TEF6601/V1

Tuner on main board IC

Rev. 0.1 — 25 August 2006 Objective specification

1. General description

The Tuner On Main board IC (TEF6601T/V1) is an AM/FM radio including PLL tuning system. The system is designed in such a way, that it can be used as a world-wide tuner covering the common FM and AM bands for radio reception. The device is controlled by the I^2C-bus. Besides the basic feature set it provides a good weak signal processing.

2. Features

- FM tuner for Japan, Europe and US reception
- AM tuner for LW and MW reception
- AM RF tracking selectivity
- Integrated PLL tuning system including automatic low/high side LO injection (not supported by /V1)
- Fully Integrated local oscillator
- No alignment needed
- Very easy application on the mainboard
- No critical RF components
- Fully integrated IF filters and FM stereo decoder
- Fully integrated FM noise blanker
- Field strength (LEVEL), multipath (WAM) and noise (USN) dependent stereo blend
- Field strength (LEVEL), multipath (WAM) and noise (USN) dependent high cut control (HCC)
- Field strength (LEVEL), multipath (WAM) and noise (USN) dependent soft mute
- Single power supply

3. Quick reference data

Table 1. Quick reference data

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
I_{CC}	supply current	at pins V_{CC1} and V_{CC2} and VREGSUP; T_{amb} = 25 °C	90	130	165	mA
FM mode						
f_{RF}	RF frequency	tuning range				
		Japan, Europe, USA	76	-	108	MHz
$V_{i(sens)}$	input sensitivity voltage	signal to noise ratio = 26 dB; f_{RF} = 97.1 MHz	-	2	-	µV

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Table 1. Quick reference data

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
S/N	ultimate signal to noise ratio	$V_{i(RF)}$ = 1 mV; Δf = 22.5 kHz	50	5960	-	dB
THD	total harmonic distortion	Δf = 75 kHz, $V_{i(RF)}$ = 1 mV	-	0.4	0.8	%
α_{image}	image rejection ratio	$f_{unwanted} = f_{wanted} \pm 2 * f_{IF}$	50	60	-	dB
α_{CS}	Stereo channel separation	$V_{i(RF)}$ = 1 mV; byte FH, CHSEP[2:0] = 100	26	40	-	dB
AM mode						
f_{RF}	RF frequency	tuning range				
		LW	144	-	288	kHz
		MW	522	-	1710	kHz
$V_{i(sens)}$	input sensitivity voltage	signal to noise ratio = 26 dB; byte 3H, DEMP[1:0] = 10 f_{RF} = 990 kHz	-	34	-	dBμV
S/N	ultimate signal to noise ratio	$V_{i(RF)}$ = 10 mV	-	55	-	dB
THD	total harmonic distortion	$V_{i(RF)}$ = 1 mV; m = 80%	-	1	-	%
α_{image}	image rejection ratio	$f_{unwanted} = f_{wanted} \pm 2 * f_{IF}$	40	55	-	dB

4. Ordering information

Table 2. Ordering information

Type number	Package		
	Name	Description	Version
TEF6601T/V1	SO32	plastic small outline package; 32 leads; body width 7.5 mm	SOT287-1

5. Block diagram

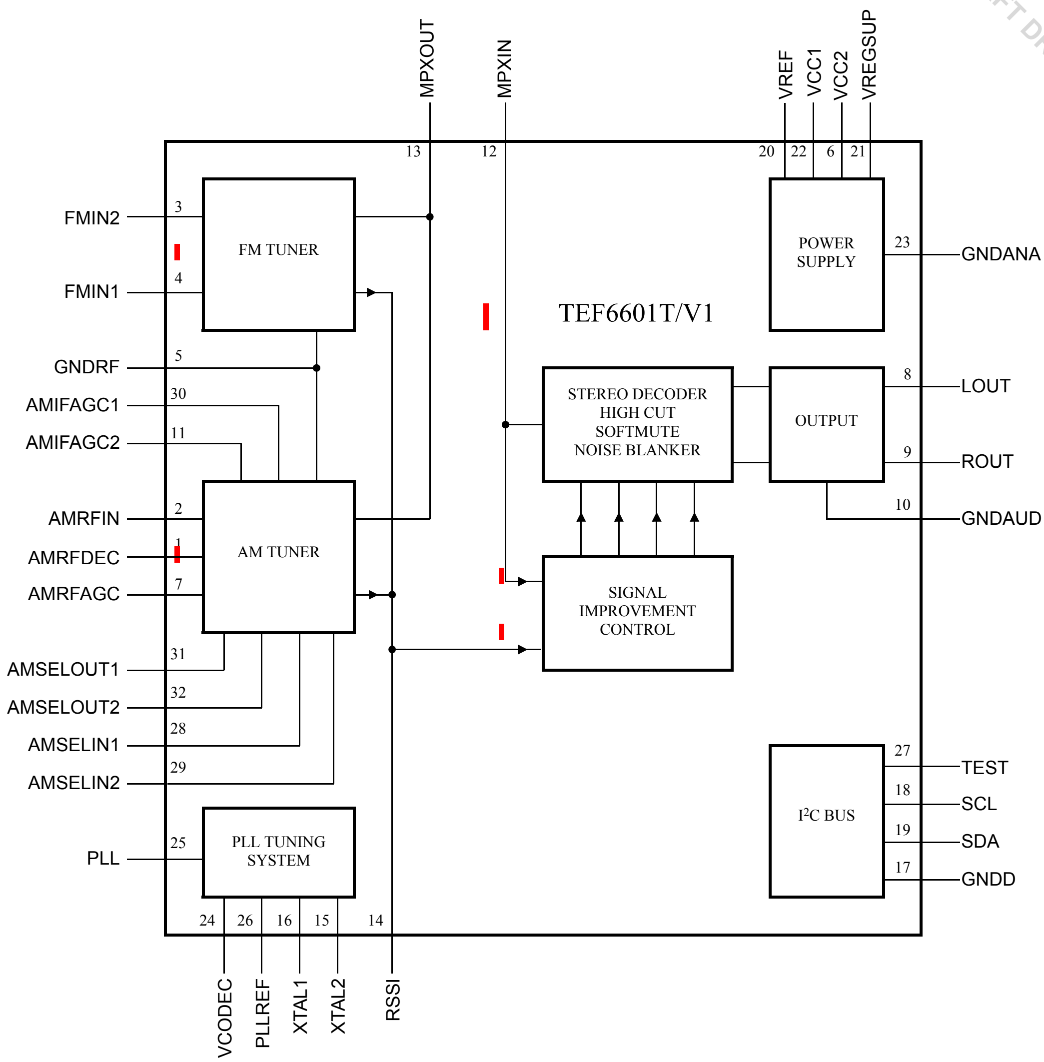


Fig 1. Block diagram of TEF6601T/V1

6. Pinning information

6.1 Pinning

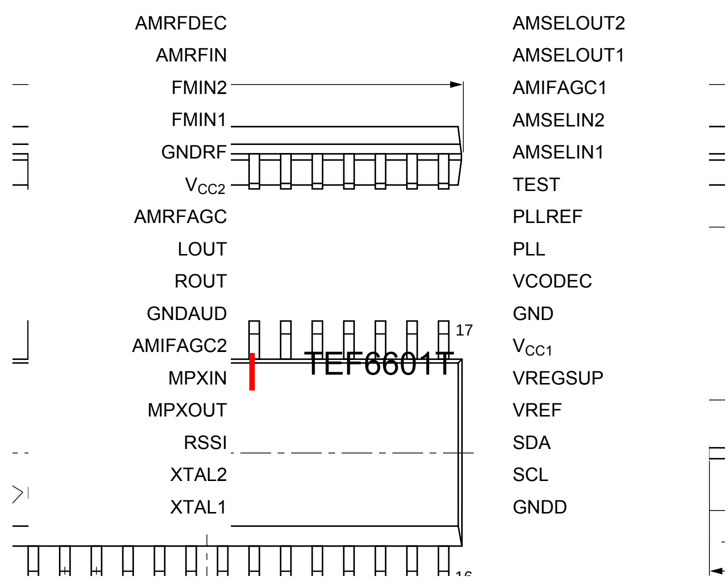


Fig 2. Pin configuration

6.2 Pin description

Table 3. Pin description

Symbol	Pin	Description
AMRFDEC	1	AM RF de-coupling
AMRFIN	2	AM RF single ended input
FMIN2	3	FM RF differential input 2
FMIN1	4	FMRF differential input 1
GNDRF	5	RF ground
V_{CC2}	6	supply voltage 2
AMRFAGC	7	AM RF AGC
LOUT	8	Audio left out
ROUT	9	Audio right out
GNDAUD	10	audio ground
AMIFAGC2	11	AM IF AGC 2
MPXIN	12	MPX and AM audio input to stereo decoder
MPXOUT	13	MPX and AM audio output from tuner part
RSSI	14	Received Signal Strength Indicator
XTAL2	15	4 MHz crystal oscillator pin 2
XTAL1	16	4 MHz crystal oscillator pin 1
GNDD	17	Digital ground
SCL	18	I^2C-bus clock input

Table 3. Pin description

Symbol	Pin	Description
SDA	19	I²C-bus data input and output
VREF	20	reference voltage de-coupling
VREGSUP	21	supply voltage internal voltage regulators
V_{CC1}	22	supply voltage 1
GND	23	ground
VCODEC	24	de coupling for VCO supply voltage
PLL	25	PLL tuning voltage
PLLREF	26	PLL reference voltage
TEST	27	Test pin; leave open in normal operation
AMSELIN1	28	AM selectivity input 1
AMSELIN2	29	AM selectivity input 2
AMIFAGC1	30	AM IF AGC 1
AMSELOUT1	31	AM selectivity output 1
AMSELOUT2	32	AM selectivity output 2

7. Functional description

7.1 FM tuner

The RF input signal is mixed to a low IF with inherent image suppression. The IF signal is filtered and demodulated. The complete signal path is fully integrated.

7.2 AM tuner

The RF signal is filtered and mixed to a low IF with inherent image suppression. The IF signals are filtered and demodulated. The signal path is highly integrated.

7.3 PLL tuning system

The PLL tuning system includes a fully integrated VCO. To avoid problems with unwanted signals on image side the receiver controls automatically high- or low- side injection (not supported by /V1).

7.4 FM stereo decoder

The MPX signal from the FM tuner is translated by the stereo decoder into a left and right audio channel. Good channel separation is achieved with no alignment required.

7.5 Weak signal processing and noise blanker

The reception quality of the station received is measured by a combination of detectors; field strength (LEVEL), multipath (WAM) and noise (USN). The audio processing functions of Soft mute, High Cut Control and mono-stereo blend are controlled accordingly to maintain the best possible audio quality in case of poor signal conditions.

Audio disturbances like e.g. ignition noise are suppressed by the noise blanker circuit, using ultrasonic noise detection on MPX and spike detection on the level signal.

7.6 I²C-bus transceiver

The IC can be controlled by means of the I²C-bus. The ‘fast mode’ I²C-bus allows up to 400 kbit/s bus speed.

8. I²C-bus protocol

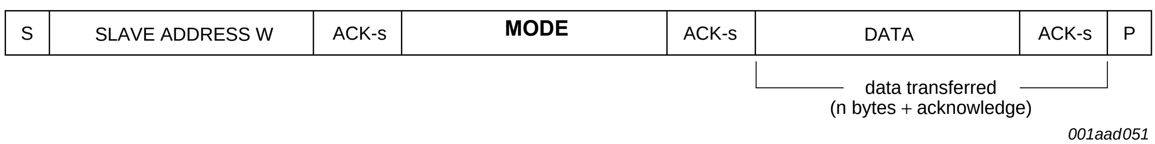


Fig 3. Write mode

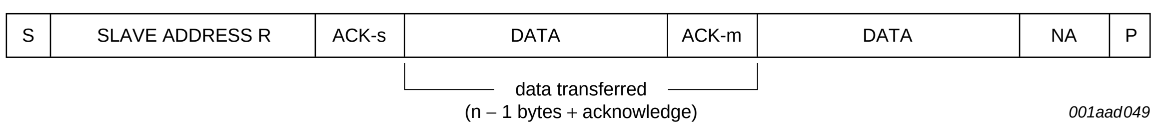


Fig 4. Read mode

Table 4. Description of I²C-bus format

Code	Description
S	START condition
Slave address W	1100 0000b
Slave address R	1100 0001b
ACK-s	acknowledge generated by the slave
ACK-m	acknowledge generated by the master
NA	not acknowledge generated by the master
MODE	mode and subaddress byte
Data	data byte
P	STOP condition

8.1 Read mode

Table 5. Read mode - STATUS (read byte 0H) bit allocation

7	6	5	4	3	2	1	0
QRS1	QRS0	POR	STIN	-	-	TAS1	TAS0

Table 6. Read mode - STATUS (read byte 0H) bit description

Bit	Symbol	Description
7 to 6	QRS[1:0]	quality read status:[1]
		00 = no quality data available (tuning is in progress or quality data is settling)
		01 = quality data (LEVEL, USN and WAM) available; for IF counter check the IFCS status
		10 = AF-update quality data available of LEVEL, USN, WAM and IF counter
5	POR	power on reset indicator;
		0 = standard operation
		1 = power-on or power dip detected. I^2C settings are lost
4	STIN	stereo indicator:
		0 = no pilot detected
		1 = stereo pilot detected
3 to 2	-	reserved
1 to 0	TAS[1:0]	tuning action state:
		00 = tuning not active, not muted
		01 = muting in progress
		10 = tuning in progress
		11 = tuning ready and muted

[1] When PLL tuning is ready the quality detectors are reset for fastest result. In FM mode the first reliable quality result of LEVEL, USN and WAM is available from 1 ms after reset. In AM mode the first level result is available from 1 ms, gradually changing from peak LEVEL towards average LEVEL realizing the maximum attenuation of AM modulation influence from 32 ms. The quality result of an AF-update tuning is stored and can be read at any time later.

