- **Applications Include GSM 900, PCS 1900, and DCS 1800 Cellular Telephones**
- **80-Pin TQFP (0.4 mm or 0.5 mm Lead Pitch) or 80-Ball MicroStar BGA™ Packages**
- **Single 3-V Supply Voltage**
- **Internal Voltage Reference**
- **Extended RF Control Voltages**
- **Advanced Power Management**
- **GSM-Digital Audio Interface (DAI)**
- **MCU and DSP Serial Interface**
- **Five Ports Auxiliary A/D**
- **Meets JTAG Testability Standard (IEEE Std 1131.1-1990)**
- **Baseband Codec-GMSK Modulator With On-Chip Burst Buffer**
- **Voice Codec Features: Microphone Amplifier and Bias Source, Programmable Gain Amplifiers, Volume Control, and Side-Tone Control**

description

The TCM4400E global system for mobile communication (GSM) baseband RF interface circuit is designed for GSM 900 , PCS1900, and DCS 1800 European digital cellular telecommunication systems. It performs the interface and processing of voice signals, generates baseband in-phase (I) and quadrature (Q) signals, and controls the signals between a digital signal processor (DSP) and associated RF circuits.

The TCM4400E includes a second serial interface for use with a microcontroller. Through this interface, a microcontroller can access all the internal registers that can be accessed through the DSP digital serial interface. This option is intended for applications in which part of the L1 software is implemented in the microcontroller.

A four-pin parallel port is dedicated to the full control of the digital audio interface (DAI) to the GSM system simulator; the DAI consists of system simulator reset (SSRST) control, clock generation, and rate adaptation with the DSP.

The voice processing portion of the device includes microphone and earphone amplifiers, analog-to-digital (A/D) and digital-to-analog (D/A) converters, speech digital filtering, and a serial port.

The baseband processing portion of the device includes a two-channel uplink path, a two-channel downlink path, a serial port, and a parallel port. The uplink path performs Gaussian minimum shift keying (GMSK) modulation and D/A conversion, and it has smoothing filters to provide the external RF circuit with I and Q baseband signals. The downlink path performs antialiasing, A/D conversion, and channel separation filtering of the baseband I and Q signals. The serial port allows baseband data exchange with the DSP, and the parallel port controls precise timing signals.

Auxiliary RF functions such as automatic frequency control (AFC), automatic gain control (AGC), power control, and analog monitoring are also implemented in the TCM4400E. Internal functional blocks of the device can be separately and automatically powered down with GSM RF windows.

These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

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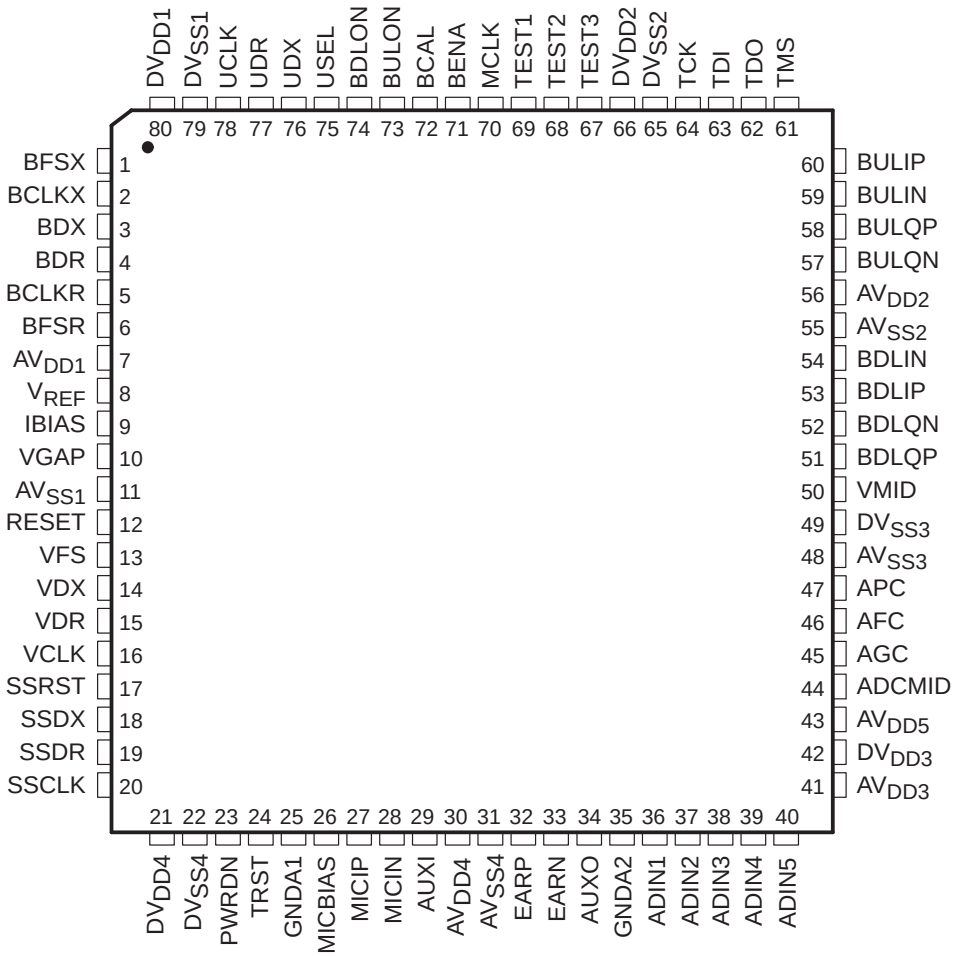
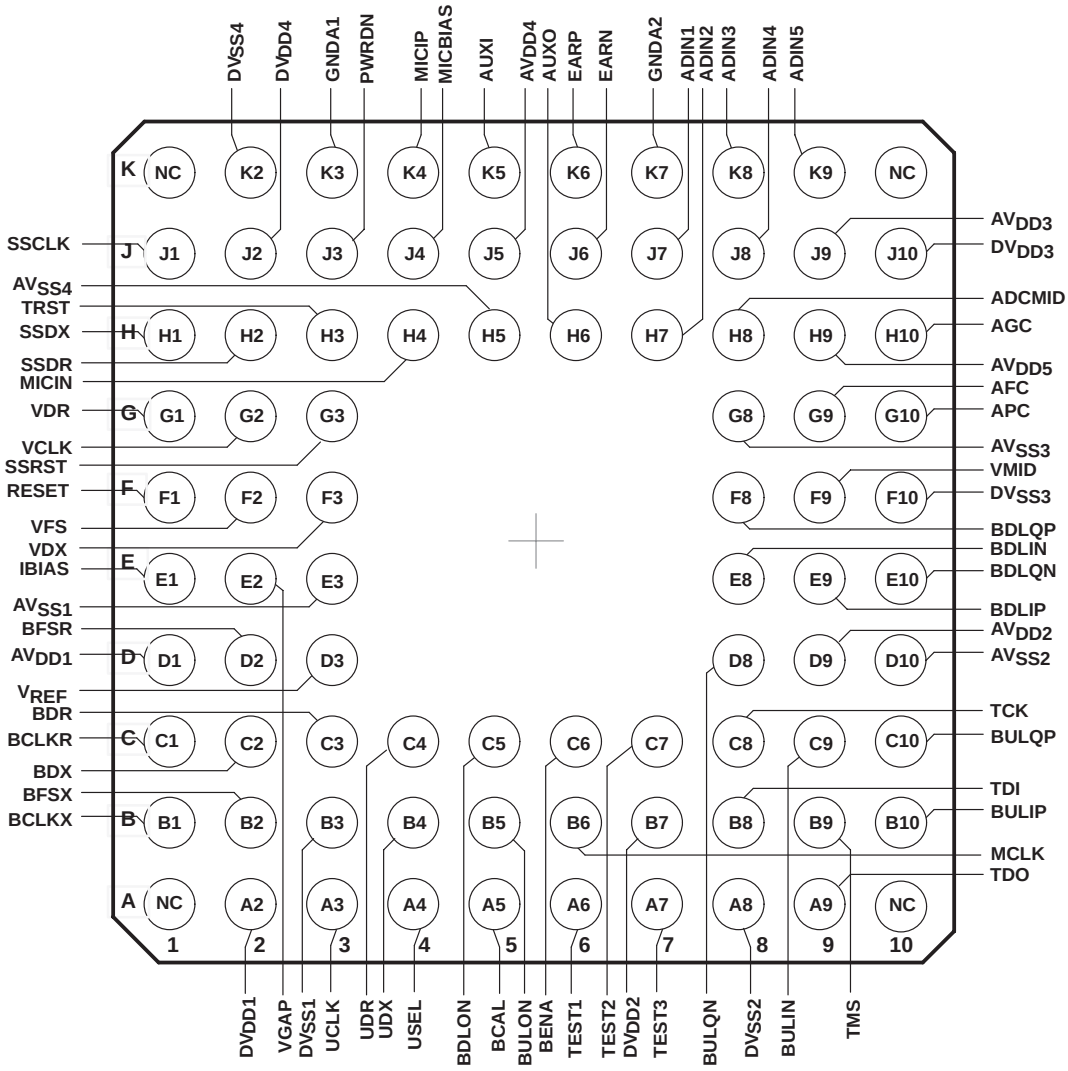
80-Pin TQFP PACKAGE
(TOP VIEW)

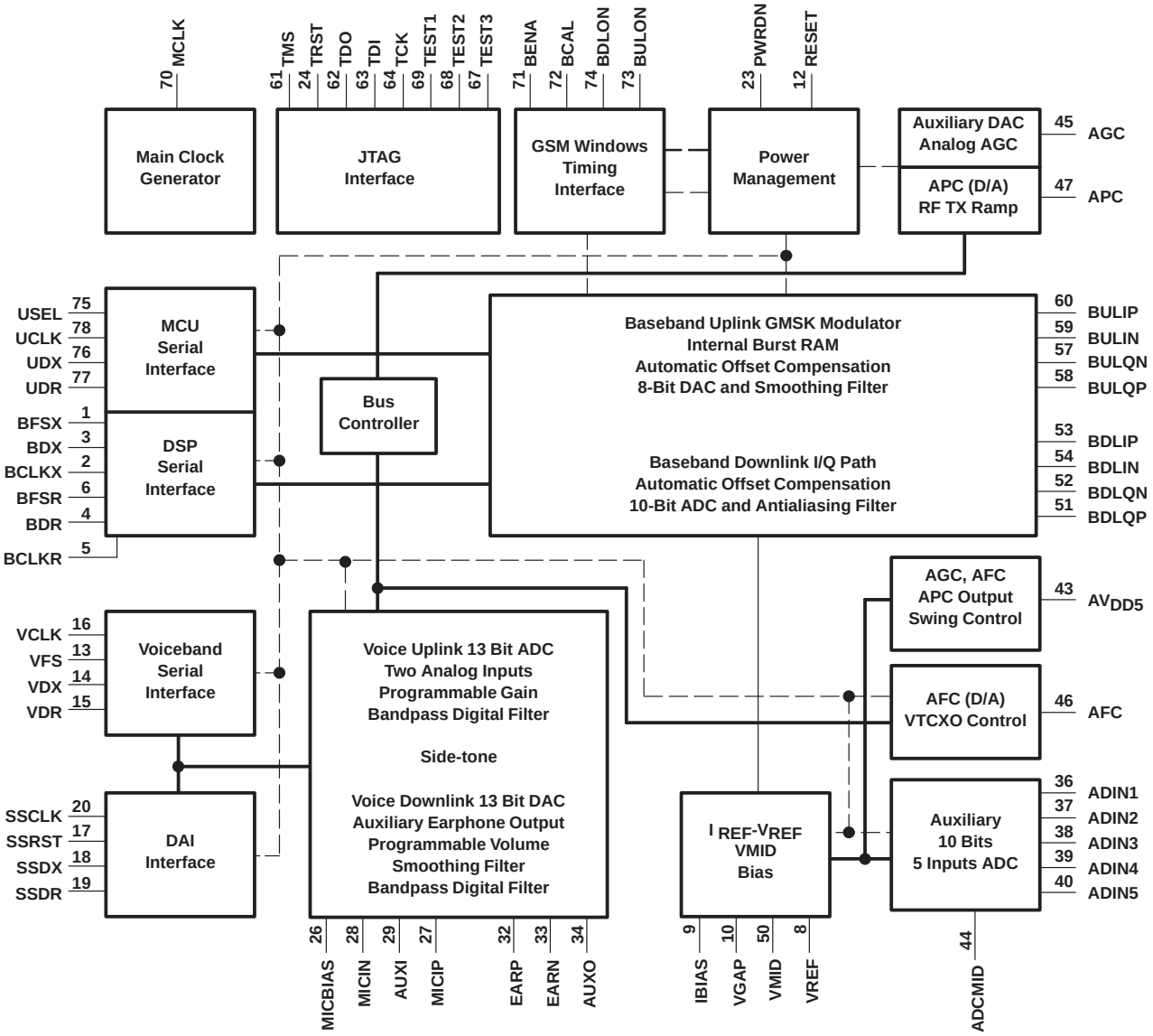


GGM PACKAGE
(TOP VIEW)



NC – No internal connection

functional block diagram



Terminal Functions

TERMINAL			I/O	DESCRIPTION
NAME	NO.			
	QFP	BGA		
ADCMID	44	H8	I/O	Reference voltage of auxiliary A/D converters; decoupling only (analog)
ADIN1	36	J7	I	Auxiliary 10-bit ADC input 1 (analog)
ADIN2	37	H7	I	Auxiliary 10-bit ADC input 2 (analog)
ADIN3	38	K8	I	Auxiliary 10-bit ADC input 5 (analog)
ADIN4	39	J8	I	Auxiliary 10-bit ADC input 4 (analog)
ADIN5	40	K9	I	Auxiliary 10-bit ADC input 3 (analog)
AFC	46	G9	O	Automatic frequency control DAC output (analog)
AGC	45	H10	O	Automatic gain control DAC output (analog)
APC	47	G10	O	Automatic power control DAC output (analog)
AUXI	29	K5	I	Auxiliary (high-level) speech signal input (analog)
AUXO	34	H6	O	Auxiliary downlink (voice codec) amplifier output, single-ended (analog)
AV_{DD1}	7	D1		Analog positive power supply (bandgap, internal common-mode generator, bias current generator).
AV_{DD2}	56	D9		Analog positive power supply (baseband CODEC)
AV_{DD3}	41	J9		Analog positive power supply (auxiliary RF functions)
AV_{DD4}	30	J5		Analog positive power supply (voice codec)
AV_{DD5}	43	H9		Analog positive power supply (output stages of auxiliary RF functions).
AV_{SS1}	11	E3		Analog negative power supply (bandgap, internal common-mode generator, bias current generator).
AV_{SS2}	55	D10		Analog negative power supply (baseband CODEC)
AV_{SS3}	48	G8		Analog negative power supply (auxiliary RF functions)
AV_{SS4}	31	H5		Analog negative power supply (voice codec)
BCAL	72	A5	I	Baseband uplink or downlink offset calibration enable (timing interface)
BCLKR	5	C1	I/O	DSP serial interface clock input. This clock signal is provided by the DSP or the TCM4400E (digital/3-state).
BCLKX	2	B1	O	DSP serial interface clock output. The frequency is the same as MCLK (digital/3-state).
BDR	4	C3	I	DSP serial interface serial data input (digital)
BDX	3	C2	O	DSP serial interface serial data output (digital/3-state)
BENA	71	C6	I	Burst transmit or receive enable (depends on status of BULON and BDLON) (digital)
BDLON	74	C5	I	Power on of baseband downlink (timing interface)
BFSR	6	D2	I	DSP serial interface receive frame synchronization input (digital)
BFSX	1	B2	O	DSP serial interface transmit frame synchronization output (digital/3-state)
BDLIN	54	E8	I	In-phase baseband input (–) downlink path (analog)
BDLIP	53	E9	I	In-phase baseband input (+) downlink path (analog)
BDLQN	52	E10	I	Quadrature baseband input (–) downlink path (analog)
BDLQP	51	F8	I	Quadrature baseband input (+) downlink path (analog)
BULIN	59	C9	O	In-phase baseband output (–) uplink path (analog)
BULIP	60	B10	O	In-phase baseband output (+) uplink path (analog)
BULON	73	B5	I	Serial clock input (serial interface) (digital)
BULQN	57	D8	O	Negative quadrature baseband output. BULQN is an uplink path (analog)
BULQP	58	C10	O	Positive quadrature baseband output. BULQN is an uplink path (analog)
DV_{DD1}	80	A2		Digital positive power supply (baseband and timing serial interfaces)
DV_{DD2}	66	B7		Digital positive power supply (baseband CODEC)
DV_{DD3}	42	J10		Digital positive power supply (auxiliary RF functions)

Terminal Functions (Continued)

TERMINAL			I/O	DESCRIPTION
NAME	NO.			
	QFP	BGA		
DV_{DD4}	21	J2		Digital positive power supply (voiceband codec and serial interface)
DV_{SS1}	79	B3		Digital negative power supply (baseband and timing serial interfaces)
DV_{SS2}	65	A8		Digital negative power supply (baseband CODEC)
DV_{SS3}	49	F10		Digital negative power supply (auxiliary RF functions)
DV_{SS4}	22	K2		Digital negative power supply (voiceband codec and serial interface)
EARN	33	J6	O	Earphone amplifier output (–) (analog)
EARP	32	K6	O	Earphone amplifier output (+) (analog)
GNDA1	25	K3		Analog signal ground for the microphone amplifier and auxiliary input
GNDA2	35	K7		Signal return (ground) for AUXO output
IBIAS	9	E1	I/O	Internal bias reference current adjust. IBIAS adjusts the reference current with an external resistor (analog).
MCLK	70	B6	I	Master system clock input (13 MHz)
MICBIAS	26	J4	I	Microphone bias supply output. MICBIAS is also used to decouple bias supply with an external capacitor (analog).
MICIP	27	K4	I	Positive microphone amplifier input (analog)
MICIN	28	H4	I	Negative microphone amplifier input (analog)
PWRDN	23	J3	I	Power-down mode control input (digital), active high
RESET	12	F1	I	Device global hardware reset (digital), active low
SSCLK	20	J1	O	DAI external 104 kHz clock output (digital)
SSDR	19	H2	I	DAI data transfer input. SSDR connects to GSM-SS TDAI (digital/pullup).
SSDX	18	H1	O	DAI data transfer output SSDX connects to GSM-SS RDAI (digital).
SSRST	17	G3	I	DAI reset input (digital/pullup)
TCK	64	C8	I	Scan test clock (digital/pulldown)
TDI	63	B8	I	Scan path input (for testing purposes) (digital/pullup)
TDO	62	A9	I	Scan path output (for testing purposes) (digital/3-state)
TEST1	69	A6	I/O	Test I/O (digital/3-state & pullup)
TEST2	68	C7	I/O	Test I/O (digital/3-state & pullup)
TEST3	67	A7	O	Test output (digital)
TMS	61	B9	I	JTAG test mode select (digital/pullup)
TRST	24	H3	I	JTAG serial interface & boundary scan register reset (digital/pullup), active low.
UCLK	78	A3	I	MCU interface clock input (digital)
UDR	77	C4	I	MCU interface data transfer input (digital)
UDX	76	B4	O	MCU interface data transfer output (digital/3-state)
USEL	75	A4	I	MCU serial interface select (digital)
VCLK	16	G2	O	Voiceband serial interface clock output (digital/3-state)
VDR	15	G1	I	Voiceband serial interface receive data input (digital)
VDX	14	F3	O	Voiceband serial interface transmit data output (digital/3-state)
VFS	13	F2	O	Voiceband serial interface transmit frame synchronization output (digital/3-state)
VGAP	10	E2	I/O	Bandgap reference voltage. VGAP decouples with an external capacitor (analog)
VMID	50	F9	O	Baseband uplink midrail voltage output. VMID serves as a reference common-mode voltage for a RF device when directly dc coupled (analog)
V_{REF}	8	D3	I/O	Reference voltage V_{REF} decouples with an external capacitor (analog).

