Atmel U4091BM-R

Programmable Telephone Audio Processor

DATASHEET

Features

- Speech circuit with anti-clipping
- Tone-ringer interface with DC/DC converter
- Speaker amplifier with anti-distortion
- Power-supply management (regulated and unregulated) and a special supply for electret microphone
- Voice switch
- Interface for answering machine and cordless phone

Applications

- Feature phone
- Answering machine
- Fax machine
- Speaker phone
- Cordless phone

Benefits

- No piezoelectric transducer necessary for tone ringing
- Complete system integration of analog signal processing on one chip
- Very few external components

1. Description

The programmable telephone audio processor Atmel® U4091BM-R is a linear integrated circuit for use in feature phones, answering machines and fax machines. It contains the speech circuit, tone-ringer interface with DC/DC converter, sidetone equivalent and ear-protection rectifiers. The circuit is line-powered and contains all components necessary for signal amplification and adaptation to the line. The Atmel U4091BM-R can also be supplied via an external power supply. An integrated voice switch with loudspeaker amplifier enables hands-free or open-listening operation. With an anti-feedback function, acoustic feedback during open listening can be reduced significantly. The generated supply voltage is suitable for a wide range of peripheral circuits.

Figure 1-1. Block Diagram

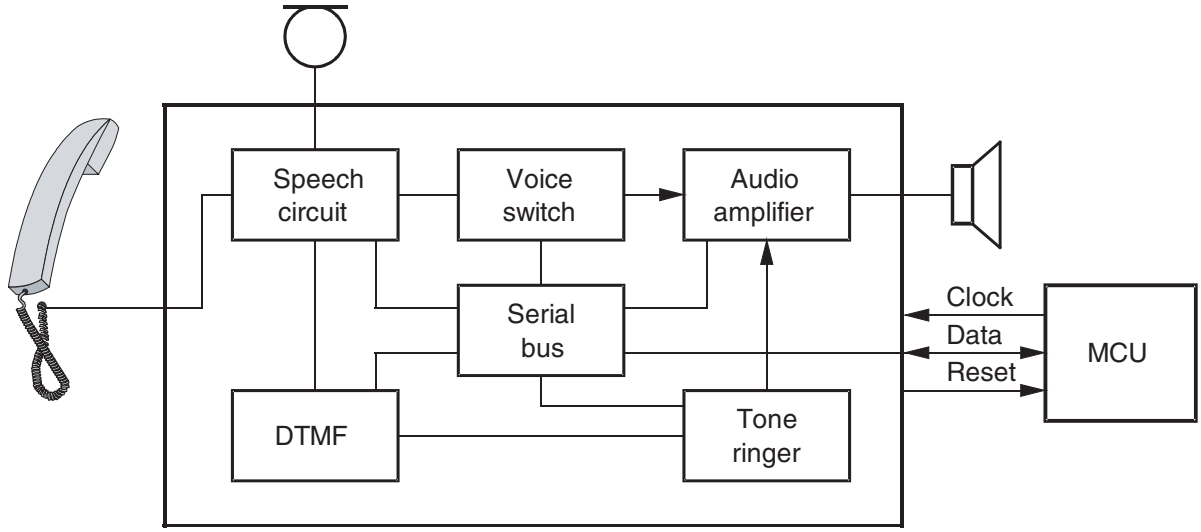
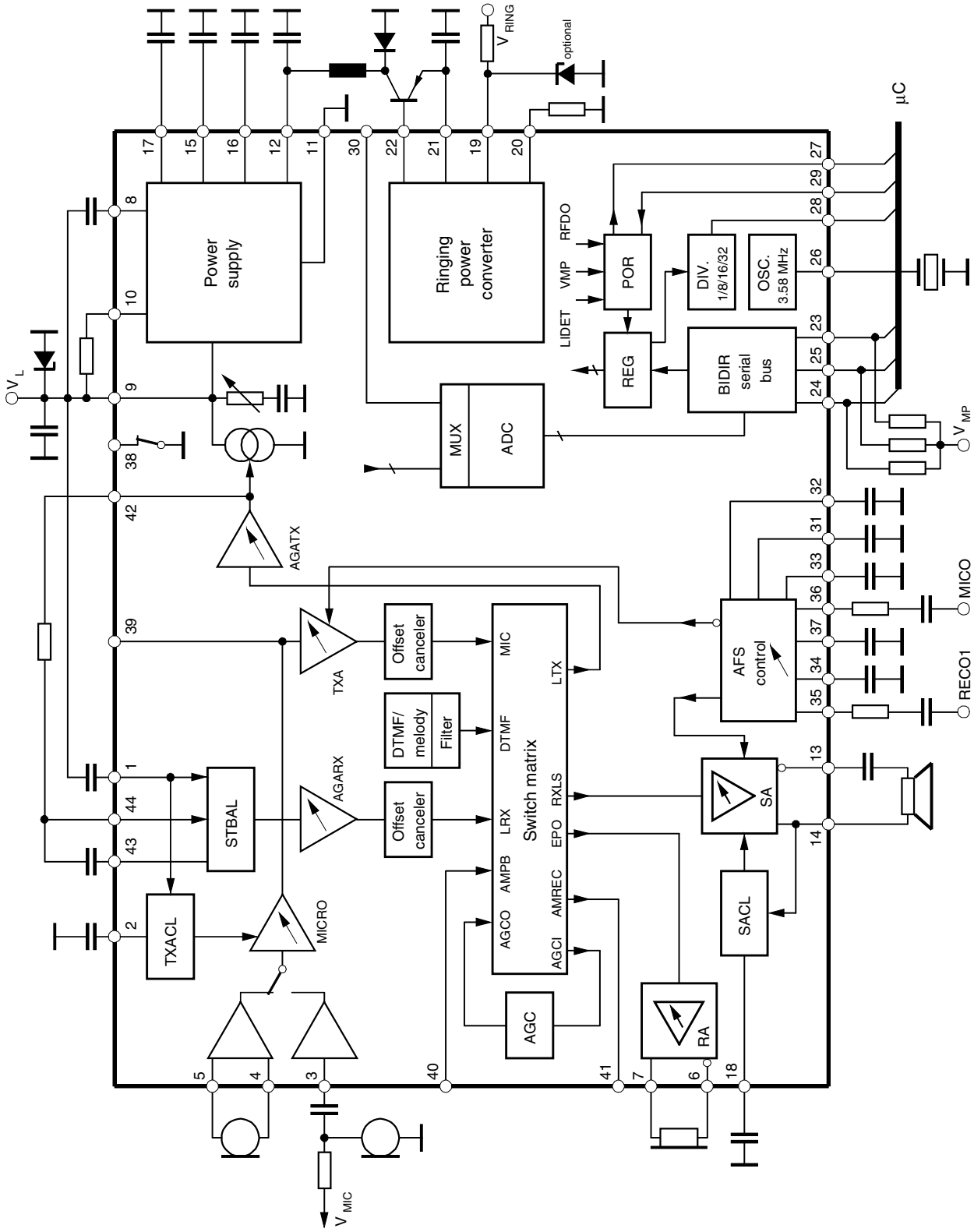


Figure 1-2. Detailed Block Diagram



2. Pin Configuration

Figure 2-1. Pinning SSO44

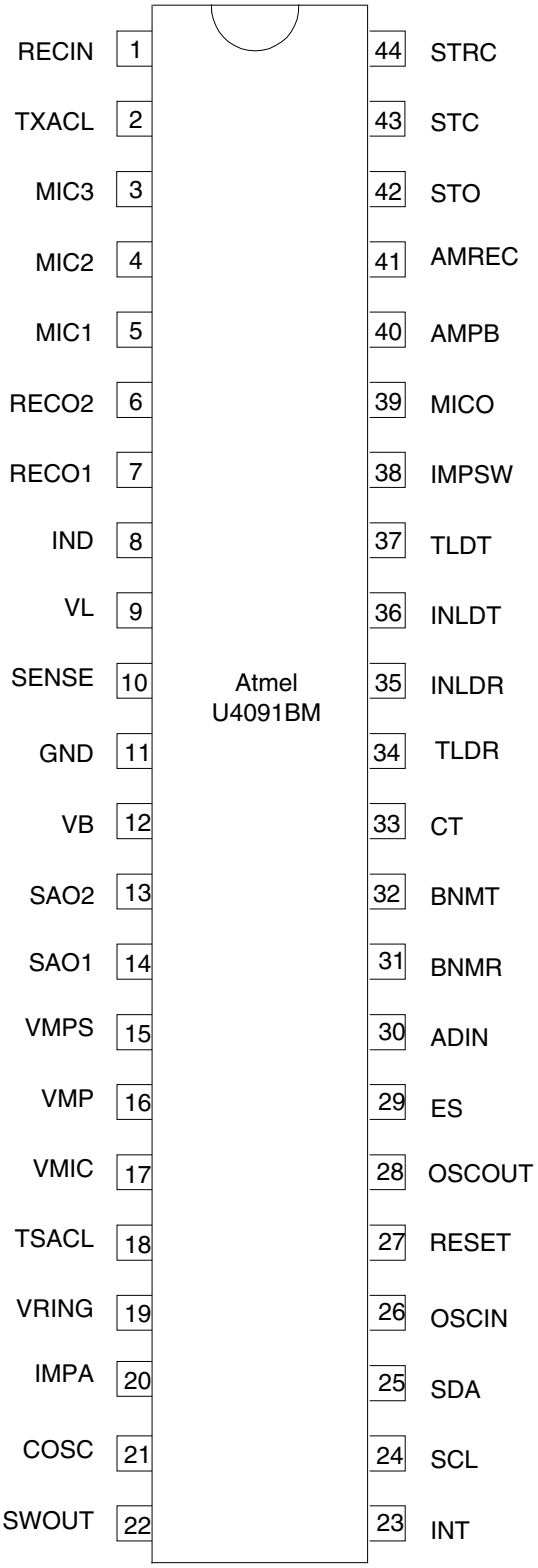


Table 2-1. Pin Description

Pin	Symbol	Function
1	RECIN	Receive amplifier input[1]
2	TXACL	Time constant adjustment for transmit anti-clipping
3	MIC3	Microphone input for hands-free operation
4	MIC2	Input of symmetrical microphone amplifier with high common-mode rejection ratio
5	MIC1	Input of symmetrical microphone amplifier with high common-mode rejection ratio
6	RECO2	Output of the receive amplifier
7	RECO1	Output of the receive amplifier, also used for sidetone network
8	IND	The internal equivalent inductance of the circuit is proportional to the value of the capacitor at this pin. A resistor connected to ground may be used to adjust the DC mask
9	VL	Positive supply-voltage input to the device in speech mode
10	SENSE	Input for sensing the available line current
11	GND	Ground, reference point for DC and AC signals
12	VB	Unstabilized supply voltage for speech network
13	SAO2	Negative output of speaker amplifier (push-pull only)
14	SAO1	Positive output of speaker amplifier (single-ended and push-pull operation)
15	VMPS	Unregulated supply voltage for the microcontroller (via series regulator to VMP)
16	VMP	Regulated output voltage for supplying the microcontroller (typically 3.3V/6mA in speech mode)
17	VMIC	Reference node for microphone amplifier, supply for electret microphones
18	TSACL	Time constant for speaker amplifier anti-clipping
19	VRING	Input for ringer supply
20	IMPA	Input for adjusting the ringer input impedance
21	COSC	70-kHz oscillator for ringing power converter
22	SWOUT	Output for driving the external switch resistor
23	INT	Interrupt line for serial bus
24	SCL	Clock input for serial bus
25	SDA	Data line for serial bus
26	OSCIN	Input for 3.58-MHz oscillator
27	RESET	Reset output for the microcontroller
28	OSCOUT	Clock output for the microcontroller
29	ES	Input for external supply indication
30	ADIN	Input of A/D converter
31	BNMR	Output of background-noise monitor receive
32	BNMT	Output of background-noise monitor transmit
33	CT	Time constant for mode switching of voice switch
34	TLDR	Time constant of receive-level detector
35	INLDR	Input of receive-level detector
36	INLDT	Input of transmit-level detector
37	TLDT	Time constant of transmit-level detector
38	IMPSW	Switch for additional line impedance
39	MICO	Microphone preamplifier output
40	AMPB	Input for playback signal of answering machine

Note: 1. The protection device at pin RECIN is disconnected.

Table 2-1. Pin Description (Continued)

Pin	Symbol	Function
41	AMREC	Output for recording signal of answering machine
42	STO	Output for connecting the sidetone network
43	STC	Input for sidetone network
44	STRC	Input for sidetone network

Note: 1. The protection device at pin RECIN is disconnected.