Table 7. Read mode - LEVEL (read byte 1H) bit allocation

7	6	5	4	3	2	1	0
LEV7	LEV6	LEV5	LEV4	LEV3	LEV2	LEV1	LEV0

Table 8. Read mode - LEVEL (read byte 1H) bit description

Bit	Symbol	Description
7 to 0	LEV[7:0]	level detector (RSSI) output signal via fast level detector timing. 0 to 255 = 0.25 V to 4.25 V

Table 9. Read mode - USN_WAM (read byte 2H) bit allocation

7	6	5	4	3	2	1	0
USN3	USN2	USN1	USN0	WAM3	WAM2	WAM1	WAM0

Table 10. Read mode - USN_WAM (read byte 2H) bit description

Bit	Symbol	Description
7 to 4	USN[3:0]	FM ultrasonic noise: ultrasonic noise content (USN)
3 to 0	WAM[3:0]	FM wide band AM (multipath): 0 to 15 = no disturbance to high disturbance, 0 to 15 = 0 to 100% AM at 20 kHz wide band AM content (WAM)

Table 11. Read mode - IFCOUNTER (read byte 3H) bit allocation

7	6	5	4	3	2	1	0
IFCS1	IFCS0	IFCN	IFC4	IFC3	IFC2	IFC1	IFC0

Table 12. Read mode - IFCOUNTER (read byte 3H) bit description

Bit	Symbol	Description
7 to6	IFCS[1:0]	IF counter status [1]
		00 = no first counter result available
		01 = first counter result available from 2 ms count time
		10 = first counter result available from 8 ms count time
		11 = counter result available from 32 ms count time
5	IFCN	IF count result negative
		0 = positive RF frequency error
		1 = negative RF frequency error
4 to 0	IFC[4:0]	IF counter result, see Table 13.

[1] When PLL tuning is ready the IF counter and other quality detectors are reset for fastest result. The first IF counter result is available from 2 ms after reset. Further results are available from 8 ms and 32 ms after reset, reducing the influence of FM modulation on the counter result. Later counter results are available at a count time of 32 ms.

Table 13. IF counter result

IFC4	IFC3	IFC2	IFC1	IFC0	Frequency error in FM	Frequency error in AM
0	0	0	0	0	0 kHz to 5 kHz	0 kHz to 0.5 kHz
0	0	0	0	1	5 kHz to 10 kHz	0.5 kHz to 1 kHz
0	0	0	1	0	10 kHz to 15 kHz	1 kHz to 1.5 kHz
0	0	0	1	1	15 kHz to 20 kHz	1.5 kHz to 2 kHz
0	0	1	0	0	20 kHz to 25 kHz	2 kHz to 2.5 kHz
1	1	1	1	0	150 kHz to 155 kHz	15 kHz to 15.5 kHz
1	1	1	1	1	> 155 kHz	> 15.5 kHz

Table 14. Read mode - (read byte 4H) bit allocation

7	6	5	4	3	2	1	0
-	-	-	-	-	ID2	ID1	ID0

Table 15. Read mode - (read byte 4H) bit description

Bit	Symbol	Description
7 to 3	not used	
2 to 0	ID[2:0]	device type identification 000 = TEF6601T/V1

8.2 Write mode

Table 16. Write mode - MODE bit allocation

7	6	5	4	3	2	1	0
MODE2	MODE1	MODE0	0	SA3	SA2	SA1	SA0

Table 17. Write mode - MODE bit description

Bit	Symbol	Description
7 to 5	MODE[2:0]	mode; see Table 18
4	-	not used, must be set to logic 0
3 to 0	SA[3:0]	subaddress

Table 18. Tuning action modes

MODE2	MODE1	MODE0	Symbol	Description
0	0	0	standard	write without tuning action
0	0	1	preset	tune to new program with short mute time; see Figure 5
0	1	0	search	tune to new program and stay muted; see Figure 6 and Figure 7
0	1	1	AF-update	tune to AF program, check AF quality and tune back to main program; see Figure 8 and Figure 9
1	0	0	AF-jump	tune to AF program in minimum mute time; see Figure 10 and Figure 11
1	0	1	AF-check	tune to AF program and stay muted; see Figure 12, Figure 13 and Figure 14
1	1	0	mirror test	check current image situation and select injection for best result; see Figure 15
1	1	1	end	end, release mute from search mode or AF-check mode