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage range, AV_{DD}, DV_{DD} (see Note 1) . . . . . –0.3 to 6 V
Maximum voltage on any input, V_I max . . . . . V_{DD} +0.3 V / V_{SS} –0.3 V
Storage temperature, T_{stg} . . . . . –65°C to 150°C
Maximum junction temperature, T_J . . . . . 150°C

† Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTE 1: Voltage measurements with respect to GND.

recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage range (AV_{DD}, DV_{DD})	2.7	3.0	3.3	Vdc
Operating temperature range	–25		85	°C
Digital I/O voltage with respect to DV_{SS}	–0.3		DV_{DD} + 0.3	Vdc
Analog I/O voltage with respect to AV_{SS}	–0.3		AV_{DD} + 0.3	V
Difference between any AV_{DD} or DV_{DD}			0.3	V

electrical characteristics over recommended operating free-air temperature range (unless otherwise noted)

digital inputs and outputs

PARAMETER	MIN	TYP	MAX	UNIT
Low-level output current with digital pad lower than 0.1 V (CMOS)	0		40	µA
Low-level output current with digital pad lower than 0.4 V (TTL)	0		1	mA
High-level output current with digital pad higher than V_{DD}–0.1 V (CMOS)	–40		0	µA
High-level output current with digital pad higher than V_{DD}–0.4 V (TTL)	–1		0	mA
Minimum high-level input voltage, V_{IH}	V_{dd}–0.3			V
Maximum low level input voltage, V_{IL}			Vss+0.3	V
Output current on high impedance state outputs	–15		15	µA
Input current (any input) when input high	–1			µA
Input current (standard inputs) when input low			1	µA
Input current (inputs with pullup TMS, TDI ,TEST1 ,TEST2) when input low			15	µA

electrical characteristics over recommended operating free-air temperature range (unless otherwise noted) (continued)

voltage references

REFERENCE		MIN	TYP	MAX	UNIT
VGAP	Voltage on band gap (used for all other references)	1.16	1.22	1.28	Vdc
	Band gap output resistance		200		KΩ
	Band gap external decoupling capacitance		0.1		µF
	Band gap start time (bit CHGUP=0)		100		ms
	Band gap start time (bit CHGUP=1)		2.5		ms
VREF	Voltage reference of GMSK internal ADC and DAC : V_{VREF}	1.66	1.75	1.84	Vdc
	Voltage reference output resistance		200		KΩ
	Voltage reference external decoupling capacitance		0.1		µF
	Voltage reference start time (bit CHGUP=0)		300		ms
	Voltage reference start time (bit CHGUP=1)		10		ms
VMID	Common-mode reference for baseband uplink: V_{VMID} (Bit SELVMID=0)	–10%	Vdd/2	10%	Vdc
	Common-mode reference for baseband uplink: V_{VMID} (Bit SELVMID=1)	1.25	1.35	1.45	Vdc
	Load resistance on Vmid output	10			KΩ
MICBIAS	Microphone-driving voltage (Bit MICBIAS=0)	1.80	2.00	2.20	Vdc
	Microphone-driving voltage(Bit MICBIAS=1)	2.25	2.5	2.75	Vdc
	Microphone-bias current drive capability (Bit MICBIAS= 1)	450	500		µA
	Microphone-bias current drive capability (Bit MICBIAS=0)	350	400		µA
ADCMID	DC bias reference of the auxiliary ADCs	–10%	Vdd/2	10%	Vdc
	ADCMID external decoupling capacitance		0.1		µF
IBIAS	Bias current adjust external resistance		100		KΩ

master clock input (MCLK)

PARAMETER	MIN	NOM	MAX	UNIT
Master clock signal frequency		13		MHz
Master clock duty cycle (Sinewave)	40%		60%	
Maximum peak-to-peak amplitude			1.3	Vpp
Minimum peak-to-peak amplitude	0.5			Vpp
Common-mode input voltage	V_{SS} +0.5		V_{DD} –0.5	Vdc
Input resistance at 13MHz (MCLK to ground)	4.1	5	6.5	KΩ
Input capacitance at 13 MHz (MCLK to ground)	12.5	15	18	pf

baseband uplink path

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
I and Q D/A converters resolution			8		bit
Dynamic range on each output	Centered on V_{VMID}		V_{VREF}		Vpp
Differential output dynamic range with OUTLEV bit = 0†	BULQP-BULQN or BULIP-BULIN		2 x V_{VREF}		Vpp
Differential output dynamic range with OUTLEV bit = 1†	BULQP-BULQN or BULIP-BULIN		8/15 x V_{VREF}		Vpp
Output load resistance, differential		10			kΩ
Output load capacitance, differential		50			pF
Output common-mode voltage	Programmable by bit SELVMID		V_{VMID}		V
I & Q output state in power down			Hi-Z		

† Initial value after reset and at beginning of each burst are BULIP–BULIN=V_{REF} and BULQP–BULQN=0 corresponding to a phase angle of 0°.

electrical characteristics over recommended operating free-air temperature range (unless otherwise noted) (continued)

dc accuracy – baseband uplink path

PARAMETER	MIN	TYP	MAX	UNIT
Offset error before calibration		±100		mV
Offset error after calibration†	–7	0	7	mV

† Calibration must be performed in normal operation mode.

dynamic parameters – baseband uplink path

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Absolute gain error relative to V_{VREF}	Measured with 67.7 kHz sinewave	–1.5	0	1.5	dB
Maximum output random modulation spectrum relative to in-band average level. Measured by average FFTs of random bursts using a window with 30 kHz bandwidth.	100 kHz			–3	dB
	200 kHz			–34	dB
	250 kHz			–37	dB
	400 kHz			–65	dB
	600 KHz			–72	dB
	800 KHz			–72	dB

smoothing filters characteristics – baseband uplink path

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Group delay	0 Hz to 100 kHz		1.5		µs

I and Q channels gain matching – baseband uplink path

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
Gain matching between channels	0 Hz to 96 kHz	Measured on 67.7 kHZ sinewave	–1	0	1	dB
I and Q gain unbalance	Programmable with bits IQSEL, G1, and G0		–0.42	–0.27	–0.12	dB
			–0.68	–0.53	–0.38	
			–0.93	–0.78	–0.63	

baseband uplink path global characteristics

PARAMETER	MIN	TYP	MAX	UNIT
GMSK phase trajectory error‡			6°	peak
			1.5°	rms
Power supply rejection		55		dB

‡ After software calibration through BBAloop

timing requirements of baseband uplink path

programmable delays – baseband uplink path (see Figure 1)

			MIN	NOM	MAX	UNIT§
t_{su1}	Setup time, BENA before APC↑	Bits DELU of register BULRUDEL	0		15	1/4-bit
t_{h1}	Hold time, ramp-down from BENA low	Bits DELD of register BULRUDEL	0		15	1/4-bit
t_r, t_f	Transition time, APC	Bit APCSPD = 0	0		64	1/16-bit
		Bit APCSPD = 1				1/8-bit

§ Bit is relative to GSM bit = 1/270 kHz. Units can be a fractional part of the GSM bit as noted. Values in the above table are given for system information only.

timing requirements of baseband uplink path (continued)

fixed delays – baseband uplink path (see Figure 1)

			MIN	NOM	MAX	UNIT†
t_{su2}	Setup time, BULON↑ to BCAL↑		15			µs
t_{w1}	Pulse duration, BCAL high		132			µs
t_{su3}	Setup time, BCAL low before BENA↑		0			µs
t_{w2}	Pulse duration, BENA high	N effective duration of burst controlled by BENA		N–32		1/4-bit
t_{h2}	Hold time, modulation low after BENA low			32		1/4 bit
t_{h3}	Hold time, BULON↓ after APC low		1			bit
$t_{dd(mod)}$	Input-to-output modulator delay	(Digital delay of modulator)		1.5		bit

† Bit is relative to GSM bit = 1/270 kHz. Units can be a fractional part of the GSM bit as noted. Values in the above table are given for system information only.

baseband downlink path

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Dynamic range on each input	Centered on external common mode (V_{BDLCOM})		V_{VREF}		Vpp
Differential input dynamic range	DLQP–DLQN or DLIP–DLIN		$2*V_{VREF}$		Vpp
Differential input resistance at BDLQP–BDLQN or BDLIP–BDLIN		130	200	270	kΩ
Differential input capacitance at BDLQP–BDLQN or BDLIP–BDLIN		1.5	4	6.5	pF
Single ended input resistance at BDLQPor BDLQN or BDLIP or BDLIN to ground.		90	130	180	kΩ
Single ended input capacitance at BDLQP or BDLQN or BDLIP or BDLIN to ground.		6	8	12	pF
External common-mode input voltage: V_{BDLCOM}		0.8	$V_{DD}/2$	V_{DD}–0.8	V
Range of digital output data	Maximum digital code value on 16-bit I and Q samples.		±21060		

dc accuracy – baseband downlink path

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Offset error before calibration ‡		–60	0	60	LSB
Offset error after calibration,	± 21 on 16-bit I and Q words ‡	–2	0	2	LSB
Offset correction range			Full scale		

‡ The LSB corresponds to the one of the ADC which is specified with 66 dB dynamic range (±1024),which means 11-bit, but the output data bits are transmitted through the serial interface with 16-bit words. On top of that, the decimation ratio of 24 (6.5 MHz/270 kHz) makes the maximum code on a 16-bit word to be 21060 instead of 32767. So one LSB of the ADC corresponds to a value of 21060/1024 = 20.57 on the 16-bit output serial words on I and Q.

channel characteristics

frequency response – baseband downlink path

PARAMETER		MIN	TYP	MAX	UNIT
Frequency response of the total path with values referenced to 18 kHz	< 67.5 Hz	–0.3		0.25	dB
	67.5 kHz	–0.3		0.25	
	96 kHz	–4		0.3	
	135 kHz			–40	
	200 kHz			–40	
	400 kHz			–40	

channel characteristics (continued)

SNR vs signal level–baseband downlink path

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Signal level	–50 dBm0	200 kHz bandwidth	21			dB
	–40 dBm0		26			
	–30 dBm0		36			
	–20 dBm0		46			
	–10 dBm0		50			
	–5 dBm0		55			
	0 dBm0		30			
Idle channel noise, 0 Hz –200 kHz					–66	dBm0

gain characteristics of the baseband downlink path

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Absolute gain error relative to V_{VREF}		at –10 dBm0 and 18 kHz	–11	–10	–9	dB
Gain tracking error. Over the range 3 dBm0 to – 50 dBm0 at 18 kHz with reference –10 dBm0	0 dBm0		–0.25		0.25	dB
	–5 dBm0		–0.25		0.25	
	–10 dBm0	Reference level		0		
	–20 dBm0		–0.25		0.25	
	–30 dBm0		–0.25		0.25	
	–40 dBm0		–0.25		0.25	
	–50 dBm0		–0.50		0.50	dB

group delay – baseband downlink path

PARAMETER		MIN	TYP	MAX	UNIT
Group delay	0 Hz to 100 kHz		28		µs

I and Q channels matching – baseband downlink path

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Gain matching between channels	0 Hz to 96 kHz	18 kHz sinewave	–0.5		0.5	dB
Delay matching between channels	0 Hz to 96 kHz	18 kHz sinewave	–8		8	ns

baseband downlink path global characteristics

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Power supply rejection, 0 Hz –100 kHz band			70		dB

timing requirements of baseband downlink path (see Figure 2)

			MIN	NOM	MAX	UNIT†
t_{su4}	Setup time, BDLON↑ to BCAL↑		5			µs
t_{w3}	Pulse duration, BCAL		60			µs
t_{su5}	Setup time BCAL low before BENA↑		0			µs
t_{w4}	Pulse duration, BENA high	N effective duration of burst controlled by BENA		N		1/4-bit
t_{su6}	Setup time, BENA↑ before DATAOUT VALID		24.3		28	µs
t_{h4}	Hold time, DATAOUT VALID after BENA↓				3.7	µs
t_{h5}	Hold time, BDLON low after BENA low		0			µs

† Values in the above table are given for system information only.

automatic power control (APC)

APC level (8-bit DAC)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Integral nonlinearity (best fitting)	Shaper at maximum full scale Load 10 kΩ, 50 pF	–1		1	LSB
Differential nonlinearity		–1		1	
Settling time				10	µs

APC shaper (5-bit DAC)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Integral nonlinearity (best fitting)		–1		1	LSB
Differential nonlinearity		–1		1	LSB
Settling time†				1	µs

† Value given for system information only.

APC output stage

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Output voltage at shape=31 & level =255		2.0	2.2	2.4	V
Output voltage at shape=0 & level=xx	Bit APCMODE = 0	0		20	mV
Output voltage at shape=0 & level =xx	Bit APCMODE =1	80	120	160	mV
Output voltage at shape=xx & level = 0			0	5	mV
Output voltage in power-down			0		V
DC power supply sensitivity				1%	
Output impedance in power-down			20		Ω
Load resistance		10			kΩ
Load capacitance				50	pF

monitoring ADC

10-bit ADC

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Integral nonlinearity (Best fitting)	Input signal range < 0.95 V_{VREF}	–4		4	LSB
Differential nonlinearity	Input signal range < 0.95 V_{VREF}	–2		2	LSB
Conversion time†				10	µs
Input range		0		V_{VREF}	V
Input leakage current		–10		10	µA
Input capacitance				25	pF

† Value given for system information only.

automatic Gain Control (AGC)

AGC 10-bit DAC

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Integral nonlinearity	Best fitting line	–1		1	LSB
Differential nonlinearity		–1		1	LSB
Settling time	From AUXAGC load			100	µs

AGC output stage

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Output voltage with code max		1.9	2.2	2.4	V
Offset voltage with code 000		0.18	0.24	0.30	V
Output voltage in power down			0		V
DC power supply sensitivity				1%	
Output impedance in power down			200		kΩ
Load resistance		10			kΩ
Load capacitance				50	pF

automatic frequency control (AFC)

AFC 13-bit DAC

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
Sampling frequency, f_S	AFCCK1=1	AFCCK0 = 1		2		MHz
	AFCCK1=1	AFCCK0 = 0		1		
	AFCCK1=0	AFCCK0 = 1		0.5		
	AFCCK1=0	AFCCK0 = 0		0.25		
Integral nonlinearity from 0 to 75% output range	Best fitting line			±1		LSB
Differential nonlinearity from 0 to 75% output range				±1		LSB
Settling time					1	µs
DC power-supply sensitivity	Over power supply range				1%	

AFC output stage

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Internal output resistance (±30 % tolerance)			25		kΩ
External filtering capacitance			33		nF
Output voltage with code max		2.0	2.5	2.8	V
Output voltage with code min		0	3	6	mV
Output voltage in power down			0		V
Output impedance in power down			25		kΩ

voice uplink path

global characteristics of voice uplink path

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
Maximum input range (MICP – MICN)	Inputs 3 dBm0 (maximum digital sample amplitude) with PGA gain, set to 0dB (default value)			32.5		mVrms
Nominal reference level (MICP – MICN)				–10		dBm0
Differential input resistance (MICP – MICN)			90	140	200	kΩ
Micro-amplifier gain				27		dB
Maximum input range at AUXI	Inputs 3 dBm0 (maximum digital sample amplitude) with PGA gain, set to 0dB (default value)			365		mVrms
Nominal reference level at AUXI				–10		dBm0
Input resistance at AUXI			140	220	300	kΩ
Auxi amplifier gain				6		dB
PGA absolute gain				4.6		dB
PGA gain step	VULPGA code =10000	–12 dB	–12.7	–12.2	–11.7	dB
	VULPGA code = 10111	–11 dB	–11.3	–10.8	–10.3	
	VULPGA code = 11000	–10 dB	–10.6	–10.1	–9.6	
	VULPGA code = 11001	–9 dB	–9.5	–9	–8.5	
	VULPGA code = 11010	–8 dB	–8.5	–8	–7.5	
	VULPGA code = 11011	–7 dB	–7.5	–7	–6.5	
	VULPGA code = 00000 (default)	–6 dB	–6.7	–6.2	–5.7	
	VULPGA code = 00001	–5 dB	–5.6	–5.1	–4.6	
	VULPGA code = 00010	–4 dB	–4.6	–4.1	–3.6	
	VULPGA code = 00011	–3 dB	–3.5	–3	–2.5	
	VULPGA code = 00100	–2 dB	–2.4	–1.9	–1.4	
	VULPGA code = 00101	–1 dB	–1.5	–1	–0.5	
	VULPGA code = 00110 (ref)	0 dB		0		
	VULPGA code = 00111	1 dB	0.7	1.2	1.7	
	VULPGA code = 01000	2 dB	1.4	1.9	2.4	
	VULPGA code = 01001	3 dB	2.6	3.1	3.6	
	VULPGA code = 01010	4 dB	3.6	4.1	4.6	
	VULPGA code = 01011	5 dB	4.5	5	5.5	
	VULPGA code = 01100	6 dB	5.3	5.8	6.3	
	VULPGA code = 10001	7 dB	6.4	6.9	7.4	
	VULPGA code = 10010	8 dB	7.4	7.9	8.4	
	VULPGA code = 10011	9 dB	8.6	9.1	9.6	
	VULPGA code = 10100	10 dB	9.6	10.1	10.6	
	VULPGA code = 10101	11 dB	10.5	11	11.5	
	VULPGA code = 10110	12 dB	11.5	12	12.5	
Power supply rejection, 0 Hz –100 kHz band				70		dB

voice uplink path (continued)

frequency response of the voiceband uplink path

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Frequency response (Gain relative to reference gain at 1 kHz)	100 Hz			–37.4	–20	dB
	150 Hz			–25.9	–15	
	200 Hz			–16.5	–10	
	300 Hz		–2	–1.46	1	
	1000 Hz	Reference point is 1000 Hz		0		
	2000 Hz		–1.5	–0.58	1	
	3000 Hz		–1.5	–0.77	1	
	3400 Hz		–2	–1	1	
	3600 Hz			–12.4	–6	
	3800 Hz			–23.3	–18	
	4000 Hz			–35	–30	
	>4600 Hz			>–52	–40	

psophometric SNR vs signal level of the voiceband uplink path

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Signal to noise + distortion	3 dBm0		35			dB
	0 dBm0		40			
	–5 dBm0		42			
	–10 dBm0		45			
	–20 dBm0		42			
	–30 dBm0		40			
	–40 dBm0		30			
	–45 dBm0		25			
Maximum idle channel noise	0 Hz –4 kHz				–72	dBm0
Crosstalk with the downlink path		Downlink path loaded with 150 Ω			–66	dB

gain characteristics of the voiceband uplink path

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Absolute gain error		at 0dBm0 and 1KHz	–1		1	dB
		at –10dBm0 and 1KHz	–11	–10	–9	
Gain tracking error. Over the range 3 dBm0 to – 45 dBm0 at 1 kHz with reference –10 dBm0	3 dBm0		–0.25		0.25	dB
	0 dBm0		–0.25		0.25	
	–5 dBm0		–0.25		0.25	
	–10 dBm0	Reference level		0		
	–20 dBm0		–0.25		0.25	
	–30 dBm0		–0.25		0.25	
	–40 dBm0		–0.35		0.35	
	–45 dBm0		–0.50		0.50	

voice downlink path

global characteristics of voice downlink path

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
Maximum output swing (EARP – EARN)	With 5% distortion and with 150 Ω			3.1	3.92		Vpp
	With 5% distortion and with 33 Ω			1.2	1.5		
Minimum output resistive load at EARP_EARN		Output swing 3.9Vpp		120	150		Ω
		Output swing 1.5Vpp		30	33		Ω
Maximum output capacitive load at EARP_EARN						100	pF
Earphone amplifier gain					0		dB
Earphone amplifier state in power down					Hi-Z		
Maximum output swing (AUXO), 5% distortion, maximum		Load = 1 kΩ		1.6	1.96		Vpeak
Minimum output resistive load at AUXO		AC coupled		1.0	1.2		kΩ
Maximum output capacitive load at AUXO						100	pF
Auxo amplifier gain					–6		dB
Auxo amplifier state in power down					Hi-Z		
Volume control gains		VOLCTL code = 010		–1	0	1	dB
		VOLCTL code = 110		–7	–6	–5	
		VOLCTL code = 000 (default & reference)			–12		
		VOLCTL code = 100		–19	–18	–17	
		VOLCTL code = 011		–25	–24	–23	
		VOLCTL code =101 or 001 or 111 (mute)				–40	
PGA gain steps		VDLPGA code = 0000 (default)	–6 dB	–6.5	–6.0	–5.5	dB
		VDLPGA code = 0001	–5 dB	–5.5	–5.0	–4.5	
		VDLPGA code = 0010	–4 dB	–4.5	–4.0	–3.5	
		VDLPGA code = 0011	–3 dB	–3.7	–3.2	–2.7	
		VDLPGA code = 0100	–2 dB	–2.3	–1.8	–1.3	
		VDLPGA code = 0101	–1 dB	–1.7	–1.2	–0.7	
		VDLPGA code = 0110 (ref.)	0 dB		0		
		VDLPGA code = 0111	1 dB	0.5	1.0	1.5	
		VDLPGA code = 1000	2 dB	1.4	1.9	2.4	
		VDLPGA code = 1001	3 dB	2.6	3.1	3.6	
		VDLPGA code = 1010	4 dB	3.4	3.9	4.4	
		VDLPGA code = 1011	5 dB	4.3	4.8	5.3	
		VDLPGA code = 1100	6 dB	5.5	6.0	6.5	
Sidetone gain steps		VDLST code = 1101	–23 dB	–24.6	–24.1	–22.6	dB
		VDLST code = 1100	–20 dB	–21.1	–20.6	–18.5	
		VDLST code = 0110	–17 dB	–18.3	–17.8	–17.3	
		VDLST code = 0010	–14 dB	–14.8	–14.3	–13.8	
		VDLST code = 0111	–11 dB	–12.3	–11.8	–11.3	
		VDLST code = 0011	–8 dB	–8.8	–8.3	–7.8	
		VDLST code = 0000 (ref.)	–5 dB	–5.9	–4.8	–4.3	
		VDLST code = 0100	–2 dB	–2.1	–1.6	–1.1	
		VDLST code = 0001	1 dB	0.7	1.2	1.7	
		VDLST code = 1000	Mute		–55	–50	
Power supply rejection, 0 Hz –100 kHz		In the band			60		dB

NOTE: All parameters are given for a 150 Ω load, unless specified.