3. DC Line Interface and Supply-voltage Generation

The DC line interface consists of an electronic inductance and a dual-port output stage which charges the capacitors at VMPS and VB. The value of the equivalent inductance is given by:

$$L = \frac{2 \times R_{SENSE} \times C_{IND} \times (R_{DC} \times R_{30})}{(R_{DC} + R_{30})}$$

The U4091BM-R contains two identical series regulators which provide a supply voltage VMP of 3.3V suitable for a microprocessor. In speech mode, both regulators are active because VMPS and VB are charged simultaneously by the DC line interface. The output current is 6mA. The capacitor at VMPS is used to provide the microcomputer with sufficient power during long line interruptions. Thus, long flash pulses can be bridged or an LCD display can be turned on for more than 2 seconds after going on-hook. When the system is in ringing mode, VB is charged by the on-chip ringing power converter. In this mode, only one regulator is used to supply VMP with maximum 3mA.

4. Supply Structure of the Chip

A main benefit of the Atmel® U4091BM is the easy implementation of various applications due to the flexible system structure of the chip.

Possible applications:

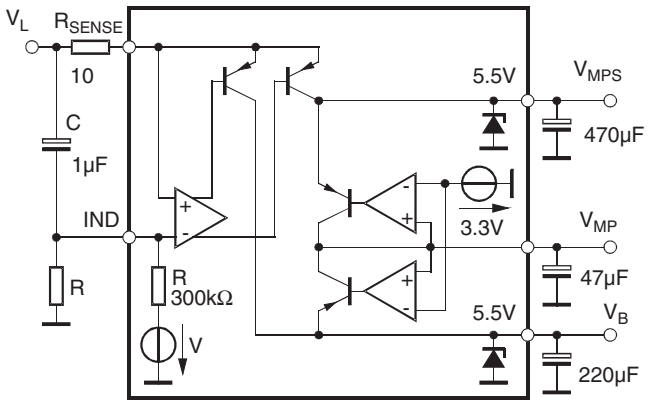
- Group listening phone
- Hands-free phone
- Phones which feature ringing with the built-in speaker amplifier
- Answering machine with external supply

The special supply topology for the various functional blocks is shown in Figure 4-1 on page 7.

There are four major supply states:

1. Speech condition
   In speech condition, the system is supplied by the line current. If the LIDET block detects a line voltage above approximately 2V, the internal signal VLON is activated. This is detected via the serial bus, all the blocks which are needed have to be switched on via the serial bus.
   For line voltages below 2V, the switches remain in quiescent state as shown in the diagram.
2. Power down (pulse dialing)
   When the chip is in power-down mode (bit LOMAKE), for example, during pulse dialing, all internal blocks are disabled via the serial bus. In this condition, the voltage regulators and their internal band gap are the only active blocks.
3. Ringing
   During ringing, the supply for the system is fed into VB via the Ringing Power Converter (RPC). Normally, the speaker amplifier in single-ended mode is used for ringing. The frequency for the melody is generated by the DTMF/Melody generator.
4. External supply
   In an answering machine, the chip is powered by an external supply via pin VB. The answering machine connections can be directly made to Atmel U4091BM-R. The answering machine is connected to the pin AMREC. For the output AMREC, an AGC function is selectable via the serial bus. The output of the answering machine will be connected to the pin AMPB, which is directly connected to the switching matrix. This enables the signal to be switched to every desired output.

Figure 4-1. Supply Generator



5. Ringing Power Converter (RPC)

The RPC transforms the input power at VRING (high voltage/low current) into an equivalent output power at VB (low voltage/high current) which is capable of driving the low-ohmic loudspeaker. The input impedance at VRING is adjustable from 3kΩ to 12kΩ by R_{IMPA} (Z_{RING} = R_{IMPA} / 100) and the efficiency of the step-down converter is approximately 65%.

6. Ringing Frequency Detector (RFD)

The Atmel® U4091BM-R provides an output signal for the microcontroller. This output signal is always double the value of the input signal (ringing frequency). It is generated by a current comparator with hysteresis. The levels for the on-threshold are programmable in 16 steps, the off-level is fixed. Every change of the comparator output generates a high level at the interrupt output INT. The information can then be read out by means of a serial bus with either normal or fast read mode. The block RFD is always enabled.

Table 6-1. Threshold Level

RINGTH[0:3]	V_{RING}
0	7V
15	22V
Step	1V

7. Clock Output Divider Adjustment

The pin OSCOUT is a clock output which is derived from the crystal oscillator. It can be used to drive a microcontroller or another remote component and thereby reduces the number of crystals required. The oscillator frequency can be divided by 1, 8, 16, or 32. During power-on reset, the divider will be reset to 1 until it is changed by setting the serial bus.

Table 7-1. Clock Output

CLK[0:1]	Divider	Frequency
0	1	3.58MHz
1	8	447kHz
2	16	224kHz
3	32	112kHz

8. Serial Bus Interface

The circuit is controlled by an external microcontroller through the serial bus.

The serial bus is a bi-directional system consisting of a single-directional clock line (SCL) which is always driven by the microcontroller, and a bi-directional data-signal line. It is driven by the microcontroller as well as by the Atmel® U4091BM-R (see Figure 20-1 on page 38).

The serial bus requires external pull-up resistors as only pull-down transistors (pin SDA) are integrated.

8.1 WRITE

The data is a 12-bit word:

A0-A3: address of the destination register (0 to 15)
D0-D7: content of the register

The data line must be stable when the clock is high. Data must be shifted serially. After 12 clock periods, the write indication is sent. Then, the transfer to the destination register is (internally) generated by a strobe signal transition of the data line when the clock is high.

8.2 READ

There is a normal and a fast-read cycle.

In the normal read cycle, the microcontroller sends a 4-bit address followed by the read indicator, then an 8-bit word is read out. The Atmel U4091BM-R drives the data line.

The fast read cycle is indicated by a strobe signal. With the following two clocks the Atmel U4091BM-R reads out the status bits RFDO and LIDET which indicate that a ringing signal or a line signal is present (see Figure 10-1 on page 12, Figure 10-2 on page 12 and Figure 10-3 on page 12).

9. DTMF Dialing

The DTMF generator sends a multi-frequency signal through the matrix to the line. The signal is the result of the sum of two frequencies and is internally filtered. The frequencies are chosen from a low and a high frequency group. The circuit conforms to the CEPT recommendation concerning DTMF option. Three different levels for the low level group and two different pre-emphasis (2.5dB and 3.5dB) can be chosen by means of the serial bus (rec. T/CF 46-03).

Attention: In high gain mode, distortion can occur if AGATX is high and DC mask is low.

10. Melody and Confidence Tone Generation

Melody and confidence tone frequencies are given in Table 10-1.

The frequencies are provided at the DTMF input of the switch matrix. A sinusoidal wave, a square wave or a pulsed wave can be selected by the serial bus. A square signal means the output is high for half of the frequency cycle, and low for the other half. A pulsed signal means high impedance phases of 1/6 of the period occur between the high and low phases.

Table 10-1. Status of Melody Generating

Decimal	DTMFM[0:2]	Status
0	000	DTMF generator OFF
1	001	Confidence tone melody on (sine)
2	010	Ringer melody (pulse)
3	011	Ringer melody (square signal)
4	100	DTMF (mid level)
5	101	DTMF (low level)
6	110	DTMF (high level)
7	111	–

Table 10-2. DTMF Frequencies

Decimal	DTMFF[0:1] in DTMF Mode	Frequency	Error (%)
0	00	697	–0.007
1	01	770	–0.156
2	10	852	0.032
3	11	941	0.316

Table 10-3. DTMF Frequencies

Decimal	DTMFF[2:3] in DTMF Mode	Frequency	Error (%)
0	00	1209	–0.110
1	01	1336	0.123
2	10	1477	–0.020
3	11	1633	–0.182

Table 10-4. DTMFF4 in DTMF Mode

Pre-emphasis Selection	Level
0	2.5dB
1	3.5dB

Table 10-5. DTMF and Melody Frequencies

Decimal	DTMFF [0:4]	f (Hz)	Tone/ Name	Error (%)	DTMF Freq.	DTMP Freq.	Key
0	00000	440.0	A^4	–0.008	697	1209	1
1	00001	466.2	$A\#^4$	–0.016	770	1209	4
2	00010	493.9	B^4	–0.003	852	1209	7
3	00011	523.2	C^4	0.014	941	1209	*
4	00100	554.4	$C\#^4$	0.018	697	1336	2
5	00101	587.3	D^4	–0.023	770	1336	5
6	00110	622.3	$D\#^4$	–0.129	852	1336	8
7	00111	659.3	E^4	0.106	941	1336	0
8	01000	698.5	F^4	–0.216	697	1477	3
9	01001	740.0	$F\#^4$	–0.222	770	1477	6
10	01010	784.0	G^4	0.126	852	1477	9
11	01011	830.0	$G\#^4$	–0.169	941	1477	#
12	01100	880.0	A^5	0.288	697	1633	A
13	01101	932.3	$A\#^5$	–0.014	770	1633	B
14	01110	987.8	B^5	–0.004	852	1633	C
15	01111	1046.5	C^5	–0.335	941	1633	D
16	10000	1108.7	$C\#^5$	–0.355	697	1209	1
17	10001	1174.7	D^5	–0.023	770	1209	4
18	10010	1244.5	$D\#^5$	–0.129	852	1209	7
19	10011	1318.5	E^5	0.106	941	1209	*
20	10100	1396.9	F^5	–0.214	697	1336	2
21	10101	1480.0	$F\#^5$	–0.222	770	1336	5
22	10110	1568.0	G^5	0.126	852	1336	8
23	10111	1661.2	$G\#^5$	–0.241	941	1336	0
24	11000	1760.0	A^6	–0.302	697	1477	3
25	11001	1864.6	$A\#^6$	–0.014	770	1477	6
26	11010	1975.5	B^6	0.665	852	1477	9
27	11011	2093.0	C^6	0.367	941	1477	#
28	11100	2217.5	$C\#^6$	0.387	697	1633	A
29	11101	2349.3	D^6	0.771	770	1633	B
30	11110	2663.3		---	852	1633	C
31	11111	2983.0		---	941	1633	D

Figure 10-1. Write Cycle

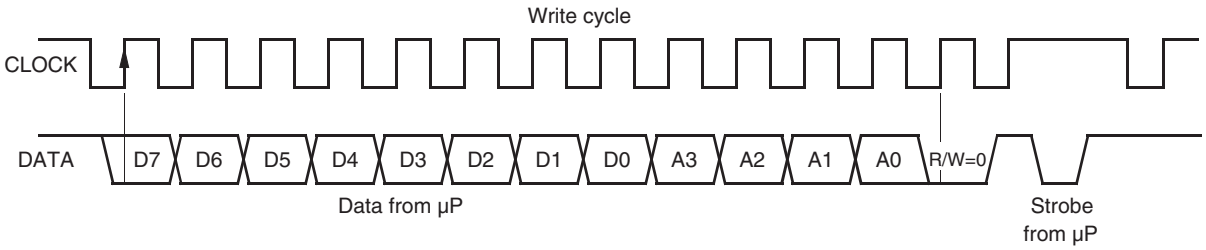


Figure 10-2. Normal Read Cycle

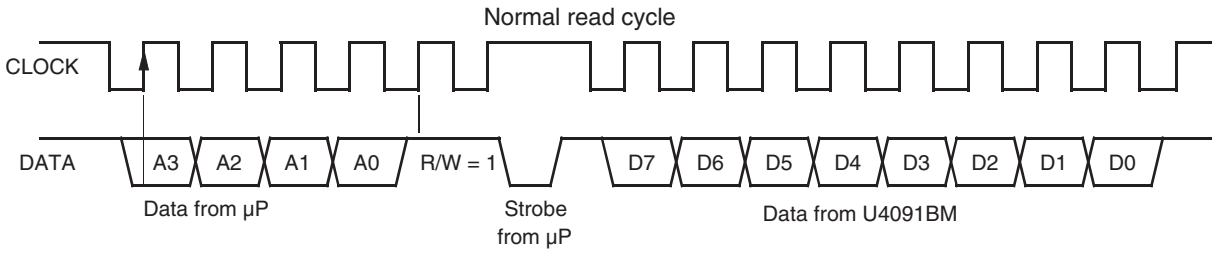


Figure 10-3. Fast Read Cycle

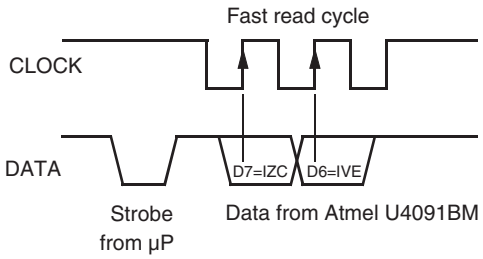


Table 10-6. Names and Functions of the Serial Registers

Register	Group	No.	Name	Description	Status	
R0	Enables	R0B0	ENRING	Enable ringer		1
		R0B1	ERX	Enable receive part	0	
		R0B2	ETX	Enable transmit part	0	
		R0B3	ENVM	Enable VM generator		1
		R0B4	ENMIC	Enable microphone	0	
		R0B5	ENSTBAL	Enable sidetone	0	
		R0B6	MUTE	Muting earpiece amplifier	0	
		R0B7	ENRLT	Enable POR low threshold		1
R1	Enables	R1B0	ENSACL	Enable anti-clipping for speaker amplifier	0	
		R1B1	ENSA	Enable speaker amplifier and AFS	0	
		R1B2	ENSAO	Enable output stage speaker amplifier	0	
		R1B3	ENAM	Enable answering machine connections	0	
		R1B4	ENAGC	Enable AGC for answering machine	0	
		R1B5	Reserved	-	0	
		R1B6	Reserved	-	0	
		R1B7	FOFFC	Speed up offset canceller	0	
R2	Matrix	R2B0	I1O1	Switch on MIC/LTX	0	
		R2B1	I1O2	Switch on MIC/SA	0	
		R2B2	I1O3	Switch on MIC/EPO	0	
		R2B3	I1O4	Switch on MIC/AMREC	0	
		R2B4	I1O5	Switch on MIC/AGCI	0	
		R2B5	I2O1	Switch on DTMF/LTX	0	
		R2B6	I2O2	Switch on DTMF/SA	0	
		R2B7	I2O3	Switch on DTMF/EPO	0	
R3	Matrix	R3B0	I2O4	Switch on DTMF/AMREC	0	
		R3B1	I2O5	Switch on DTMF/AGCI	0	
		R3B2	I3O1	Switch on LRX/LTX	0	
		R3B3	I3O2	Switch on LRX/SA	0	
		R3B4	I3O3	Switch on LRX/EPO	0	
		R3B5	I3O4	Switch on LRX/AMREC	0	
		R3B6	I3O5	Switch on LRX/AGCI	0	
		R3B7	I4O1	Switch on AMPB/LTX	0	