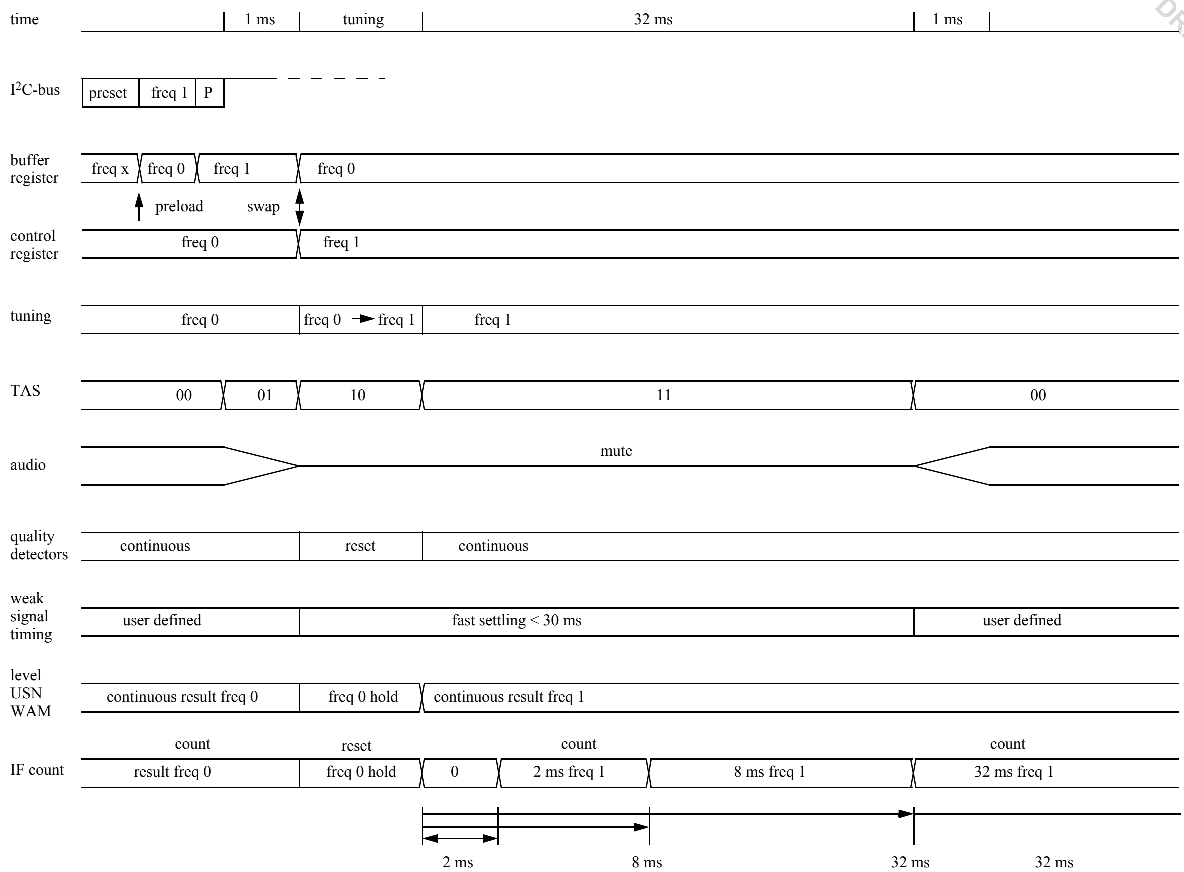


Fig 5. Preset mode

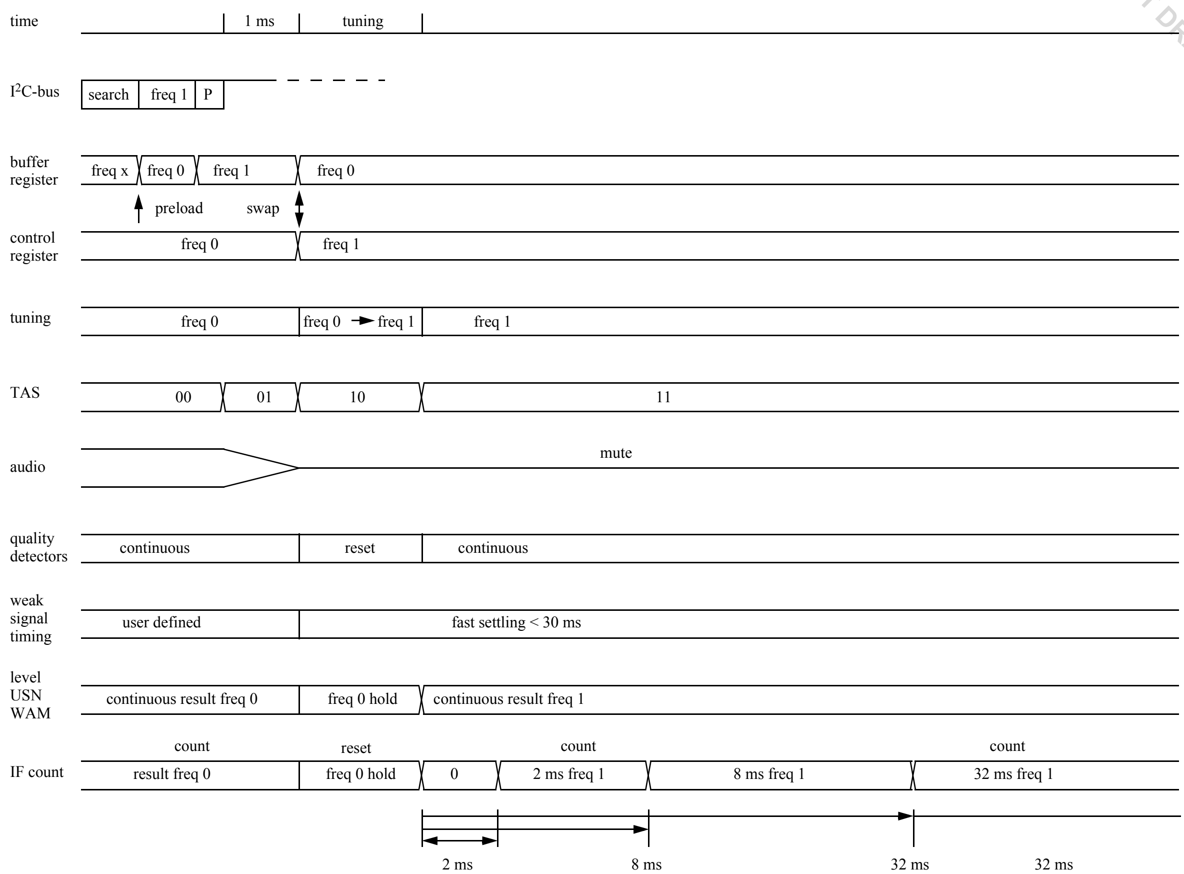


Fig 6. Search mode

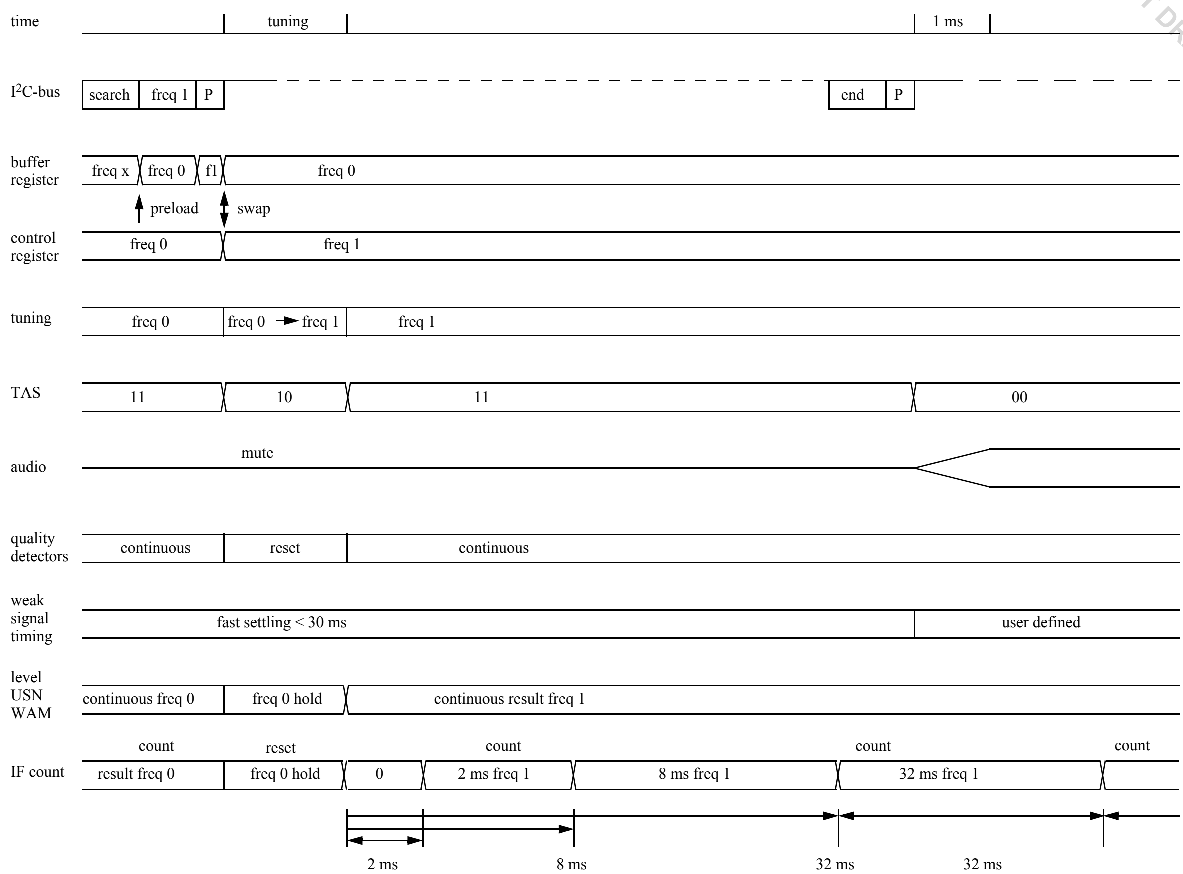


Fig 7. Search mode after Search, End

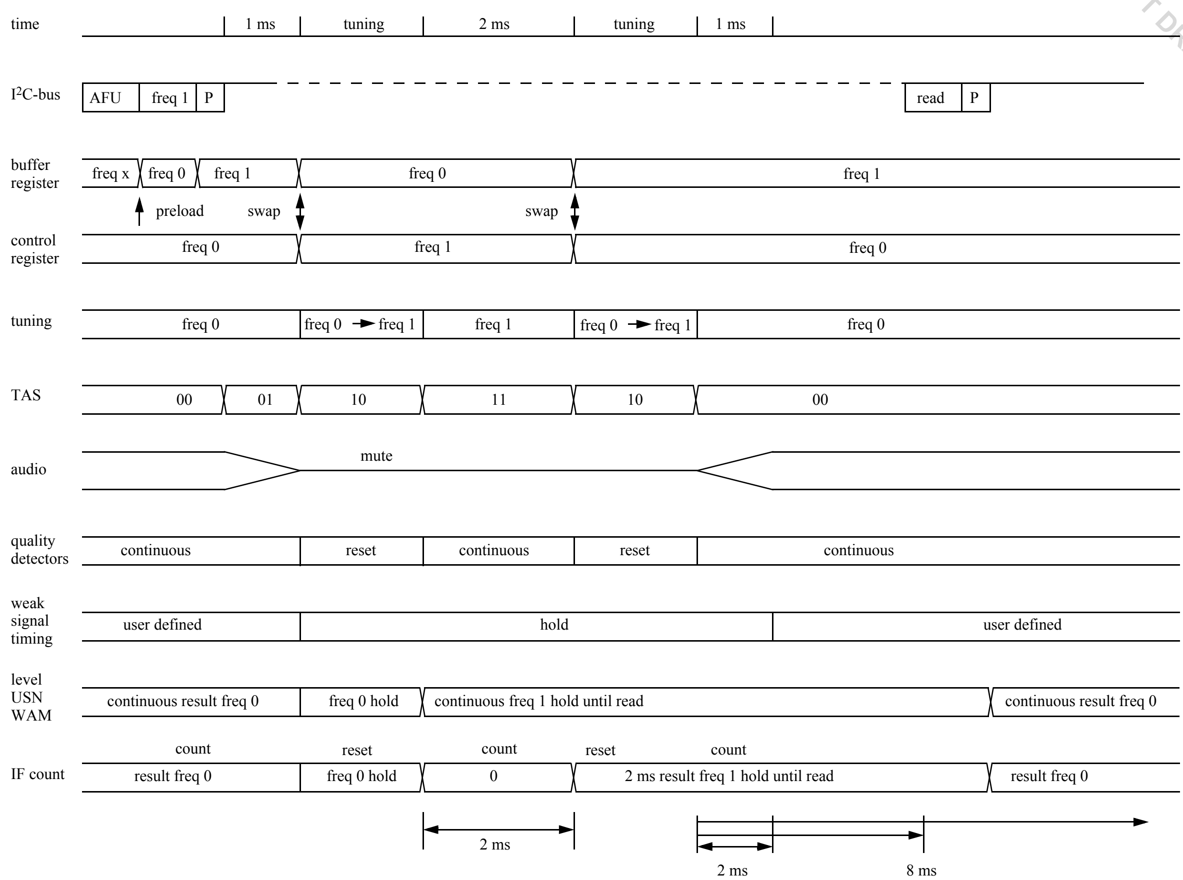


Fig 8. AF-update mode

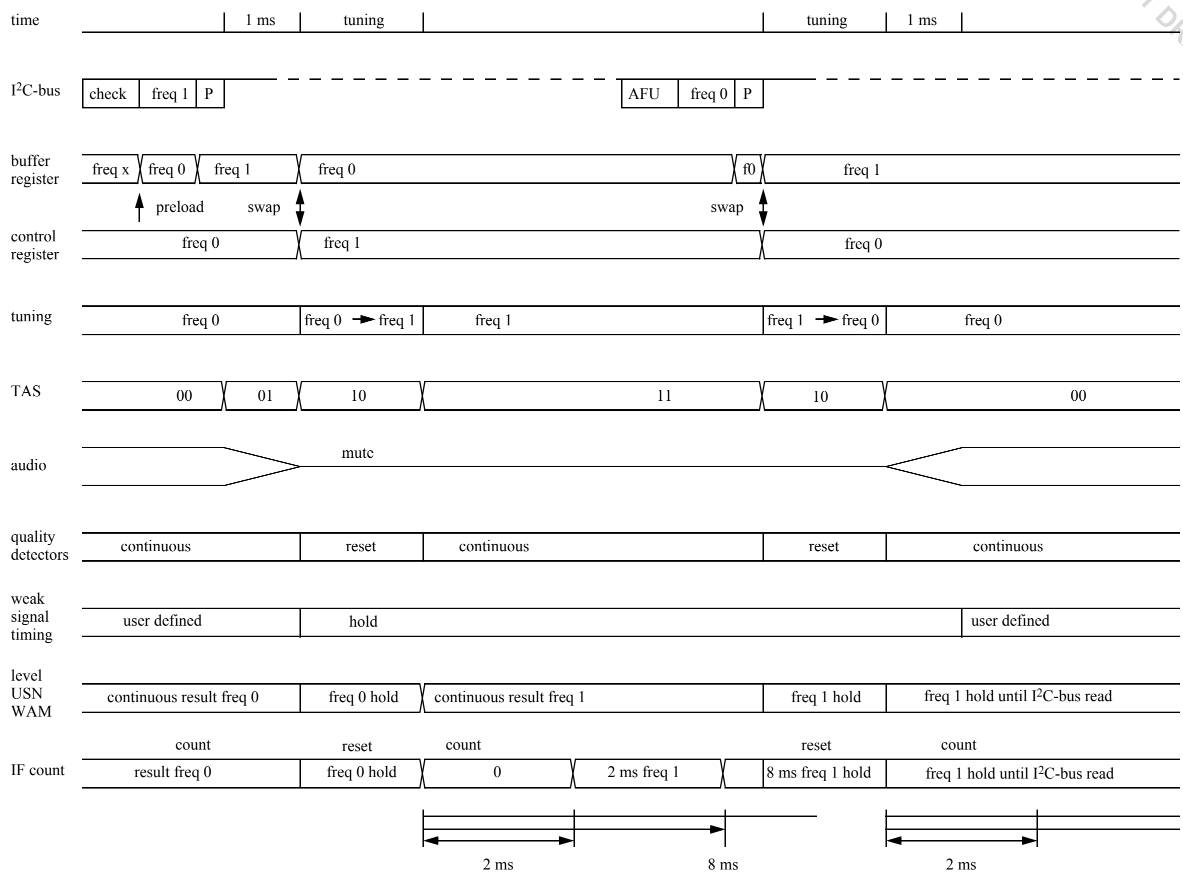


Fig 9. AF-update mode after Check

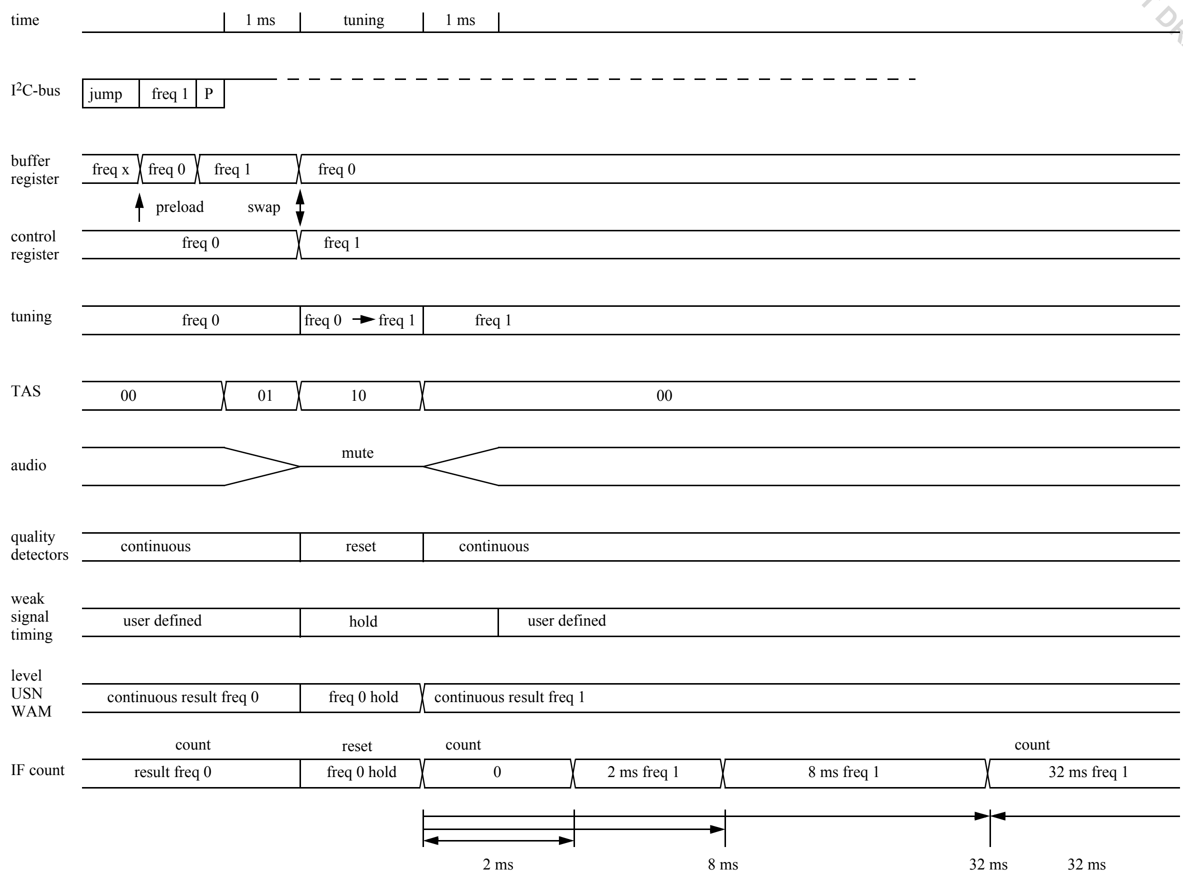


Fig 10. Jump mode

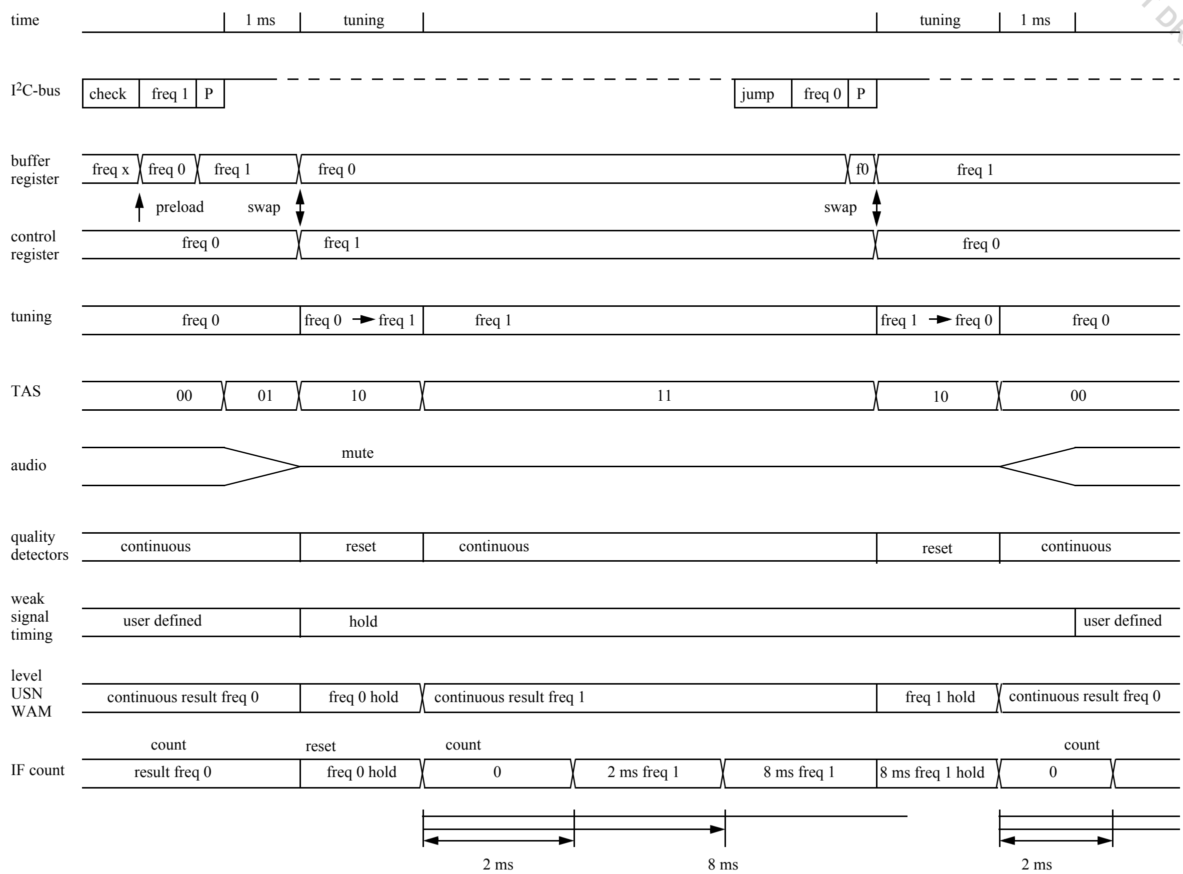


Fig 11. Jump mode after check

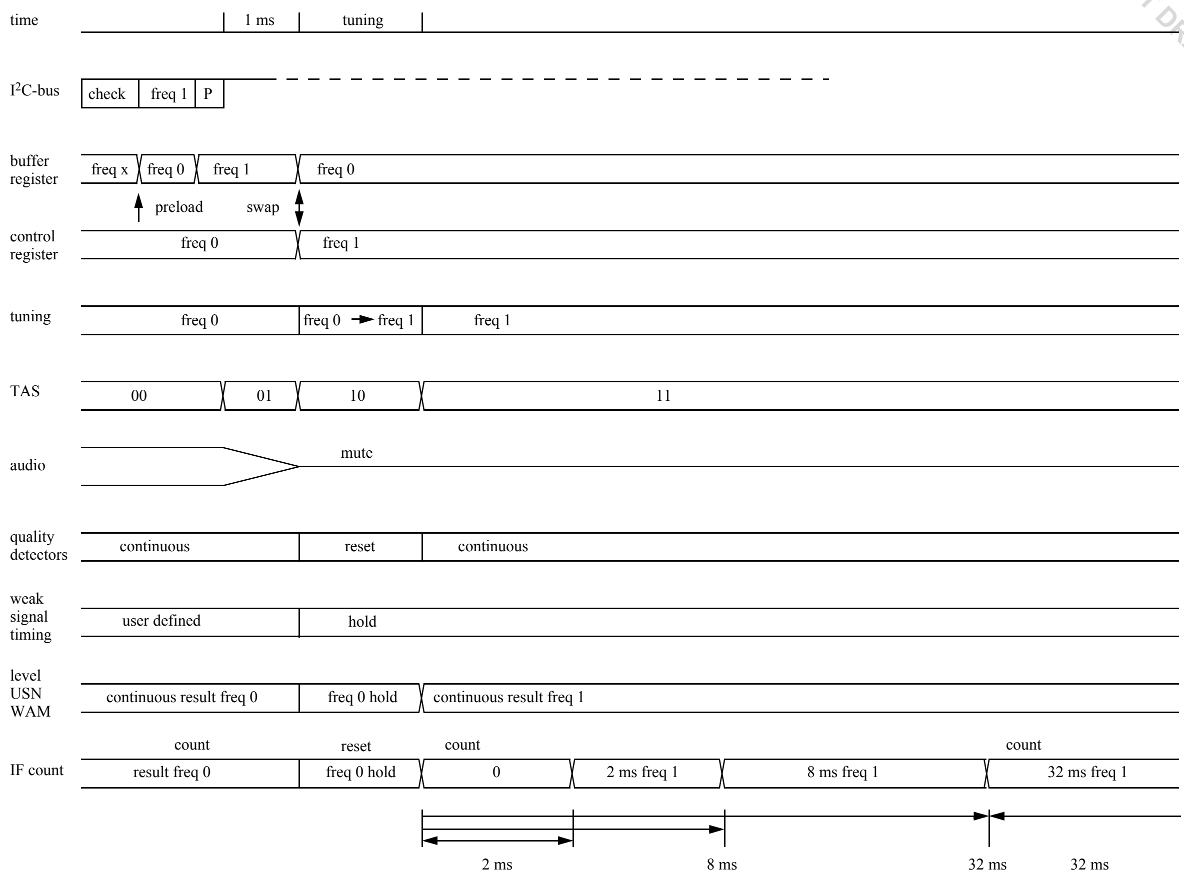


Fig 12. Check mode

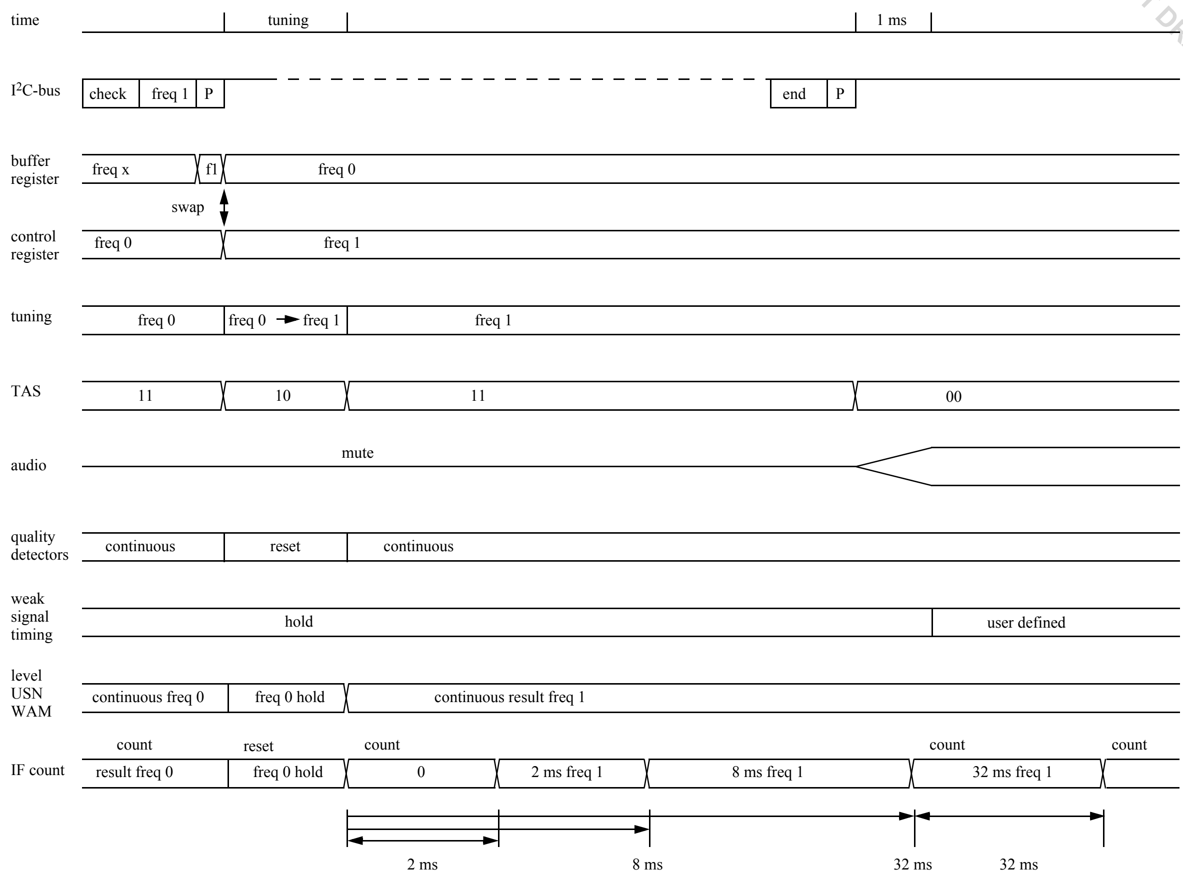


Fig 13. Check mode after Check, End

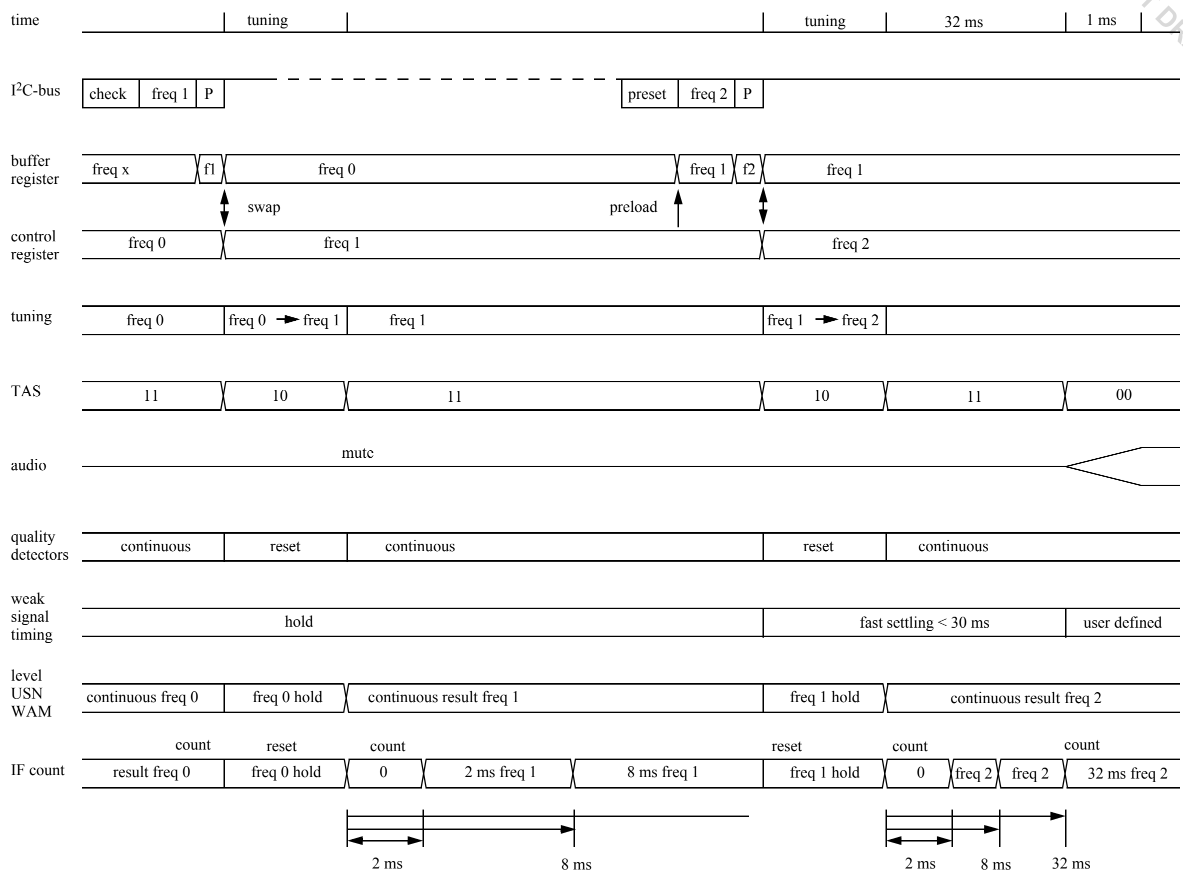


Fig 14. Check mode after Check, Preset

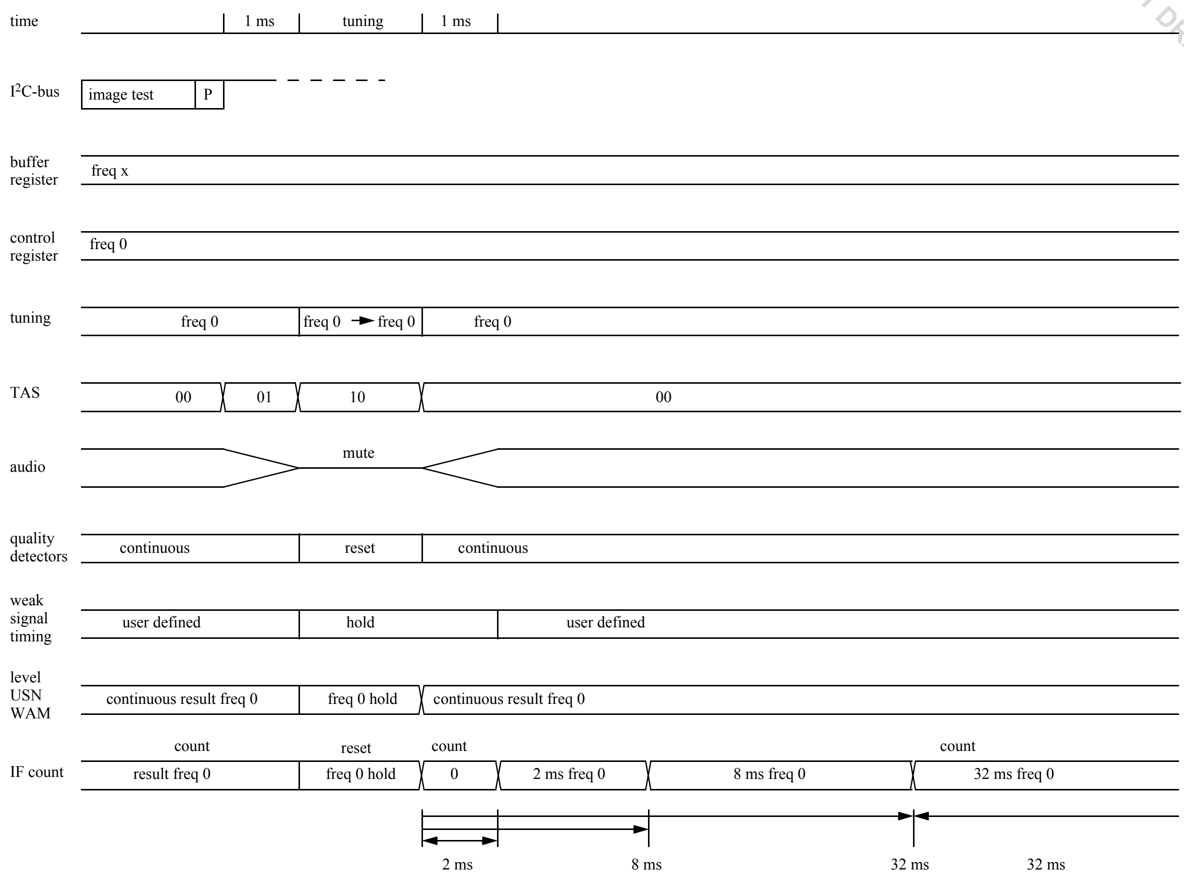


Fig 15. Image test (not supported by /V1)

Table 19. Write mode - TUNER0 (byte 0H) bit allocation

Bit	7	6	5	4	3	2	1	0
Symbol	0	0	BAND	0	FREQ11	FREQ10	FREQ9	FREQ8
Reset			1		0	1	1	0

Table 20. Write mode - TUNER1 (byte 1H) bit allocation

Bit	7	6	5	4	3	2	1	0
Symbol	FREQ7	FREQ6	FREQ5	FREQ4	FREQ3	FREQ2	FREQ1	FREQ0
Reset	1	1	1	1	1	0	1	0

Table 21. Write mode - TUNER0 (byte 0H) bit description

Bit	Symbol	Description
7 to 6	-	not used, must be set to logic 0
5	BAND	frequency band; see Table 23.[1]
4	-	not used, must be set to logic 0
3 to 0	FREQ[11:8]	upper byte of tuning frequency word; see Table 24. [1]

Table 22. Write mode - TUNER1 (byte 1H) bit description

Bit	Symbol	Description
7 to 0	FREQ[7:0]	lower byte of tuning frequency word; see Table 24. [1]

[1] For a correct tuning result a change in the BAND or FREQ setting should always be combined with a tuning action of modes 001 to 101

Table 23. Decoding of BAND bits

BAND	Description
0	AM: LW and MW
1	FM

Table 24. Tuning frequency

BAND	FREQ[12:0] value	reception frequency	frequency correlation	step
AM, LW and MW	144 to 1720	144 kHz to 1720 kHz	FREQ = f_{RF} [kHz]	1 kHz
FM	1520 to 2160	76 MHz to 108 MHz	FREQ = f_{RF} [MHz] * 20	50 kHz

Table 25. Write mode - TUNER2 (byte 2H) bit allocation

Bit	7	6	5	4	3	2	1	0
Symbol	RFAGC1	RFAGC0	0	0	0	0	0	0
Reset	0	0						

Table 26. Write mode - TUNER2 (byte 2H) bit description

Bit	Symbol	Description	
7 to 6	RFAGC[1:0]	AM RF AGC sensitivity control:	FM RF AGC sensitivity control:
		00 = default AM LNA AGC threshold	00 = AGC threshold reduced by 6 dB
		01 = AGC threshold reduced by 2 dB	01 = AGC threshold reduced by 4 dB