voice downlink path (continued)

frequency response of the voiceband downlink path

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Frequency response (Gain relative to reference gain at 1 kHz)	100 Hz			–5.8	–5	dB
	150 Hz			–3.6	–2	
	200 Hz			–2.5	1	
	300 Hz		–3	–1.4	1	
	1000 Hz	Reference point		0		
	2000 Hz		–1	–0.6	1	
	3000 Hz		–1	–0.15	1	
	3400 Hz		–3	–0.35	1	
	3600 Hz			–9.0	–6	
	3800 Hz			–21.0	–15	
	4000 Hz			–32.0	–28	
	> 4600 Hz			–60.0		

psophometric SNR vs signal level of the voiceband downlink path

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Signal level	–45 dBm0		25			dB
	–40 dBm0		30			
	–30 dBm0		40			
	–20 dBm0		42			
	–10 dBm0		45			
	–5 dBm0		42			
	0 dBm0		40			
	3 dBm0		35			
Idle channel noise, 0 Hz –4 kHz					–71	dBm
Crosstalk with the uplink path					–50	dB

gain characteristics of the voiceband downlink path

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Absolute gain error		at 0 dbm0 and 1 kHz	–1.8	0	0.2	dB
		at –10 dbm0 and 1 kHz	–11.8	–10	–9.8	
Gain tracking error. Over the range 3 dBm0 to – 45 dBm0 at 1 kHz with reference –10 dBm0 PGA gain = 0dB. Volume control = –12 dB	3 dBm0		–0.25		0.25	dB
	0 dBm0		–0.25		0.25	
	–5 dBm0		–0.25		0.25	
	–10 dBm0	Reference level		0		
	–20 dBm0		–0.25		0.25	
	–30 dBm0		–0.25		0.25	
	–40 dBm0		–0.35		0.35	
	–45 dBm0		–0.50		0.50	

power consumption

consumption by circuit block

CIRCUIT BLOCK		TEST CONDITIONS	MIN	TYP	MAX	UNIT
ADC						
AFC	DVDD3			0.013		mA
	AVDD3			0.021		
	AVDD5			0.027		
AGC	AVDD3			0.054		mA
	AVDD5			0.683		
APC	DVDD3			0.133		mA
	AVDD3			0.108		
	AVDD5			0.442		
Auxiliary input stage	AVDD4			2.240		mA
Auxiliary output stage	AVDD4			1.550		
Band gap	AVDD1			0.163		mA
Baseband downlink	DVDD2			2.810		mA
	AVDD2			9.310		
Baseband uplink	DVDD2			0.460		mA
	AVDD2			4.910		
BBIF	DVDD1	BDL Active		1.490		mA
Clock generator BBIF	DVDD1			0.122		mA
Clock generator Idle	DVDD1			0.204		mA
Clock generator TIIF	DVDD1			0.181		mA
Clock generator VBIF	DVDD1			0.144		mA
Digital modulator	DVDD4			0.183		mA
Earphone output stage	AVDD4			4.170		mA
Microphone input stage	AVDD4			3.000		mA
Voiceband downlink	DVDD4			1.380		mA
	AVDD4			2.990		
Voiceband uplink	DVDD4			1.200		mA
	AVDD4			0.115		

current consumption for typical configurations

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Deep power down	13-MHz clock applied; PWRDN active; Band-gap voltage reference off			200	μA
Power down with AFC active	AFC programmed with internal 50-kΩ and 1-MHz clock		0.7	1.1	mA
AFC + GMSK – Rx	Paging		14	16	mA
Audio + GMSK – Tx + APC + AFC	Transmit burst		19	21	mA
Audio + GMSK – Rx +AGC+ AFC	Receive burst		27	30	mA

MCU serial interface timing requirements (see Figure 3)

PARAMETER		MIN	NOM	MAX	UNIT
t_{su10}	Setup time, UCLK stable before USEL↓	20			ns
t_{v1}	Hold time, UDX valid after USEL↓			20	ns
t_{v2}	Hold time, UDX valid after UCLK↑			20	ns
t_{h9}	Sequential transfer delay between 16-bit word acquisition t_w pulse duration, USEL high	3000			ns
t_{h10}	Hold time, UCLK↑ after USEL↓	20			ns
t_{h11}	Hold time, UCLK unknown after USEL↑	20			ns
t_{su11}	Setup time, data valid before UCLK↓	20			ns
t_{h12}	Hold time, data valid after UCLK↓	20			ns
t_c	Cycle time, ULCK	154			ns

DSP serial interface timing requirements (see Figure 4)

PARAMETER			MIN	NOM	MAX	UNIT
BCLKX	BCLKX signal frequency (Burst mode or Continuous mode depending on bit BCLKMODE)			13		MHz
BCLKX	BCLKX duty cycle		40%	50%	60%	
t_{su12}	Setup time, BFSX high before BCLKX ↓		20			ns
t_{h12}	Hold time, BFSX high after BCLKX ↓		20			ns
t_{su13}	Setup time, BDX valid before BCLKX ↓		20			ns
t_{h13}	Hold time, BDX valid after BCLKX ↓		20			ns
BCLKR	BCLKR signal frequency	(Output BCLKDIR = 0)		4.33		MHz
		(Input BCLKDIR = 1)			13	
BCLKR	BCLKR duty cycle		40%	50%	60%	
t_{su14}	Setup time, BFSR high before BCLKR ↓		20			ns
t_{h14}	Hold time, BFSR high after BCLKR ↓		20			ns
t_{su16}	Setup time, BDR valid before BCLKR ↓		20			ns
t_{h15}	Setup time, BDR valid after BCLKR ↓		20			ns

voice timing requirements (see Figure 5)

PARAMETER		MIN	NOM	MAX	UNIT
VCLK	VCLK signal frequency (Burst mode or Continuous mode depending on bit VCLKMODE)		520		kHz
VCLK	VCLK duty cycle	40%	50%	60%	
t_{su7}	Setup time, VFS high before VCLK ↓	100			ns
t_{h6}	Hold time, VFS high after VCLK ↓	100			ns
t_{su8}	Setup time, VDX valid before VCLK ↓	100			ns
t_{h8}	Hold time, VDX valid after VCLK ↓	100			ns
t_{su9}	Setup time, VDR valid before VCLK ↓	100			ns
t_{h7}	Hold time, VDR valid after VCLK ↓	100			ns

PARAMETER MEASUREMENT INFORMATION

uplink timing considerations

Figure 1 shows the timing diagram for the uplink operation.

Timing for power up, offset calibration, data transmission, and power ramp-up are driven by control bits applied to BULON (base uplink on), BCAL (calibration) and BENA (enable). The burst content including guard bits, tail bits, and data bits is sent by the DSP by way of the DSP interface and then stored by the TCM4400E in a burst buffer. Transmission start is indicated by the control bit BENA when the BULON is active. The transmission, sequencing, and power ramp-up are then controlled by an on-chip burst sequencer with a one-quarter-bit timing accuracy. For a detailed description of the baseband in length path, see the functional description of the baseband uplink path in the *Principles of Operation* section.

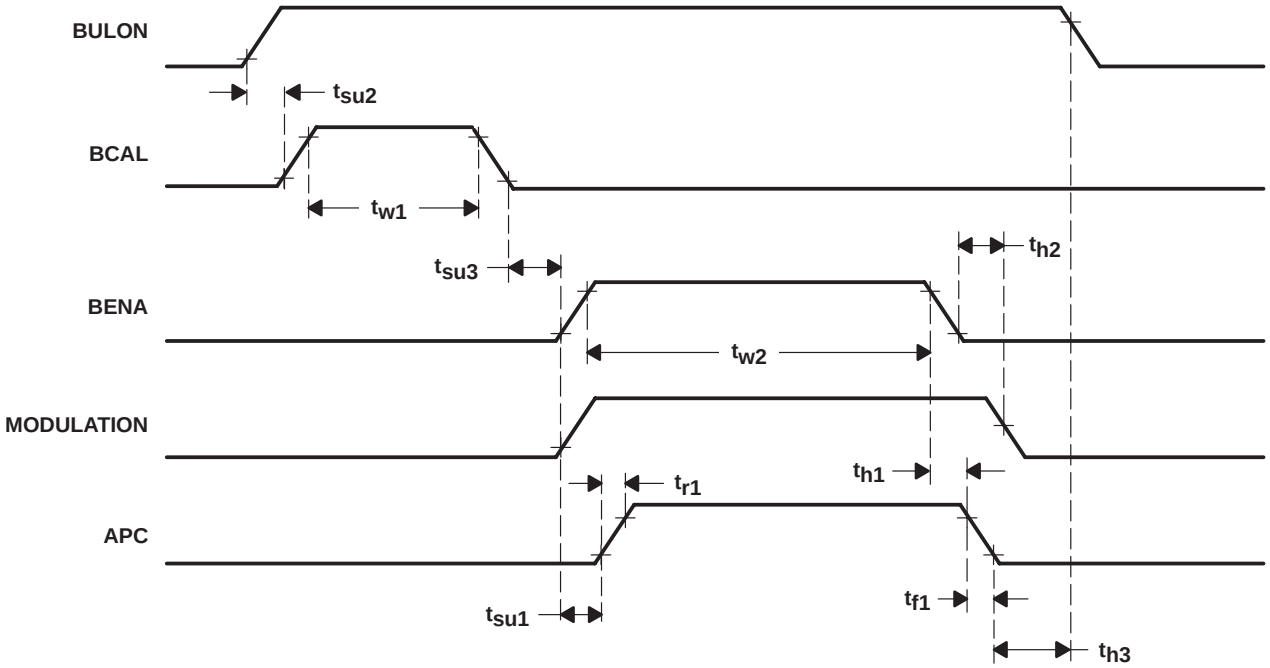


Figure 1. Uplink Timing Diagram

PARAMETER MEASUREMENT INFORMATION

downlink timing considerations

Figure 2 shows the timing diagram for downlink operation.

Timing control of the baseband downlink path is controlled by bits DLON (downlink on), BCAL (calibration) and BENA (enable) when BDLON is active (see the topic, timing and interface). BDLON controls the power up of the baseband downlink path, BCAL controls the start and duration of the autocalibration sequence, and BENA controls the beginning and the duration of data transmission to the DSP, using the DSP serial interface.

The power-down sequence is controlled with two bits, the first bit (BBDLW of PWDNRG1 register) determines whether the baseband downlink path can be powered down with external GSM receive window activation (BDLON); the second bit (BBDLPD of PWDNRG1 register) controls the activation of the baseband downlink path. See the topic, *power-down functional description*, for more details about power-down control.

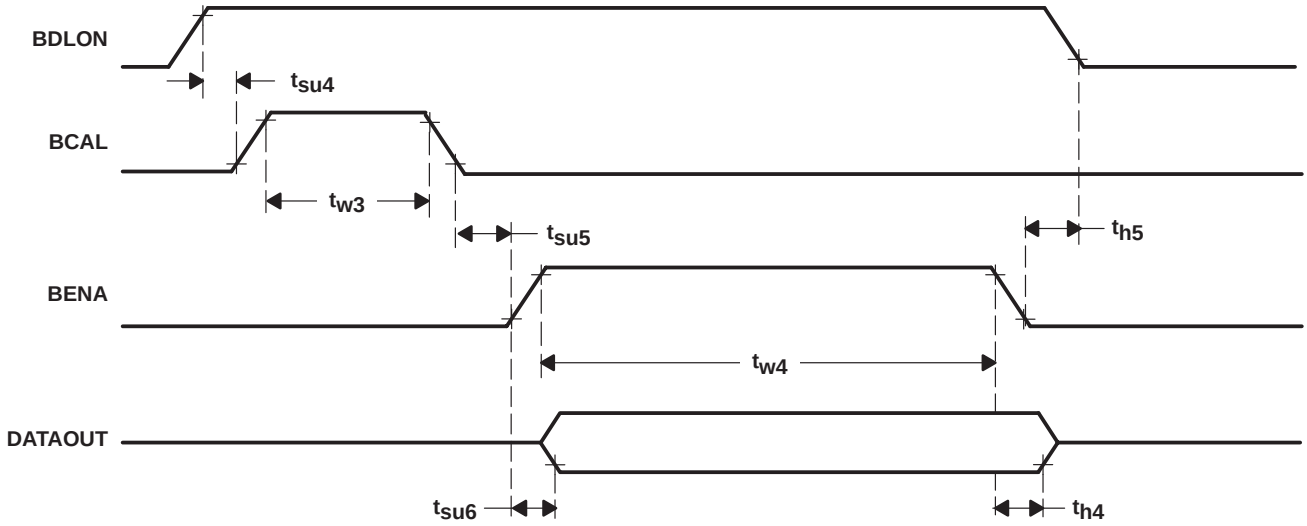


Figure 2. Downlink Timing Sequence

PARAMETER MEASUREMENT INFORMATION

microcontroller serial interface timing considerations

Figure 3 shows the timing diagram for the microcontroller serial interface.

The microcontroller serial interface is designed to be compliant with 8-bit standard synchronous serial ports. The microcontroller operates on 16-bit words; this interface consists of four pins.

UCLK: A clock provided by the microcontroller to control access to baseband, voiceband, and auxiliary functions registers

UDR: An input terminal to control read and write access to baseband, voiceband, and auxiliary functions registers

UDX: An output terminal to transmit data from read access of baseband, voiceband, and auxiliary functions registers

USEL: An input terminal to enable read and write access to baseband, voiceband, and auxiliary functions registers through the microcontroller interface

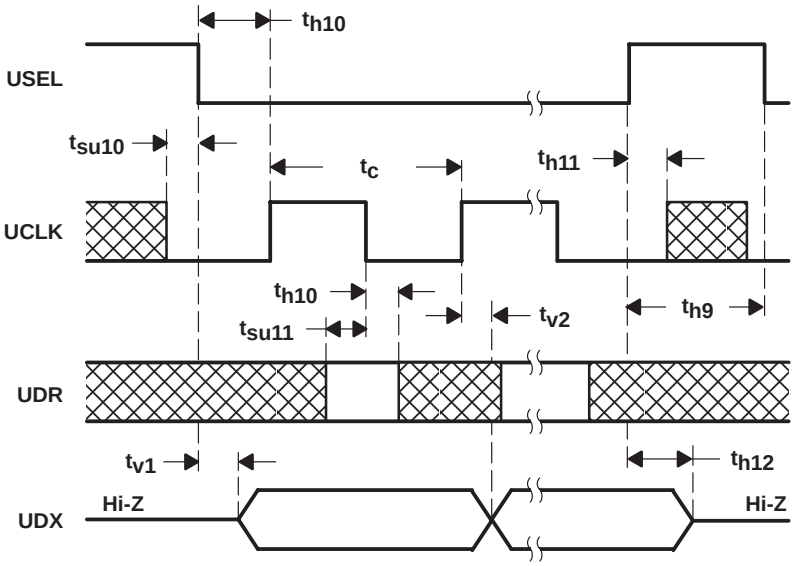


Figure 3. Microcontroller Serial Interface Timing Waveforms (Mode Rising Edge Without Delay)

PARAMETER MEASUREMENT INFORMATION

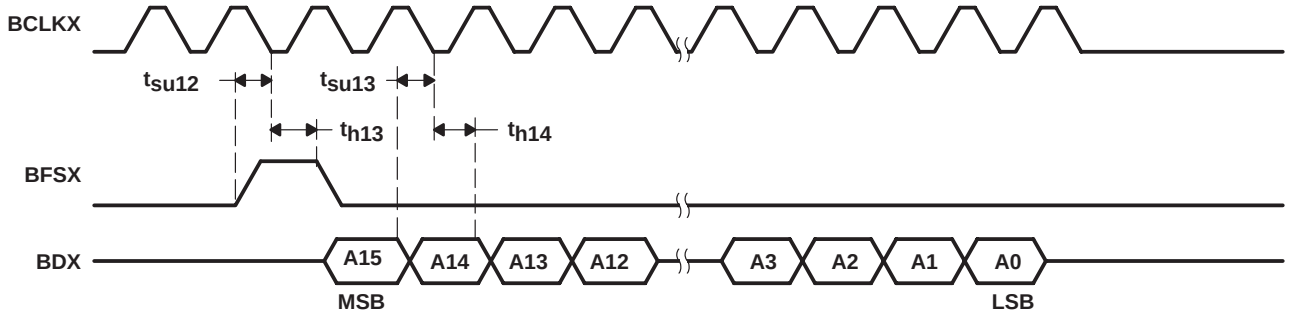
DSP serial port timing considerations

Figure 4 shows the timing diagram for DSP serial port operation.

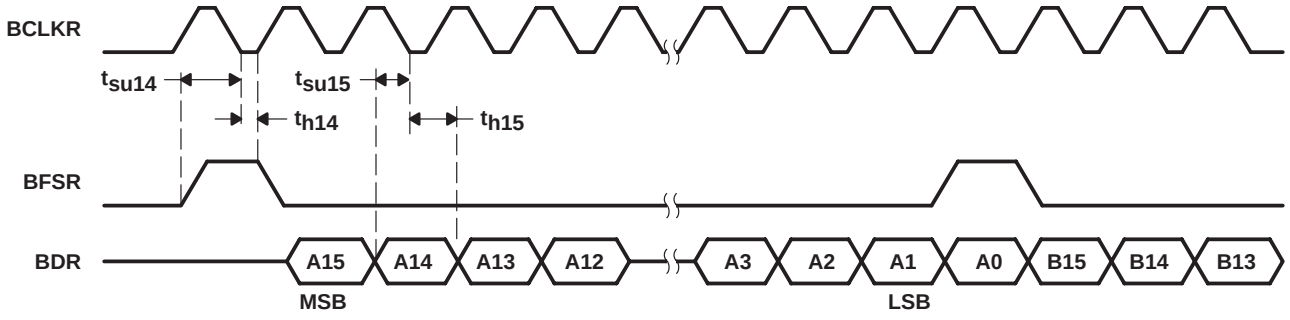
Six pins are used for the serial port interface; see Figure 14. The terminal BCLKR is an I/O port for the serial clock used to control the reception of the data BDR. At reset BCLKR is configured as an output and the clock frequency is set to MCLK/3 (4.333 MHz with MCLK = 13 MHz); the clock signal is running permanently. The port BCLKR can be reconfigured as an input by programming an internal register. In this case BCLKR is provided by the DSP and can run in burst mode to reduce power consumption. The receive frame synchronization (BFSR) identifies the beginning of a data packet transfer on port BDR.

The transmitted serial data (BDX) is the serial data input; the transmit frame synchronization (BFSX) is used to initiate the transmission of data. The transmit clock (BCLKX) is provided by the GSM baseband and voice A/D and D/A converters with a frequency of MCLK. The downlink data bus (BFSX, BCLKX, BDX) can be driven to VSS or placed in high-impedance when no data is to be transferred to the DSP. The bit BCLKDIR of the register BCTLREG controls the direction of the BCLKR clock.

Similar to the voice serial interface, an extra clock cycle must be generated, since the last 16-bit word received on the DSP serial interface is latched on the next two falling BCLKR edges, following the least significant bit (LSB). As for the voice serial interface, one extra clock period is generated on the BCLKX before the first synchronization BFSX of downlink data sequence.



a. Burst-Mode Serial-Port Transmit Operation



b. Burst-Mode Serial-Port Receive Operation

Figure 4. DSP Serial Port Timings

PARAMETER MEASUREMENT INFORMATION

voiceband serial interface timing considerations

Figure 5 shows the timing diagram for both transmit and receive voiceband serial interface operation.

The signal VCLK is the output serial clock used to control the transmission or reception of the data (see Figure 5). The transmitted serial data (VDX) is the serial data output; the frame synchronization (VFS) is used to initiate the transfer of transmit and receive data. The received data (VDR) is the serial data input.

Each serial port includes four registers that include the data transmit register (DXR), the data receive register (DRR), the transmit shift register (XSR), and the receive shift register (RSR).

The voice serial interface has the same structure and timing diagram as the serial interface; one extra cycle is generated before VFS, and two extra cycles are generated after the LSB.

XLOAD and RLOAD are internal signals.

