deemphasis}} = 75 \mu\text{s}$ and $50 \mu\text{s}$ <sup>(3)</sup>	15.2			kHz
BW	Lower Audio Bandwidth (-3 dB point)	for both $T_{\text{deemphasis}} = 75 \mu\text{s}$ and $50 \mu\text{s}$ <sup>(3)</sup>			10	Hz
	Audio response flatness	100 Hz to 13 kHz, for both $T_{\text{deemphasis}} = 75 \mu\text{s}$ and $50 \mu\text{s}$ , pre-emphasis applied, after de-emphasis <sup>(3)</sup>			$\pm 0.8$	dB
	Audio output impedance	When FM function enabled and in auto-search or when soft mute active			50	$\Omega$
<b>Digital Audio outputs only</b> <sup>(4)(5)(6)</sup>						
VAF	Audio output level	Mono <sup>(1)</sup> , $\Delta f_{\text{audio}} = 75 \text{ kHz}$		-7.5		dB/fullscale
Fs	Audio output sample rate		8		192	kHz
<b>Synthesizer</b> <sup>(4)(5)(6)</sup>						
Fstep	Minimum frequency step		30		200	kHz
Tsweep	Sweep time	Total time taken for an automatic search to sweep from 88 to 108 MHz			5	s

		or 76 to 90 MHz (or reverse direction) assuming no channels found.				
<b>RSSI level</b> <sup>(4)(5)(6)</sup>						
Range	Range		10		60	dB $\mu$ V
$\Delta L$	Relative Level error				$\pm 1$	dB
$\Delta L$	Absolute Level error				$\pm 3$	dB

1. Mono,  $\Delta f_{\text{audio}} = 22.5 \text{ kHz}$ ,  $f_{\text{mod}} = 1 \text{ kHz}$ , unless otherwise stated
2. Stereo,  $\Delta f_{\text{audio}} = 22.5 \text{ kHz}$ ,  $f_{\text{mod}} = 1 \text{ kHz}$ ,  $\Delta f_{\text{Pilot}} = 6.75 \text{ kHz}$ ,  $L = R$ , no RDS, unless otherwise stated
3.  $V_{\text{in}} = 60 \text{ dB}\mu\text{V}$
4.  $F_{\text{RF}} = 65.9 \text{ to } 108 \text{ MHz}$ , unless otherwise stated
5. with 15 kHz LP filter in the audio analyzer, A-weighted, unless otherwise stated
6. @FM\_RFINx and with a  $50 \Omega$  matching network, see section 4.2.1, unless otherwise stated
7. Depending on application conditions, when BT is enabled, at 2 FM frequencies exceptions might occur.

#### 4.4.2 FM radio transmitter performance

**Table 31. FM Radio transmitter performance**

(Typical is defined at  $T_{\text{amb}} = 25 \text{ }^{\circ}\text{C}$ ,  $V_{\text{DD\_HV\_x}} = 1.8 \text{ V}$ . Minimum and Maximum are worst cases over corner lots and temperature.)

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
<b>FM General Parameters</b>						
$F_{\text{RF}}$	Operating Frequency		76		108	MHz
<b>Synthesizer</b>						
$F_{\text{step}}$	Frequency Step		50		200	kHz
	Frequency Accuracy <sup>(3)</sup>		-10		10	kHz
<b>RF output</b>						
	Maximum spacing of dual FM TX channels	The spacing is programmable		1.6		MHz
	Maximum transmit output level	With as load a loop antenna with inductance of 120 - 150 nH and a minimum Q of 30		120		dB $\mu$ Vpdifff
	Gain range	With as load a loop antenna with inductance of 120 - 150 nH and a minimum Q of 30.	-28		0	dB
	Gain step at high output levels		0.4	1	1.6	dB
	Transmitter Output accuracy	Over entire output power range	-1		1	dB
	Load inductance range that can be supported	$F_{\text{RF}} = 76 \text{ to } 108 \text{ MHz}$ , with a minimum Q of 30, without external capacitance added	120		150	nH
	Occupied BW	$\pm 100 \text{ kHz}$ offset from nominal channel frequency			-20	dBc
ACP	Adjacent channel power, at max output power, single FM TX channel	$> \pm 120 \text{ kHz}$		-35	-30	dBc
	Transmitter Noise floor <sup>(4)(5)(6)(8)</sup>	746 - 764 MHz		-140		dBm/Hz
	Transmitter Noise floor <sup>(4)(5)(6)(8)</sup>	869 - 894 MHz, 925 - 960 MHz, 1805 - 1880 MHz, 1930 - 1990 MHz		-140		dBm/Hz
	Transmitter Noise floor <sup>(4)(5)(6)(8)</sup>	2110 - 2170 MHz		-140		dBm/Hz