		10 = AGC threshold reduced by 4 dB	10 = AGC threshold reduced by 2 dB
		11 = AGC threshold reduced by 6 dB	11 = standard FM RF AGC threshold
5 to 4	INJ[1:0]	LO injection:	
		00 = automatic (standard control) (not supported by /V1)	
		01 = high injection	
		10 = low injection	
3 to 0	-	not used, must be set to logic 0	

Table 27. Write mode - TUNER3 (byte 3H) bit allocation

Bit	7	6	5	4	3	2	1	0
Symbol	NBS1	NBS0	LOCUT	MONO	DEMP1	DEMP0	0	OUTA
Reset	1	0	0	0	0	0		0

Table 28. Write mode - TUNER3 (byte 3H) bit description

Bit	Symbol	Description
7 to 6	NBS[1:0]	FM noise blanker sensitivity control:
		00 = FM noise blanker off
		01 to 11 = low to high FM noise blanker sensitivity
5	LOCUT	control of audio high pass filter:
		0 = no limitation (-3 dB at 7 Hz)
		1 = high pass function (-3 dB at 100 Hz); only for AM use
4	MONO	mono/stereo switch:
		0 = FM stereo enabled
		1 = FM stereo disabled (forced mono)
3 to 2	DEMP[1:0]	de-emphasis setting:
		00 = 50 μs de-emphasis
		01 = 75 μs de-emphasis
		10 = 103 μs low pass
1	-	not used, must be set to logic 0
0	OUTA	audio output gain:
		0 = low audio gain at LOUT and ROUT
		1 = high audio gain at LOUT and ROUT

Table 29. Write mode - SOFTMUTE0 (byte 4H) bit allocation

Bit	7	6	5	4	3	2	1	0
Symbol	0	0	0	MAT2	MAT1	MAT0	MRT1	MRT0
Reset				0	0	0	0	0

Table 30. Write mode - SOFTMUTE0 (byte 4H) bit description

Bit	Symbol	Description
7 to 5	-	not used, must be set to logic 0
4 to 2	MAT[2:0]	softmute slow attack time, see Table 31.
1 to 0	MRT[1:0]	softmute slow recovery time:
		00 = 1 times attack time
		01 = 2 times attack time
		10 = 4 times attack time
		11 = 8 times attack time according Table 31.

Table 31. Softmute attack time

MAT2	MAT1	MAT0	softmute attack time
0	0	0	125 ms
0	0	1	250 ms
0	1	0	0.5 s
0	1	1	1 s
1	0	0	2 s

Table 31. Softmute attack time

MAT2	MAT1	MAT0	softmute attack time
1	0	1	4 s
1	1	0	8 s
1	1	1	16 s

Table 32. Write mode - SOFTMUTE1 (byte 5H) bit allocation

Bit	7	6	5	4	3	2	1	0
Symbol	MFOL	MSOL	0	MST2	MST1	MST0	MSL1	MSL0
Reset	0	0		0	0	0	0	0

Table 33. Write mode - SOFTMUTE1 (byte 5H) bit description

Bit	Symbol	Description
7	MFOL	softmute fast on level:
		0 = no fast control on level
		1 = fast control on level active
6	MSOL	softmute slow on level
		0 = no slow control on level (not supported by /V1)
		1 = slow control on level active
5	-	not used, must be set to logic 0
4 to 2	MST[2:0]	softmute start on level:
		000 to 111 = high to low threshold of weak signal softmute control
1 to 0	MSL[1:0]	softmute slope on level:
		00 to 11 = low to high steepness of slope of weak signal softmute control

Table 34. Write mode - SOFTMUTE2_FM (byte 6H) bit allocation

Bit	7	6	5	4	3	2	1	0
Symbol	MFON	MSON	MNS1	MNS0	MFOM	MSOM	MMS1	MMS0
Reset	0	0	0	0	0	0	0	0

Table 35. Write mode - SOFTMUTE2_FM (byte 6H) bit description

Bit	Symbol	Description
7	MFON	softmute fast on noise (USN):
		0 = no fast control on noise (USN)
		1 = fast control on noise (USN) active
6	MSON	softmute slow on noise (USN):
		0 = no slow control on noise (USN)
		1 = slow control on noise (USN) active
5 to 4	MNS[1:0]	sensitivity of softmute on noise
		00 to 11 = weak to strong softmute control by FM ultrasonic noise (USN)
3	MFOM	softmute fast on multipath (WAM)
		0 = no fast control on multipath (WAM)
		1 = fast control on multipath (WAM) active

Table 35. Write mode - SOFTMUTE2_FM (byte 6H) bit description

Bit	Symbol	Description
2	MSOM	softmute slow on multipath (WAM)
		0 = no slow control on multipath (WAM)
		1 = slow control on multipath (WAM) active
1 to 0	MMS[1:0]	sensitivity of softmute on multipath (WAM)
		00 to 11 = weak to strong softmute control by FM multipath (WAM)

Table 36. Write mode - SOFTMUTE2_AM (byte 6H) bit allocation

Bit	7	6	5	4	3	2	1	0
Symbol	0	0	0	MLIM4	MLIM3	MLIM2	MLIM1	MLIM0
Reset				0	0	0	0	0

Table 37. Write mode - SOFTMUTE2_AM (byte 6H) bit description

Bit	Symbol	Description
7 to 5	-	not used, must be set to logic 0
4 to 0	MLIM[4:0]	softmute limit
		00000 to 11110 = softmute control limited at 0 dB to 30 dB the softmute control can be limited to the point at which natural softmute starts

Table 38. Write mode - HIGHCUT0 (byte 7H) bit allocation

Bit	7	6	5	4	3	2	1	0
Symbol	0	0	HLIM	HAT2	HAT1	HAT0	HRT1	HRT0
Reset			0	0	0	0	0	0

Table 39. Write mode - HIGHCUT0 (byte 7H) bit description

Bit	Symbol	Description
7 to 6	-	not used, must be set to logic 0
5	HLIM	limitation of highcut control on level, noise and multipath
		0 = highcut limit at 165 μs, -10 dB at 10 kHz (for 50 μs de-emphasis)
		1 = highcut limit at 103 μs, -6 dB at 10 kHz (for 50 μs de-emphasis)
4 to 2	HAT[2:0]	highcut slow attack time, see Table 40.
1 to 0	HRT[1:0]	highcut slow recovery time:
		00 = 1 times attack time
		01 = 2 times attack time
		10 = 4 times attack time
		11 = 8 times attack time according Table 40.