Table 10-6. Names and Functions of the Serial Registers (Continued)

Register	Group	No.	Name	Description	Status	
R4	Matrix	R4B0	I4O2	Switch on AMPB/SA	0	
		R4B1	I4O3	Switch on AMPB/EPO	0	
		R4B2	I4O4	Switch on AMPB/AMREC	0	
R5	AGATX MICLIM	R4B3	I4O5	Switch on AMPB/AGCI	0	
		R4B4	I5O1	Switch on AGCO/LTX	0	
		R4B5	I5O2	Switch on AGCO/SA	0	
		R4B6	I5O3	Switch on AGCO/EPO	0	
		R4B7	I5O4	Switch on AGCO/AMREC	0	
		R5B0	EAFS	Enable AFS block	0	
		R5B1	AGATX0	Gain transmit AGA LSB	0	
		R5B2	AGATX1	Gain transmit AGA	0	
		R5B3	AGATX2	Gain transmit AGA MSB	0	
		R5B4	MICHF	Select RF-microphone input	0	
		R5B5	DBM5	Maximum transmit level for anti-clipping	0	
		R5B6	MIC0	Gain microphone amplifier LSB	0	
		R5B7	MIC1	Gain microphone amplifier MSB	0	
R6	Shut down Sidetone	R6B0	SD	Shut down	0	
		R6B1	Reserved	-	0	
		R6B2	SL0	Slope adjustment for sidetone LSB	0	
		R6B3	SL1	Slope adjustment for sidetone MSB	0	
		R6B4	LF0	Low frequency adjustment for sidetone LSB	0	
		R6B5	LF1	Low frequency adjustment for sidetone	0	
		R6B6	LF2	Low frequency adjustment for sidetone	0	
		R6B7	LF3	Low frequency adjustment for sidetone MSB	0	
R7	Sidetone AGARX	R7B0	P0	Pole adjustment for sidetone LSB	0	
		R7B1	P1	Pole adjustment for sidetone	0	
		R7B2	P2	Pole adjustment for sidetone	0	
		R7B3	P3	Pole adjustment for sidetone	0	
		R7B4	P4	Pole adjustment for sidetone MSB	0	
		R7B5	AGARX0	Gain receive AGC LSB	0	
		R7B6	AGARX1	Gain receive AGC	0	
		R7B7	AGARX2	Gain receive AGC MSB	0	
R8	EARA Line impedance	R8B0	EA0	Gain earpiece amplifier LSB	0	
		R8B1	EA1	Gain earpiece amplifier	0	
		R8B2	EA2	Gain earpiece amplifier	0	
		R8B3	EA3	Gain earpiece amplifier	0	
		R8B4	EA4	Gain earpiece amplifier MSB	0	
		R8B5	IMPH	Line impedance selection (1 = 1kΩ)	0	
		R8B6	LOMAKE	Short circuit during pulse dialing	0	
		R8B7	AIMP	Switch for additional external line impedance	0	

Table 10-6. Names and Functions of the Serial Registers (Continued)

Register	Group	No.	Name	Description	Status	
R9	AFS	R9B0	AFS0	AFS gain adjustment LSB	0	
		R9B1	AFS1	AFS gain adjustment	0	
		R9B2	AFS2	AFS gain adjustment	0	
		R9B3	AFS3	AFS gain adjustment	0	
		R9B4	AFS4	AFS gain adjustment	0	
		R9B5	AFS5	AFS gain adjustment MSB	0	
		R9B6	AFS4PS	Enable 4-point sensing	0	
		R9B7	Reserved	-	0	
R10	SA	R10B0	SA0	Gain speaker amplifier LSB	0	
		R10B1	SA1	Gain speaker amplifier	0	
		R10B2	SA2	Gain speaker amplifier	0	
		R10B3	SA3	Gain speaker amplifier	0	
		R10B4	SA4	Gain speaker amplifier MSB	0	
		R10B5	SE	Speaker amplifier single-ended mode	0	
		R10B6	LSCUR0	Speaker amplifier charge-current adjustment LSB	0	
		R10B7	LSCUR1	Speaker amplifier charge-current adjustment MSB	0	
R11	ADC	R11B0	ADC0	Input selection ADC	0	
		R11B1	ADC1	Input selection ADC	0	
		R11B2	ADC2	Input selection ADC	0	
		R11B3	ADC3	Input selection ADC	0	
		R11B4	NWT	Network tuning	0	
		R11B5	SOC	Start of ADC conversion	0	
		R11B6	ADCR	Selection of ADC range	0	
		R11B7	MSKIT	Mask for interrupt bits	0	
R12	DTMF	R12B0	DTMFF0	DTMF frequency selection	0	
		R12B1	DTMFF1	DTMF frequency selection	0	
		R12B2	DTMFF2	DTMF frequency selection	0	
		R12B3	DTMFF3	DTMF frequency selection	0	
		R12B4	DTMFF4	DTMF frequency selection	0	
		R12B5	DTMFM0	Generator mode selection	0	
		R12B6	DTMFM1	Generator mode selection	0	
		R12B7	DTMFM2	Generator mode selection	0	
R13	CLK RTH TM	R13B0	CLK0	Selection clock frequency for microcontroller	0	
		R13B1	CLK1	Selection clock frequency for microcontroller	0	
		R13B2	RTH0	Ringer threshold adjustment LSB	0	
		R13B3	RTH1	Ringer threshold adjustment	0	
		R13B4	RTH2	Ringer threshold adjustment	0	
		R13B5	RTH3	Ringer threshold adjustment MSB	0	
		R13B6	TME0	Test mode enable (low active)	0	
		R13B7	TME1	Test mode enable (high active)	0	

Table 10-6. Names and Functions of the Serial Registers (Continued)

Register	Group	No.	Name	Description	Status	
R14	TM CLOR	R14B0	TME2	Test mode enable (high active)	0	
		R14B1	TME3	Test mode enable (low active)	0	
		R14B2	Reserved	-	0	
		R14B3	CLOR0	Adjustment for calculated receive log amp LSB	0	
		R14B4	CLOR1	Adjustment for calculated receive log amp	0	
		R14B5	CLOR2	Adjustment for calculated receive log amp	0	
		R14B6	CLOR3	Adjustment for calculated receive log amp	0	
		R14B7	CLOR4	Adjustment for calculated receive log amp MSB	0	
R15	CLOT	R15B0	Reserved	-	0	
		R15B1	Reserved	-	0	
		R15B2	Reserved	-	0	
		R15B3	CLOT0	Adjustment for calculated transmit log amp LSB	0	
		R15B4	CLOT1	Adjustment for calculated transmit log amp	0	
		R15B5	CLOT2	Adjustment for calculated transmit log amp	0	
		R15B6	CLOT3	Adjustment for calculated transmit log amp	0	
		R15B7	CLOT4	Adjustment for calculated transmit log amp MSB	0	

10.1 Power-on Reset

To avoid undefined states of the system when it is powered on, an internal reset clears the internal registers.

The system (Atmel® U4091BM-R + microcontroller) is woken up by any of the following conditions:

- VMP > 2.75V and VB > 2.95V
- and line voltage (VL)
- or ringer (VRING)
- or external supply (ES)

The power-down of the circuit is caused by a shut-down sent by the serial bus (SD = 1), low-voltage reset, or by the watchdog function (see Figure 12-2 on page 18, Figure 12-3 on page 18 and Figure 12-4 on page 18).

11. Watchdog Function

To avoid the system operating the microcontroller in a fault state, the circuit provides a watchdog function. The watchdog has to be retriggered every second by triggering the serial bus (sending information to the IC or other remote components at the serial bus). If there has been no bus transmission for more than one second, the watchdog initiates a reset.

The watchdog provides a reset for the external microcontroller, but does not change the Atmel U4091BM-R's registers.

12. Acoustic Feedback Suppression

Acoustical feedback from the loudspeaker to the hands-free microphone may cause instability of the system. The Atmel® U4091BM-R has a very efficient feedback-suppression circuit which offers a 4-point or (alternatively) a 2-point signal-sensing topology (see Figure 12-1).

Two attenuators (TXA and SAI) reduce the critical loop gain via the serial bus either in the transmit or in the receive path. The overall loop gain remains constant under all operating conditions.

The LOGs produce a logarithmically-compressed signal of the TX- and RX-envelope curve. The AFSCON block determines whether the TX or the RX signal has to be attenuated.

The voice-switch topology can be selected by the serial bus. In 2-point-sensing mode, AFSCON is controlled directly by the LOG outputs.

Figure 12-1. Basic System Configurations

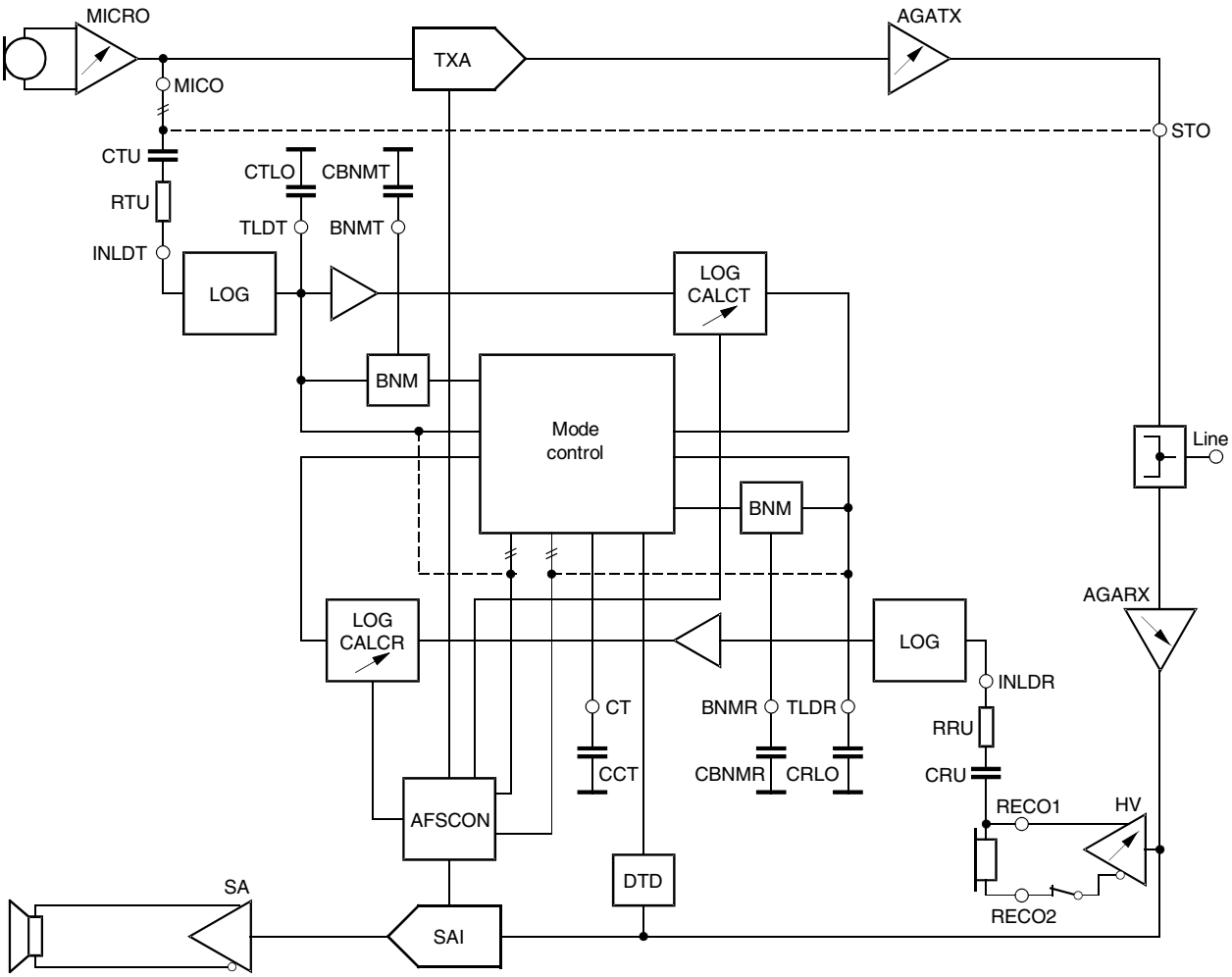


Figure 12-2. Power-on Reset (Line)