	Transmitter Noise floor <sup>(4)(5)(6)(8)</sup>	1570 - 1580 MHz		-140		dBm/Hz
	Transmitter Spurious <sup>(4)(5)(6)(8)</sup>	746 - 764 MHz		-99		dBm
	Transmitter Spurious <sup>(4)(5)(6)(8)</sup>	869 - 894 MHz, 925 - 960 MHz, 1805 - 1880 MHz, 1930 - 1990 MHz		-109		dBm
	Transmitter Spurious <sup>(4)(5)(6)(8)</sup>	2110 - 2170 MHz		-96		dBm
	Transmitter Spurious <sup>(4)(5)(6)(8)</sup>	1570 - 1580 MHz		-106		dBm
<b>Analog audio input</b>						
VAF1	Analog audio input level <sup>(7)</sup>	Mono <sup>(1)</sup> , $\Delta f_{audio} = 75$ kHz Stereo <sup>(2)</sup> , $\Delta f_{audio} = 67.5$ kHz with input gain step 1			78	mVp
VAF1	Analog audio input level <sup>(7)</sup>	Mono <sup>(1)</sup> , $\Delta f_{audio} = 75$ kHz Stereo <sup>(2)</sup> , $\Delta f_{audio} = 67.5$ kHz with input gain step 2			134	mVp
VAF1	Analog audio input level <sup>(7)</sup>	Mono <sup>(1)</sup> , $\Delta f_{audio} = 75$ kHz Stereo <sup>(2)</sup> , $\Delta f_{audio} = 67.5$ kHz with input gain step 3			212	mVp
ZAF	Analog Input impedance			25		kΩ
<b>Digital audio input (I2S)</b>						
	Audio input level	Mono <sup>(1)</sup> , $\Delta f_{audio} = 75$ kHz Stereo <sup>(2)</sup> , $\Delta f_{audio} = 67.5$ kHz		-6		dB/fullscale
Fs	Audio input sample rate		8		192	kHz
<b>Stereo encoder and Base band</b>						
Δf	Total peak deviation	Absolute maximum peak deviation - programmable		75	100	kHz
Δf <sub>Pilot</sub>	Pilot deviation	Relative to maximum peak deviation - programmable	8		10	%
Δf <sub>RDS</sub>	RDS deviation	Absolute maximum peak deviation - programmable		1.2	10	kHz
	Transmitted deviation flatness	Stereo <sup>(2)</sup> , $\Delta f_{audio} = 67.5$ kHz over $F_{RF} = 76 - 108$ MHz			±1	dB
	Channel imbalance	Stereo <sup>(2)</sup>	-1		1	dB
	Stereo Separation	Stereo <sup>(2)</sup> , R = 0, L = 1	30	42		dB
	Lower Audio Bandwidth (-3 dB point)	For both $T_{preemphasis} = 75$ µs and 50 µs.			50	Hz
	Upper Audio Bandwidth (-3 dB point)	For both $T_{preemphasis} = 75$ µs and 50 µs, for analog audio input or digital audio input with sample rates $Fs \geq 32$ kHz	15			kHz
	Upper Audio Bandwidth (-3 dB point)	for digital audio input with sample rates $Fs < 32$ kHz	0.8 * Fnyq			kHz
	Audio response flatness	100 Hz to 13 kHz, for both $T_{preemphasis} = 75$ µs and 50 µs, pre-emphasis applied, measured after de-emphasis, for sample rates $> 32$ kHz	-1.5		+1.5	dB
$T_{preemphasis}$	Pre-emphasis time constant High value			75		µs
$T_{preemphasis}$	Pre-emphasis time constant Low value			50		µs
	Pre-emphasis time constant				±5	%