Table 40. Highcut attack time

HAT2	HAT1	HAT0	highcut attack time
0	0	0	125 ms
0	0	1	250 ms
0	1	0	0.5 s
0	1	1	1 s

Table 40. Highcut attack time

HAT2	HAT1	HAT0	highcut attack time
1	0	0	2 s
1	0	1	4 s
1	1	0	8 s
1	1	1	16 s

Table 41. Write mode - HIGHCUT1 (byte 8H) bit allocation

Bit	7	6	5	4	3	2	1	0
Symbol	HFOL	HSOL	0	HST2	HST1	HST0	HSL1	HSL0
Reset	0	0		0	0	0	0	0

Table 42. Write mode - HIGHCUT1 (byte 8H) bit description

Bit	Symbol	Description
7	HFOL	highcut fast on level:
		0 = no fast control on level
		1 = fast control on level active
6	HSOL	highcut slow on level
		0 = no slow control on level (not supported by /V1)
		1 = slow control on level active
5	-	not used, must be set to logic 0
4 to 2	HST[2:0]	highcut start on level:
		000 to 111 = high to low threshold of weak signal highcut control
1 to 0	HSL[1:0]	highcut slope on level:
		00 to 11 = low to high steepness of slope of weak signal highcut control

Table 43. Write mode - HIGHCUT2 (byte 9H) bit allocation

Bit	7	6	5	4	3	2	1	0
Symbol	HFON	HSON	HNS1	HNS0	HFOM	HSOM	HMS1	HMS0
Reset	0	0	0	0	0	0	0	0

Table 44. Write mode - HIGHCUT2 (byte 9H) bit description

Bit	Symbol	Description
7	HFON	highcut fast on noise (USN):
		0 = no fast control on noise (USN)
		1 = fast control on noise (USN) active
6	HSON	highcut slow on noise (USN):
		0 = no slow control on noise (USN)
		1 = slow control on noise (USN) active
5 to 4	HNS[1:0]	sensitivity of highcut on noise
		00 to 11 = weak to strong highcut control by FM ultrasonic noise (USN)

Table 44. Write mode - HIGHCUT2 (byte 9H) bit description

Bit	Symbol	Description
3	HFOM	highcut fast on multipath (WAM)
		0 = no fast control on multipath (WAM)
		1 = fast control on multipath (WAM) active
2	HSOM	highcut slow on multipath (WAM)
		0 = no slow control on multipath (WAM)
		1 = slow control on multipath (WAM) active
1 to 0	HMS[1:0]	sensitivity of highcut on multipath (WAM)
		00 to 11 = weak to strong highcut control by FM multipath (WAM)

Table 45. Write mode - STEREO0 (byte AH) bit allocation

Bit	7	6	5	4	3	2	1	0
Symbol	0	0	0	SAT2	SAT1	SAT0	SRT1	SRT0
Reset				0	0	0	0	0

Table 46. Write mode - STEREO0 (byte AH) bit description

Bit	Symbol	Description
7 to 5	-	not used, must be set to logic 0
4 to 2	SAT[2:0]	stereo blend slow attack time, see Table 47.
1 to 0	SRT[1:0]	stereo blend slow recovery time:
		00 = 1 times attack time
		01 = 2 times attack time
		10 = 4 times attack time
		11 = 8 times attack time according Table 47.

Table 47. Stereo blend attack time

SAT2	SAT1	SAT0	stereo blend attack time
0	0	0	125 ms
0	0	1	250 ms
0	1	0	0.5 s
0	1	1	1 s
1	0	0	2 s
1	0	1	4 s
1	1	0	8 s
1	1	1	16 s

Table 48. Write mode - STEREO1 (byte BH) bit allocation

Bit	7	6	5	4	3	2	1	0
Symbol	SFOL	SSOL	0	SST2	SST1	SST0	SSL1	SSL0
Reset	0	0		0	0	0	0	0

Table 49. Write mode - STEREO1 (byte BH) bit description

Bit	Symbol	Description
7	SFOL	stereo blend fast on level:
		0 = no fast control on level
		1 = fast control on level active
6	SSOL	stereo blend slow on level
		0 = no slow control on level (not supported by /V1)
		1 = slow control on level active
5	-	not used, must be set to logic 0
4 to 2	SST[2:0]	stereo blend start on level:
		000 to 111 = high to low threshold of weak signal stereo blend control
1 to 0	SSL[1:0]	stereo blend slope on level:
		00 to 11 = low to high steepness of slope of weak signal stereo blend control

Table 50. Write mode - STEREO2 (byte CH) bit allocation

Bit	7	6	5	4	3	2	1	0
Symbol	SFON	SSON	SNS1	SNS0	SFOM	SSOM	SMS1	SMS0
Reset	0	0	0	0	0	0	0	0

Table 51. Write mode - STEREO2 (byte CH) bit description

Bit	Symbol	Description
7	SFON	stereo blend fast on noise (USN):
		0 = no fast control on noise (USN)
		1 = fast control on noise (USN) active
6	SSON	stereo blend slow on noise (USN):
		0 = no slow control on noise (USN)
		1 = slow control on noise (USN) active
5 to 4	SNS[1:0]	sensitivity of stereo blend on noise
		00 to 11 = weak to strong stereo blend control by FM ultrasonic noise (USN)
3	SFOM	stereo blend fast on multipath (WAM)
		0 = no fast control on multipath (WAM)
		1 = fast control on multipath (WAM) active
2	SSOM	stereo blend slow on multipath (WAM)
		0 = no slow control on multipath (WAM)
		1 = slow control on multipath (WAM) active
1 to 0	SMS[1:0]	sensitivity of stereo blend on multipath (WAM)
		00 to 11 = weak to strong highcut control by FM multipath (WAM)

Table 52. Write mode - LEVEL_ALIGN (byte EH) bit allocation

Bit	7	6	5	4	3	2	1	0
Symbol	LEVAT	LEVA6	LEVA5	LEVA4	LEVA3	LEVA2	LEVA1	LEVA0
Reset	0	1	0	0	0	0	0	0

Table 53. Write mode - LEVEL_ALIGN (byte EH) bit description

Bit	Symbol	Description
7	LEVAT	level alignment test signal
		0 = normal operation
		1 = insertion of level alignment test signal
6 to 0	LEVA[6:0]	level alignment
		0 to 127 = correction of level voltage by -1 V to +1 V [1]

[1] The level correction is included in the weak signal processing and the LEVEL read data via I^{2}C-bus. The level correction is not included in the analog voltage at pin RSSI

Table 54. Write mode - AM_LNA (byte FH) bit allocation

Bit	7	6	5	4	3	2	1	0
Symbol	0	0	ALAFT1	ALAFT0	ALAFM	CHSEP2	CHSEP1	CHSEP0
Reset			1	1	1	1	0	0

Table 55. Write mode - AM_LNA (byte FH) bit description

Bit	Symbol	Description
7 to 6	-	not used, must be set to logic 0
5 to 4	ALAFT[1:0]	AM LNA AGC step control
		00 = no fast control of linear AGCs at AM LNA AGC step
		01 = 2 ms fast control of linear AGCs at AM LNA AGC step
		10 = 4 ms fast control of linear AGCs at AM LNA AGC step
		11 = 7 ms fast control of linear AGCs at AM LNA AGC step
3	ALAFM	AGC mute
		0 = no mute during fast control of linear AGCs at AM LNA AGC step
		1 = mute during fast control of linear AGCs at AM LNA AGC step
2 to 0	CHSEP[1:0]	stereo channel separation alignment
		100 = default setting (no alignment)
		000 to 111 optional channel separation

9. Limiting values

Table 56. Limiting values

In accordance with the Absolute Maximum Rating System (IEC 60134).

Symbol	Parameter	Conditions	Min	Max	Unit
V_{CC}	analog supply voltage at pins V_{CC1} and V_{CC2}		-0.3	10	V
ΔV_{CC}	voltage difference between V_{CC1} and V_{CC2}		-0.3	0.3	V
V_I	voltage on pins SDA and SCL		-0.5	5.5tbf	V
V_{REGSUP}	analog supply voltage at pin VREGSUP		-0.3	V_{CC}	V
V_n	DC voltage at all other pins		-0.3	V_{CC}	V

Table 56. Limiting values

In accordance with the Absolute Maximum Rating System (IEC 60134).

Symbol	Parameter	Conditions	Min	Max	Unit
V_{FMIN}	RF input voltage between pins FMIN1 and FMIN2 (peak value)		-	6	V
V_{AMRFIN}	RF input voltage at pin AMRFIN (peak value)		-	3	V
T_{stg}	storage temperature		-40	150	°C
T_{amb}	ambient temperature	[1]	-40	85	°C
$T_{j(max)}$	maximum junction temperature		-	150	°C
V_{esd}	electrostatic discharge voltage	[2]	-2000	2000	V
		[3]	-200	200	V

[1] For use of full operating supply voltage range and operating temperature range, the thermal resistance R_{th} should be less than 54 K/W.

[2] Human body model: C = 100 pF; R = 1.5 kΩ

[3] Machine model: C = 200 pF; L = 0.75 µH; R = 10 Ω

10. Thermal characteristics

Table 57. Thermal characteristics

Symbol	Parameter	Conditions	Typ	Unit
$R_{th(j-a)}$	thermal resistance from junction to ambient	[1]	45	K/W

[1] single layer board 70 mm by 100 mm with a copper thickness of 35 µm and a copper area coverage of 20%.

11. Static characteristics

Table 58. Static characteristics

V_{CC} = 8.5 V; T_{amb} = 25 °C; unless otherwise specified

Symbol	Parameter	Conditions	ID	Min	Typ	Max	Unit
V_{CC}	supply voltage	at pins V_{CC1} and V_{CC2}	003	8	8.5	9	V
Supply current in FM mode							
I_{CC}	supply current	into pins V_{CC1}, V_{CC2} and VREGSUP					
		T_{amb} = -40 °C	611	-	tbf	220	mA
		T_{amb} = 25 °C	624	90	130	165	mA
		T_{amb} = 85 °C	625	90	tbf	155	mA
Supply current in AM mode							
I_{CC}	supply current	into pins V_{CC1}, V_{CC2} and VREGSUP					
		T_{amb} = -40 °C	612	-	tbf	220	mA
		T_{amb} = 25 °C	626	90	130	165	mA
		T_{amb} = 85 °C	627	90	tbf	155	mA
Power-on reset							
$V_{P(POR)}$	power-on reset supply voltage	reset at power-on	035	6.5	6.7	6.9	V

Table 58. Static characteristics

V_{CC} = 8.5 V; T_{amb} = 25 °C; unless otherwise specified

Symbol	Parameter	Conditions	ID	Min	Typ	Max
$V_{hys(POR)}$	power-on reset hysteresis voltage			-	0.2	-
Logic pins SDA and SCL (voltage referenced to pin GNDD)						
V_{IH}	high level input voltage		030[1]	1.951.58	-	-
V_{IL}	low level input voltage		031[1]	-	-	0.751.09

[1] SDA and SCL HIGH and LOW internal thresholds are specified according to an I²C-bus voltage range from 2.5 V to 3.3 V including I²C-bus voltage tolerances of ±10%. The I²C-bus interface tolerates also SDA and SCL signals from a 5 V bus, but does not fulfill the 5 V bus specification completelyof this IC version (/V1) are not in accordance with the generic I²C-bus specification.

12. Dynamic characteristics

Table 59. Dynamic characteristics

VCC = 8.5 V; Tamb = 25 °C; unless otherwise specified

FM condition: all RF voltages are RMS values measured at the input of a 75 Ω dummy aerial; f_{mod} = 1 kHz, Δf = 22.5 kHz, de-emphasis = 50 μs, f_{RF} = 97.1 MHz unless otherwise specified

AM condition: all RF voltages are RMS values measured at the input 15 pF / 60 pF dummy aerial; f_{mod} = 400 Hz, m = 30%, f_{RF} = 990 kHz unless otherwise specified

Symbol	Parameter	Conditions	ID	Min	Typ	Max	Unit
FM path							
f_{RF}	RF frequency	tuning range	040	76	-	108	MHz
		minimum grid step	040		50	-	kHz
$V_{i(sens)}$	input sensitivity voltage	signal to noise ratio = 26 dB	043[1]	-	6	-	dBμV
		signal to noise ratio = 46 dB	044[1]	-	19	-	dBμV
V_{LO}	LO leakage	LO residue at antenna input; $R_{antenna}$ = 75 Ω	279	-	-6	-	dBμV
V_{VCO}	VCO leakage	VCO residue at antenna input; $R_{antenna}$ = 75 Ω		-	46	-	dBμV
S/N	ultimate signal to noise ratio	$V_{i(RF)}$ = 1 mV; Δf = 22.5 kHz	046	50	5960	-	dB
THD	total harmonic distortion	Δf = 75 kHz, $V_{i(RF)}$ = 1 mV	049	-	0.4	0.8	%
PSRR	power supply ripple rejection	V_{ripple}/V_{audio}, V_{ripple} = 100 mV, f_{ripple} = 100 Hz	618	24	36	-	dB
f_{IF}	IF frequency		613	-	150	-	kHz
Δf_{max}	maximum deviation	THD = 3%, $V_{i(RF)}$ = 10 mV	050	115	140	-	kHz
α_{image}	image rejection	$f_{unwanted} = f_{wanted} \pm 2 * f_{IF}$	052	50	60	-	dB
IP3	third order intercept point	f_{u1} = 97.5 MHz, f_{u2} = 97.9 MHz, $V_{i(RF)}$ = 80 dBμV	053	-	110116	-	dBμV
α_{cs}	channel separation	$V_{i(RF)}$ = 1 mV; byte FH, CHSEP[2:0] = 100	054	26	40	-	dB

Table 59. Dynamic characteristics

VCC = 8.5 V; Tamb = 25 °C; unless otherwise specified
FM condition: all RF voltages are RMS values measured at the input of a 75 Ω dummy aerial; f_{mod} = 1 kHz, Δf = 22.5 kHz, de-emphasis = 50 μs, f_{RF} = 97.1 MHz unless otherwise specified
AM condition: all RF voltages are RMS values measured at the input 15 pF / 60 pF dummy aerial; f_{mod} = 400 Hz, m = 30%, f_{RF} = 990 kHz unless otherwise specified