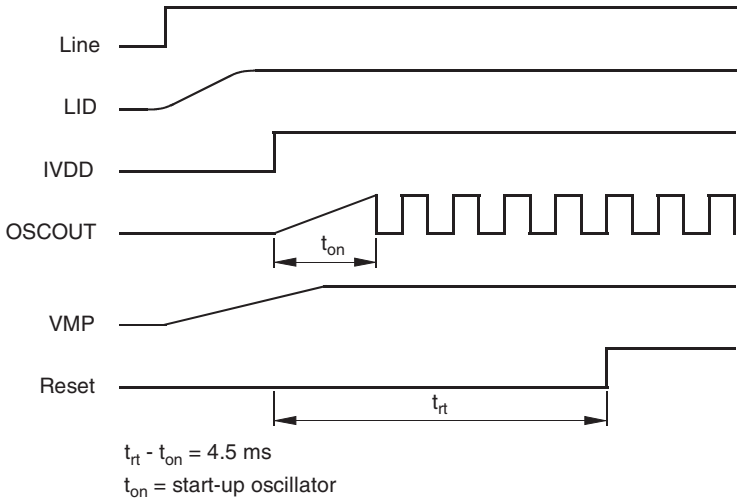


Figure 12-3. Power-on Reset (Ringing)

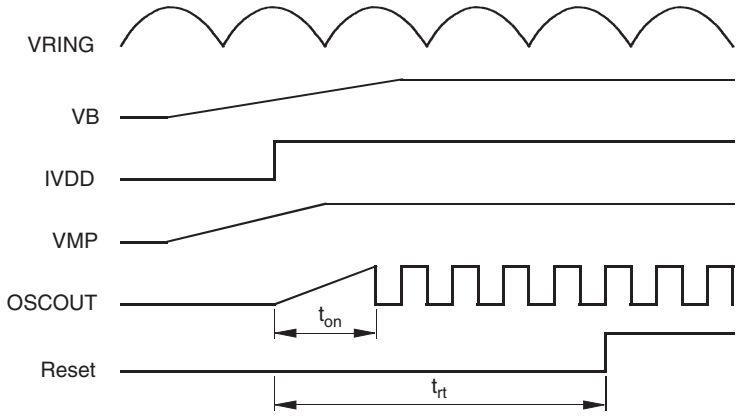
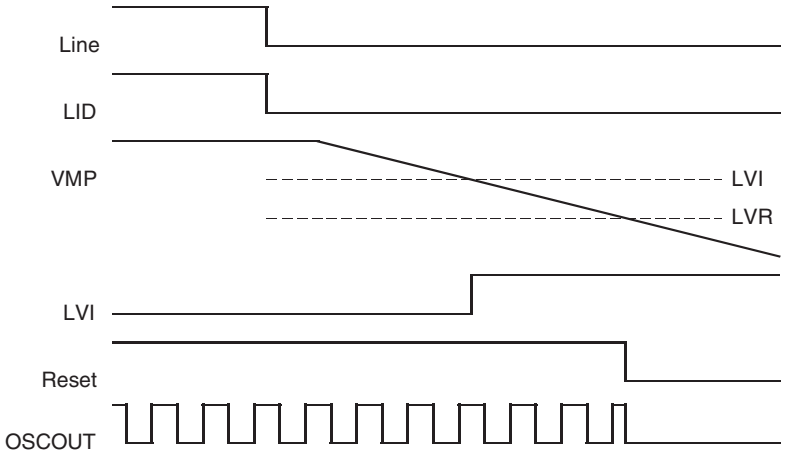


Figure 12-4. Power-on Reset (Low Voltage Reset)



12.1 Dial-tone Detector

The dial-tone detector is a comparator with one side connected to the speaker amplifier input and the other to VM with a 35-mV offset (see Figure 12-5 on page 21). If the circuit is in idle mode, and the incoming signal is greater than 35mV ($25mV_{rms}$), the comparator's output will change thus disabling the receive idle mode. This circuit prevents the dial tone (which would be considered as continuous noise) from fading away as the circuit would have the tendency to switch to idle mode. By disabling the receive idle mode, the dial tone remains at the normally expected full level.

12.2 Background Noise Monitors

This circuit distinguishes speech (which consists of bursts) from background noise (a relatively constant signal level). There are two background-noise monitors, one for the receive path and the other for the transmit path. The receive background-noise monitor is operated on by the receive level detector, while the transmit background noise monitor is operated on by the transmit level detector (see Figure 12-6 on page 21). They monitor the background noise by storing a DC voltage representative of the respective noise levels in capacitors at CBNMR and CBNMT. The voltages at these pins have slow rise times (determined by the internal current source and an external capacitor), but fast decay times. If the signal at TLDR (or TLDT) changes slowly, the voltage at BNMR (or BNMT) will remain more positive than the voltage at the non-inverting input of the monitor's output comparator. When speech is present, the voltage at the non-inverting input of the comparator will rise more quickly than the voltage at the inverting input (due to the burst characteristic of speech), causing its output to change. This output is sensed by the mode-control block.

12.3 4-point Sensing

In 4-point-sensing mode, the receive- and the transmit-sensing paths include additional CLOGs (calculated logarithmic amplifiers). The block MODECON compares the detector output signals and decides whether receive, transmit or idle mode has to be activated. Depending on the mode decision, MODECON generates a differential voltage to control AFSCON.

The MODECON block has seven inputs:

- The output of the transmit log (LOGT) – the comparison of LOGT, CLOGR
- The output of the receive clog (CLOGR) – designated I1
- The output of the transmit clog (CLOGT) – the comparison of CLOGT, LOGR
- The output of the receive log (LOGR) – designated I2
- The output of the transmit background-noise monitor (BNMT) – designated I3
- The output of the receive background-noise monitor (BNMR) – designated I4
- The output of the dial-tone detector

The differential output (AFST, AFSR) of the block MODECON controls AFSCON. The effect of I1-I4 in Table 12-1 on page 19.

Table 12-1. Mode Decision for Signal Sensing

Input				Output
I1	I2	I3	I4	Mode
T	T	S	X	Transmit
T	R	Y	Y	Change mode
R	T	Y	Y	Change mode
R	R	X	S	Receive
T	T	N	X	Idle
T	R	N	N	Idle
R	T	N	N	Idle
R	R	X	N	Idle

Note: X = don't care; Y = I3 and I4 are not both noise.

LOGT > CLOGR	I1 = T
LOGT < CLOGR	I1 = R
LOGR < CLOGT	I2 = T
LOGR > CLOGT	I2 = R
BNMT detects speech	I3 = S
BNMT detects noise	I3 = N
BNMR detects speech	I4 = S
BNMR detects noise	I4 = N

12.4 Term Definitions

1. Transmit means the transmit attenuator is fully on, and the receive attenuator is at maximum attenuation.
2. Receive means the receive attenuator is fully on, and the transmit attenuator is at maximum attenuation.
3. In idle mode, the transmit and receive attenuator are at half of their maximum attenuation.
   - Change mode means both the transmit and receive speech are present in approximately equal levels. The attenuators are quickly switched (30ms) to the opposite mode until one speech level dominates the other.
   - Idle means speech has ceased in both transmit and receive paths. The attenuators are then slowly switched (1.5s) to idle mode.
4. Switching to full transmit or receive modes from the idle mode is done at a fast rate (30ms).

12.5 Summary of Truth Table

1. The circuit will switch to transmit mode if
   - Both transmit level detectors sense higher signal levels than the respective receive level detectors, and
   - The transmit background-noise monitor indicates the presence of speech
2. The circuit will switch to receive mode if
   - Both receive level detectors sense higher signal levels than the respective transmit level detectors, and
   - The receive background-noise monitor indicates the presence of speech
3. The circuit will switch to the reverse mode if
   - The level detectors disagree on the relative strengths of the signal levels, and
   - At least one of the background-noise monitors indicates speech
4. The circuit will switch to idle mode when
   - Both speakers are quiet (no speech present), or
   - When one speaker speech level is continuously overridden by noise at the other speaker’s location

The time required to switch the circuit between transmit, receive and idle is determined by internal current sources and the capacitor at pin CT. A diagram of the CT circuitry is shown in Figure 12-7 on page 21. It operates as follows:

- CCT is typically 4.7µF.
- To switch to transmit mode, ITX is turned on (IRX is off), charging the external capacitor to –240mV below VM. (An internal clamp prevents further charging of the capacitor.)
- To switch to receive mode, IRX is turned on (ITX is off), increasing the voltage on the capacitor to +240mV with respect to VM.
- To switch to reverse mode, the current sources ITX, IRX are turned off, and the current source IFI is switched on, discharging the capacitor to VM.
- To switch to idle mode, the current sources ITX, IRX, IFI are turned off, and the current source ISI charges the capacitor to VM.

Figure 12-5. Dial Tone Detector

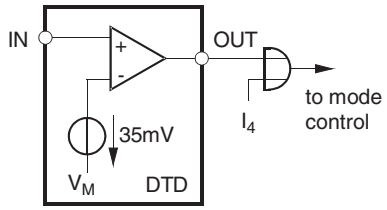


Figure 12-6. Background Noise Monitor

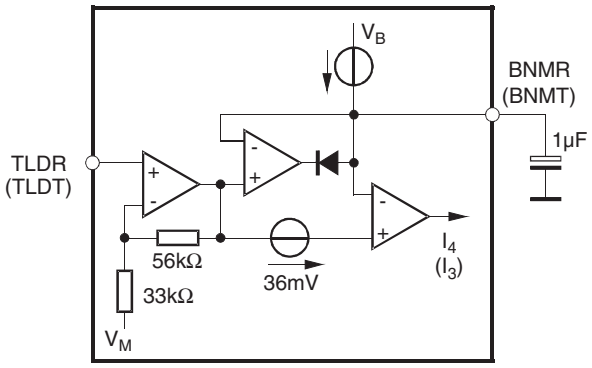


Figure 12-7. Generation of Control Voltage (CT) for Mode Switching

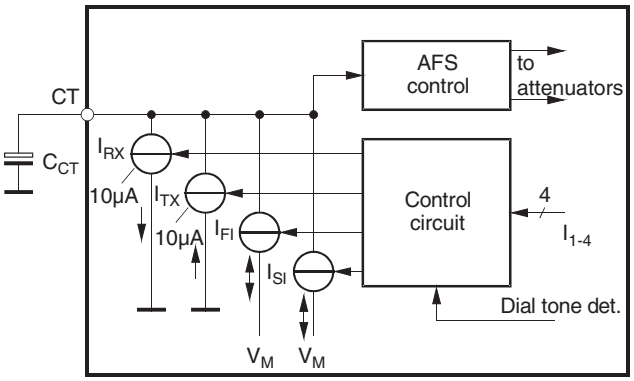


Figure 12-8. Block Diagram Hands-free Mode Atmel® U4091BM-R 2-point Signal Sensing