	Tolerance					
THDdig	Total Harmonic Distortion for digital input	Stereo <sup>(2)</sup> , $\Delta f_{\text{audio}} = 67.5 \text{ kHz}$		0.07	1	%
THDana	Total Harmonic Distortion for analog input	Stereo <sup>(2)</sup> , $\Delta f_{\text{audio}} = 67.5 \text{ kHz}$		0.18	1	%
S/Nmono,d	Transmitted S/N for mono for digital input	Mono <sup>(1)(7)</sup> for digital input. A-weighted filter on RX measurement equipment.	60			dB
S/Nmono,a	Transmitted S/N for mono for analog input	Mono <sup>(1)(7)</sup> for analog input. A-weighted filter on RX measurement equipment.	56.5			dB
S/Nstereo,d	Transmitted S/N for stereo for digital input	Stereo <sup>(2)(7)</sup> for digital input. A-weighted filter on RX measurement equipment.	57			dB
S/Nstereo,a	Transmitted S/N for stereo for analog input	Stereo <sup>(2)(7)</sup> for analog input. A-weighted filter on RX measurement equipment.	54			dB
	Audio Spurious Products	Mono <sup>(1)</sup> , $F_{\text{RF}} = 76 \text{ to } 108 \text{ MHz}$			-60	dBc

1. Mono,  $\Delta f_{\text{audio}} = 22.5 \text{ kHz}$ , fmod = 1 kHz, unless otherwise stated
2. Stereo,  $\Delta f_{\text{audio}} = 22.5 \text{ kHz}$ , fmod = 1 kHz,  $\Delta f_{\text{pilot}} = 6.75 \text{ kHz}$ , L = R, no RDS, unless otherwise stated
3. For use of the slow clock for FM, in case the accuracy of the externally applied slow clock is not sufficient, the STLC2690 provides a calibration mechanism to calibrate the slow clock versus the fast clock.
4. This is at the chip output.
5. With a load a loop antenna with inductance of 120 - 150 nH and a minimum Q of 30.
6. The integrated resonance tank and integrated RF filtering provide this transmit noise and spurious levels in cellular bands.
7. The Host needs to set the correct gain level. For input levels other than those specified in this table and still above 58 mVp, the SNR can be up to 4 dB lower.
8. At max output power

## 4.5 FM Interfaces

### 4.5.1 Control interface

The FM subsystem can either be controlled via the I2C interface, or via the Bluetooth HCI interface. In the latter case vendor-specific HCI commands and events are used.

#### 4.5.1.1 FM I2C interface

The FM I2C interface offers one way to control the FM subsystem of the chip. Based on the standard I2C protocol, commands can be sent over this interface to boot and control the FM subsystem, and to retrieve settings. A dedicated interrupt pin can be used to notify the Host.

A Host-level API has been defined along with the underlying Host-level C functions. This allows the Host to address the FM subsystem in a user-friendly and straightforward way and allows for a fast integration at Host level. See also section 4.1.1. The command encoding is exactly the same when using FM I2C or BT HCI such that the Host driver can be the same for both.

The physical aspects of the FM I2C interface are described in section 2.12.4.

#### 4.5.1.2 Bluetooth HCI interface

Alternatively the FM subsystem can be controlled from the Bluetooth chip using the Bluetooth HCI interface. For this purpose a set of vendor-proprietary HCI commands has been defined. This set allows the Host to control the FM subsystem and to retrieve information on the control settings. To notify the Host a vendor-specific HCI event is used.

The command encoding is exactly the same when using I2C or BT HCI such that the Host driver can be the same for both.

#### 4.5.2 Audio interface

The FM receiver output can be routed to an I2S output interface, to a PCM output interface, to a stereo analog output interface or to an on-chip interface to the Bluetooth subsystem.

Similarly the FM transmitter can be configured to receive its input from an I2S input interface, from a PCM input interface, from a stereo analog input interface or from an on-chip interface linked to the Bluetooth subsystem.

##### 4.5.2.1 Dedicated PCM and I2S interfaces

The PCM and I2S interfaces can be configured as Master or as Slave.

When acting as a Master, the I2S interface can be configured to any arbitrary sample rate between 8 and 192 kHz. The PCM interface can be configured to sample rates between 8 and 48 kHz.

The physical aspects of the PCM and I2S interfaces are described in sections 2.12.7 and 2.12.8.

##### 4.5.2.2 Routing to/from Bluetooth

For specific user applications the Bluetooth voice or audio air traffic can directly be taken from or routed to the FM subsystem (for receiver or transmitter, respectively). Another possibility is to route the received FM signal directly to the Bluetooth PCM/I2S port, or to route the Bluetooth PCM/I2S port directly to the FM transmitter. See section 2.10 to have an overview of all use cases.

Control of this kind of routing is only possible via dedicated HCI commands.

##### 4.5.2.3 Stereo analog audio codec output and input

Analog audio input and output requires external AC coupling components.