Symbol	Parameter	Conditions	ID	Min	Typ	Max	Unit
$DS_{\delta f}$	dynamic selectivity	$V_{i(RF)}$ = 10 μV; Δf = 22.5 kHz; f_{AF} = 1 kHz;; S/N = 26 dB; δf = 100 kHz	058	-	3	-	dB
		δf = 200 kHz	059	-	50	-	dB
		δf ≥ 300 kHz	060	-	70	-	dB
α_{MS}	AM suppression	AM: f_{AF} = 1 kHz; m = 30%;					
		$V_{i(RF)}$ = 0.05 mV to 10 mV	062	-	55	-	dB
		$V_{i(RF)}$ = 10 mV to 500 mV	063	-	50	-	dB
$V_{desense}$	desensitization	unwanted signal voltage for 6 dB desensitization; $\|f_{unwanted} - f_{wanted}\|$ > 400 kHz $V_{i(RF),wanted}$ = 30 dBμV	065	-	90	-	dBμV
FM-front-end; pins FMIN1 and FMIN2							
R_i	input resistance	differential	076	-	300	-	Ω
C_i	input capacitance	differential	077	-	4	-	pF
$V_{i(RF)AGC}$	RF AGC	$V_{i(RF)}$ value, at which the RF gain decreases by 6 dB with increasing $V_{i(RF)}$; byte 2H, RFAGC[1:0] = 10					
		step1	081	-	82	-	dBμV
		step2	082	-	88	-	dBμV
		step3	083	-	94	-	dBμV
		step4	084	-	100	-	dBμV
		step5	085	-	106	-	dBμV
		step6	086	-	112	-	dBμV
		$V_{i(RF)}$ value, at which the RF gain increases by 6 dB with decreasing $V_{i(RF)}$; byte 2H, RFAGC[1:0] = 10					
		step1	088	-	80	-	dBμV
		step2	089	-	86	-	dBμV
		step3	090	-	92	-	dBμV
		step4	091	-	98	-	dBμV
		step5	092	-	103	-	dBμV
		step6	093	-	107	-	dBμV

Table 59. Dynamic characteristics

VCC = 8.5 V; Tamb = 25 °C; unless otherwise specified

FM condition: all RF voltages are RMS values measured at the input of a 75 Ω dummy aerial; f_{mod} = 1 kHz, Δf = 22.5 kHz, de-emphasis = 50 μs, f_{RF} = 97.1 MHz unless otherwise specified

AM condition: all RF voltages are RMS values measured at the input 15 pF / 60 pF dummy aerial; f_{mod} = 400 Hz, m = 30%, f_{RF} = 990 kHz unless otherwise specified

Symbol	Parameter	Conditions	ID	Min	Typ	Max	Unit
$V_{i(RF)AGC}$	IF AGC	$V_{i(RF)}$ value, at which the IF gain decreases by 6 dB with increasing $V_{i(RF)}$;					
		step1		-	76	-	dBμV
		$V_{i(RF)}$ value, at which the IF gain increases by 6 dB with decreasing $V_{i(RF)}$;					
		step1		-	73	-	dBμV
SS	static selectivity	± 100 kHz	135	-	12	-	dB
		± 200 kHz	137	-	60	-	dB
		± 300 kHz	138	-	70	-	dB
FM-RSSI; pin RSSI							
V_{RSSI}	RSSI voltage	$V_{i(RF)}$ = 0 μV	614	tbf	0.75	tbf	V
		$V_{i(RF)}$ = 20 μV	155	tbf	2	tbf	V
V_{ld}	start of level detection (corner of level curve)		615	-	0.7	tbf	μV
$V_{RSSISLOPE}$	slope of RSSI voltage	$V_{i(RF)}$ = 500 μV	157	-	0.8	-	V/ 20 dB
$f_{-3dB(RSSI)}$	cut off frequency of RSSI	$V_{i(RF)}$ = 500 μV; m = 30%	158	-	60	-	kHz
FM IF counter							
$V_{i(sens)}$	input sensitivity voltage	$V_{i(RF)}$ at which IF counter starts; Δf = 0	160	-	3	-	μV
res	IF count resolution		162	-	5	-	kHz
FM-Demodulator, pin MPXOUT							
V_o	output voltage	Δf = 22.5 kHz; f_{AF} = 1 kHz; R_L = 5 kΩ, C_L = 20 pF	166	180	230	300	mV
R_o	output resistance		169	-	-	100	Ω
R_L	load resistance		170	5	-	-	kΩ
C_L	load capacitance		171	-	-	20	pF
Audio output, pins LOUT and ROUT							
V_o	output voltage	Δf = 22.5 kHz; f_{AF} = 1 kHz; byte 3H, OUTA = 1	631	200tbf	285	410tbf	mV
		byte 3H, OUTA = 0	632	80tbf	120	175tbf	mV
R_o	output resistance			-	-	100	Ω
R_L	load resistance			10	-	-	kΩ
C_L	load capacitance			-	-	20	pF
AM path							

Table 59. Dynamic characteristics

VCC = 8.5 V; Tamb = 25 ℃; unless otherwise specified
FM condition: all RF voltages are RMS values measured at the input of a 75 Ω dummy aerial; f_{mod} = 1 kHz, Δf = 22.5 kHz, de-emphasis = 50 μs, f_{RF} = 97.1 MHz unless otherwise specified
AM condition: all RF voltages are RMS values measured at the input 15 pF / 60 pF dummy aerial; f_{mod} = 400 Hz, m = 30%, f_{RF} = 990 kHz unless otherwise specified

Symbol	Parameter	Conditions	ID	Min	Typ	Max	Unit
f_{RF}	RF frequency	tuning range					
		LW	187	144	-	288	kHz
		MW	188	522	-	1710	kHz
		minimum grid step	169	-	1	-	kHz
$V_{i(sens)}$	input sensitivity voltage	S/N = 26 dB; byte 3H, DEMP[1:0] = 10	190	-	34	-	dBμV
S/N	ultimate signal to noise	$V_{i(RF)}$ = 10 mV	191	tbf46	55	-	dB
THD	total harmonic distortion	$V_{i(RF)}$ = 1 mV; m = 80%	193	-	1	2-	%
PSRR	power supply ripple rejection	V_{ripple}/V_{audio}, V_{ripple} = 100 mV, f_{ripple} = 100 Hz	618	24	36	-	dB
f_{IF}	IF frequency		194	-	25	-	kHz
α_{image}	image rejection ratio	$f_{unwanted} = f_{wanted} \pm 2 * f_{IF}$	195	40	55	-	dB
α_{LOsens}	local oscillator sensitivity	$f_{unwanted} = N * (f_{wanted} \pm f_{IF}) \pm f_{IF}$; N = 7	196	-	50	-	dB
		N = 2, 3, 4, 5, 6		-	90	-	dB
SS	static selectivity	±10 kHz	197	tbf	48	-	dB
		±20 kHz	198	tbf	78	-	dB
$V_{i(RF)(max)}$	maximum RF input voltage	THD = 10%; m = 80%	199	tbf	130	-	dBμV
IP2	second order intercept point		200	-	170	-	dBμV
IP3	third order intercept point	δf = 40 kHz	201	-	127	-	dBμV
AM-Demodulator (pin MPXOUT)							
V_o	output voltage	m = 30%	204	195tbf	230	265tbf	mV
Audio output (pins LOUT and ROUT)							
V_o	output voltage	m = 30%; f_{AF} = 400 Hz; byte TUNER3, bit OUTA = 1	659	220tbf	290	375tbf	mV
		byte TUNER3, bit OUTA = 0		90tbf	120	155tbf	mV
AM LNA and AM RF AGC							

Table 59. Dynamic characteristics

VCC = 8.5 V; Tamb = 25 °C; unless otherwise specified
FM condition: all RF voltages are RMS values measured at the input of a 75 Ω dummy aerial; f_{mod} = 1 kHz, Δf = 22.5 kHz, de-emphasis = 50 µs, f_{RF} = 97.1 MHz unless otherwise specified
AM condition: all RF voltages are RMS values measured at the input 15 pF / 60 pF dummy aerial; f_{mod} = 400 Hz, m = 30%, f_{RF} = 990 kHz unless otherwise specified

Symbol	Parameter	Conditions	ID	Min	Typ	Max	Unit
$V_{i(RF)AGC}$	switched LNA AGC	$V_{i(RF)}$ value, at which the LNA gain decreases with increasing $V_{i(RF)}$; m = 0%					
		step1		-	112	-	dBµV
		step2		-	128	-	dBµV
		step3		-	134	-	dBµV
		$V_{i(RF)}$ value, at which the LNA gain increases with decreasing $V_{i(RF)}$; m = 0%					
		step1		-	108	-	dBµV
		step2		-	114	-	dBµV
		step3		-	126	-	dBµV
$V_{i(RF)AGC}$	linear RF AGC	$V_{i(RF)}$ AGC start; m = 0%	267				
		byte 2H, RFAGC[1:0] = 00		-	90	-	dBµV
		byte 2H, RFAGC[1:0] = 01		-	88	-	dBµV
		byte 2H, RFAGC[1:0] = 10		-	86	-	dBµV
		byte 2H, RFAGC[1:0] = 11		-	84	-	dBµV
$V_{i(RF)AGC}$	linear IF AGC	$V_{i(RF)}$ AGC start; m = 0%		-	60	-	dBµV
t_s	settling time	linear RF AGC settling time; $V_{i(RF)}$ = 10 mV to 600 mV	276	-	64	-	ms
		$V_{i(RF)}$ = 600 mV to 10 mV	277	-	3.2	-	s
AM-RSSI; pin RSSI							
V_{RSSI}	RSSI voltage	$V_{i(RF)}$ = 0 µV	616	-	1	-	V
		$V_{i(RF)}$ = 50 µV	411	-	2.5	-	V
		$V_{i(RF)}$ = 500 µV	412	-	3.3	-	V
V_{ld}	start of level detection (corner of level curve)		617	-	1	-	µV
$V_{RSSISLOPE}$	slope of RSSI voltage	5 µV < $V_{i(RF)}$ < 500 µV	413	-	0.8	-	V/ 20 dB
AM IF counter							
$V_{i(sens)}$	input sensitivity voltage	$V_{i(RF)}$ at which IF counter starts; m = 0	416	-	3	-	µV
res	IF count resolution		418	-	500	-	Hz

[1] The noise limited sensitivity is degraded by interferences at certain RF frequencies

13. Application information

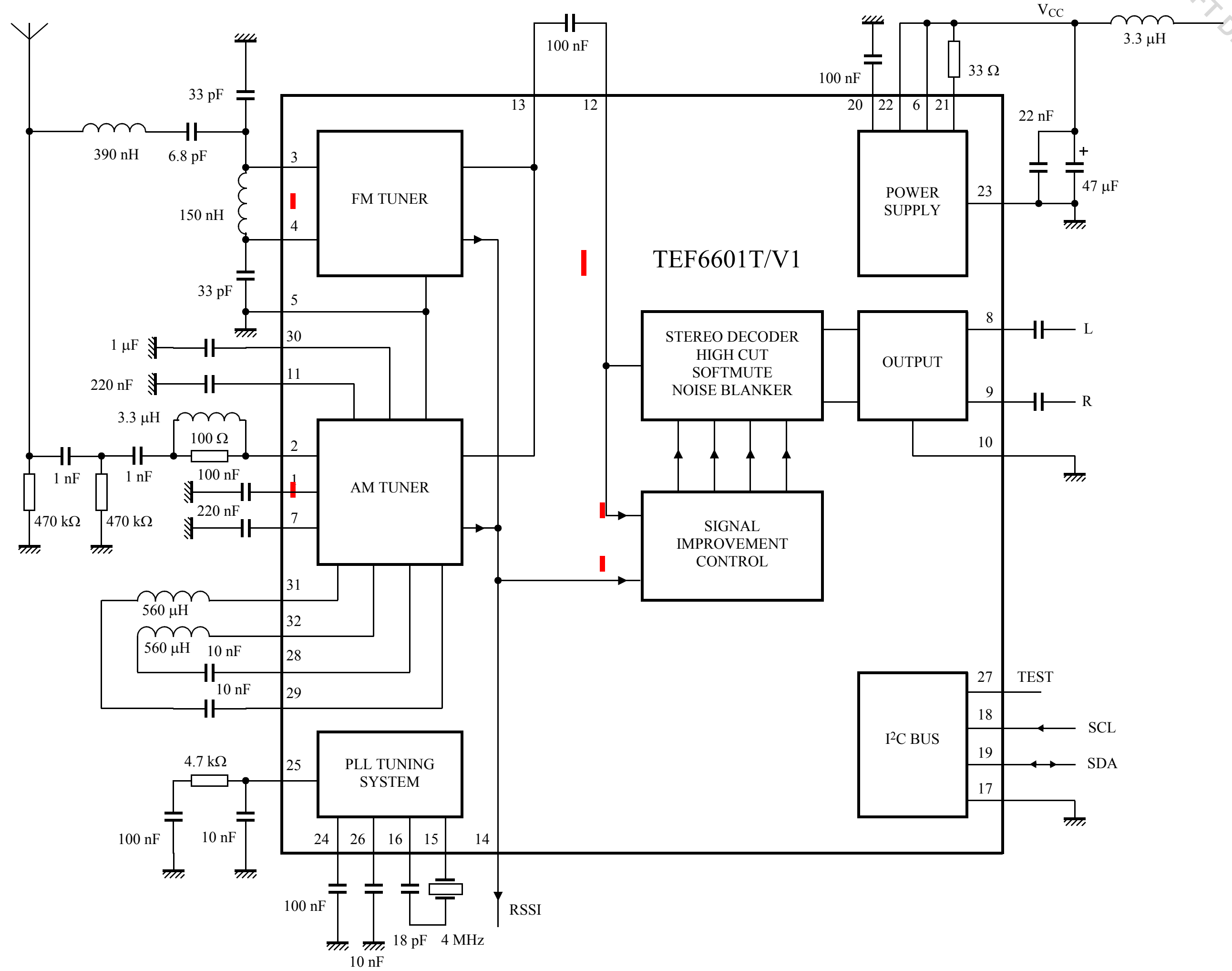


Fig 16. Application diagram of TEF6601T/V1

Table 60. DC operating point

values measured at $V_{i(RF)}$ = 0 µV, audio output gain low

Symbol	Pin	Unloaded DC voltage (V)					
		AM mode			FM mode		
		min.	typ	max	min.	typ	max
AMRFDEC	1	-	4.2	-		floating	
AMRFIN	2	-	2.9	-			
FMIN2	3				-	3.1	-
FMIN1	4				-	3.1	-
GNDRF	5		ext. 0			ext. 0	
V_{CC2}	6		ext. 8.5			ext. 8.5	
AMRFAGC	7		floating			1.8	