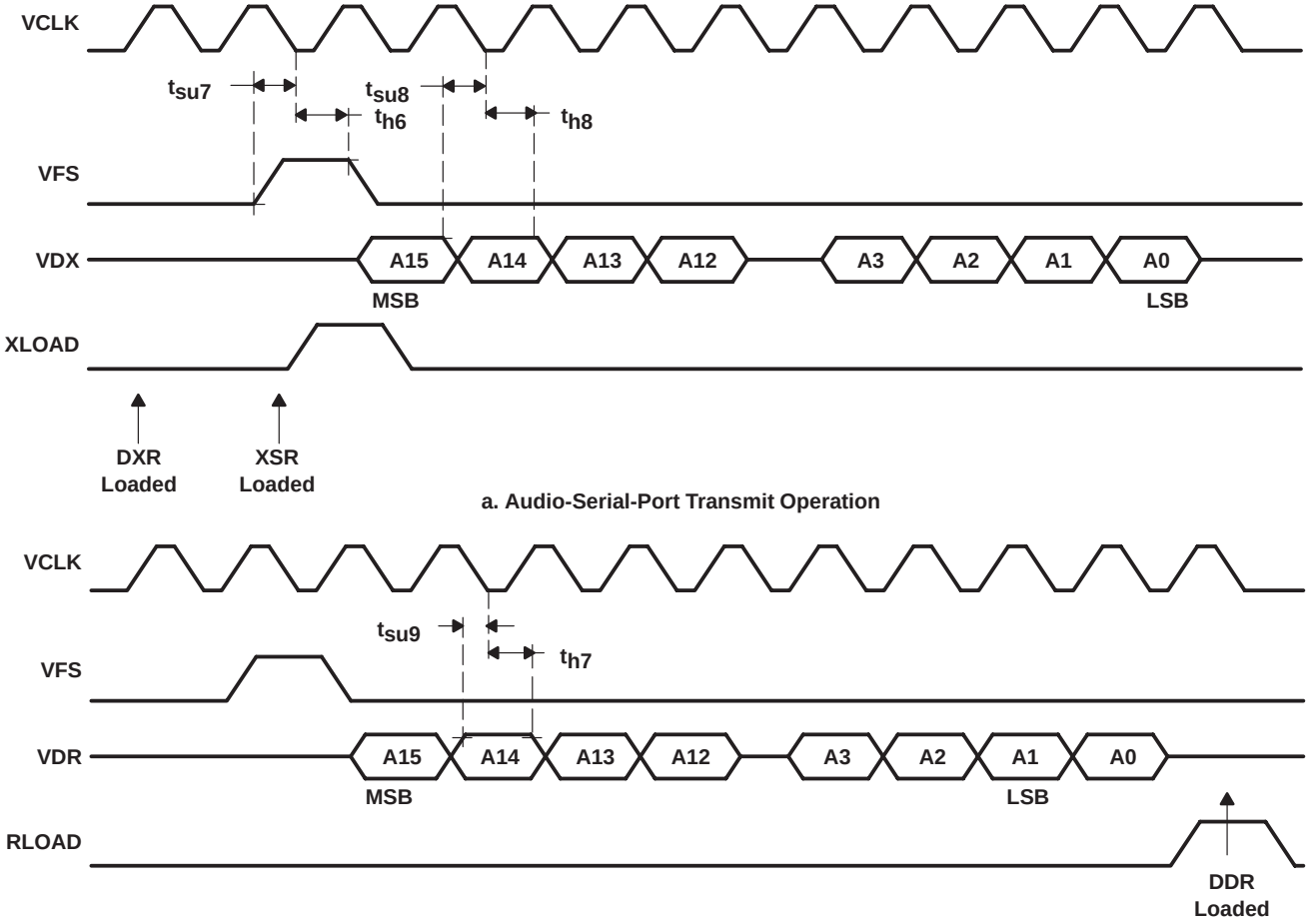


Figure 5. Voiceband Serial Interface Timing Waveforms

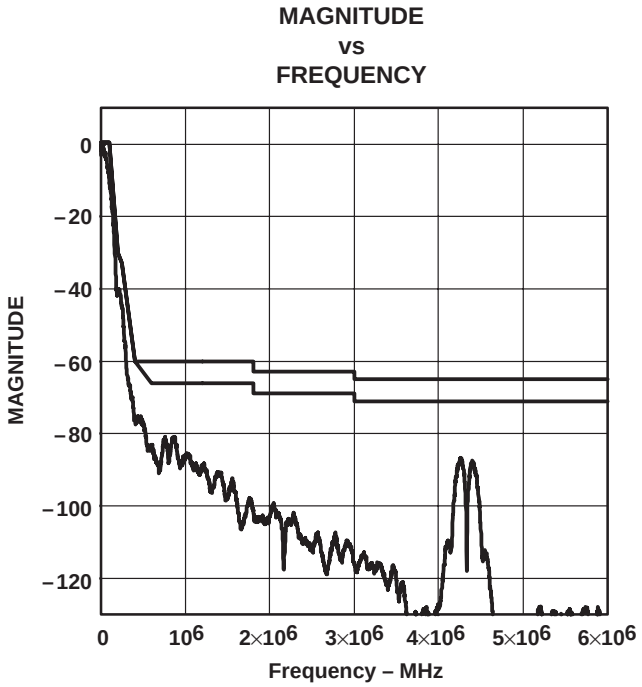
PRINCIPLE OF OPERATION

baseband uplink path

Traditional transmit and receive terms can be confusing when describing a cellular telephone two-way communication. This document uses the terms *uplink*, meaning from a user device to a remote station, and *downlink* meaning from a remote station, whether earthbound or satellite, to indicate the signal-flow direction.

The modulator circuit in the baseband uplink path performs the Gaussian minimum shift keying (GMSK) in accordance with the GSM specification 5.04. The data to be modulated flows from the DSP through the serial interface, it is differentially encoded, and it is applied to the input of the GMSK modulator. The GMSK modulator, implemented with digital logic and a sin/cos look-up table in ROM, generates the I and Q components (words) with an interpolation ratio of 16.

These digital I and Q words are sampled at a 4.33 MHz rate and applied to the inputs of a pair of high-speed 8-bit DACs. The analog outputs are then processed by third-order Bessel filters to reduce image frequencies due to sampling and to obtain a spectrum consistent with GSM specification 05.05 (see Figure 6).



NOTE A: Conformance with GSM Rec 05.05: simulated spectrum of an infinite modulation of random data with a Blackman Harris analysis window.

Figure 6. Typical GSM Modulation Spectrum

Full-differential buffered signals are available at ULIP, ULIN, ULQP, and ULQN. These signals are suitable for use in the RF circuit for generating a phase-modulated signal of the form:

$$s(t) = A \cos(2 \pi f_c t + \Phi(t, \alpha))$$

where fc is the RF carrier frequency, and Phi (t, alpha) is the phase component generated by the GMSK modulator from the differential encoded data.

PRINCIPLES OF OPERATION

baseband uplink path (continued)

Timing for power up, offset calibration, data transmission, and power ramp-up is driven by control bits applied to BULON (base uplink on), BCAL (calibration) and BENA (enable) (see Figure 1). The entire content of a burst, including guard bits, tail bits, and data bits, is sent by the DSP using the DSP interface and then stored by the TCM4400E in a burst buffer. Transmission start is indicated by the control bit BENA when the BULON is active. The transmission, sequencing, and power ramp-up are then controlled by an on-chip burst timing control circuit having a one-quarter-bit timing accuracy (see Figure 7). All data related to a burst to be transmitted, such as bit data, ramp-up & ramp-down delay programmation, have to be loaded before the rising edge of BENA.

The burst length is determined by the time during which the BENA signal is active. Effective burst length is equal to the duration of BENA + 32 one-quarter bits. The tail of the burst is controlled internally, which means that the modulation is maintained for 32 one-quarter bits after BENA turns off to generate the ramp-down sequence and complete modulation.

For each burst, the power control level can be controlled by using the serial interfaces to write the power level value into the power register of the auxiliary RF power control circuitry. The power ramp-up and ramp-down sequences are controlled by the burst sequencer, while the shape of the power control is generated internally by dedicated circuitry, which drives the power control 5-bit and 8-bit D/A converters.

To minimize phase error, the I and Q channel dc offset can be minimized using offset calibration. Each channel includes an offset register in which a value corresponding to the required dc offset is stored, controlling the dc offset of the I channel and Q channel D/A converters. This value is set by a calibration sequence. Starting and stopping the calibration sequence is controlled by the control bit BCAL using the timing interface when BULON is active. During the calibration sequence, the digital value of I and Q is forced to zero so that only the offset register value drives the D/A converters, and a low-offset comparator senses the dc level at the BULIP/BULIN and BULQP/BULQN outputs and modifies the content of the offset registers to minimize the dc offset (see Figure 7).

Gain unbalance can be introduced between I and Q channels to allow compensation of imperfections in RF circuits. This gain unbalance is controlled through the mean of three program bits: IQSEL,G1, and G0 of baseband uplink register BULCTL.

The power-down function is controlled with two bits. The first bit (BBULW of the PWDNRG1 register), determines whether the baseband uplink path can be powered down with external GSM transmit window activation (BULON). The second bit (BBULPD of the PWDNREG1 register) controls the activation of the baseband uplink path. For more details about power-down control, see the *power-down functional description* section.

PRINCIPLES OF OPERATION

baseband uplink path (continued)

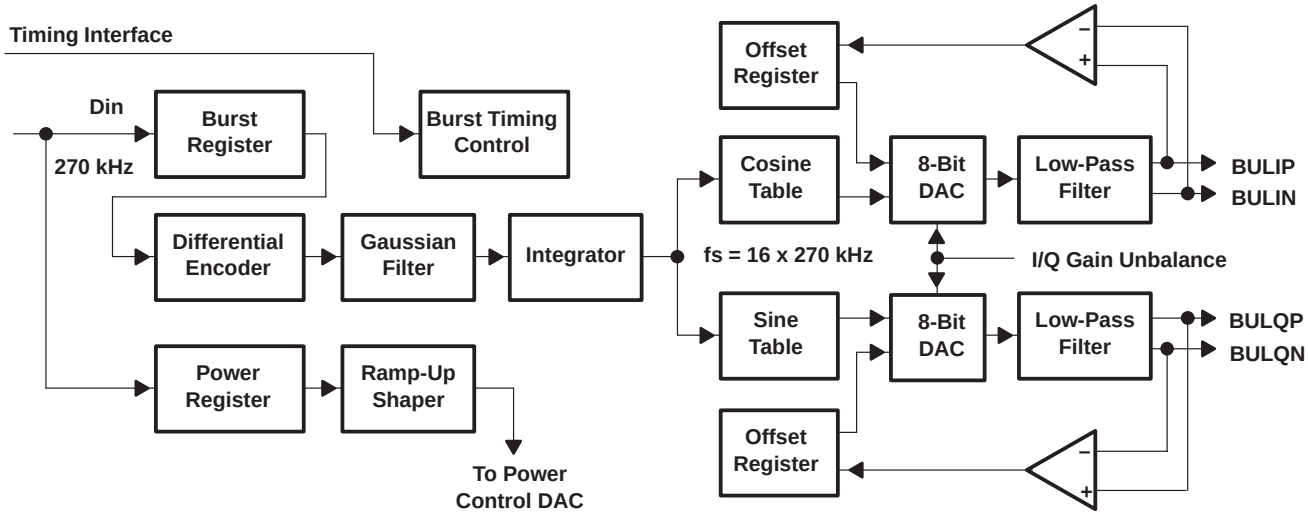


Figure 7. Functional Structure of the Baseband Uplink Path

baseband downlink path

The baseband downlink path includes two identical circuits for processing the baseband I and Q components generated by the RF circuits. The first stage of the downlink path is a continuous-time second-order antialiasing filter (see Figure 8) that prevents aliasing due to sampling in the A/D converter. This filter also serves as an adaptation stage (input impedance and common-mode level) between external-world and on-chip circuitry.

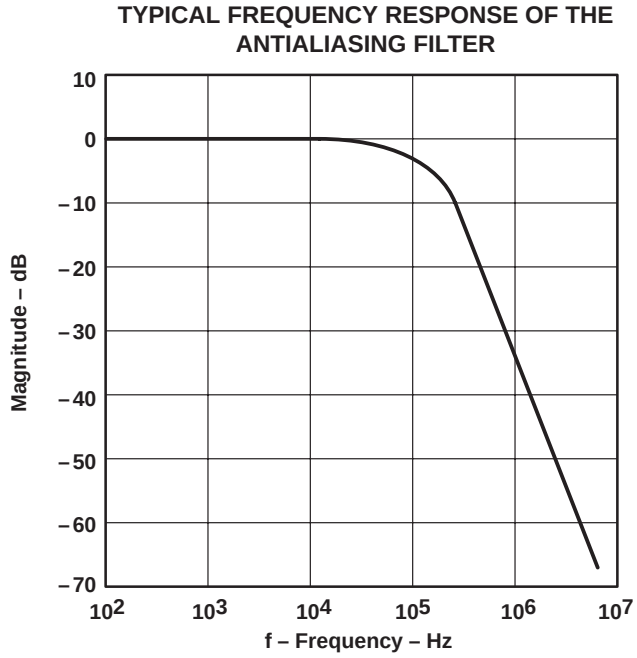


Figure 8. Antialiasing Filter

PRINCIPLES OF OPERATION

baseband downlink path (continued)

The antialiasing filter is followed by a third-order sigma-delta modulator that performs A/D conversion at a sampling rate of 6.5 MHz. The A/D converter provides 3-bit words that are fed to a digital filter (see Figure 9) that performs the decimation by a ratio of 24 to lower the sampling rate down to 270.8 KHz and the channel separation by rejecting enough of the adjacent channels to allow the demodulation performances required by the GSM specification. Figure 10 shows the frequency response curve for the downlink digital filter and Figure 11 shows the in-band response curve for the same digital filter.

The baseband downlink path includes an offset register in which the value representing the channel dc offset is stored; this value is subtracted from the output of the digital filter before transmitting the digital samples to the DSP using the serial interface. Upon reset, the offset register is loaded with 0 and updated with the BCAL calibrating signal (see Figure 2).

The content of the offset register results from a calibration sequence. The input BDLIP is shorted with the input BDLIN, and the input BDLQP is shorted with the input BDLQN. The digital outputs are evaluated and the values are stored in the corresponding offset registers in accordance with the dc offset of the GSM baseband and voice A/D and D/A downlink path. When the external autocalibration sequence is selected, the inputs BDLIP and BDLIN and the inputs BDLQP and BDLQN remain connected to the external circuitry. The digital outputs are evaluated, and the values stored in the corresponding offset registers take into account the dc offset of the external circuitry.

Timing control of the baseband downlink path is controlled by bits BDLON (downlink on), BCAL (calibration), and BENA (enable) when BDLON is active (please see *timing interface* section). BDLON controls the power up of the baseband downlink path; BCAL controls the start and duration of the autocalibration sequence (which can be internal or external depending on bit EXTCAL of PWDNRG1 register); and BENA controls the beginning and the duration of data transmission to the DSP by using the DSP serial interface. To avoid transmission of irrelevant data corresponding to the settling time of the digital filter, the eight first I&Q computed samples are not sent to the DSP; first data are transmitted though the DSP interface about 30 μs after the BENA rising edge.

The power-down sequence is controlled with two bits. The first bit (BBDLW of PWDNRG1 register) determines whether the baseband downlink path can be powered down with external GSM receive window activation (BDLON): The second bit, BBDLPD of register PWDNRG1, controls the activation of the baseband downlink path. Please see *power-down functional description* section for more details about power-down control.

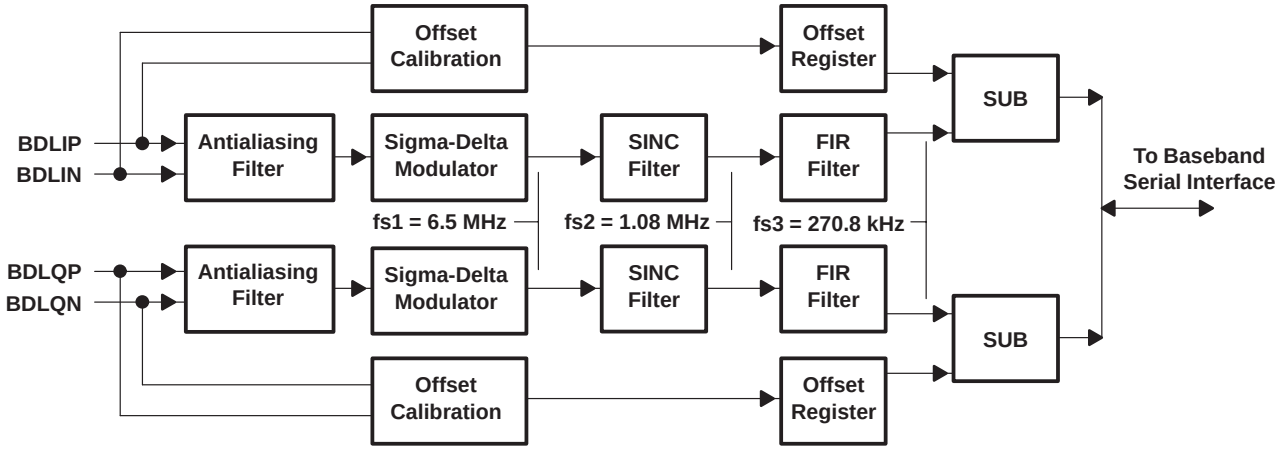


Figure 9. Functional Structure of the Baseband Downlink Path

PRINCIPLES OF OPERATION

baseband downlink path (continued)

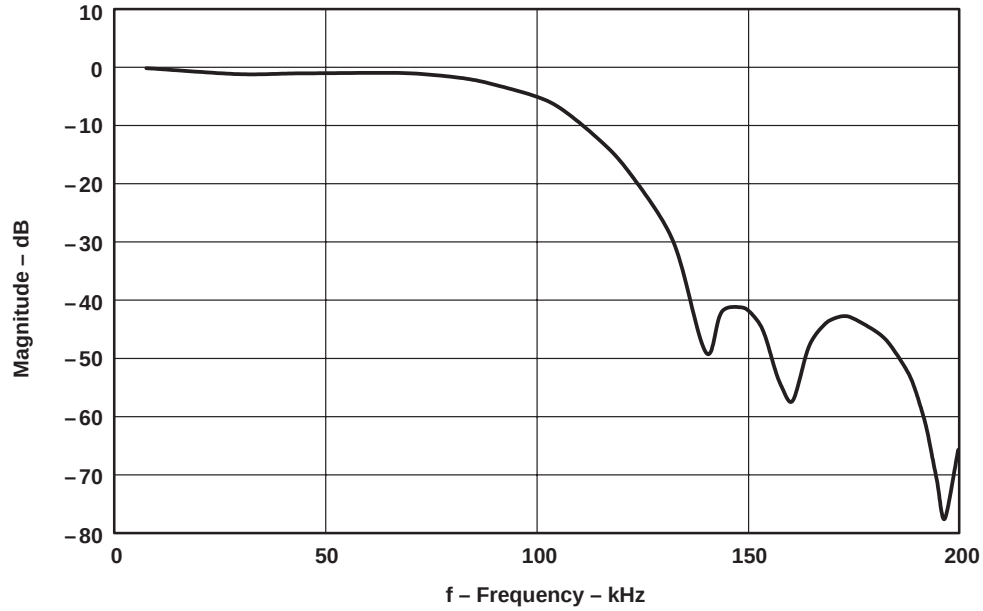


Figure 10. Downlink Digital Filter Frequency Response

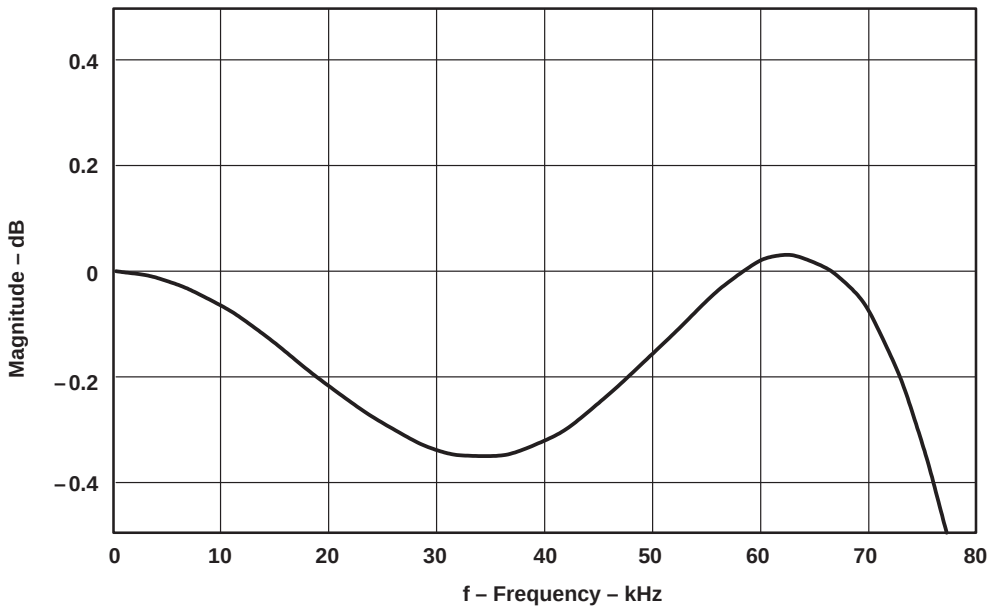


Figure 11. Downlink Digital Filter In-Band Response

PRINCIPLES OF OPERATION

auxiliary RF functions

The auxiliary RF functions include the following:

- Automatic frequency control
- Auxiliary analog converter (Automatic gain control)
- RF power control
- Monitoring

Each of these functions is discussed in the following paragraphs.

automatic frequency control (AFC)

The automatic frequency control function consists of a DAC converter optimized for high-resolution dc conversion. The AFC digital interface includes two registers that can be written using the serial interfaces. The content of these registers controls a 13-bit DAC, whose purpose is to correct frequency shifts of the oscillator maintaining the master clock frequency in a 0.1 ppm range.

Optimizing the AFC function depends on the type of oscillator used and whether its sampling frequency is programmable. This means that the lower the selected frequency the lower the resolution and power consumption. Using a high-quality resonance oscillator filter permits the AFC circuit to operate at low frequency. Thus, a low-cost oscillator permits operation at a higher internal frequency to ensure 13-bit resolution.

The AFC value is programmed with registers AUXAFC1, which contains the ten LSBs, and AUXAFC2, which contains the three MSBs. The three MSBs are sent to the DAC through a shadow register the contents of which is updated when LSBs are written in AUXAFC1, so proper operation of the AFC is ensured by writing the MSB's first and then the LSBs.

Internal resistance and output voltage swing selection are controlled with bit AFZ of AUXCTL2 register. Power down is controlled with two bits: the first bit, AFCPN of AUXCTL1 register, determines whether the AFC can be powered down from the external PWRDN terminal; the second bit, AFCPD of AUXCTL1 register, controls the activation of the the AFC function. See the topic, power-down functional description for more details about power-down control.

The auxiliary analog functions of the GSM baseband A/D and D/A conversions are independently powered from the AV_{DD5} external terminal.

auxiliary analog converter (automatic gain control (AGC))

The auxiliary analog converter control function includes a register which can be written to using the serial interfaces and a 10-bit D/A converter that provides a control signal to set the gain of the RF section receive amplifier. The 10-bit D/A converter is accessed through the internal register AUXAGC.

Power down is controlled with two bits. The first bit (AGCW of AUXCTL2 register) determines whether the AGC can be powered down with the external GSM receive window activation (BDLON). The second bit (AGCPD of AUXCTL2 register) controls the activation of AGC function. See the topic, power-down functional description for more details about power-down control.