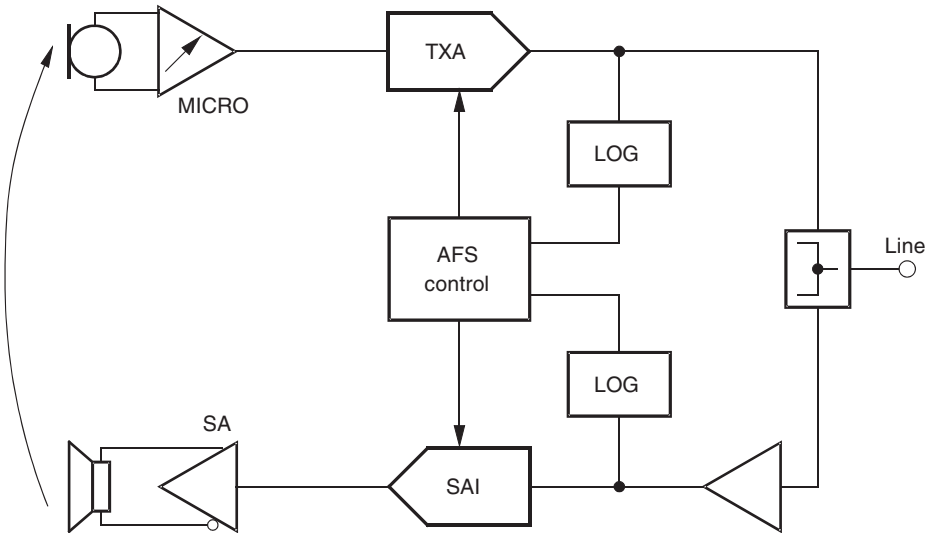
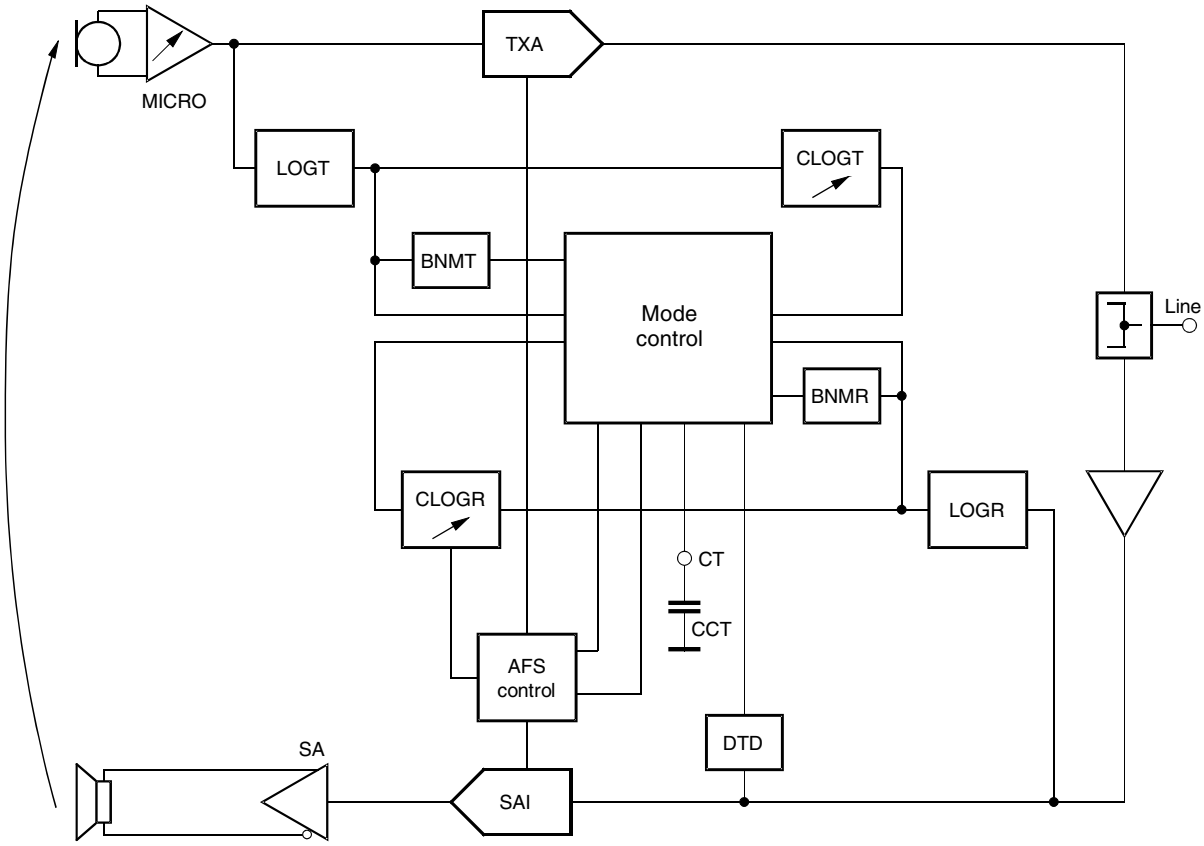


Figure 12-9. Block Diagram Hands-free Mode Atmel U4091BM-R 4-point Signal Sensing



13. Analog-to-Digital Converter (ADC)

This circuit is a 7-bit successive-approximation analog-to-digital converter in switched capacitor technique. An internal band gap circuit generates a 1.25-V reference voltage which is the equivalent of 1 MSB (1 LSB = 19.5mV). The possible input voltage at ADIN is 0V to 2.48V.

The ADC needs an SOC (Start Of Conversion) signal. In the High phase of the SOC signal, the ADC is reset. Then, 50µs after the beginning of the Low phase of the SOC signal, the ADC generates an EOC (End Of Conversion) signal which indicates that the conversion is finished. The rising edge of EOC generates an interrupt at the INT output. The result can be read out by the serial bus.

Voltages higher than 2.45V have to be divided. The signal connected to the ADC is determined by 4 bits: ADC0, ADC1, ADC2 and ADC3. TLDR/TLDT measuring is possible relative to a preceding reference measurement. The current range of IL can be doubled by ADCR. If ADCR is High, S has the value 0.5, otherwise S = 1.

The source impedance at ADIN must be lower than 250kΩ

Accuracy: 1 LSB + 3%

Figure 13-1. Timing of ADC

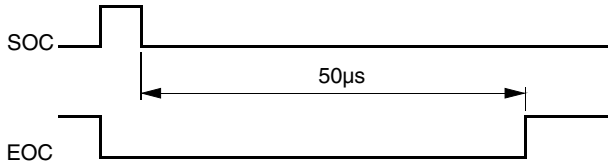


Figure 13-2. ADC Input Selection

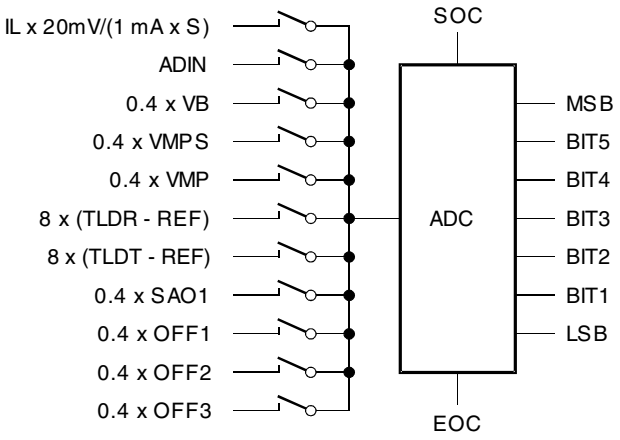


Table 13-1. Input Selection ADC

Decimal	ADC[1:4]	Symbol	Value
0	0000	OFF	-
1	0001	IL	I1 = S × 127mA × D / 128
2	0010	ADIN extern	V2 = 2.5V × D / 128 (maximum 2.5V)
3	0011	VB	V3 = (2.5V / 0.4) × D / 128
4	0100	VMPS	V4 = (2.5V / 0.4) × D / 128
5	0101	VMP	V5 = (2.5V / 0.4) × D / 128
6	0110	TLDR	V6 = 8 × (V_p – Ref) × D / 128
7	0111	TLDT	V7 = 8 × (V_p – Ref) × D / 128
8	1000	Not used	-
9	1001	SAO1	V4 = (2.5V / 0.4) × D / 128
10	1010	Offcan1	Atmel's internal use
11	1011	Offcan2	-
12	1100	Offcan3	-
13	1101	Not used	-
14	1110	Not used	-
15	1111	Not used	-

Note: D = measured digital word (0 ≤ D ≤ 127)
S = programmable gain 0.5 or 1
V_p = peak value of the measured signal

14. Switch Matrix

The switch matrix has 5 inputs and 5 outputs. Every pair of I/Os except AGCO and AGCI can be connected. The inputs and outputs used must be enabled. If 2 or more inputs are switched to an output, the sum of the inputs is available at the output.

The inputs MIC and LRX have offset cancellers with a 3-dB corner frequency of 270Hz. AMPB has a 60-kΩ input impedance. The TXO output has a digitally-programmable gain stage with a gain of 2dB to 9dB (in 1dB steps) depending on AGATX0 (LSB), AGATX1, AGATX2 (MSB), and a first order low-pass filter with 0.5dB damping at 3300Hz and 3dB damping at 9450Hz. The outputs RXLS, EPO and AMREC have a gain of 0dB. The offset at the outputs of the matrix is less than 30mV. If a switch is open, the path has a damping of more than 60dB.

Figure 14-1. Switch Matrix Diagram

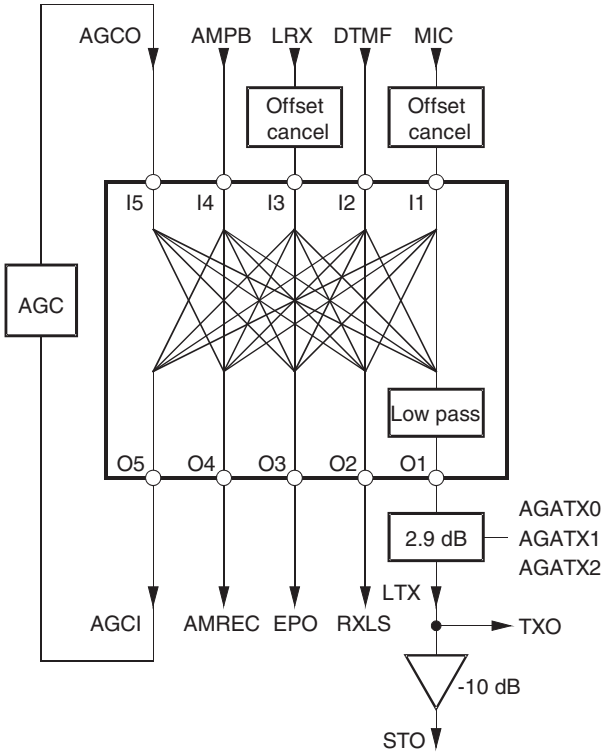
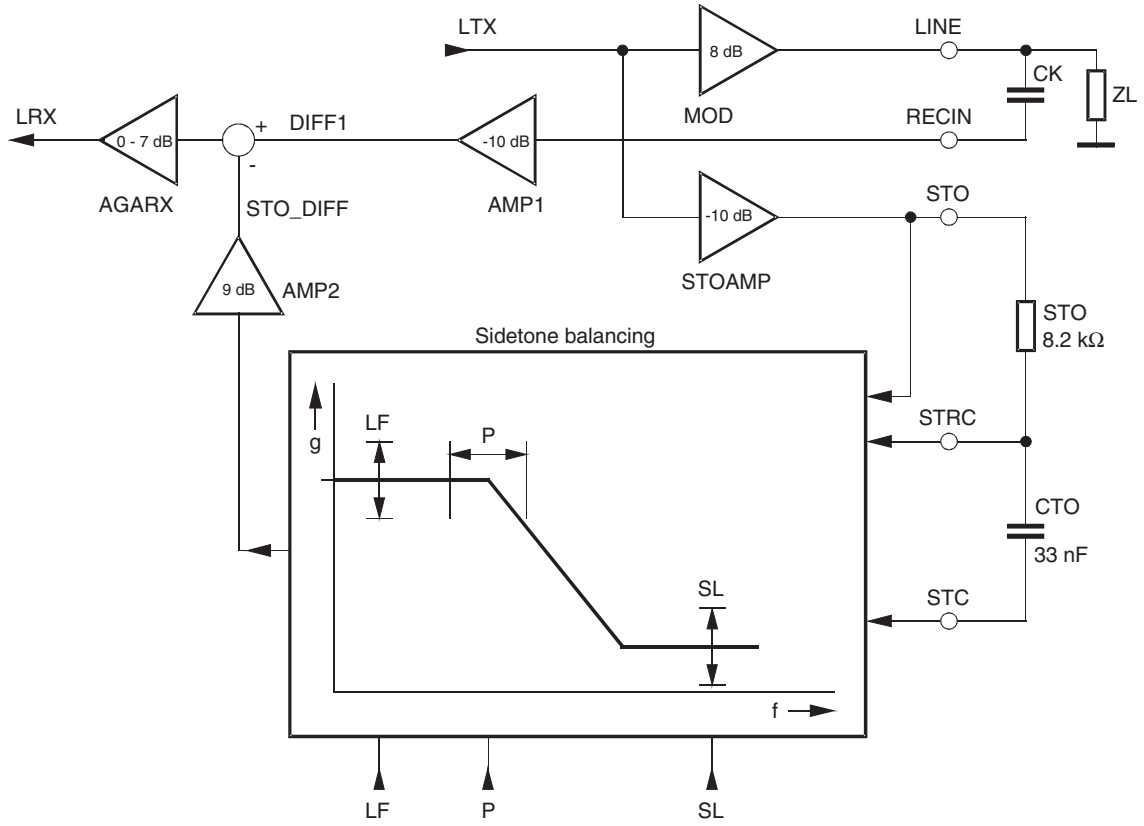


Table 14-1. Bits and Corresponding Switches

Register	No.	Name	Description
R2	R2B0	I1O1	Switch on MIC/LTX
	R2B1	I1O2	Switch on MIC/RXLS
	R2B2	I1O3	Switch on MIC/EPO
	R2B3	I1O4	Switch on MIC/AMREC
	R2B4	I1O5	Switch on MIC/AGCI
	R2B5	I2O1	Switch on DTMF/LTX
	R2B6	I2O2	Switch on DTMF/RXLS
	R2B7	I2O3	Switch on DTMF/EPO
R3	R3B0	I2O4	Switch on DTMF/AMREC
	R3B1	I2O5	Switch on DTMF/AGCI
	R3B2	I3O1	Switch on LRX/LTX
	R3B3	I3O2	Switch on LRX/RXLS
	R3B4	I3O3	Switch on LRX/EPO
	R3B5	I3O4	Switch on LRX/AMREC
	R3B6	I3O5	Switch on LRX/AGCI
	R3B7	I4O1	Switch on AMPB/LTX
R4	R4B0	I4O2	Switch on AMPB/RXLS
	R4B1	I4O3	Switch on AMPB/EPO
	R4B2	I4O4	Switch on AMPB/AMREC
	R4B3	I4O5	Switch on AMPB/AGCI
	R4B4	I5O1	Switch on AGCO/LTX
	R4B5	I5O2	Switch on AGCO/RXLS
	R4B6	I5O3	Switch on AGCO/EPO
	R4B7	I5O4	Switch on AGCO/AMREC

15. Sidetone System

Figure 15-1. Principle Circuit of Sidetone Balancing



The Sidetone Balancing (STB) has the task of reducing the cross-talk from LTX (microphone) to LRX (earpiece) in the frequency range of 0.3kHz to 3.4kHz. The LTX signal is converted into a current in the MOD block. This current is transformed into a voltage signal (LINE) by the line impedance ZL. The LINE signal is fed into the summing amplifier DIFF1 via capacitor CK and attenuator AMP1.