## 5 PACKAGE OUTLINE ASSEMBLY

The device STLC2690 is in lead-free/RoHs-compliant WLCSP package, 61 pins.

The picture below shows the package drawings and dimensions. See the below table for more detailed information.

**Figure 21. WLCSP 3.315x3.56x0.6 61 F8 (B6 C6 G7 OUT) PITCH 0.4 B 0.25**

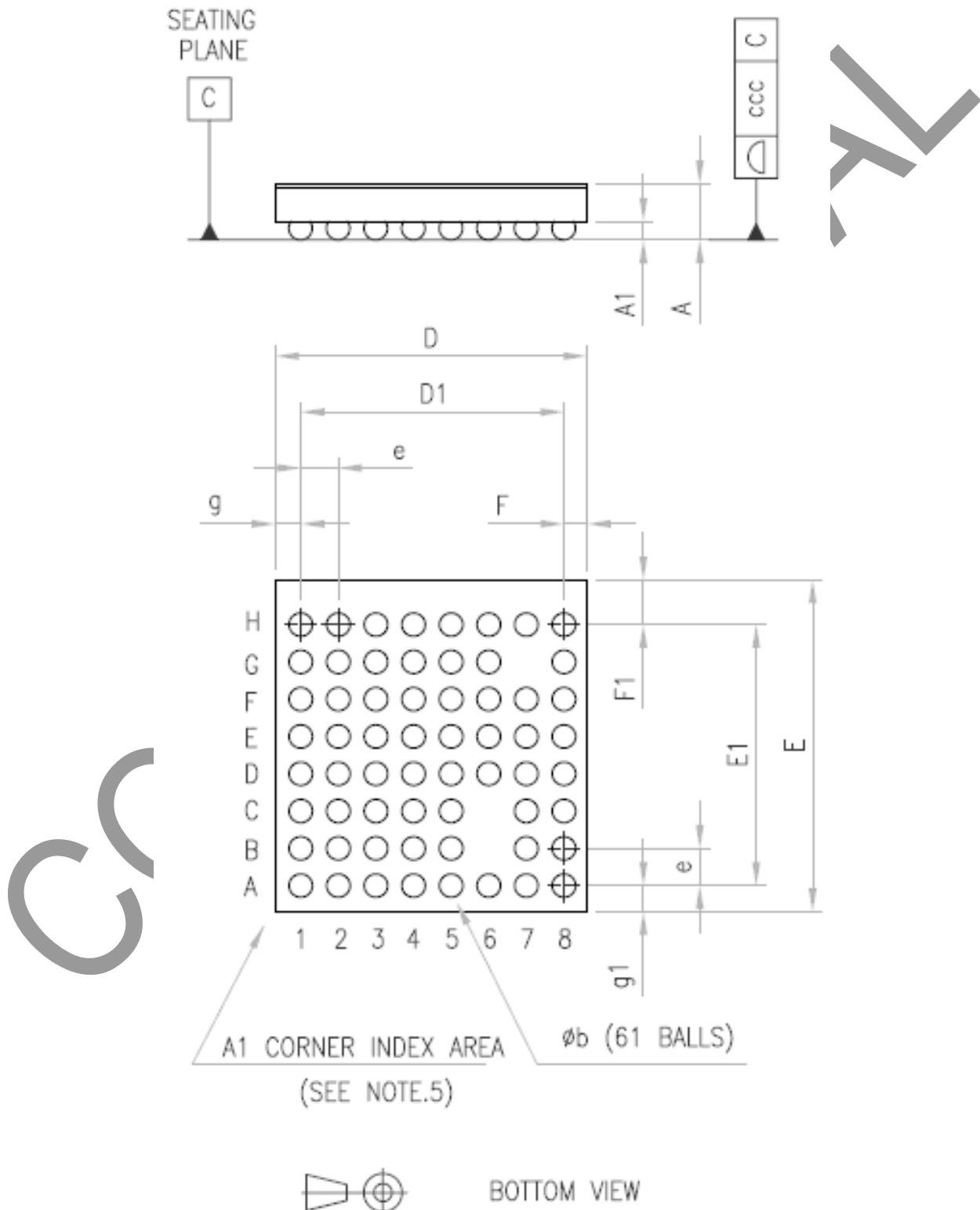


Table 32. Package dimensions

Reference	Dimensions (mm)			Notes
	Min.	Typ.	Max.	
A			0.60	
A1		0.20		
b	0.24	0.27	0.30	<sup>(2)</sup>
D	3.275	3.315	3.355	
D1		2.80		
E	3.52	3.56	3.60	
E1		2.80		
e		0.40		
F		0.245		<sup>(3)</sup>
F1		0.48		<sup>(3)</sup>
g		0.27		<sup>(3)</sup>
g1		0.28		<sup>(3)</sup>
ccc			0.05	

1. WLCSP stands for Wafer Level Chip Scale Package.
2. The typical ball diameter before mounting is 0.25 mm.
3. The matrix ball array is not centered
4. The matrix ball array is depopulated (Balls B6 C6 G7 out)
5. The terminal A1 corner must be identified on the top surface by using a laser marking dot.