The auxiliary analog functions of the GSM baseband A/D and D/A conversions are independently powered from the AV_{DD5} external terminal.

PRINCIPLES OF OPERATION

RF power control

The RF power control section includes a register that is written to using the serial interfaces. An 8-bit D/A converter processes the content of this register and determines the gain of the RF section power amplifier.

The reference of the 8-bit D/A converter (accessed by register AUXAPC) is provided by the ramp-up-shaper D/A converter, which is a 5-bit D/A converter controlled by the APCRAM registers located in random access memory (RAM). This area of RAM contains sixty-four 10-bit words. These are read from address 0 through address 62 during the ramp-up sequence. They are read from 63 through 1 during the ramp-down sequence at a rate of 4 MHz when bit APCSPD is at zero or at a rate of 2 MHz when bit APCSPD is at 1. The ramp-up parameters are obtained from the five least significant bits of the RAM words. The ramp-down parameters are obtained from the most significant bits of the RAM words. Content of address 0 must be identical with content of address 1. Content of address 62 must be identical with content of address 63.

This RAM is loaded once, and its content determines the shape of the ramp-up and ramp-down control signal. This means these control signals can be adapted to the response of the power amplifier used in the RF section. The shape and timing of ramp-up and ramp-down waveforms are independent.

Timing of the ramp-up and ramp-down sequences is controlled internally; however, programming of the delay register allows adjusting the power-control start time in a 4-bit range in 1/4-bit steps. The contents of the delay register are referenced to the BENA signal, which determines the beginning of the burst-signal modulation. This feature allows adjusting the timing of the control signal versus the I and Q components within 1/4-bit accuracy as defined in the specification GSM 05.05.

When APC is in power-down mode or when APC level is zero, the analog output is driven to V_{SS}; see Figure 12. During inactivity periods, the APC output is switched to V_{SS} to give low-current consumption to the power amplifier (drain cutoff current of the RF amplifier);

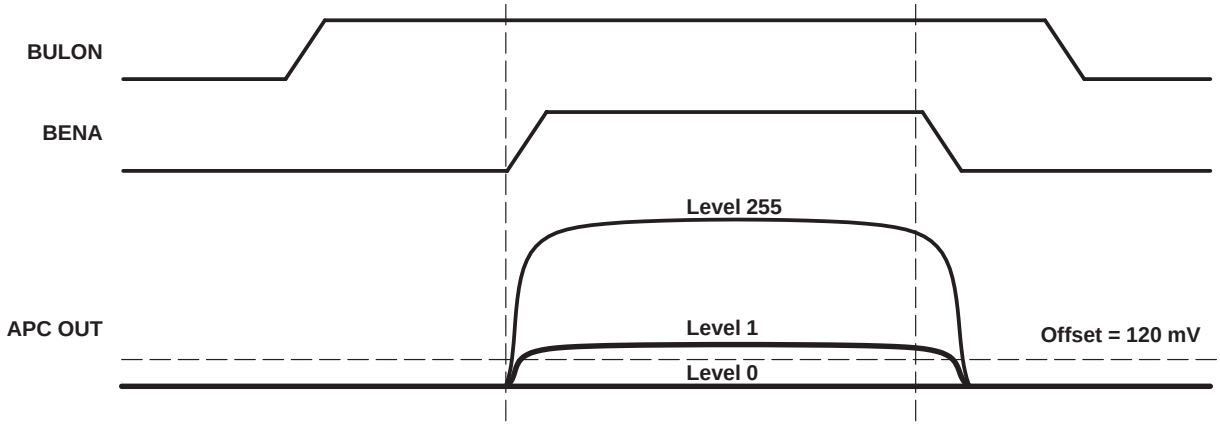


Figure 12. APC Output When APCMODE = 0

An offset of typically 120 mV (2 V swing) is added to the APC output to ensure level DAC linearity. Bit APCMODE controls how this offset is added. When APCMODE is zero the APC output is given by

APCout = Shape value * (Level value + Offset)

PRINCIPLES OF OPERATION

RF power control (continued)

When APCMODE is one (see Figure 13) the APC output is given by formula

APCout = (Shape value * Level value) + Offset

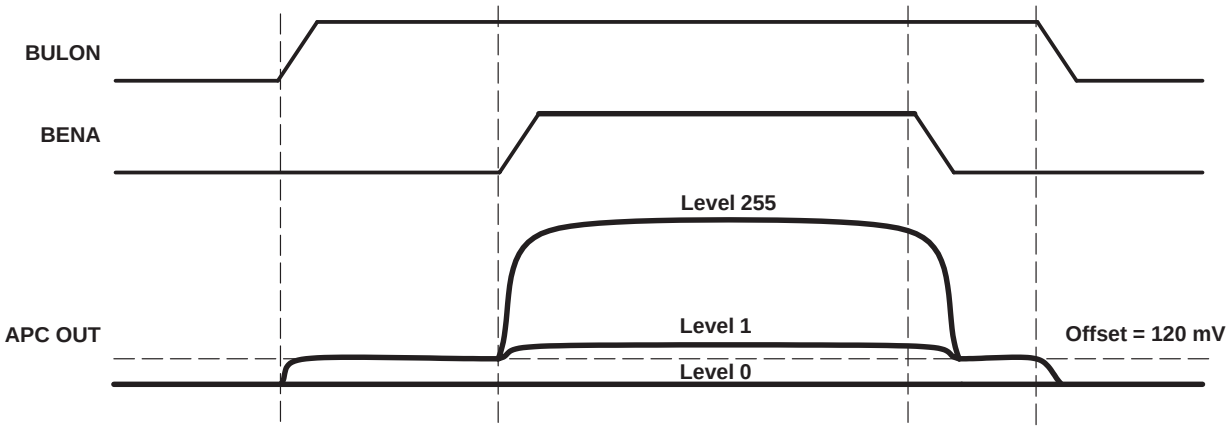


Figure 13. APC Output When APCMODE = 1

Power down is controlled with two bits. The first bit (APCW of AUXCTL2 register) determines whether the APC can be powered down by activating external GSM transmit window activation (BULON): The second bit (APCPD of AUXCTL2 register) controls the activation of APC function. See the topic, *power-down functional description*, for more details about power-down control. The auxiliary analog functions of the GSM baseband A/D and D/A conversions are independently powered from the AV_{DD5} terminal.

monitoring

The monitoring section includes a 10-bit A/D converter and one result register that allows monitoring of five external analog values such as the temperature and the battery voltage. The selection of the input and reading of the control registers is done using the serial interfaces.

The selection of the input channel is done with the bits ADCCH0 – ADCCH2 of the AUXCTL1 register; the data is read from the AUXADC register. Power down is controlled with two bits. The first bit (ADCPN of AUXCTL1 register) determines whether the A/D converter can be powered down from the external PWRDN terminal. The second bit (ADCPD of AUXCTL1 register) controls the activation of the A/D conversion function. See the topic, *power-down functional description*, for more details about power-down control.

Conversion is started with a write access to the AUXCTL1 register. During the conversion, the ADCEOC bit of BSTATUS register stays at 1 and resets to 0 when the converted data is loaded into the AUXADC register. This way the power consumption of the main parts of the converter is limited to the useful part of the conversion time.

PRINCIPLES OF OPERATION

voice codec

The voice coder/decoder (codec) circuitry processes analog audio components in the uplink path and applies this signal to the voice signal interface for eventual baseband modulation. In the downlink path, the codec circuitry changes voice-component data received from the voice serial interface into analog audio. The following paragraphs describe these uplink/downlink functions in more detail.

voice uplink path

The voice uplink path includes two input stages; refer to Figure 14. The first stage is a microphone amplifier, compatible with an electret-type microphone, that contains a FET-buffer with an open-drain output, that has a gain of typically 27 dB, and provides an external voltage of 2 V to 2.5 V to bias the microphone. The auxiliary audio input can be used as an alternative source for a higher level speech signal. This stage performs single-ended to differential conversion and provides a gain of 6 dB. When auxiliary audio input is used, the microphone input is disabled and powered down. If both microphone and auxiliary amplifiers are powered up at the same time, only the signal of the microphone amplifier will be transmitted to the voice uplink path.

The resulting fully differential signal is fed to a programmable gain amplifier that allows adjustment of the level of the speech signal to the dynamic range of the A/D converter, which is determined by the value of the internal voltage reference. Programmable gain can be set from –12 dB to +12 dB in 1-dB steps. It is programmed with bits VULPG to VULPG4 of VBCTL1 register.

Analog-to-digital conversion is made with a third-order sigma-delta modulator whose sampling rate is 1 MHz. Output of the A/D converter is fed to a speech digital filter, which performs the decimation down to 8 KHz and band limits the signal with both low-pass and high-pass transfer functions. The speech samples are then transmitted to the DSP, using the voice serial interface, at a rate of 8 kHz.

Programmable functions of the voice uplink path, power-up, input selection and gain are controlled by the DSP or the MCU using the serial interfaces. The uplink voice path can be powered down with the bit VULON of the VBCTL1 internal register.

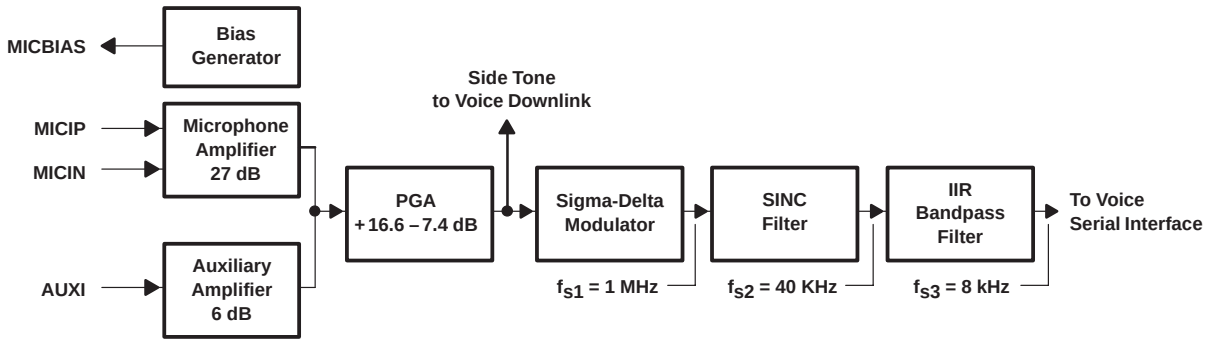


Figure 14. Uplink Path Block Diagram

PRINCIPLES OF OPERATION

voice downlink path

The voice downlink path receives speech samples at an 8-kHz rate from the voice serial interface and converts them to analog signals to drive the external speech transducer.

The digital speech coming from the voice serial interface is first fed to a speech-digital infinite-duration impulse response (IIR) filter, which has two functions (see Figure 15). The first function is to interpolate the input signal and increase the sampling rate form 8 kHz up to 1 MHz to permit D/A conversion by an oversampling digital modulator. The second function is to band limit the speech signal, using both low-pass and high-pass transfer functions.

The interpolated and band-limited signal is fed to a second-order sigma-delta modulator and sampled at 1 MHz to generate a 1-bit oversampled signal that drives a 1-bit D/A converter.

Due to the oversampling conversion, the analog signal obtained at the output of the one-bit D/A converter is mixed with high frequency noise. This noise is filtered by a switched-capacitor third-order low-pass filter and the remaining signal is fed to a programmable gain amplifier (PGA) to adjust the volume control. Volume control is done in 6-dB steps from 0 dB through –24 dB; in the mute state, attenuation is higher than 40 dB. A fine adjustment of gain is possible from –6 to +6 dB in 1-dB steps to calibrate the system, depending on the earphone characteristics. This configuration is programmed using the VBCTL2 register.

The PGA output is fed to two output stages: the earphone amplifier that provides a full differential signal on the terminals EARP/EARN and an auxiliary output amplifier that provides a single-ended signal on terminal AUXO. Both earphone and auxiliary output amplifiers can be active at the same time. The downlink voice path can be powered down with bit VDLON of the VBCTL2 internal register.

A side-tone path is connected between the output of the voice uplink PGA and the input of the voice downlink PGA. This path provides seven programmable gains (+1 dB, –2dB, –5 dB, –8 dB, –11 dB, –14 dB, –17 dB, –20 dB, –23 dB) and one mute position. Side-tone path gain can be selected by a programming bit at register address 23.

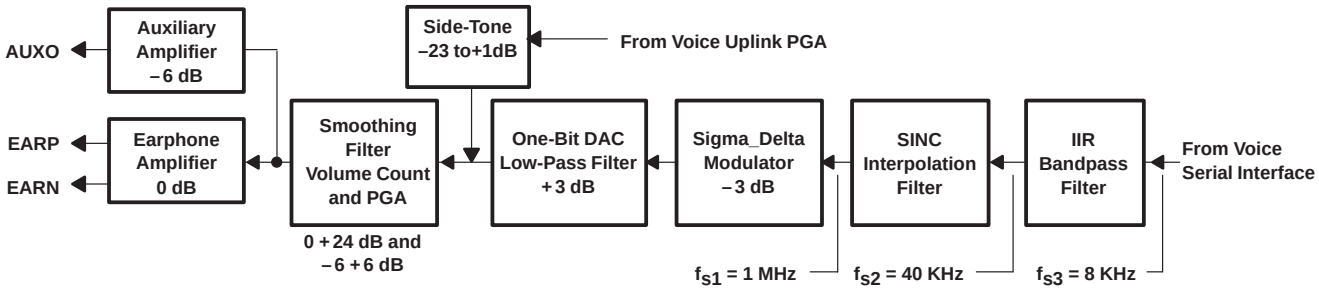


Figure 15. Downlink Path Block Diagram

PRINCIPLES OF OPERATION

DAI interface

This digital audio interface (DAI) consists of four terminals: SSRST, SSCLK, SSDR, and SSDX. It is compatible with the digital audio interface described in the GSM recommendation 11.10. This interface is designed to offer minimum CPU overhead during audio tests and speech transcoding tests and to minimize the extra hardware and the number of external terminals of the mobile system (MS). With this interface the DSP does not have to deal with rate adaptation. In normal operation the DSP works with an 8-kHz sampling rate with a 16-bit word format and frame synchronization, but the DAI interface works with an 8-kHz sampling rate with a 13-bit word format without frame synchronization. The DSP (or the MCU) does not have real time constraints with SSRST, since the reset of the internal transmitters is done automatically.

The DAI is controlled with four internal bits of VBCTL3 register:

DAION: When 0, the DAI block is put in low power. When 1, the DAI block is active.

VDAI: This bit controls the start of the clock SSCLK. The falling edges of SSRST automatically resets the VDAI.

DAIMD 0/1: These two bits are used to switch the internal data path of the three types of DAI tests:
Tests of acoustic performance of the uplink/downlink voice path
Tests of speech decoder/DTX functions (downlink path)
Tests of speech encoder/DTX functions (uplink path)

In order to correctly execute these tests, the bits DAION/VULON/VDLON must be reset before starting the DAI test. In the case of acoustic tests the following must be set with the sequence: DAION and VDAI, then VULON, and finally VDLON. In case of vocoder tests, when the speech samples are ready to be exchanged with the system simulator, the bits DAION and VDAI must be set at the same time.

PRINCIPLES OF OPERATION

JTAG interface

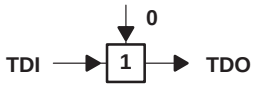
TCM4400E provides a JTAG interface according to IEEE Std1149.1. This interface uses five dedicated IOs: TCK (test clock), TMS (test mode select), TDI (scan input), TDO (scan output), and TRST (test reset). Inputs TMS,TDI, and TRST contain a pullup device which makes their state high when they are not driven. Output TDO is a 3-state output which is Hi-Z except when data are shifted between TDI and TDO. TRST input is intended for proper initialization of the state machine test access port (TAP) and boundary scan cells. System RESET is sent into the device through a boundary-scan register, which has to be initialized by TRST to allow the RESET signal to be propagated into the device; a good practice should be to connect RESET and TRST terminals together.

standard user instructions available.

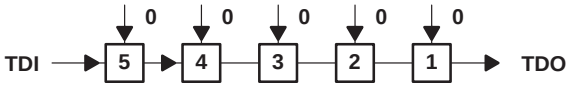
NAME	OPCODE	DESCRIPTION
BYPASS	11111	Connects the by-pass register between TDI and TDO.
SAMPLE/PRELOAD	00010	Connects the boundary scan register between TDI and TDO. This mode captures a snapshot of the state of the digital I/Os of the device.
EXTEST	00000	Connects the boundary scan register between TDI and TDO. This mode captures the state of the input terminals and forces the state of the output pins. This mode is intended for printed-circuit board connections testing between devices.
IDCODE	00001	Connects the identification register between TDI and TDO. This is the default configuration at reset.
INTEST	00011	Connects the boundary scan register between TDI and TDO. This mode forces the internal system input signals via the parallel latches of the boundary register and captures internal system outputs. The mode performs device internal tests independently of the state of its input terminals. In this mode the internal system master clock is derived from TCK and is active in the run-test-idle state of the state machine to allow step-by-step operation of the device.

JTAG interface scan chains description

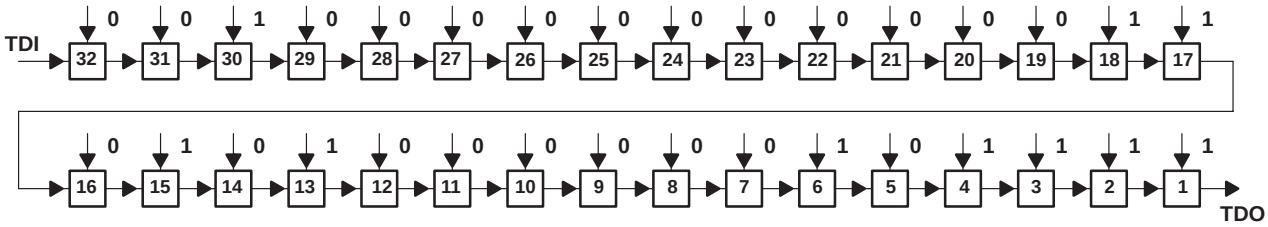
bypass register



instruction register

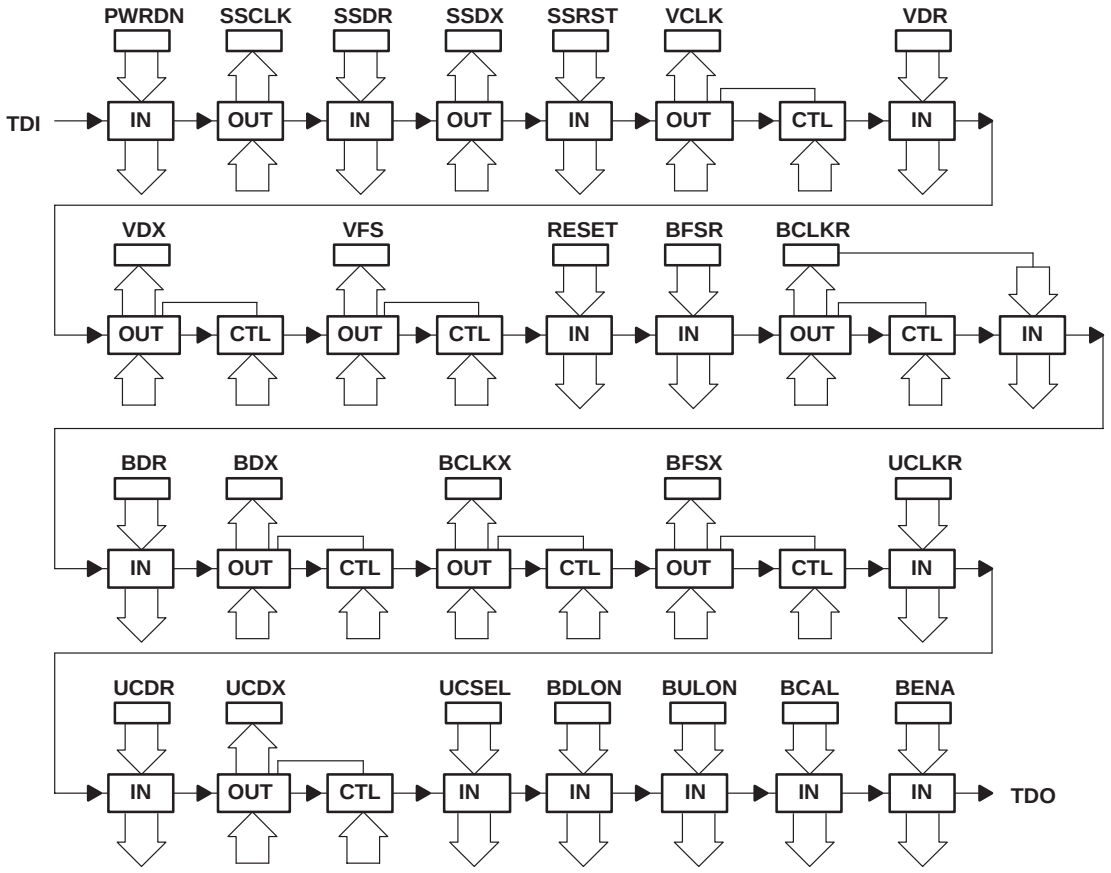


identification register



PRINCIPLES OF OPERATION

boundary scan register



power-down functional description

During certain mobile activity (such as paging, conversation mode, or idle) it is possible to disable some TCM4400E functions in order to lower the power consumption. For example, it is possible to disable the internal functions dedicated to radio transmission during GSM-idle mode. It is also possible to disable the internal demodulator path during transmit window.