On the other hand the LTX buffered by STOAMP drives an external low-pass filter (RST, CST). The external low-pass filter and the internal STB have the transfer function drawn in the STB box. The amplified STB output signal drives the negative input of the summing block. If both signals at the DIFF1 block are equal in level and phase, we have good suppression of the LTX signal. In this condition, the frequency and phase response of the STB block will represent the frequency curve on line.

In real life, the line impedance ZL varies strongly for different users. To obtain good suppression with one application for all different line impedances, the STB function is programmable.

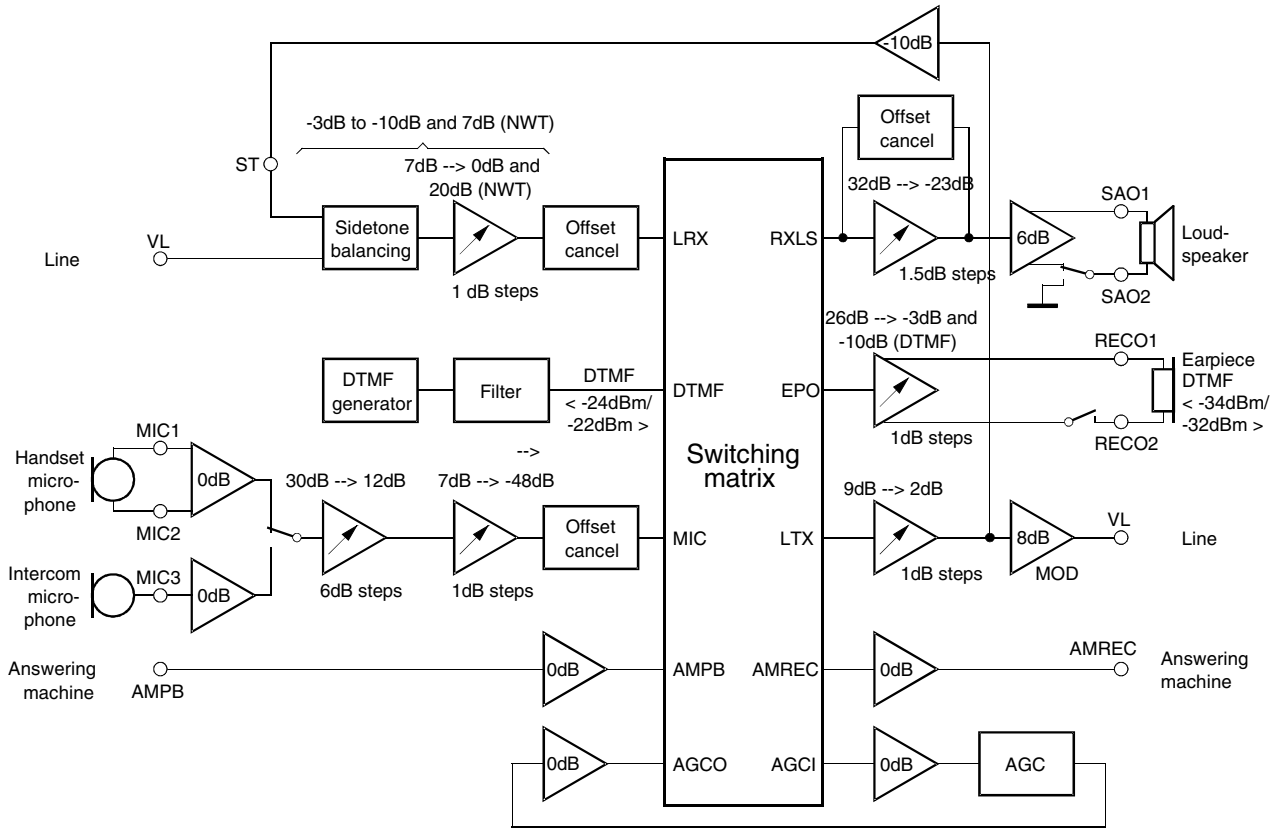
The 3 programmable parameters are

1. LF (gain at low frequency)
   LF has 15 programming steps of 0.5dB
   LF(0) provides –2dB gain, LF(15) provides 5.5dB gain
   STO_DIFF(LF) = (–10dB – 2dB + 0.5dB × LF + 9dB) × LTX
2. P (the pole position of the low-pass)
   The P adjustment has 31 steps. P(0) means the lowpass determined by the external application (RST, CST). The internally processed low-pass frequency is fixed by the following equation.

$$f(P) = \frac{1}{2 \times \pi \times CST \times RST} \times 1.122^{P}$$

3. SL (sidetone slope; the pole frequency of the high-pass)
   The SL has 3 steps. SL(0) is a lower frequency of the high-pass. SL(3) is a higher frequency of the high-pass. SL can be used to influence the suppression at high frequencies.

Figure 15-2. Audio Frequency Signal Management Atmel® U4091BM-R



16. Absolute Maximum Ratings

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

Parameters	Symbol	Value	Unit
Line current	I_L	140	mA
DC line voltage	V_L	12	V
Maximum input current	I_{RING}	15	mA
Junction temperature	T_j	125	°C
Ambient temperature	T_{amb}	–25 to +75	°C
Storage temperature	T_{stg}	–55 to +150	°C
Total power dissipation, T_{amb} = 60°C	P_{tot}	0.9	W

17. Thermal Resistance

Parameters	Symbol	Value	Unit
Junction ambient SSO44	R_{thJA}	70	K/W

18. Electrical Characteristics

f = 1kHz, 0dBm = 775mV$_{rms}$, IVMIC = 0.3mA, IMP = 3mA, R_{DC} = 1.3MΩ, T_{amb} = 25°C, Z_{ear} = 68nF + 100Ω, RLS = 50Ω, Z_M = 68nF, resonator: f = 3.58MHz, all bits in reset condition, unless otherwise specified.

Parameters	Test Conditions	Symbol	Min.	Typ.	Max.	Unit
DC Characteristics						
DC voltage drop over circuit	I_L = 2mA I_L = 14mA I_L = 60mA I_L = 100mA	V_L	 4.4 8.6	1.6 4.8 7.2 9.2	 5.2 9.8	V V V V
Transmission Amplifier, I_L = 14mA, V_{MIC} = 2mV, MICG[0:1] = 2, AGATX[0:2] = 7 ERX = ETX = ENMIC = ENSTBAL = I1O1 = I3O3 = 1, (G_T = 48dB)						
Transmit amplification	MICG[0:1] = 2 AGATX[0:2] = 7	G_T	45.3	46.5	47.7	dB
Frequency response due to internal filters	I_L ≥ 14mA, f = 1kHz to 3.4kHz	ΔG_T	–1		0	dB
Gain change with current	I_L = 14mA to 100mA	ΔG_T			±0.5	dB
Gain deviation	T_{amb} = –10°C to +60°C	ΔG_T			±0.5	dB
CMRR of microphone amplifier		CMRR	60	80		dB
Input resistance of MIC amplifier		R_i		50		kΩ
Input resistance of MIC3 amplifier	MICHF = 1	R_i	75	150	300	kΩ
Gain difference between MIC1/MIC2 to MIC3	MICHF = 1	ΔG_T			±0.4	dB
Distortion at line	I_L ≥ 14mA, V_L = 700mV$_{rms}$	d_t			2	%

Note: 1. This is a period of time the bus requires from the end of a data transmission and before a new transmission can be started

18. Electrical Characteristics (Continued)

f = 1kHz, 0dBm = 775mV$_{rms}$, IVMIC = 0.3mA, IMP = 3mA, R_{DC} = 1.3MΩ, T_{amb} = 25°C, Z_{ear} = 68nF + 100Ω, RLS = 50Ω, Z_M = 68nF, resonator: f = 3.58MHz, all bits in reset condition, unless otherwise specified.

Parameters	Test Conditions	Symbol	Min.	Typ.	Max.	Unit
Maximum output voltage	I_L ≥ 19mA, d < 5%, V_{MIC} = 10mV CTXA = 1µF, DBM5 = 0	V_{Lmax}	1.8	3.0	4.2	dBm
	DBM5 = 1	V_{Lmax}	4.8	6.0	6.6	dBm
	V_{MIC} = 20mV, MICG[0:1] = 3	$V_{MICOmax}$		–4.2		dBm
Noise at line psophometrically weighted	I_L ≥ 14mA, MICG[0:1] = 2 AGATX[0:2] = 7	No		–73	–70	dBmp
Anti-clipping attack time release time	 CTXA = 1µF each 3 dB overdrive	 t_a t_r		 2 80		 ms ms
Gain at low operating current	I_L = 8mA, I_{MP} = 1mA V_{MIC} = 0.5mV I_{VMIC} = 300µA	G_T	45		48	dB
Distortion at low operating current	I_L = 8mA, I_{MP} = 1mA V_{MIC} = 5mV I_{VMIC} = 300µA	d_t			5	%
Receiving Amplifier I_L = 14mA, V_{GEN} = 300mV, ERX = ETX = ENMIC = ENSTBAL = I1O1 = I3O3 = 1, SL[0:1] = 0, LF[0:3] = 1, P[0:4] = 31, AFS[0:5] = 54, AGARX[0:2] = 0						
Adjustment range of receiving gain	Single ended, I_L ≥ 14mA, Mute = 1, EA[0:4] = 2 to 31 AGARX[0:2] = 0 to 7	G_R	–19		+17	dB
Receiving amplification	Differential AGARX[0:2] = 0 EA[0:4] = 15 EA[0:4] = 31	G_R	 –1 14.7	 0 15.7	 1 16.7	 dB dB
Frequency response	I_L ≥ 14mA, f = 1kHz to 3.4kHz	ΔG_{RF}	–1		0	dB
Gain change with current	I_L = 14mA to 100mA	ΔG_R			±0.5	dB
Gain deviation	T_{amb} = –10°C to +60°C	ΔG_R			±0.5	dB
Ear protection differential	I_L ≥ 14mA, V_{GEN} = 11V_{rms} EA[0:4] = 15	EP			3	V_{rms}
MUTE suppression (earpiece disconnect from matrix)	I_L = 14mA, I303 = 0	ΔG_R	60			dB
Output voltage d < 2% differential	I_L = 14mA Z_{ear} = 68nF + 100Ω EA[0:4] = 11		0.775			V_{rms}
Maximum output current d < 2%	Z_{ear} = 100Ω EA[0:4] = 31	I_{out}	4			mA_p
Receiving noise psophometrically weighted	I_L = 14mA Z_{ear} = 68nF + 100Ω EA[0:4] = 15			–79	–76	dBmp
Sidetone suppression	Z = 600Ω		20			dB
Output resistance	Each output against GND	R_o			10	Ω

Note: 1. This is a period of time the bus requires from the end of a data transmission and before a new transmission can be started

18. Electrical Characteristics (Continued)

f = 1kHz, 0dBm = 775mV$_{rms}$, IVMIC = 0.3mA, IMP = 3mA, R_{DC} = 1.3MΩ, T_{amb} = 25°C, Z_{ear} = 68nF + 100Ω, RLS = 50Ω, Z_M = 68nF, resonator: f = 3.58MHz, all bits in reset condition, unless otherwise specified.