Figure 22. Package Markings

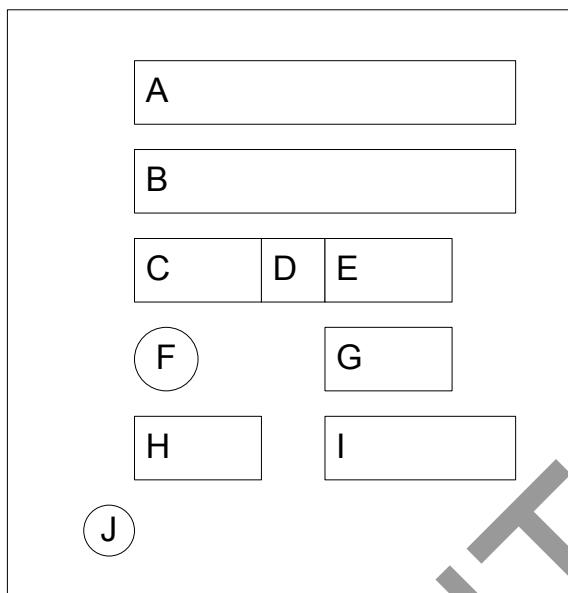


Table 33. Package Markings: Legend

Item	Description	Format	Value
A	MARKING AREA	XXXXXX	2690W5
B	Operator Input (Diff lot)		
C	Assembly Plant	PP	
D	Assembly Year	Y	
E	Assembly Week	WW	
F	Second lvl_intct		
G	MARKING AREA (Wafer Number)		
H	Diffusion Traceability Plant	WX	
I	Country of Origin	max 3 char	
J	Dot (Indicates pin A1)		

## 6 REFERENCES

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## 7 ACRONYMS AND ABBREVIATIONS