There are three ways to control the power consumption of the internal blocks as described in the following paragraphs.

direct control with internal register

With this method these internal blocks are powered down:

- DAI GSM tests: bit DAION of register VBCTL3
- Transmit and receive voice path: bit VULON of register VBCTL1 and bit VDLON of register VBCTL2

PRINCIPLES OF OPERATION

radio window activation control

These internal blocks are powered up with the control of two bits. The first bit enables the window control of the block activity; the second bit enables the power down.

First bit (PN): If cleared to 0, the function is powered down with the control of the corresponding GSM window (BDLON/BULON terminal). If this first bit is set to 1, the power down is only controlled by the second bit.

Second bit (PD): This bit is functionally associated with the first one. When this bit is loaded with 1, the function is in power-down mode.

During transmit windows designated by the activity of the BULON terminal:

- Automatic power control (APC): bits APCW and APCPD of register AUXCTL2 are paired.
- Baseband uplink path: bits BBULW and BBULPD of register PWDNRG1 are paired.
- External reference voltage buffers VMID: bits VMIDW and VMIDPD are paired.

During receive windows designated by the activity of the BDLON terminal:

- Automatic gain control (AGC): bits AGCW and AGCPD of register AUXCTL2 are paired.
- Baseband downlink path: bits BBDLW and BBDLPD of register PWDNRG1 are paired.

external terminal PWRDN control

These internal blocks are powered under the control of two bits. The first bit enables the external terminal PWRDN control of the block activity, the second bit enables the power down. Terminal PWRDN is active high.

First bit (PN): If cleared to 0, the function is powered down with the control of PWRDN terminal. If this first bit is set to 1, the power down is only controlled by the second bit (PD).

Second bit (PD): This bit is functionally associated with the first one. When this bit is set to 1, the function is in power-down mode.

- For the digital serial interface to the DSP, bits BBSIPN and BBSIPD of register PWDNRG2 are paired.
- For the timing interface, bits TIMGPN and TIMGPD of register PWDNRG2 are paired.
- For the auxiliary A/D converters, bits ADCPN and ADCPD of register AUXCTL1 are paired.
- For the automatic frequency control (AFC) block, bits AFCPN and AFCPD of register AUXCTL1 are paired.
- For the external reference voltage buffers MICBIAS, bits VREFPN and VREFPD of register PWDNRG2 are paired.
- For the internal reference band-gap buffers, bit VGAPPN determines whether the bandgap power down is under control of the PWRDN bit.

PRINCIPLES OF OPERATION

DSP voiceband serial interface

Voiceband serial digital interface consists of a bidirectional serial port. Both receive and transmit operations are double buffered, thus allowing a continuous communication stream. The serial port is fully static and, thus, functions with any arbitrary low-clocking frequency.

The transfer mode available on this port is:

Clock frequency	520 kHz	16-bit data packet	frame synchronization

VCLK is the output serial clock used to control the transmission or reception of the data, (see Figure 5). VCLK can run in burst mode or continuous mode, depending on the VCLKMODE bit. The transmitted serial data (VDX) is the serial data output; the frame synchronization (VFS) is used to initiate the transfer of transmit and receive data. The received data (VDR) is the serial data input.

Each serial port includes four registers: the data transmit register (DXR), the data receive register (DRR), the transmit shift register (XSR), and the receive shift register (RSR).

The voice serial interface has the same structure and timing diagram as the serial interface. One extra cycle is generated before VFS, and two extra cycles are generated after the least significant bit (see Figure 5).

PRINCIPLES OF OPERATION

voltage references

Voltage and current generators are integrated inside the GSM converter. Some additional components are required for the decoupling and regulation of the internal references. In addition, the internal buffers are automatically shut down with the corresponding functions being powered down.

There are six terminals reserved for voltage references decoupling and use: VGAP, IBIAS, VREF, MICBIAS, and VMID (see Table 1):

VGAP: This terminal is connected to the internal band gap reference voltage. It must be externally connected to a 0.1-µF capacitor. The band gap drives the current generator and the voltage reference. This bandgap may be powered down by the PWRDN pin, depending on bit VGAPPN of register PWDNRG2.

IBIAS: This terminal is connected to the current reference. It must be externally connected to a 100 kΩ resistor. As this block is connected to the AFC function, the power down is controlled with similar means. The current generator is shut down with the same bits as the band gap – one bit for the power down selection of a hardware solution (with the external PWRDN terminal).

VREF: This terminal is connected to the internal reference voltage. It must be externally connected to a 0.1-µF capacitor. This band gap may be powered down with the control of the bits VREFPN and VREFPD of the register PWDNRG2. This voltage reference is internally connected to three buffers corresponding to the blocks of speech downlink, speech uplink, and GMSK downlink. The two first blocks are powered down with the inactivity of the corresponding speech blocks. This last block is shut down outside the radio downlink activations.

VMID: This buffer gives the $V_{DD}/2$ or 1.35 V common-mode output voltage of the baseband uplink path. This voltage value is selected with the SELVMID bit.

MICBIAS: This buffer is designed to drive an electret-type microphone. The output voltage can be chosen by software (bit MICBIAS of VBCTL1 register) between the value 2 V to 2.5 V.

ADCMID: For decoupling purposes, the ADCMID terminal is connected to the internal comparison threshold of the ADC. Setup time before the ADC is powered on is dependent on the value of the external decoupling capacitor.

Table 1. Voltage References

REFERENCE	VOLTAGE	DEFINITION
VGAP	1.22 V	Band gap used for all other references
VREF	1.75 V	Voltage reference of GMSK internal ADC and DAC
VMID	$AV_{DD2}/2$	Common-mode reference for uplink/downlink GMSK
MICBIAS	2 V / 2.5 V	Microphone-driving voltage
ADCMID	$A_{VDD3}/2$	Voltage dc biasing of the auxiliary ADCs

PRINCIPLES OF OPERATION

MCU serial baseband digital interface

The GSM baseband and voice A/D and D/A conversion provide two digital serial 16-bit interfaces intended for use with the DSP and a microcontroller device. Through this interface a microcontroller can access all the internal registers that can be accessed through the DSP digital serial interface.

This option is intended for an application in which a part of layer-1 software is implemented into the microcontroller needs access to some functions implemented into the GSM baseband and voice A/D and D/A conversion circuitry.

serial interface

The microcontroller serial interface is designed to be compliant with 8-bit standard synchronous serial ports. This interface consists of four terminals (see Figure 3 for timing diagram).

UCLK: A clock provided by the microcontroller to GSM baseband and voice A/D and D/A conversion

UDR: An input terminal of the GSM baseband and voice A/D and D/A components intended for reception of data

UDX: An output terminal of the GSM baseband and voice A/D and D/A components intended for transmission of data

USEL: An input terminal of GSM baseband and voice A/D and D/A components intended for activation of the serial interface

When USEL = V_{DD}, the serial interface is deactivated and UDX is placed in a high-impedance state. A high level on USEL resets the internal serial interface; the 16-bit transfers must be completed with USEL = V_{SS}.

The external MCU initiates data transfer by driving the selection terminal and sending a clock signal. For both the GSM baseband and voice A/D and D/A components, the MCU data is shifted out of the shift registers on one edge of the clock and latched into the shift registers on the opposite clock edge.

As a result, both controllers send and receive data simultaneously. For the MCU portion, the software determines whether the data is meaningful or dummy data. On the GSM baseband and voice A/D and D/A conversion portion, dummy data is data with all zeroes.

The 16-bit word data format is identical to the DSP data format. After a read-register command, there is a sequential transfer delay between two 16-bit word acquisitions to let the internal sequencer extract the data going from internal registers to the serial shift register.

Three internal bits control the data serial flow as follows:

- UDIR determines whether data is transferred with MSB or LSB first.
- UPOL determines the polarity of the clock.
- UPHA determines the insertion of a half-clock period in the data serial flow.

With UPOL and UPHA there are four clock schemes (see Table 2):

- Falling edge without delay. The MCU serial interface transmits data on the falling edge of the UCLK and receives data on the rising edge of the UCLK.
- Falling edge with delay. The MCU serial interface transmits data one half-cycle ahead of the falling edge of the UCLK and receives data on the falling edge of the UCLK.
- Rising edge without delay. The MCU serial interface transmits data on the rising edge of the UCLK and receives data on the falling edge of the UCLK.
- Rising edge with delay. The MCU serial interface transmits data one half-cycle ahead of the rising edge of the UCLK and receives data on the rising edge of the UCLK.

PRINCIPLES OF OPERATION

serial interface (continued)

Table 2. Microcontroller Clocking Schemes

UPOL	UPHA	MCU CLOCKING SCHEME
1	1	Falling edge without delay
1	0	Falling edge with delay
0	1	Rising edge without delay
0	0	Rising edge with delay

DSP/MCU serial interface

The DSP/MCU serial interface not only configures the GSM baseboard and voice A/D and D/A conversion but also transmits data to the DSP during downlink burst reactions. The following paragraphs describe the operation of the serial interface in more detail.

DSP serial digital interface

The DSP serial digital interface (Figure 16) is used to transfer the baseband transmit and receive data, and it is also used to access all internal programming registers of the device (baseband codec, voice codec, and auxiliary RF functions). The format for the serial interface is 16 bits.

The baseband serial digital interface is a bidirectional (transmit/receive) serial port. Both receive and transmit operations are double buffered and permit a continuous communication stream (16-bit data packets). The serial port is fully static and functions with any arbitrary, low-clocking frequency.

Six terminals are used for the serial port interface (see Figure 4 for timing diagram). BCLKR is an I/O port for the serial clock used to control the reception of the data BDR. At reset BCLKR is configured as an output and the clock frequency is set to MCLK/3 (4.333 MHz with MCLK = 13 MHz); the clock signal is running permanently. The port BCLKR can be reconfigured as an input by programming an internal register. In this case BCLKR is provided by the DSP. It can run in burst mode to reduce power consumption. The receive frame synchronization (BFSR) is used to identify the beginning of a data packet transfer on port BDR.

The transmitted serial data (BDX) is the serial data input; the transmit frame synchronization (BFSX) is used to initiate the transmission of data. The transmit clock (BCLKX) is provided by the GSM baseband and voice A/D and D/A converters with a MCLK frequency. The clock signal BCLKX can run in burst mode or continuous mode, depending on the BCLKMODE bit. The downlink data bus (BFSX, BCLKX, BDX) can be driven to VSS or placed in a high-impedance state when no data is to be transferred to the DSP. The BCLKDIR bit of the BCTLREG register controls the direction of the BCLKR clock.

As with the voice serial interface, on extra clock cycle must be generated because the last 16-bit word received on the DSP serial interface is latched on the next two falling BCLKR edges following the LSB. As for the voice serial interface, one extra clock period is generated on the BCLKX before the first synchronization BFSX of the downlink data sequence.

PRINCIPLES OF OPERATION

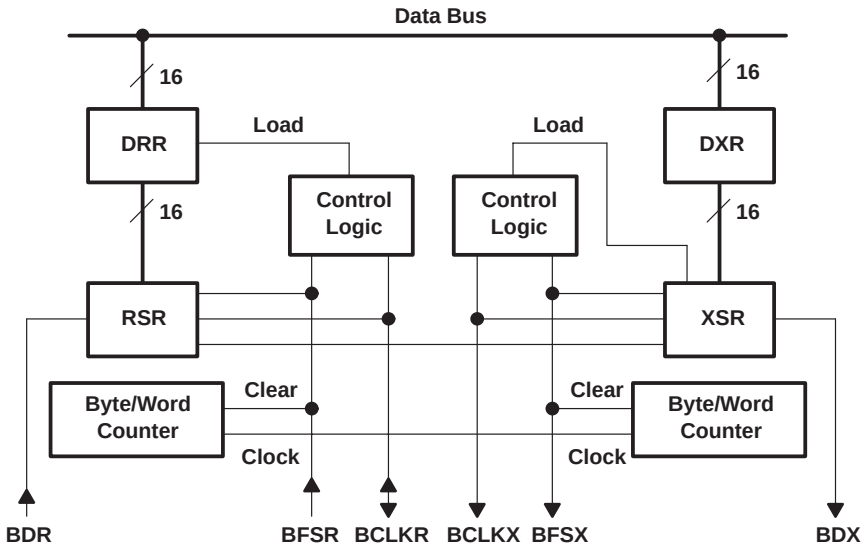


Figure 16. DSP Serial Digital Interface

timing interface

The timing interface performs accurate timing control of baseband uplink and downlink paths. The timing interface is a parallel asynchronous port with four control signals, refer to Figure 17. The BDLON bit controls power on the downlink path of the baseband codec; the BULON bit controls power on the uplink path of the baseband codec, and the BCAL bit controls the calibration of the active parts of the baseband codec selected by BULON or BDLON.

The BENA bit controls the transmission of the reception of burst depending on which part of the baseband codec is selected by the signals BULON or BDLON. These asynchronous inputs are internally synchronized with the uplink and downlink internal clocks and stored in timing register TR. The timing register, TR, is a 6-bit register containing the bits defined in Table 3.

Table 3. 6-Bit TR Register

BIT5	BIT4	BIT3	BIT2	BIT1	BIT0
ULON	ULCAL	ULSEND	DLON	DLCAL	DLREC

TR bit signification

ULON: If set to 1, this bit turns on the uplink path of the baseband codec; if cleared to 0, the uplink path is in power-down mode.

ULCAL: When this bit is set to 1, the uplink offset autocalibration is active.

ULSEND: A transition from 0 to 1 of ULSEND initiates the emission of a burst. The burst information data, burst length, and power level need to be loaded in the corresponding registers using the serial interface.

DLON: If set at 1, this bit turns on the downlink path of the baseband codec; if cleared to 0, the downlink path is in power-down mode.

DLCAL: When this bit is set at 1, the downlink offset autocalibration is active.

DLREC: A transition from 0 to 1 of DLREC initiates the transmission of data from the baseband codec to the DSP using the serial interface.

PRINCIPLES OF OPERATION

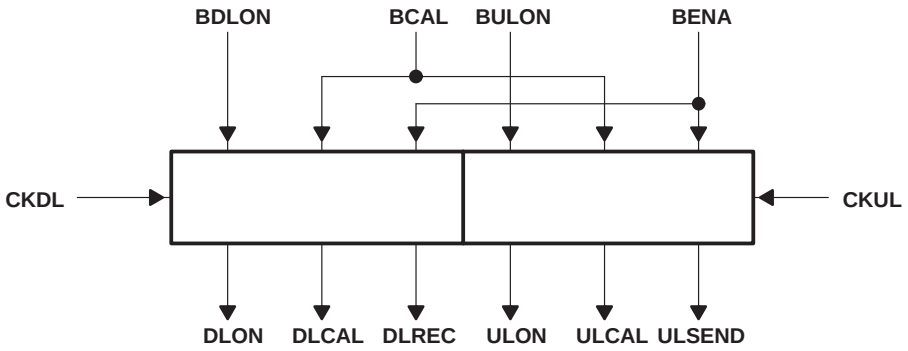


Figure 17. Timing Interface

DSP/MCU serial interface operation and format

The DSP/MCU serial interface configures the GSM baseband, the voice A/D and D/A converters (read and write operation in internal registers), and transmits RF data to the DSP during the reception of a burst by the downlink path of the GSM baseband and voice A/D and D/A circuitry.

During reception of a burst (bit DLR of the status register is 1) and DSP serial interface and associated internal bus are dedicated to the transfer of RF data from the GSM baseband A/D and D/A converters to the DSP. During this period only a write operation of internal registers can be done through the DSP serial interface. However, all registers can be accessed by the serial MCU interface.

During transmission of a burst (bit ULX of the status register is 1) no read or write operation can be done in the registers of the baseband uplink part of the GSM baseband, APC RAM, and APC shape register.

Writing or reading registers using the serial interface is done by transferring 16-bit words to the serial interface. Each word is split into three fields as shown in Table 4.

Table 4. Read/Write Data Word

DATA										ADDRESS					R/W
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	1 / 0

When writing to internal registers observe the following convention:

Bit 0 : A 0 indicates a write operation.

Bits 1 to 5 : This field contains the address of the register to be accessed.

Bits 6 to 15 : This field contains the data to be written into the internal register.

When reading from internal registers observe the following convention:

Bit 0 : A 1 indicates a read operation.

Bits 1 to 5 : This field contains the address of the register to be accessed.

Bits 6 to 15 : This field is an irrelevant status in a read request operation.

PRINCIPLES OF OPERATION

Read operation from the downlink baseband codec is done using the TX part of the DSP/MCU serial interface in the following 16-bit word format given in Table 5.

Table 5. 16-Bit Word Format

DATA										ADDRESS					
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
D9	D8	D7	D6	D5	D4	D3	D2	D1	D0	A4	A3	A2	A1	A0	0

During reception of a burst, transfer of RF data from the downlink baseband codec is done using the transmit part of the DSP serial interface in the following 16-bit word format: As the I and Q samples are coded with 16-bit words, the data rate is $270833 \times 16 \times 2$ which equals 8.66 Mbps. I & Q samples are differentiated by setting the LSB to zero for I samples and to one for Q samples. Since the digital clock MCLK is 13 MHz, transfer is done at 13 Mbps in burst mode. During burst reception the DSP serial interface is idled about 33% of the time.

Table 6. Format of 16-Bit Word Transfer

DATA															I/Q
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0

DSP/MCU serial interface registers

The following internal register buffers are accessed using the DSP/MCU serial interface during manual operation of the TCM4400E.

baseband uplink ramp delay register

Each bit position of the baseband uplink ramp-delay register is given in Table 7.

Table 7. Uplink Ramp-Delay Register

BULRUDEL: BASEBAND UPLINK RAMP DELAY REG.										ADDRESS: 1					R/W
RESERVD	IBUFPTR	DELD3	DELD2	DELD1	DELD0	DELU3	DELU2	DELU1	DELU0	0	0	0	0	1	1 / 0
R = 0	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	<—— ACCESS TYPE					
0	0	0	0	0	0	0	0	0	0	<——VALUE AT RESET					

DELU0 to DELU3 : Value of the delay of ramp-up start versus the rising edge of BENA

DELD0 to DELD3 : Value of the delay of ramp-down start versus the falling edge of BENA

IBUFPTR : Writing a 1 in this bit initializes the pointer of the burst buffer to the base address. (This is not a toggle bit and has to be set back to 0 to allow writing into the burst buffer).

RESERVD : Reserved bits for testing purposes

R/W : A 1 indicates a read operation; a 0 indicates a write operation.

PRINCIPLES OF OPERATION

baseband uplink data buffer

The baseband uplink data buffer is used to transmit the uplink burst data. The uplink data buffer contents are shown in Table 8.

Table 8. Uplink Data Buffer

BULDATA: BASEBAND UPLINK DATA BUFFER										ADDRESS: 2 (16 WORDS)					W
BIT0	BIT1	BIT2	BIT3	BIT4	BIT5	BIT6	BIT7	BIT8	BIT9	0	0	0	1	0	0
BIT10	BIT11	BIT12	BIT13	BIT14	BIT15	BIT16	BIT17	BIT18	BIT19	0	0	0	1	0	0
BIT20	BIT21	BIT22	BIT23	BIT24	BIT25	BIT26	BIT27	BIT28	BIT29	0	0	0	1	0	0
BIT30	BIT31	BIT32	BIT33	BIT34	BIT35	BIT36	BIT37	BIT38	BIT39	0	0	0	1	0	0
BIT40	BIT41	BIT42	BIT43	BIT44	BIT45	BIT46	BIT47	BIT48	BIT49	0	0	0	1	0	0
BIT50	BIT51	BIT52	BIT53	BIT54	BIT55	BIT56	BIT57	BIT58	BIT59	0	0	0	1	0	0
BIT60	BIT61	BIT62	BIT63	BIT64	BIT65	BIT66	BIT67	BIT68	BIT69	0	0	0	1	0	0
BIT70	BIT71	BIT72	BIT73	BIT74	BIT75	BIT76	BIT77	BIT78	BIT79	0	0	0	1	0	0
BIT80	BIT81	BIT82	BIT83	BIT84	BIT85	BIT86	BIT87	BIT88	BIT89	0	0	0	1	0	0
BIT90	BIT91	BIT92	BIT93	BIT94	BIT95	BIT96	BIT97	BIT98	BIT99	0	0	0	1	0	0
BIT100	BIT101	BIT102	BIT103	BIT104	BIT105	BIT106	BIT107	BIT108	BIT109	0	0	0	1	0	0
BIT110	BIT111	BIT112	BIT113	BIT114	BIT115	BIT116	BIT117	BIT118	BIT119	0	0	0	1	0	0
BIT120	BIT121	BIT122	BIT123	BIT124	BIT125	BIT126	BIT127	BIT128	BIT129	0	0	0	1	0	0
BIT130	BIT131	BIT132	BIT133	BIT134	BIT135	BIT136	BIT137	BIT138	BIT139	0	0	0	1	0	0
BIT140	BIT141	BIT142	BIT143	BIT144	BIT145	BIT146	BIT147	BIT148	BIT149	0	0	0	1	0	0
BIT150	BIT151	BIT152	BIT153	BIT154	BIT155	BIT156	BIT157	BIT158	BIT159	0	0	0	1	0	0
W	W	W	W	W	W	W	W	W	W	<——ACCESS TYPE					
1	1	1	1	1	1	1	1	1	1	<——VALUE AT RESET					

Bit 0 – Bit 159 are the bits composing the sequence of the transmitted burst, bit 0 is transmitted first. For a normal burst, the uplink data buffer is loaded as follows:

Bit 0 to 3 : 4 guard bits

Bit 4 to 6 : 3 tail bits

Bit 7 to 66 : 58 data bits

Bit 67 to 92 : 26 training sequence bits

Bit 93 to 92 : 58 training sequence bits

Bit 151 to 153 : 3 tail bits

Bit 154 to 159 : 8 guard bits

At reset and after each transmission, the burst buffer is reinitialized with guard bits (all bits = 1). An address pointer is incremented after each word written into the buffer so that next write operation affects the next word of the buffer. This address pointer is set to the base address (Word 0) by a RESET, after transmission of a burst or by setting the IBUFPTR bit to 1(this bit has to be set back to zero to release the address pointer).