Parameters	Test Conditions	Symbol	Min.	Typ.	Max.	Unit
Gain at low operating current (receive only)	I_L = 6.5mA, I_{MP} = 1mA I_M = 300mA V_{GEN} = 200mV EA[0:4] = 21, ENMIC = ETX = I101 = 0	G_R	–2	0	2	dB
Distortion at low operating current	I_L = 6.5mA, I_{MP} = 1mA I_M = 300µA, EA[0:4] = 15, ENMIC = ETX = I101 = 0	dR			5	%
Adjustment step: earpiece amplifier	DEA[0:4] = 1 for EA[0:4] = 2 to 31		0.8	1	1.2	dB
Adjustment step: AGARX	DAGARX[0:2] = 1		0.8	1	1.2	dB
Gain for DTMF signal	AMPB → RECO1/2 EA[0:4] = 1			–10		dB
AC impedance	IMPH = 0 IMPH = 1	Z_{impl} Z_{imph}	595 980	625 1030	655 1080	Ω Ω
DTMF, I_L = 14 mA, ETX = I201 = 1, AGATX[0:2] = 7, DTMFM[0:2] = 4, DTMFF[0:4] = 0						
DTMF level at line (mid gain)	Sum level, 600Ω, DTMFM[0:2] = 4		–5.1	–3.6	–2.1	dBm
DTMF level at line (low gain)	Sum level, 600Ω, DTMFM[0:2] = 5		–7.6	–6.1	–4.6	dBm
DTMF level at line (high gain)	Sum level, 600Ω, DTMFM[0:2] = 6 AGATX[0:2] = 1		–5.2	–3.7	–2.2	dBm
Pre-emphasis	600Ω, DTMFF4 = 0 DTMFF4 = 1		2 3	2.5 3.5	3 4	dBm dBm
Speaker Amplifier, Differential Mode AMPB → SAO1/2 ENSACL = ENSA = ENSAO = ENAM = I4O2 = 1, SA[0:4] = 31, ERX = ETX = ENMIC = ENSTBAL = I1O1 = I3O3 = 1						
Minimum line current for operation	ENAM = I4O2 = 0 SE = 0, I3O2 = 1 IMP 1mA, V_{GEN} = 300mV	I_{Lmin}			11	mA
Gain from AMPB to SAO	V_{AMPB} = 3mV, I_L = 15mA, SA[0:4] = 31 SA[0:4] = 0	G_{SA}	36	37 –5.5	38	dB
Adjustment step speaker amplifier	DSA[0:4] = –1		1.15	1.35	1.55	dB
Output power single ended	Load resistance: R_{LS} = 50Ω V_{AMPB} = 40mV, SE = 1 I_L = 15mA I_L = 20mA	 P_{SA} P_{SA}	3	7 20		mW mW
Maximum output power differential	Load resistance: R_L = 50Ω V_{AMPB} = 60mV, SE = 0 V_B = 5V	P_{SA}		150		mW

Note: 1. This is a period of time the bus requires from the end of a data transmission and before a new transmission can be started

18. Electrical Characteristics (Continued)

f = 1kHz, 0dBm = 775mV$_{rms}$, IVMIC = 0.3mA, IMP = 3mA, R_{DC} = 1.3MΩ, T_{amb} = 25°C, Z_{ear} = 68nF + 100Ω, RLS = 50Ω, Z_M = 68nF, resonator: f = 3.58MHz, all bits in reset condition, unless otherwise specified.

Parameters	Test Conditions	Symbol	Min.	Typ.	Max.	Unit
Output noise (input AMPB open) psophometrically weighted	I_L > 15mA	n_{SA}			240	mV_{psoph}
Gain deviation	I_L = 15mA T_{amb} = –10°C to +60°C	ΔG_{SA}			±1	dB
Mute suppression	I_L = 15mA, V_L = 0dBm, V_{AMPB} = 4mV I4O2 = 0	VSAO			–56	dBm
Gain change with current	I_L = 15mA to 100mA	ΔG_{SA}			1	dB
Gain change with frequency	I_L = 15mA f = 1kHz to 3.4kHz	ΔG_{SA}	–1		0	dB
Attack time of anti-clipping	20dB overdrive	t_r		2		ms
Release time of anti-clipping		t_f		170		ms
Adjustment step of charge current	ENSAO = 0, SE = 1 DLSCUR[0:1] = 1		–480	–400	–320	µA
Adjustment step of discharge current	ENSAO = 0, SE = 0 DLSCUR[0:1] = 1		320	400	480	µA
Charge current Pin SAO2	ENSAO = 0, SE = 1 LSCUR[0:1] = 3	I_{CHA}	–1.45	–1.2	–0.95	mA
Discharge current pin SAO2	ENSAO = 0, SE = 0 LSCUR[0:1] = 3	I_{DIS}	0.95	1.2	1.45	mA
Microphone Amplifier, V_B = 5V, V_{MIC} = 2mV, V_{MIC3} = 2mV, ENMIC = ENAM = I1O4 = 1, MICHF = 0						
Gain MIC amp.: MIC1/2 →AMREC	MICG[0:1] = 0		17.4	18.1	18.8	dB
	MICG[0:1] = 1		23.2	23.7	24.6	dB
	MICG[0:1] = 2		29.1	29.8	30.5	dB
	MICG[0:1] = 3		35.0	35.7	36.4	dB
MIC3 to AMREC	MICHF = 1, MICG[0:1] = 3		35.0	35.7	36.5	dB
Input suppression: MIC3 to MIC1/2	MICG[0:1] = 0, MICHF = 0		60			dB
MIC1/2 to MIC3	MICHF = 1		60			dB
Settling time offset cancellers	5τ, FOFFC = 0			9	12	ms
Settling time offset cancellers in speed-up mode	5τ, FOFFC = 1			1.8	2.4	ms
AGC for Answering Machine, AMPB to AMREC, ENAM = ENAGC = I4O5 = I5O4 = 1						
Nominal gain	V_{AMPB} = 5mV		23.5	25.5	27.5	dB
Maximum output level	V_{AMPB} = 50mV, d< 5%		240	300	360	mVp
Attack time	20dB overdrive			1		ms
Release time				45		ms

Note: 1. This is a period of time the bus requires from the end of a data transmission and before a new transmission can be started

18. Electrical Characteristics (Continued)

f = 1kHz, 0dBm = 775mV$_{rms}$, IVMIC = 0.3mA, IMP = 3mA, R_{DC} = 1.3MΩ, T_{amb} = 25°C, Z_{ear} = 68nF + 100Ω, RLS = 50Ω, Z_M = 68nF, resonator: f = 3.58MHz, all bits in reset condition, unless otherwise specified.

Parameters	Test Conditions	Symbol	Min.	Typ.	Max.	Unit
Switching Matrix, VL = 0, VB = 5V, ENAM = I4O4 = 1, V_{AMPB} = 0.6V$_{rms}$						
Input impedance AMPB			50	60	70	kΩ
Gain AMPB to AMREC			–0.7	–0.3	+0.1	dB
Maximum input level AMPB	I4O5 = I5O4 = 1, I4O4 = 0				600	mV
Maximum output level AMREC	I4O4 = 1				VB – 600mV	V_{PP}
Offset	I4O4: 1 to 0	ΔV_{AMREC}			±30	mV
Mute switching matrix	I4O4 = 0		60			dB
Power-on Reset VL = 0, V_{MP} = 3.3V, V_B = 5V, U4091 in Power-down Mode						
Power-on reset by ES VB high, VMP threshold	VB = 4V, ES = 4V, raise VMP until RESET goes to low	VMP_{on}	2.65	2.75	2.85	V
Power-on reset by ES VMP high, VB threshold	VMP = 3V, ES = 4V, raise VB until RESET goes to low	VB_{on}		3.2		V
Low-voltage Interrupt VL = 0, V_{MP} = 3.3V, V_B = 0V						
VMP decreasing	Decrease VMP until INT returns to high	VLVI	2.5	2.6	2.7	V
Power-off Reset VL = 0, V_{MP} = 3.3V, V_B = 0V						
Low-voltage reset	Decrease VMP until RESET returns to low	VLVR	2.35	2.45	2.55	V
Difference voltage between low-voltage interrupt and reset	VLVI – VLVR		100	150		mV
Logical Part V_{MP} = 3.3V, V_B = 5V						
Output impedance at OSCOUT			0.6	0.9	1.2	kΩ
Pins SCL, SDA (input mode) Input leakage current	Low level High level $0 < V_i < V_{MP}$		0.8 × V_{MP} –1		0.2 × V_{MP} +1	V V µA
Pins INT, SDA (output mode)	Output low (resistance to GND)		150	230	350	Ω
Switch for Additional Impedance (Pin IMPSW) V_{MP} = 3.3V, V_B = 3V						
Switch-off leakage current	$0 < V_i < V_{MP}$ IMPSW = 0		–0.5		5	µA
Resistance to GND	IMPSW = 1			50	80	Ω
Maximum current	IMPSW = 1		–5		5	mA

Note: 1. This is a period of time the bus requires from the end of a data transmission and before a new transmission can be started

18. Electrical Characteristics (Continued)

f = 1kHz, 0dBm = 775mV$_{rms}$, IVMIC = 0.3mA, IMP = 3mA, R_{DC} = 1.3MΩ, T_{amb} = 25°C, Z_{ear} = 68nF + 100Ω, RLS = 50Ω, Z_M = 68nF, resonator: f = 3.58MHz, all bits in reset condition, unless otherwise specified.

Parameters	Test Conditions	Symbol	Min.	Typ.	Max.	Unit
AFS (Acoustic Feedback Suppression), I_L = 14mA, V_{GEN} = 300mV, ERX = ETX = ENMIC = ENSTBAL = I1O1 = I3O3 = 1, SL[0:1] = 0, LF[0:3] = 1, P[0:4] = 31, AGARX[0:2] = 0						
Adjustment range of attenuation	I_L ≥ 15mA		0		50	dB
Attenuation of transmit gain	I_L ≥ 15mA, I_{INLDT} = 0µA I_{INLDR} = 10µA	ΔG_T	47	50	53	dB
Attenuation of speaker amplifier	I_L ≥ 15mA, I_{INLDT} = 10µA I_{INLDR} = 0µA	G_{SA}	47	50	53	dB
Supply Voltages, V_{MIC} = 25mV, T_{amb} = –10°C to + 60°C						
V_{MP}	I_L = 14mA, R_{DC} = 680kΩ I_{MP} = 3mA	V_{MP}	3.1	3.3	3.5	V
V_{MPS}	I_L = 100mA, R_{DC} = inf., I_{MP} = 0mA	V_{MPS}			5.5	V
V_{MIC}	I_L = 14mA, R_{DC} = 1.3MΩ I_M = 700A	V_{MIC}	1.5		4	V
V_B	I_B = +20mA, I_L = 0mA	V_B		5.5	6.3	V
Ringing Power Converter, IMP = 1mA, IM = 0, R_{IMPA} = 500kΩ						
Maximum output power	V_{RING} = 20.6V ENSA = ENSAO = SE = 1	P_{SA}		15		mW
Threshold	V_{RING}: high to low				7.4	V
	Low to high, RINGTH [0:3] = 0		6.0	6.7	7.4	V
	Low to high, RINGTH [0:3] = 15		19	21	23	V
Adjustment steps threshold	DRINGTH = 1		0.8	1	1.2	V
Input impedance	V_{RING} = 30V		4.6	5.8	7.0	kΩ
Maximum input voltage		$V_{RINGmax}$	30			V
Serial Bus SCL, SDA, AS, VMP = 3.3V, RSDA = RSCL = RINT = 12kΩ						
Input voltage HIGH LOW	SDA, SCL, INT	V_{iBUS}	 3.0 0		 V_{DD} 1.5	 V V
Output voltage Acknowledge LOW	SDA I_{SDA} = 3mA	V_O			0.4	V
Clock frequency	SCL	f_{SCL}			100	kHz
Rise time SDA, SCL		t_r			1	µs
Fall time SDA, SCL		t_f			300	ns
Period of SCL HIGH LOW	 HIGH LOW	 t_H t_L	 4.0 4.7		 	 µs µs
Setup Time						

Note: 1. This is a period of time the bus requires from the end of a data transmission and before a new transmission can be started

18. Electrical Characteristics (Continued)

f = 1kHz, 0dBm = 775mV$_{rms}$, IVMIC = 0.3mA, IMP = 3mA, R_{DC} = 1.3MΩ, T_{amb} = 25°C, Z_{ear} = 68nF + 100Ω, RLS = 50Ω, Z_M = 68nF, resonator: f = 3.58MHz, all bits in reset condition, unless otherwise specified.