2-DH1	Bluetooth 2 Mbps ACL packet type	GSM	Global System for Mobile communications
2-DH3	Bluetooth 2 Mbps ACL packet type	H4	UART based HCI transport
2-DH5	Bluetooth 2 Mbps ACL packet type	HCI	Host Controller Interface
2-EV3	Bluetooth 2 Mbps synchronous packet type	HV1	Bluetooth 1 Mbps synchronous packet type
2-EV5	Bluetooth 2 Mbps synchronous packet type	HV3	Bluetooth 1 Mbps synchronous packet type
3-DH1	Bluetooth 3 Mbps ACL packet type	HW	HardWare
3-DH3	Bluetooth 3 Mbps ACL packet type	I/O	Input/Output
3-DH5	Bluetooth 3 Mbps ACL packet type	I2C	Inter-Integrated Circuit
3-EV3	Bluetooth 3 Mbps synchronous packet type	I2S	Inter-Integrated Circuit Sound
3-EV5	Bluetooth 3 Mbps synchronous packet type	IF	Intermediate Frequency
8-DPSK	8 phase Differential Phase Shift Keying	ISM	Industrial, Scientific and Medical
A2DP	Advanced Audio Distribution Profile	JTAG	Joint Test Action Group
AC	Alternating Current	L2CAP	Logical Link Control and Adaptation Protocol
ACL	Asynchronous Connection Oriented	LMP	Link Manager Protocol
ADC	Analog to Digital Converter	LNA	Low Noise Amplifier
AF	Alternate Frequency	LO	Local Oscillator
AHB	Advanced High-performance Bus	LSTO	Link Supervision Time Out
A-law	Audio encoding standard	MPX	MultiPleX
AMR	Absolute Maximum Rating	PA	Power Amplifier
APB	Advanced Peripheral Bus	PBF	Packet Boundary Flag
API	Application Program Interface	PCB	Printed Circuit Board
ARM7	Micro-processor	PCM	Pulse Code Modulation
ARM7TDMI	Micro-processor	PD	Pull-Down
AWMA	Alternating Wireless Medium Access	PDA	Personal Digital Assistant
B-BPF	Balanced Band Pass Filter	PLL	Phase Locked Loop
BER	Bit Error Rate	PPEC	Pitch-Period Error Concealment
BOM	Bill Of Materials	PTA	Packet Traffic Arbitration
BR	Basic Rate	PU	Pull-Up
BT	Bluetooth	QoS	Quality of Service
BW	Band Width	RAM	Random Access Memory
C/I	Carrier-to-co-channel Interference	RBDS	Radio Broadcast Data System
CODEC	COder DECoder	RC	Resistance-Capacitance
CPU	Central Processing Unit	RDS	Radio Data System
CQDDR	Channel Quality Driven Data Rate change	RF	Radio Frequency
CVSD	Continuous Variable Slope Delta modulation	rms	root mean squared
DC	Direct Current	ROM	Read Only Memory
DEVM	Differential Error Vector Amplitude	RSSI	Receive Signal Strength Indication
DH1	Bluetooth 1 Mbps ACL packet type	RX	Receive
DH3	Bluetooth 1 Mbps ACL packet type	SBC	Sub Band Coding
DH5	Bluetooth 1 Mbps ACL packet type	SCO	Synchronous Connection Oriented
DM1	Bluetooth 1 Mbps ACL packet type	SIG	Bluetooth Special Interest Group
DM3	Bluetooth 1 Mbps ACL packet type	SPI	Serial Peripheral Interface
DM5	Bluetooth 1 Mbps ACL packet type	SSP	Secure Simple Pairing
DMA	Direct Memory Access	SSR	Sniff Subrating
DSP	Digital Signal Processor	ST	STMicroelectronics
DUN	Dial-Up Networking Profile	SW	SoftWare
DV	Bluetooth 1 Mbps synchronous packet type	$T_{esco}$	eSCO interval
ED	Erroneous Data Delivery	$T_{sco}$	SCO interval
EDR	Enhanced Data Rate	$T_{sniff}$	Sniff interval
EIR	Extended Inquiry Response	TX	Transmit
EPR	Encryption Pause/Resume	UART	Universal Asynchronous Receiver/Transmitter
eSCO	extended SCO	VCO	Voltage Controlled Oscillator
EV3	Bluetooth 1 Mbps synchronous packet type	VGA	Variable Gain Amplifier
EV4	Bluetooth 1 Mbps synchronous packet type	WCDMA	Wideband Code Division Multiple Access
EV5	Bluetooth 1 Mbps synchronous packet type	WFBGA	Very Very Thin Profile Fine Pitch Ball Grid Array
FHS	Frequency Hopping Synchronization	WLAN	Wireless Local Area Network
FIFO	First In First Out	WLCSP	Wafer-Level Chip Scale Package
FLL	Frequency Locked Loop	$\mu$ -law	Audio encoding standard
FM	Frequency Modulation	$\pi/4$ -DQPSK	$\pi/4$ rotated Differential Quaternary Phase Shift Keying
GFSK	Gaussian Frequency Shift Keying		
GPIO	General Purpose I/O pin		

## 8 REVISION HISTORY

**Table 34. Revision history**

Date	Revision	Description of changes
March 2007	Rev1.0	First version
April 2007	Rev1.1	Editorial updates
October 2007	Rev1.2	Editorial updates
January 2008	Rev1.3	Update according to preliminary measurement results
January 2008	Rev1.4	Further update according to preliminary measurement results
January 2008	Rev1.5	Further update according to preliminary measurement results Update pinout
February 2008	Rev1.6	Further update according to preliminary measurement results
May 2008	Rev1.7	Editorial updates
July 2008	Rev1.8	Update of FM performances according to preliminary measurement results Addition of the audioprocessor and A2DP encapsulation Package marking information updated Editorial updates
January 2009	Rev1.9	Add package dimensions Update of pinout
February 2009	Rev1.10	Remove Power Class 1 support Remove 3.2 kHz slow clock support Remove internal RC oscillator Remove SDIO support Remove tone generation and A2DP decapsulation Remove FM RX fast fading Update performances according to measurement results Editorial updates
June 2009	Rev1.11	Update performances according to measurement results Update pinout Update Marking Remove fast clock tuning Add FM CNR based scan Update to Bluetooth V3.0 specification Editorial updates
September 2009	Rev1.12	Update Marking
November 2009	Rev1.13	Update ball diameter (erratum) Update performances according to measurement results Remove Wide Band speech Add WiMAX coexistence
January 2010	Rev2.0	Update performances according to measurement results

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