PRINCIPLES OF OPERATION

baseband uplink I and Q offset registers

The baseband uplink I and Q offset registers contain the offset values for the I and Q components, respectively, as shown in Tables 9 and 10.

Table 9. Uplink I Offset Register

BULIOFF: BASEBAND UPLINK I OFFSET REGISTER										ADDRESS: 3					R/W
RESERVD	ULIOFF8	ULIOFF7	ULIOFF6	ULIOFF5	ULIOFF4	ULIOFF3	ULIOFF2	ULIOFF1	ULIOFF	0	0	0	1	1	1/0
R	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	<–ACCESS TYPE					
0	0	1	1	1	1	1	1	1	1	<–VALUE AT RESET					

ULIOFF0 to ULIOFF1 : Integration bits during calibration (to minimize sensitivity to noise)

ULIOFF2 to ULIOFF8 : Value of the offset on I channel

RESERVD : Reserved bits for testing purposes

R/W : A 1 indicates a read operation; a 0 indicates a write operation.

Table 10. Uplink Q Offset Register

BULQOFF: BASEBAND UPLINK Q OFFSET REGISTER										ADDRESS: 4					R/W
RESERVD	ULQOFF8	ULQOFF7	ULQOFF6	ULQOFF5	ULQOFF4	ULQOFF3	ULQOFF2	ULQOFF1	ULQOFF0	0	0	1	0	0	1/0
R	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	<–ACCESS TYPE					
0	0	1	1	1	1	1	1	1	1	<–VALUE AT RESET					

ULQOFF0 to ULQOFF1 : Integration bits during calibration (to minimize sensitivity to noise)

ULQOFF2 to ULQOFF8 : Value of the offset on Q channel

RESERVD : Reserved bits for testing purposes

R/W : A 1 indicates a read operation; a 0 indicates a write operation.

baseband uplink I and Q D/A conversion registers

The I and Q component values generated by the I and Q uplink D/A converter during the conversion of analog data are written to and read from the uplink I and Q D/A converter registers as shown in Tables 11 and 12.

Table 11. Uplink I DAC Register

BULIDAC: BASEBAND UPLINK I DAC REGISTER										ADDRESS: 6					R/W
RESERVD	RESERVD	RESERVD	RESERVD	RESERVD	RESERVD	RESERVD	RESERVD	RESERVD	RESERVD	0	0	1	1	0	1/0
R	R	R	R	R	R	R	R	R	R	<–ACCE0S TYPE					
0	0	0	0	0	0	0	0	0	0	<–VALUE AT RESET					

RESERVD : Reserved bits for testing purposes

PRINCIPLES OF OPERATION

Table 12. Uplink Q DAC Register

BULQDAC: BASEBAND UPLINK Q DAC REGISTER										ADDRESS: 5					R/W
RESERVD	RESERVD	RESERVD	RESERVD	RESERVD	RESERVD	RESERVD	RESERVD	RESERVD	RESERVD	0	0	1	0	0	1/0
R	R	R	R	R	R	R	R	R	R	<–ACCE0S TYPE					
0	0	0	1	1	1	1	1	1	1	<–VALUE AT RESET					

RESERVD : Reserved bits for testing purposes

Power down register No. 2

The values in each bit position of power-down register No. 2 have the meaning outlined in Table 13.

Table 13. PWDNRG2 Register

PWDNRG2: REGISTER FOR POWERING DOWN										ADDRESS: 8					R/W
RESERVD	RESERVD	TIMGPN	TIMGPD	BBSIPN	BBSIPD	VGAPPN	CHGUP	VREFPN	VREFPD	0	1	0	0	0	1/0
R = 0	R = 0	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	<–ACCESS TYPE					
0	0	0	0	0	0	0	0	0	0	<–VALUE AT RESET					

VREFPN: If cleared to 0, the internal reference voltage is powered down under the control of terminal PWRDN and bit VREFPD. If bit VREFPN is set to 1, the power down is only controlled by bit VREFPD.

VREFPD: This bit is functionally associated with bit VREFPN.

VGAPPN: If cleared to 0, the internal reference VGAP is powered down under the control of terminal PWRDN. If this bit is set to 1, the VGAP is not placed in power-down mode.

TIMGPN: If cleared to 0, the internal reference VGAP is powered down under the control of terminal PWRDN. If this bit is set to 1, the power-down control is only controlled by bit TIMPGD

TIMGPD: This bit is functionally associated with bit TIMGPN.

BBSIPN: If cleared to 0, the baseband serial interface is powered down under the control of terminal PWRDN. If this bit is set to 1, the power down is only controlled by bit BBSIPD.

BBSIPD: This bit is functionally associated with bit BBSIPN. When this bit is set to 1, baseband serial interface is in power-down mode.

CHGUP: This bit is used for testing purposes to accelerate the bandgap settling time.

RESRVD: Reserved bits for testing purpose

PRINCIPLES OF OPERATION

power down register No. 1

The values in each bit position of power down register No. 1 have the meaning outlined in Table 14.

Table 14. PWDNRG1 Register

PWDNRG1: REGISTER FOR POWERING DOWN										ADDRESS: 7					R/W
SELVMID	BALOOP	VMIDW	VMIDPD	BBULW	BBULPD	BBDLW	BBDLPD	EXTCAL	BBRST	0	0	1	1	1	1/0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	<–ACCESS TYPE					
0	0	0	0	0	0	0	0	0	0	<–VALUE AT RESET					

BBRST: This is the digital reset of the baseband codec (active at 1); the uplink burst buffer is loaded with all 1s and the memory and registers of the downlink digital filter is cleared to 0. This is not a toggle bit as it has to be set to 0 to remove the reset condition.

EXTCAL: Downlink autocalibration mode (at 0: autocalibration; at 1: external calibration)

BBULW: If cleared to 0, the baseband uplink path is powered down under the control of the GSM transmit window (BULON terminal). If this bit is set to 1, the power down is only controlled by bit BBULPD.

BBULPD: This bit is functionally associated with bit BBULW. When this bit is set to 1, the baseband uplink path is in power-down mode.

BBDLW: If cleared to 0, the baseband downlink path is powered down under the control of GSM receive window (BDLON terminal). If this bit is set to 1, the power down is only controlled by bit BBDLPD.

BBDLPD: This bit is functionally associated with bit BBDLW. When this bit is set to 1, the baseband downlink path is in power-down mode.

VMIDW: If cleared to 0, the VMID output driver is powered down under the control of GSM transmit window (BULON terminal). If this bit is set to 1, the power down is only controlled by bit VMIDPD.

VMIDPD: This bit is functionally associated and paired with bit VMIDW. When VMIDW bit is set to 1, the VMID output driver is active. When VMIDPD bit is set to 1, the VMID output driver is in power-down mode.

BALOOP: When set to 1, the internal analog loop of I and Q uplink terminals are connected to I and Q downlink terminals.

SELVMID: When cleared to 0, this sets the common-mode voltage of the baseband uplink and VMID at $V_{DD}/2$; when set to 1, these voltages are set to 1.35 V.

PRINCIPLES OF OPERATION

baseband control register (see Table 15)

The values in the baseband control register bit positions determine whether the data is shifted left or right. Note that the microcontroller unit (MCU) clocking scheme determines on which edge of the clock that data is received or transmitted using the serial interface.

Table 15. Baseband Control Register

BCTLREG: BASEBAND CONTROL REGISTER										ADDRESS: 9					R/W
RESERVD	RESERVD	RESERVD	MCLKBP	BCLKMODE	BIZBUS	BCLKDIR	UDIR	UPHA	UPOL	0	1	0	0	1	1/0
R = 0	R = 0	R = 0	R /W	R /W	R/W	R/W	R/W	R/W	R/W	<–ACCESS TYPE					
0	0	0	0	0	0	0	0	0	0	<–VALUE AT RESET					

UDIR: This bit determines whether the data is shifted in from right (see serial register description) to left, MSB first (bit value 0), or from left to right, LSB first (bit value 1).

BCLKMODE: When cleared to 0, BLCKX runs in the burst mode; when set to 1, BCLKX is continuous.

MCLKBP: When cleared to 0, MCLK signal passes through the clock slicer; when set to 1, the clock slicer is bypassed (in this case, the signal at the MCLK terminal must be digital).

MCU clocking schemes

Falling edge without delay: The MCU serial interface transmits data on the falling edge of the UCLK and receives data on the rising edge of UCLK.

Falling edge with delay: The MCU serial interface transmits data one half-cycle ahead of the falling edge of the UCLK and receives data on the falling edge of the UCLK.

Rising edge without delay: The MCU serial interface transmits data on the rising edge of the UCLK and receives data on the falling edge of the UCLK.

Rising edge with delay: The MCU serial interface transmits data one half-cycle ahead of the rising edge of the UCLK and receives data on the rising edge of UCLK.

Table 16. MCU Clocking Schemes

UPOL	UPHA	MCU CLOCKING SCHEME
1	1	Falling edge without delay
1	0	Falling edge with delay
0	1	Rising edge without delay
0	0	Rising edge with delay

BCLKDIR: Direction of the BCLKR port (0 –> Output, 1–> Input).

BIZBUS: When set to 1, BDX, BCLKX, BFSX are in hi-Z when there is nothing to transfer to the DSP; when cleared to 0, DBX, BCLKX, BFSX are set to V_{SS} when there is nothing to transfer to the DSP.

RESRVD: Reserved bits for testing purpose

PRINCIPLES OF OPERATION

voiceband uplink control register

The values in the voiceband uplink control register bit positions control not only the power level of the audio in the uplink path but also set the gain of the PGA from –12 dB to 12 dB in 1 dB steps. Bit MICBIAS and VULMIC and VULAUX are shifted by one position to the left. This is shown in Table 17.

Table 17. Voiceband Uplink Control Register

VBCTL1: VOICEBAND UPLINK CONTROL REGISTER										ADDRESS: 10					R/W
VDXMUTE	MICBIAS	VULMIC	VULAUX	VULPG4	VULPG3	VULPG2	VULPG1	VULPG0	VULON	0	1	0	1	0	1/0
R/W	R /W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	<–ACCESS TYPE					
0	0	0	0	0	0	0	0	0	0	<–VALUE AT RESET					

VULON: Power on the uplink path of the audio codec

VULAUX: Enables the auxiliary input amplifier if bit VULON is 1

VULMICL: Enables the microphone input amplifier if bit VULON is 1

MICBIAS: When MICBIAS = 0, the analog bias for the electret-type microphone and external decoupling is driven to 2 V; when the value is 1, the bias is 2.5 V.

VDXMUTE: When VDXMUTE = 1, the VDX output is forced to zero, when the value is 0, VDX is transmitted normally. To avoid cutting a VDX word during transmission due to asynchronism of writing this bit via DSP or MCU serial interface, VDXMUTE is internally resynchronized with the 8 KHz voice frame.

VULPG (0–4): Gain of the voice uplink programmable gain amplifier (–12 dB to 12 dB in 1 dB step), see Table 18.

PRINCIPLES OF OPERATION

Table 18. Uplink PGA Gain

VULPG 4	VULPG 3	VULPG 2	VULPG 1	VULPG 0	RELATIVE GAIN
1	0	0	0	0	–12 dB
1	0	1	1	1	–11 dB
1	1	0	0	0	–10 dB
1	1	0	0	1	–9 dB
1	1	0	1	0	–8 dB
1	1	0	1	1	–7 dB
0	0	0	0	0	–6 dB
0	0	0	0	1	–5 dB
0	0	0	1	0	–4 dB
0	0	0	1	1	–3 dB
0	0	1	0	0	–2 dB
0	0	1	0	1	–1 dB
0	0	1	1	0	0 dB
0	0	1	1	1	1 dB
0	1	0	0	0	2 dB
0	1	0	0	1	3 dB
0	1	0	1	0	4 dB
0	1	0	1	1	5 dB
0	1	1	0	0	6 dB
1	0	0	0	1	7 dB
1	0	0	1	0	8 dB
1	0	0	1	1	9 dB
1	0	1	0	0	10 dB
1	0	1	0	1	11 dB
1	0	1	1	0	12 dB

voiceband downlink control register

The values in the voiceband downlink control register bit positions control the audio power level in the downlink path. Earphone volume is set (three bits VOLCTL0 –VOLCTL2) and PGA gain is set from –6 dB to 6 dB in 1 dB steps. This is shown in Table 19.

Table 19. Voiceband Downlink Control Register

VBCTL2: VOICEBAND DOWNLINK CONTROL REGISTER										ADDRESS: 11					R/W
VDLAUX	VDLEAR	VOLCTL2	VOLCTL1	VOLCTL0	VDLG3	VDLG2	VDLG1	VDLG0	VDLON	0	1	0	1	1	1 / 0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	<–ACCESS TYPE					
0	0	0	0	0	0	0	0	0	0	<–VALUE AT RESET					

VDLON: Power on of the downlink path of the audio codec

VDLEAR: Enables the earphone amplifier if the VDLON bit is 1

VDLAUX: Enables the auxiliary output amplifier if the VDLON bit is 1

VGLG (0–3) 1 dB: Gain of the voice-downlink programmable gain amplifier (–6 dB to 6 dB in 1-dB steps); see Table 20.

PRINCIPLES OF OPERATION

Table 20. Downlink PGA Gain

	VDLG3	VDLG2	VDLG1	VDLG0	RELATIVE GAIN
0	0	0	0	0	–6 dB
1	0	0	0	1	–5 dB
2	0	0	1	0	–4 dB
3	0	0	1	1	–3 dB
4	0	1	0	0	–2 dB
5	0	1	0	1	–1 dB
6	0	1	1	0	0 dB
7	0	1	1	1	1 dB
8	1	0	0	0	2 dB
9	1	0	0	1	3 dB
10	1	0	1	0	4 dB
11	1	0	1	1	5 dB
12	1	1	0	0	6 dB
13	1	1	0	1	–6 dB
14	1	1	1	0	–6 dB
15	1	1	1	1	–6 dB

VOLCTL (0–2): Volume control (0, –6 ,–12, 18, –24, Mute), see Table 21.

Table 21. Volume Control Gain Settings

	VOLCTL2	VOLCTL1	VOLCTL0	RELATIVE GAIN
0	0	1	0	0 dB
1	1	1	0	–6 dB
2	0	0	0	–12 dB
3	1	0	0	–18 dB
4	0	1	1	–24 dB
5	1	0	1	Mute
6	0	0	1	Mute
7	1	1	1	Mute

PRINCIPLES OF OPERATION

voiceband control register

The values in the voiceband control register have the meaning shown in Table 22.

Table 22. Voiceband Control Register

VBCTL3: VOICEBAND CONTROL REGISTER										ADDRESS: 12					R/W
RESERVD	RESERVD	VCLKMODE	DAIMD1	DAIMD0	VDAI	DAION	VALOOP	VIZBUS	VRST	0	1	1	0	0	1 / 0
R = 0	R = 0	R /W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	<–ACCESS TYPE					
0	0	0	0	0	0	0	0	0	0	<–VALUE AT RESET					

VALOOP: When set to 1, the internal analog loop of output samples are sent to the audio input terminal; standard audio paths are connected together, and auxiliary audio paths are connected together.

VIZBUS: When set to 1, VFS, VCLK, and VDX are put in a hi-Z state when there is nothing to transfer to the DSP. When cleared to 0, VFS and VCLK are put in V_{SS} when there is nothing to transfer to the DSP, and the VDX bus drives an undefined value (value depends on the previous serial data transfers).

VRST: When 1, resets the digital parts of the audio codec (digital filter and modulator). This is not a toggle bit and has to be set to 0 to remove the reset condition

DAION: When cleared to 0, the DAI block is in power down; when set to 1, the DAI block is active.

VDAI: Writing a 1 to this bit starts the SSCLK (104 kHz DAI clock) on reception of the first sample. This bit is automatically reset to 0 by SSRST after reception of the last sample.

RESERVD: Reserved bits for testing

DAIMD (0–1): DAI mode selection as given in Table 23.

VCLKMODE: When cleared to 0, allows selection of VCLK in burst mode. When set to 1, allows selection of VCLK in continuous mode.

Table 23. DAI Mode Selection

DAIMD1	DAIMD0	DAI MODE
0	0	Normal operation (no tested device using DAI)
0	1	Test of speech decoder / DTX functions (downlink)
1	0	Test of speech encoder / DTX functions (uplink)
1	1	Test of acoustic devices and A/D and D/A (voice path)

PRINCIPLES OF OPERATION

auxiliary functions control register 1

The bit values in the auxiliary functions control register 1 resets the APC generator or the AFC modulator, selects the A/D counter input, and selects the AFC sampling frequency. This is shown in Table 24.

Table 24. AUX Functions Control Register 1

UXCTL1: AUXILIARY FUNCTIONS CONTROL REGISTER										ADDRESS: 13					R/W
AFCPN	AFCPD	ADCPN	ADCPD	AFCCK1	AFCCK0	ADCCH2	ADCCH1	ADCCH0	ARST	0	1	1	0	1	1/0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	<–ACCESS TYPE					
0	0	0	0	0	0	0	0	0	0	<–VALUE AT RESET					

ARST: Reset of the digital parts for the auxiliary function (APC generator and AFC modulator). This is not a toggle bit and has to be set to 0 to remove the reset condition.

ADCCH (0–2): Selection of the input of the A/D converter; see Table 25.

Table 25. A/D Converter Selection

ADCCH2	ADCCH1	ADCCH0	A/D CONVERTER INPUT SELECTION
0	0	0	A/D conversion of ADIN1
0	0	1	A/D conversion of ADIN2
0	1	0	A/D conversion of ADIN3
0	1	1	A/D conversion of ADIN4
1	0	0	A/D conversion of ADIN5
1	0	1	A/D conversion of ADIN5
1	1	0	A/D conversion of ADIN5
1	1	1	A/D conversion of ADIN5

AFCCK (0–1): Selection of the sampling frequency of the AFC, see Table 26.

Table 26. AFC Selection

AFCCK1	AFCCK0	AFC INTERNAL FREQUENCY
0	0	0.25 MHz
0	1	0.50 MHz
1	0	1 MHz
1	1	2 MHz

AFCPN: If cleared to 0, the AFC block is powered down under the control of the PWRDN terminal. If this bit is set to 1, the power down is only controlled by bit AFCPD.

AFCPD: This bit is functionally associated and paired with bit AFCPN. When the AFCPN bit is 1, the AFC block is active. When the AFCPD bit is set to 1, the AFCPD block is in power-down mode.

ADCPN: If cleared to 0, the auxiliary ADC block is powered down when under the control of PWRDN. If this bit is set to 1, the power down is only controlled by bit ADCPD.

ADCPD: This bit is functionally associated and paired with bit ADCPN. When the ADCPN bit is set to 1, an auxiliary ADC is active. When the ADCPD bit is set to 1, the auxiliary ADCPD is in power-down mode.

PRINCIPLES OF OPERATION

automatic frequency control registers (1 and 2)

There are two AFC control registers; each is 10 bits wide. AFC control register No. 1 contains the least significant bit of the AFC D/A converter output. AFC control register No. 2 contains the most significant bit of the AFC D/A converter input. See Tables 27 and 28. The AFC value is loaded after writing to the AFC MSB register (first) and then the LSB register (second) .

Table 27. AFC Control Register 1

AUXAFC1: AUTOMATIC FREQUENCY CONTROL REG1										ADDRESS: 14	R/W
BIT9	BIT8	BIT7	BIT6	BIT5	BIT4	BIT3	BIT2	BIT1	BIT0	0 1 1 1 0	1/0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	<–ACCESS TYPE	
0	0	0	0	0	0	0	0	0	0	<–VALUE AT RESET	

BIT 9–0: LSB input of the 13-bit AFC D/A converter in 2s complement.

Table 28. AFC Control Register 2

AUXAFC2: AUTOMATIC FREQUENCY CONTROL REG2										ADDRESS: 15	R/W
RESRVD	RESRVD	RESRVD	RESRVD	RESRVD	RESRVD	RESRVD	BIT12	BIT11	BIT10	0 1 1 1 1	1/0
R = 0	R = 0	R = 0	R = 0	R = 0	R = 0	R = 0	R/W	R/W	R/W	<–ACCESS TYPE	
0	0	0	0	0	0	0	0	0	0	<–VALUE AT RESET	

BIT 12–10: MSB input of the 13-bit AFC D/A converter in 2s complement.

automatic power control register

The values in the automatic power control (APC) register set the operating conditions for the APC circuit, see Table 29.

Table 29. APC Register

AUXAPC: AUTOMATIC POWER CONTROL REGISTER										ADDRESS: 16	R/W
RESERVD	RESERVD	BIT7	BIT6	BIT5	BIT4	BIT3	BIT2	BIT1	BIT0	1 0 0 0 0	1/0
R = 0	R = 0	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	<–ACCESS TYPE	
0	0	0	0	0	0	0	0	0	0	<–VALUE AT RESET	

BIT 7–0: Input of the 8-bit level APC DAC.