Parameters	Test Conditions	Symbol	Min.	Typ.	Max.	Unit
Start condition		t_{sSTA}	4.7			µs
Data		t_{sDAT}	250			ns
Stop condition		t_{sSTOP}	4.7			µs
Time space(1)		t_{wSTA}	4.7			µs
Hold Time						
Start condition		t_{hSTA}	4.0			µs
DATA		t_{hDAT}	0			µs

Note: 1. This is a period of time the bus requires from the end of a data transmission and before a new transmission can be started

19. Test Circuits

Figure 19-1. Basic Test Circuit

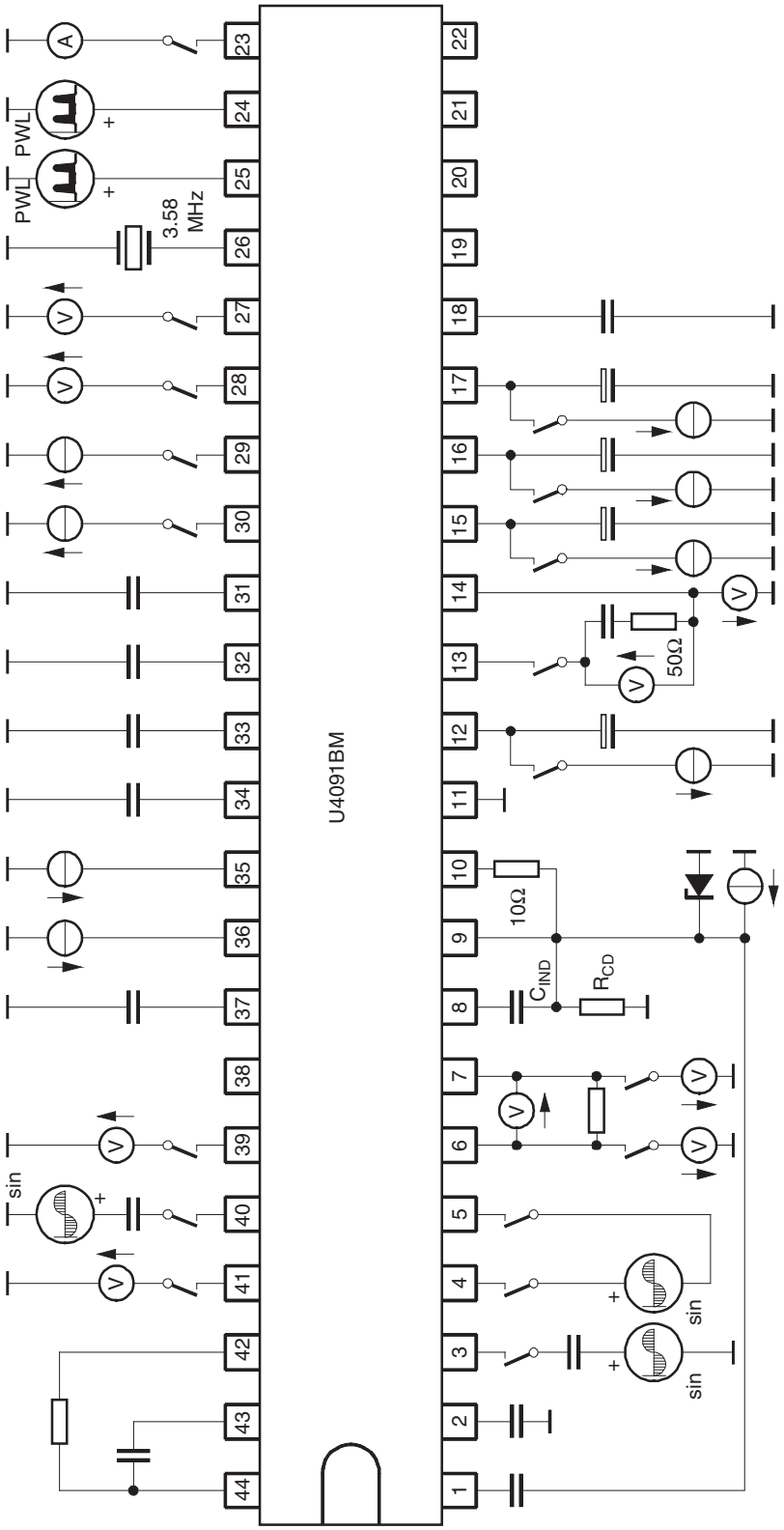
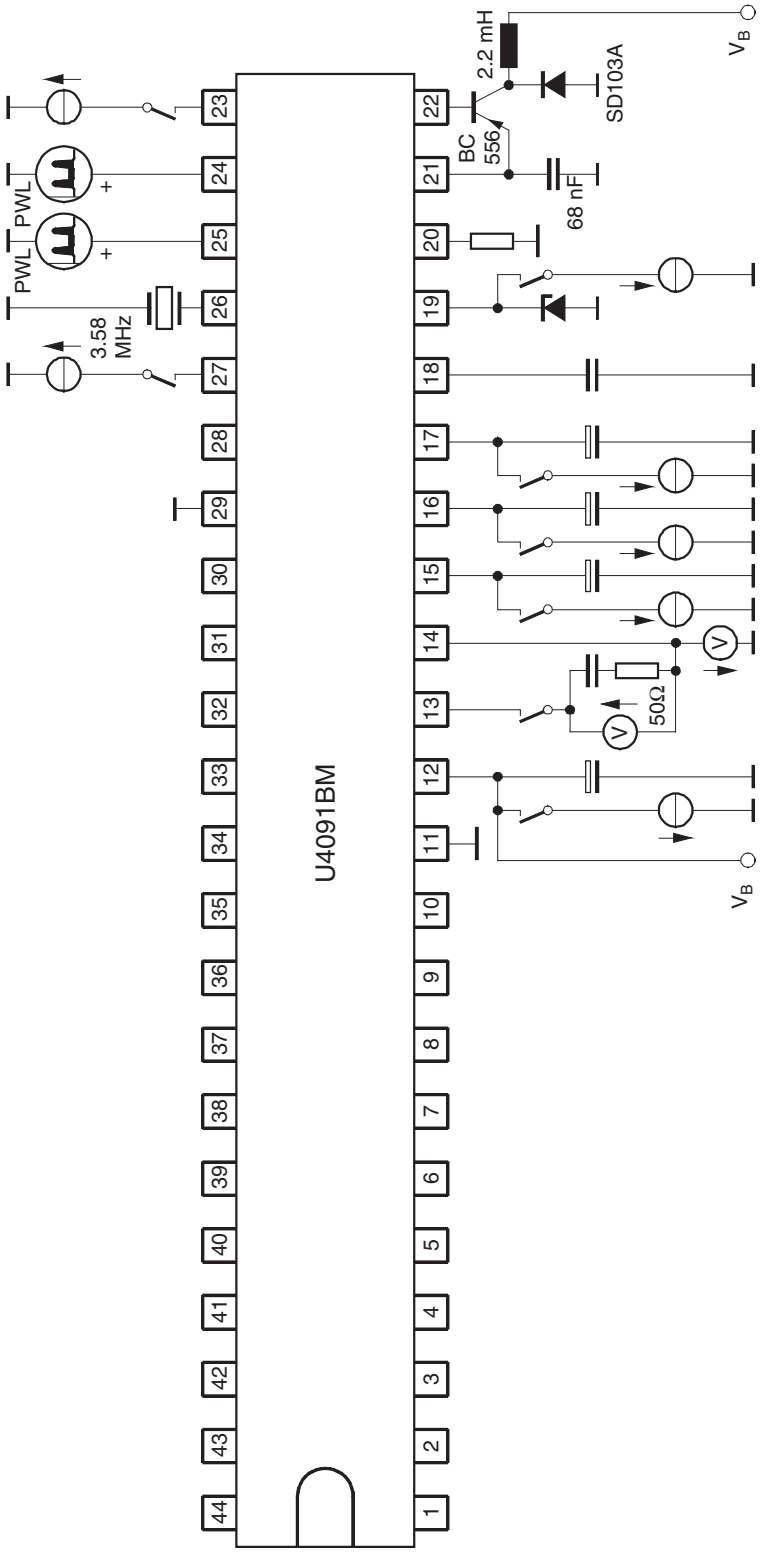
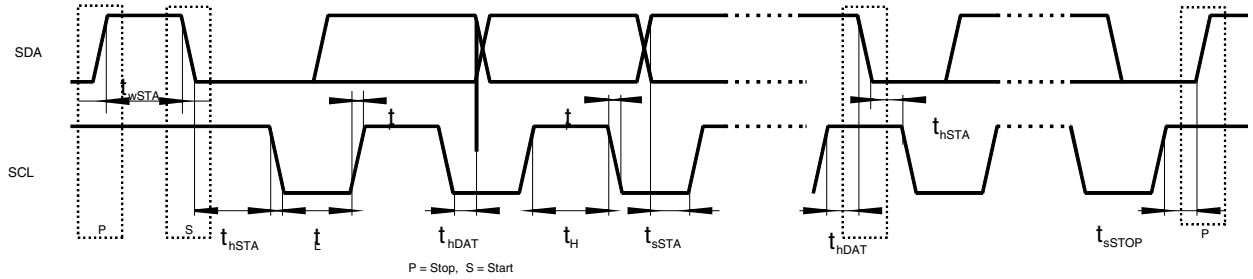


Figure 19-2. Test Circuit for Ringing



20. Bus Timing

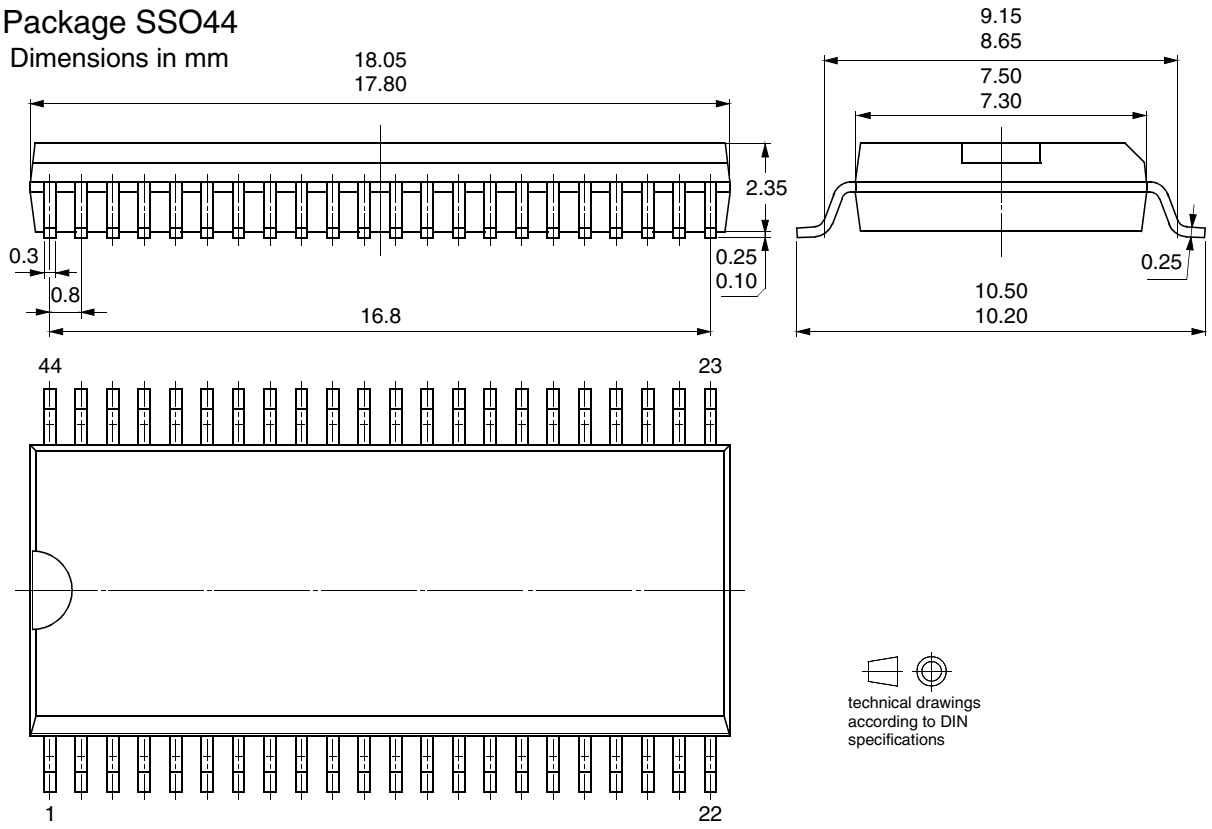
Figure 20-1. Bus Timing Diagram



21. Ordering Information

Extended Type Number	Package	Remarks
U4091BMC-RFNG3Y	SSO44	Taped and reeled
T4091RC-DDB	Die	Die on foil

22. Package Information



23. Revision History

Please note that the following page numbers referred to in this section refer to the specific revision mentioned, not to this document.

Revision No.	History
4872C-CORD-09/12	• Section 21 “Ordering Information” on page 39 changed
4872B-CORD-01/11	• Section 21 “Ordering Information” on page 38 changed

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