RESERVD: Reserved bits for testing

PRINCIPLES OF OPERATION

automatic frequency control registers (1 and 2)

The content of the APC RAM describes the shape of the ramp-up and ramp-down control; see Table 30.

Table 30. APC Ramp Control

APCRAM: AUTOMATIC POWER CONTROL RAM										ADDRESS: 17 (64 Words)					W
RDWN WORD0 (5 BIT)					RUP WORD0 (5 BIT)					1	0	0	0	1	0
RDWN WORD1 (5BIT)					RUP WORD2 (5 BIT)					1	0	0	0	1	0
. . .					. . .					. . .	. . .	. . .	. . .	. . .	. . .
. . .					. . .					. . .	. . .	. . .	. . .	. . .	. . .
RDWNWORD62 (5BIT)					RUP WORD62 (5 BIT)					1	0	0	0	1	0
RDWNWORD63 (5BIT)					RUP WORD63 (5 BIT)					1	0	0	0	1	0
W	W	W	W	W	W	W	W	W	W	<—ACCESS TYPE					
X	X	X	X	X	X	X	X	X	X	<—VALUE AT RESET					

Actual shape values (five bits long) are contained in the shape D/A converter input register as shown in Table 31.

Table 31. Shape DAC Input Register

APCSHAP: SHAPE DAC INPUT REGISTER										ADDRESS: 18	R/W
RESERVD	RESERVD	RESERVD	RESERVD	RESERVD	BIT4	BIT3	BIT2	BIT1	BIT0	1 0 0 1 0	1/0
R = 0	R = 0	R = 0	R = 0	R = 0	R/W	R/W	R/W	R/W	R/W	<–ACCESS TYPE	
0	0	0	0	0	0	0	0	0	0	<–VALUE AT RESET	

BIT 4–0: Input of the 5-bit APC DAC.

RESERVD: Reserved bits for testing

AGC control register

The AGC control register is 10-bits wide and controls operations of the analog AGC circuit as shown in Table 32.

Table 32. Analog AGC Gain Control Register

AUXAGC: AUTOMATIC GAIN CONTROL REGISTER										ADDRESS: 19	R/W
BIT9	BIT8	BIT7	BIT6	BIT5	BIT4	BIT3	BIT2	BIT1	BIT0	1 0 0 1 1	1/0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	<–ACCESS TYPE	
0	0	0	0	0	0	0	0	0	0	<–VALUE AT RESET	

BIT 9 to 0: Input of the 10-bit AAGC DAC.

RESERVD: Reserved bits testing.

PRINCIPLES OF OPERATION

auxiliary functions control register 2 (see Table 33)

The values in the auxiliary function control register No. 2 set the operation parameters as described below:

APCSPD: When cleared to 0, the APC clock is at 4 MHz; when set to 1, the APC clock is at 2 MHz.

IAPCPTR: Setting to 1 initializes the pointer of the APC RAM to the base address. This is not a toggle bit and has to be set to 0 to set APC RAM operational.

APCMODE: Select the equation used for APC waveform generation.

AGCW: If cleared to 0, the automatic gain control path is powered down with the control of GSM receive window (BDLON terminal) and AGCPD bit. If the AGCPD bit is set to 1, the power down is controlled by AGCPD bit.

AGCPD: This bit is functionally associated with AGCW bit. When this bit is set to 1, the automatic gain control path is in power-down mode.

APCW: If 0, the RF power control path is down powered with the control of GSM transmit window (BULON) and with the control of APCPD bit. If the APCPD bit is set to 1, power down is only controlled by APCPD bit.

APCPD: This bit is functionally associated with the BBULW bit. When this bit is set to 1, the RF power control path is in power-down mode.

Table 33. AUX Functions Control Register No. 2

AUXCTL2: AUXILIARY FUNCTIONS CONTROL REGISTER										ADDRESS: 20					R/W
AGCW	AGCPD	APCW	APCPD	IAPCTR	APCMODE	RESERVD	RESERVD	APCSPD	RESERVD	1	0	1	0	0	1/0
R/W	R/W	R/W	R/W	R/W	R/W	R	R	R/W	R	<–ACCESS TYPE					
0	0	0	0	0	0	0	0	0	0	<–VALUE AT RESET					

auxiliary A/D converter output register

This register is read-only; however, if there is an attempt to write into it, an A/D conversion operation starts; see Table 34. When the A/D conversion is finished, the AUXADC register is loaded and the A/D converter is automatically down powered. During the conversion process the ADCEOC bit of the BSTATUS register is set. This bit is reset automatically after AUXADC is loaded.

Table 34. AUX A/D Converter Output Register

AUXADC: AUXILIARY A/D CONVERTER OUTPUT REGISTER										ADDRESS: 21					R
BIT9	BIT8	BIT7	BIT6	BIT5	BIT4	BIT3	BIT2	BIT1	BIT0	1	0	1	0	1	1/0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	<–ACCESS TYPE					
0	0	0	0	0	0	0	0	0	0	<–VALUE AT RESET					

BIT 9 to 0: Output pf the 10-bit monitoring ADC.

PRINCIPLES OF OPERATION

baseband status register

The baseband status register stores the baseband status as described in Table 35.

Table 35. Baseband Status Register

BSTATUS: BASEBAND STATUS REGISTER										ADDRESS: 22					R
RESERVD	ADCEOC	RAMPTR	BUFPTR	ULON	ULCAL	ULX	DLON	DLCAL	DLR	1	0	1	1	0	1
R = 0	R	R	R	R	R	R	R	R	R	<–ACCESS TYPE					
0	0	0	0	0	0	0	0	0	0	<–VALUE AT RESET					

DLR: This bit is set to 1 during conversion of a burst in the downlink path.

DLCAL: This bit is set to 1 during offset calibration of the downlink path.

DLON: When set to 1, it indicates that the downlink path is powered on.

ULX: This bit is set to 1 during transmission of the burst in the uplink path.

ULCAL: This bit is set to 1 during offset calibration of the uplink path.

ULON: When set to 1, it indicates that the uplink path is powered on.

BUFPTR: When set to 1, it indicates that the pointer of the burst buffer is at address zero.

RAMPTR: When set to 1, it indicates that the pointer of the APC RAM is at address zero.

ADCEOC: (ADC-end of conversion) when this bit is set to 1, an ADC conversion is in process.

Voiceband control register 4 (address 23)

Voiceband control register 4 (VBCTL4) is a read/write register (see Table 36) and contains the four programming bits of VDLST as shown in Table 37.

Table 36. Voiceband Control Register 4

VBCTL4: VOICEBAND CONTROL REGISTER 4										ADDRESS: 23					R/W
RESERVD	RESERVD	RESERVD	RESERVD	RESERVD	RESERVD	VDLST3	VDLST2	VDLST1	VDLST0	1	0	1	1	1	1/0
R=0	R=0	R=0	R=0	R=0	R=0	R/W	R/W	R/W	R/W	<–ACCESS TYPE					
0	0	0	0	0	0	0	0	0	0	<–VALUE AT RESET					

Table 37. VDLST Status

VDLST3	VDLST2	VDLST1	VDLST0	SIDE TONE GAIN
1	0	0	0	Mute
1	1	0	1	–23 dB
1	1	0	0	–20 dB
0	1	1	0	–17 dB
0	0	1	0	–14 dB
0	1	1	1	–11 dB
0	0	1	1	–8 dB
0	0	0	0	–5 dB (nominal)
0	1	0	0	–2 dB
0	0	0	1	+1 dB
0	1	0	1	+1 dB

PRINCIPLES OF OPERATION

baseband uplink register (address 24)

The baseband uplink register (BULCTL) is a 3-bit register (see Table 38) that permits mismatch compensation in the RF transmit mixer, and 1 bit (OUTLEV) to set the differential output dynamic range (V_{PP}) to 2 times V_{ref} when OUTLEV = 0 or to 8/15 V_{ref} when OUTLEV = 1. Gain mismatches of 0 dB, –0.25 dB, –0.5 dB, and –0.75 dB are permitted between the I and Q channel as shown in Table 39.

Table 38. Uplink Register BULCTL

BULCTL: BASEBAND UPLINK CONTROL REGISTER										ADDRESS: 24					R/W
RESERVD	RESERVD	RESERVD	RESERVD	RESERVD	RESERVD	OUTLEV	IQSEL	G1	G0	1	1	0	0	0	1/0
R=0	R=0	R=0	R=0	R=0	R=0	R/W	R/W	R/W	R/W	<–ACCESS TYPE					
0	0	0	0	0	0	0	0	0	0	<–VALUE AT RESET					

Table 39. BLKCTL Register

BIT2	BIT1	BIT0	GAIN I	GAIN Q
IQSEL	G1	G0		
0	0	0	0 dB	0 dB
0	0	1	–0.25 dB	0 dB
0	1	0	–0.50 dB	0 dB
0	1	1	–0.75 dB	0 dB
1	0	0	0 dB	0 dB
1	0	1	0 dB	– 0.25 dB
1	1	0	0 dB	–0.50 dB
1	1	1	0 dB	–0.75 dB

power on status register (address 25)

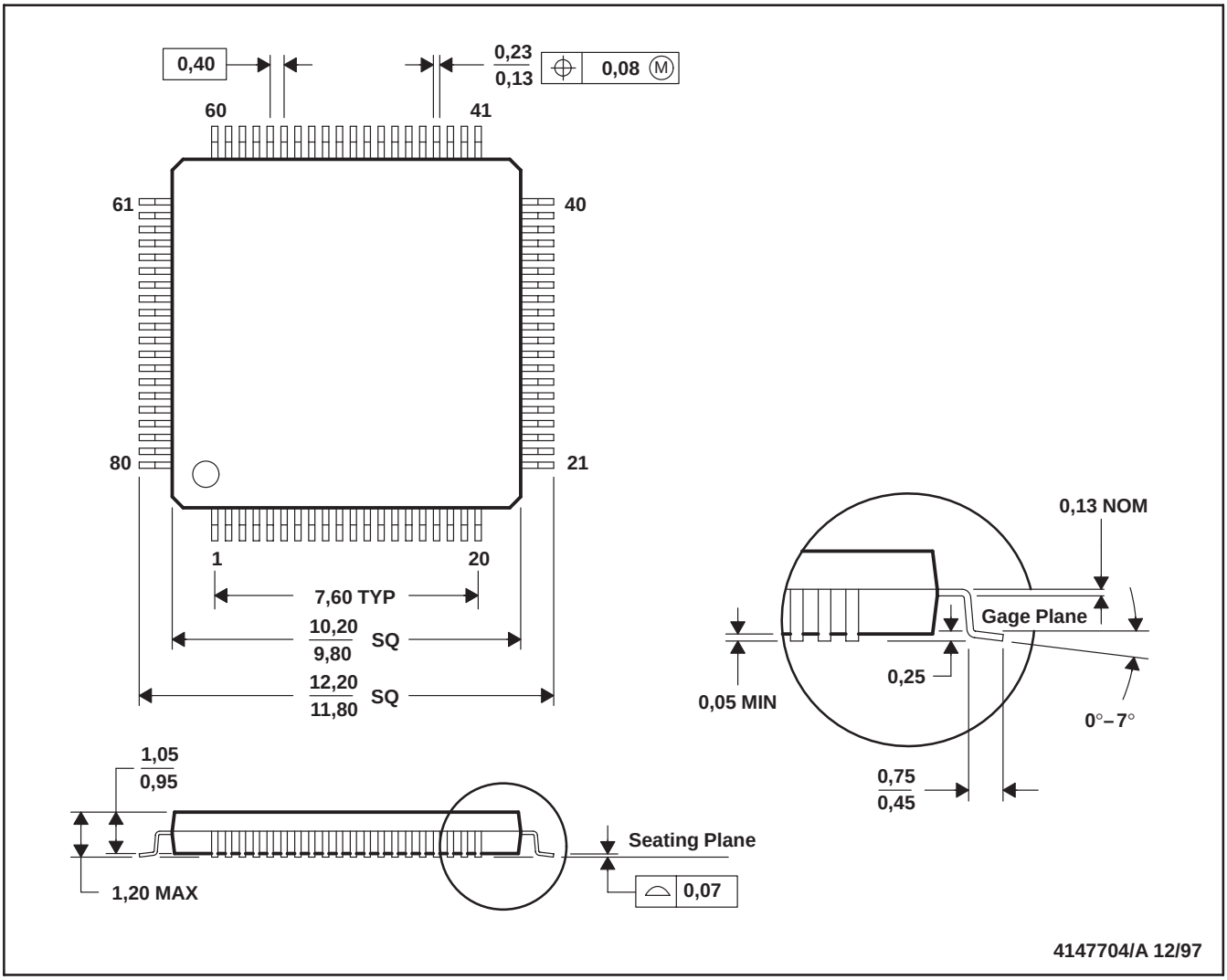
The power-on status register is a 9 bit read-only register which displays the status power-on / power-down of the functions having several power on/off controls. When the function is in power-on the corresponding bit is at 1.

Table 40. Power On Register PWONCTL

PWONCTL: POWER-ON STATUS REGISTER										ADDRESS: 25					R/W
RESERVD	BGAPON	VREFON	BBIFON	TIMIFON	VMIDON	AFCON	ADCON	AGCON	APCON	1	1	0	0	1	1/0
R=0	R	R	R	R	R	R	R	R	R	<–ACCESS TYPE					
0	0	0	0	0	0	0	0	0	0	<–VALUE AT RESET					

MECHANICAL DATA

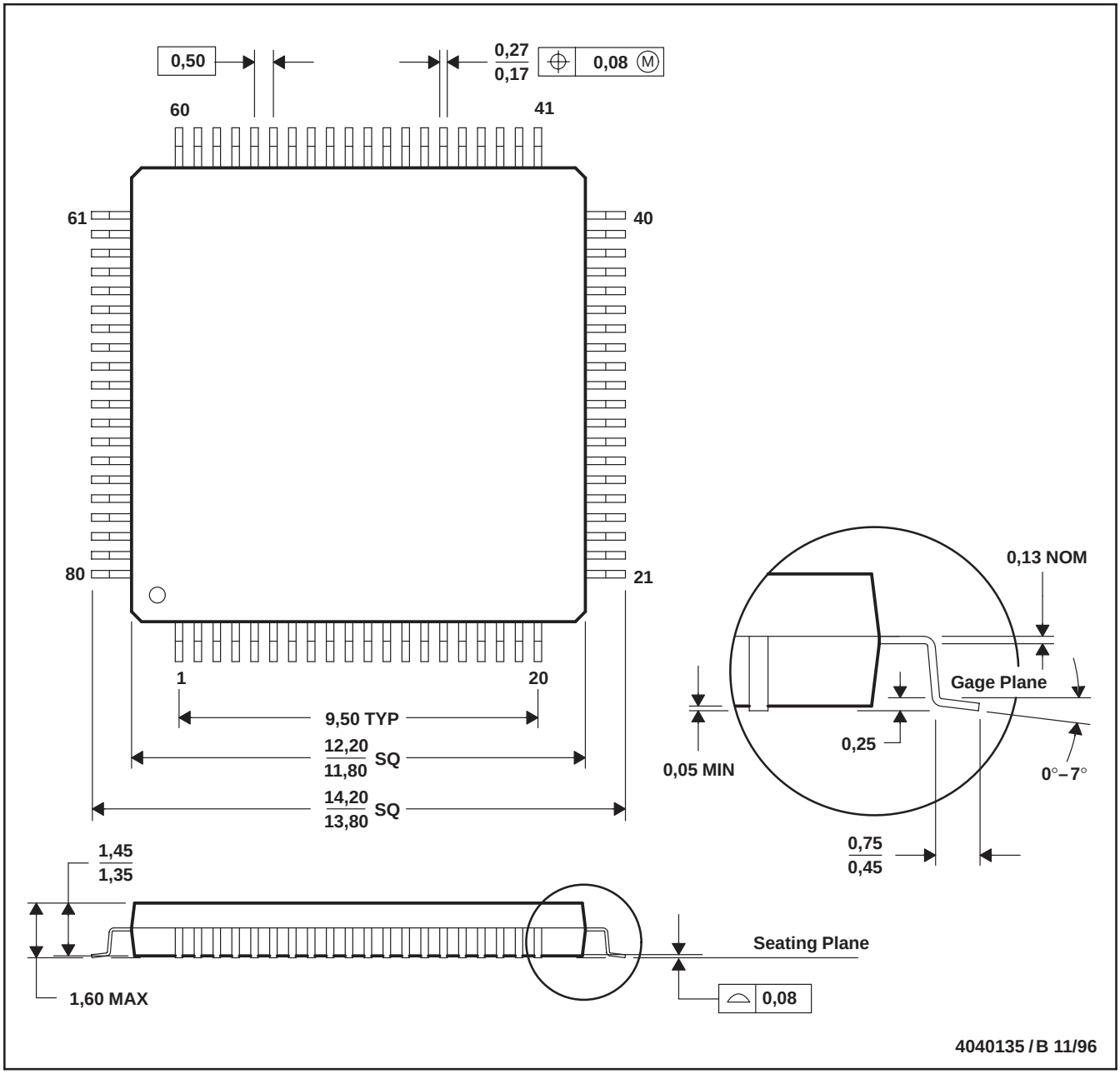
PET (S-PQFP-G80) **PLASTIC QUAD FLATPACK**



NOTES: A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Falls within JEDEC MS-026

MECHANICAL DATA

PN (S-PQFP-G80) **PLASTIC QUAD FLATPACK**



NOTES: A. All linear dimensions are in millimeters.
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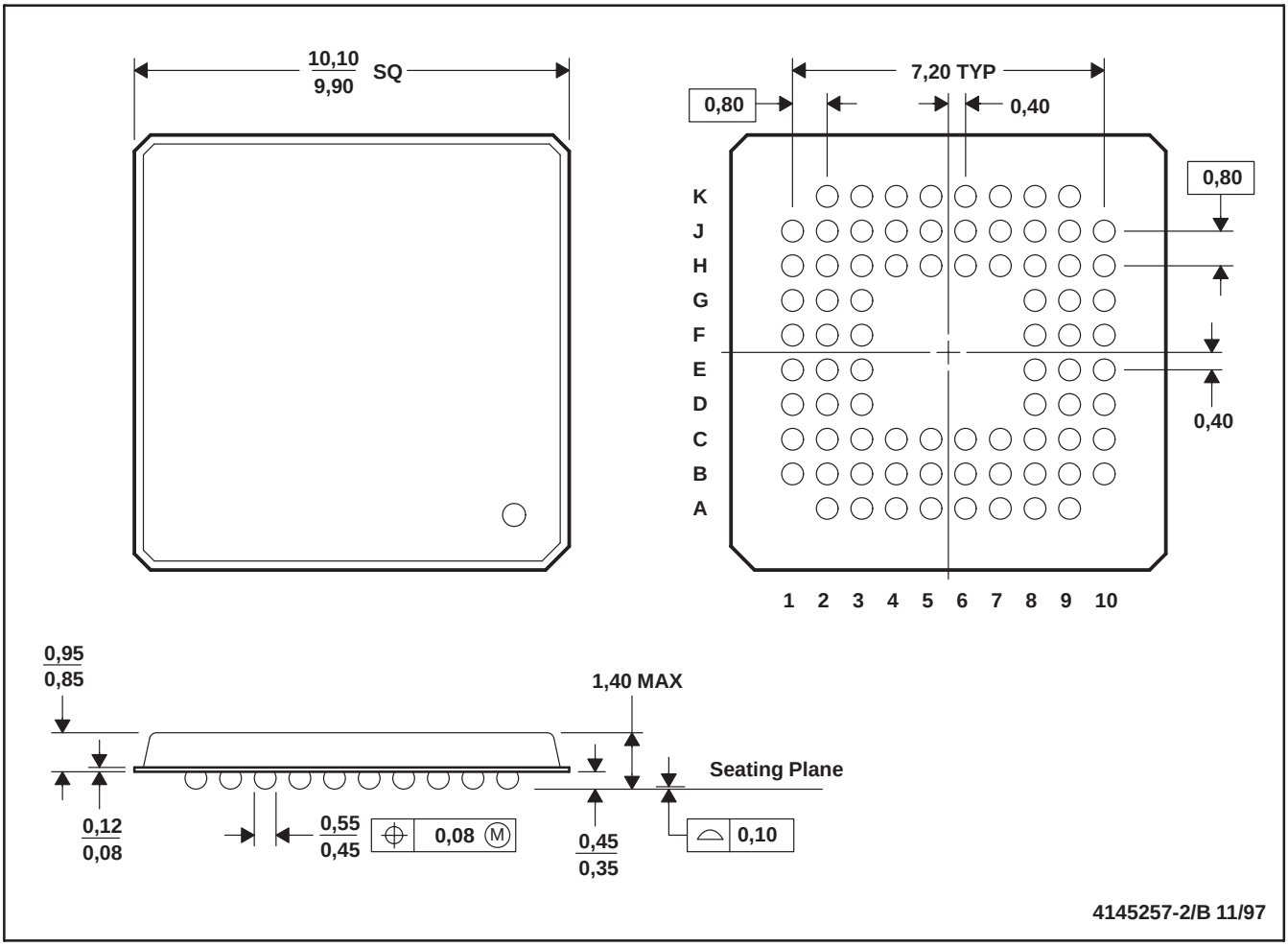
MECHANICAL DATA

GGM (S-PBGA-N80) **PLASTIC BALL GRID ARRAY**



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C. MicroStar BGA™ configuration

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