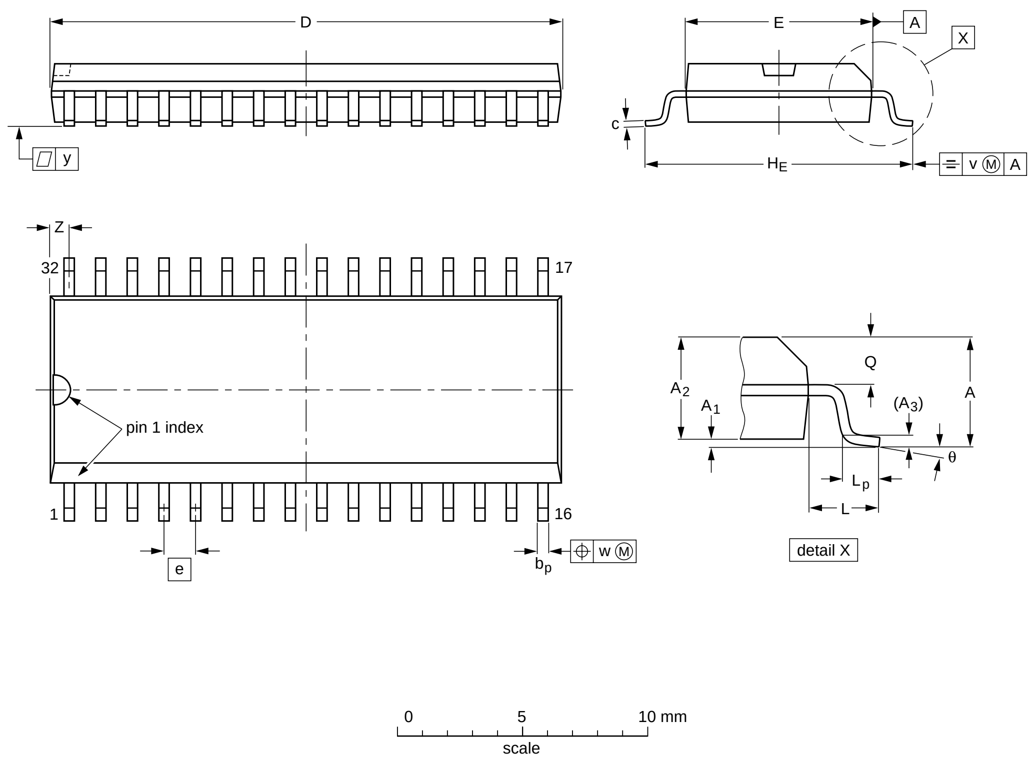
Table 60. DC operating point

values measured at $V_{i(RF)}$ = 0 μV, audio output gain low

Symbol	Pin	Unloaded DC voltage (V)					
		AM mode			FM mode		
		min.	typ	max	min.	typ	max
LOUT	8		3.85			3.85	
ROUT	9		3.85			3.85	
GNDAUD	10		ext. 0			ext. 0	
AMIFAGC2	11		-			tbf	
MPXIN	12		3.7			3.7	
MPXOUT	13		4.1			4.1	
RSSI	14		1.3			1.3	
XTAL2	15		6.5			6.5	
XTAL1	16		6.5			6.5	
GNDD	17		ext. 0			ext. 0	
SCL	18	.	ext			ext	
SDA	19	.	ext			ext	
VREF	20		4.0			4.0	
VREGSUP	21	5.6	6.5	7	5.6	6.5	7
V_{CC1}	22		ext. 8.5			ext. 8.5	
GND	23		ext. 0			ext. 0	
VCODEC	24		5.6			5.6	
PLL	25	1.2		5.5	1.2		5.5
PLLREF	26		2.25			2.25	
TEST	27		-			-	
AMSELIN1	28	7		V_{CC}	7		V_{CC}
AMSELIN2	29	7		V_{CC}	7		V_{CC}
AMIFAGC1	30		5.5				
AMSELOUT1	31	7		V_{CC}	7		V_{CC}
AMSELOUT2	32	7		V_{CC}	7		V_{CC}

14. Package outline

SO32: plastic small outline package; 32 leads; body width 7.5 mm **SOT287-1**



DIMENSIONS (inch dimensions are derived from the original mm dimensions)

UNIT	A max.	A_1	A_2	A_3	b_p	c	D(1)	E(1)	e	H_E	L	L_p	Q	v	w	y	Z(1)	θ
mm	2.65	0.3 0.1	2.45 2.25	0.25	0.49 0.36	0.27 0.18	20.7 20.3	7.6 7.4	1.27	10.65 10.00	1.4	1.1 0.4	1.2 1.0	0.25	0.25	0.1	0.95 0.55	8^o 0^o
inches	0.1	0.012 0.004	0.096 0.089	0.01	0.02 0.01	0.011 0.007	0.81 0.80	0.30 0.29	0.05	0.419 0.394	0.055	0.043 0.016	0.047 0.039	0.01	0.01	0.004	0.037 0.022	

Note

1. Plastic or metal protrusions of 0.15 mm (0.006 inch) maximum per side are not included.

OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	JEITA			
SOT287-1		MO-119				~~00-08-17~~ 03-02-19

Fig 17. Package outline SOT287-1 (SO32)

15. Soldering

15.1 Introduction to soldering surface mount packages

This text gives a very brief insight to a complex technology. A more in-depth account of soldering ICs can be found in our *Data Handbook IC26; Integrated Circuit Packages* (document order number 9398 652 90011).

There is no soldering method that is ideal for all surface mount IC packages. Wave soldering can still be used for certain surface mount ICs, but it is not suitable for fine pitch SMDs. In these situations reflow soldering is recommended.

15.2 Reflow soldering

Reflow soldering requires solder paste (a suspension of fine solder particles, flux and binding agent) to be applied to the printed-circuit board by screen printing, stencilling or pressure-syringe dispensing before package placement. Driven by legislation and environmental forces the worldwide use of lead-free solder pastes is increasing.

Several methods exist for reflowing; for example, convection or convection/infrared heating in a conveyor type oven. Throughput times (preheating, soldering and cooling) vary between 100 seconds and 200 seconds depending on heating method.

Typical reflow peak temperatures range from 215 °C to 270 °C depending on solder paste material. The top-surface temperature of the packages should preferably be kept:

- below 225 °C (SnPb process) or below 245 °C (Pb-free process)
  - for all BGA, HTSSON..T and SSOP..T packages
  - for packages with a thickness ≥ 2.5 mm
  - for packages with a thickness < 2.5 mm and a volume ≥ 350 mm^3 so called thick/large packages.
- below 240 °C (SnPb process) or below 260 °C (Pb-free process) for packages with a thickness < 2.5 mm and a volume < 350 mm^3 so called small/thin packages.

Moisture sensitivity precautions, as indicated on packing, must be respected at all times.

15.3 Wave soldering

Conventional single wave soldering is not recommended for surface mount devices (SMDs) or printed-circuit boards with a high component density, as solder bridging and non-wetting can present major problems.

To overcome these problems the double-wave soldering method was specifically developed.

If wave soldering is used the following conditions must be observed for optimal results:

- Use a double-wave soldering method comprising a turbulent wave with high upward pressure followed by a smooth laminar wave.
- For packages with leads on two sides and a pitch (e):
  - larger than or equal to 1.27 mm, the footprint longitudinal axis is **preferred** to be parallel to the transport direction of the printed-circuit board;
  - smaller than 1.27 mm, the footprint longitudinal axis **must** be parallel to the transport direction of the printed-circuit board.

  The footprint must incorporate solder thieves at the downstream end.

- For packages with leads on four sides, the footprint must be placed at a 45° angle to the transport direction of the printed-circuit board. The footprint must incorporate solder thieves downstream and at the side corners.

During placement and before soldering, the package must be fixed with a droplet of adhesive. The adhesive can be applied by screen printing, pin transfer or syringe dispensing. The package can be soldered after the adhesive is cured.

Typical dwell time of the leads in the wave ranges from 3 seconds to 4 seconds at 250 °C or 265 °C, depending on solder material applied, SnPb or Pb-free respectively.

A mildly-activated flux will eliminate the need for removal of corrosive residues in most applications.

15.4 Manual soldering

Fix the component by first soldering two diagonally-opposite end leads. Use a low voltage (24 V or less) soldering iron applied to the flat part of the lead. Contact time must be limited to 10 seconds at up to 300 °C.

When using a dedicated tool, all other leads can be soldered in one operation within 2 seconds to 5 seconds between 270 °C and 320 °C.

15.5 Package related soldering information

Table 61. Suitability of surface mount IC packages for wave and reflow soldering methods

Package[1]	Soldering method	
	Wave	Reflow[2]
BGA, HTSSON..T[3], LBGA, LFBGA, SQFP, SSOP..T[3], TFBGA, VFBGA, XSON	not suitable	suitable
DHVQFN, HBCC, HBGA, HLQFP, HSO, HSOP, HSQFP, HSSON, HTQFP, HTSSOP, HVQFN, HVSON, SMS	not suitable[4]	suitable
PLCC[5], SO, SOJ	suitable	suitable
LQFP, QFP, TQFP	not recommended[5][6]	suitable
SSOP, TSSOP, VSO, VSSOP	not recommended[7]	suitable
CWQCCN..L[8], PMFP[9], WQCCN..L[8]	not suitable	not suitable

[1] For more detailed information on the BGA packages refer to the *(LF)BGA Application Note* (AN01026); order a copy from your Philips Semiconductors sales office.

[2] All surface mount (SMD) packages are moisture sensitive. Depending upon the moisture content, the maximum temperature (with respect to time) and body size of the package, there is a risk that internal or external package cracks may occur due to vaporization of the moisture in them (the so called popcorn effect). For details, refer to the Drypack information in the *Data Handbook IC26; Integrated Circuit Packages; Section: Packing Methods*.

[3] These transparent plastic packages are extremely sensitive to reflow soldering conditions and must on no account be processed through more than one soldering cycle or subjected to infrared reflow soldering with peak temperature exceeding 217 °C ± 10 °C measured in the atmosphere of the reflow oven. The package body peak temperature must be kept as low as possible.

[4] These packages are not suitable for wave soldering. On versions with the heatsink on the bottom side, the solder cannot penetrate between the printed-circuit board and the heatsink. On versions with the heatsink on the top side, the solder might be deposited on the heatsink surface.

[5] If wave soldering is considered, then the package must be placed at a 45° angle to the solder wave direction. The package footprint must incorporate solder thieves downstream and at the side corners.

[6] Wave soldering is suitable for LQFP, QFP and TQFP packages with a pitch (e) larger than 0.8 mm; it is definitely not suitable for packages with a pitch (e) equal to or smaller than 0.65 mm.

[7] Wave soldering is suitable for SSOP, TSSOP, VSO and VSSOP packages with a pitch (e) equal to or larger than 0.65 mm; it is definitely not suitable for packages with a pitch (e) equal to or smaller than 0.5 mm.

[8] Image sensor packages in principle should not be soldered. They are mounted in sockets or delivered pre-mounted on flex foil. However, the image sensor package can be mounted by the client on a flex foil by using a hot bar soldering process. The appropriate soldering profile can be provided on request.

[9] Hot bar soldering or manual soldering is suitable for PMFP packages.

16. Revision history

Table 62. Revision history

Document ID	Release date	Data sheet status	Change notice	Supersedes
	2006-04-18	Objective Specification		initial version
	2006-05-05		draft	

Modifications:	• 0049, 0050, 0135 to 0138, 0169, 0196, 0276 • new ID: 0613 to 0618

Modifications:	• • <Modification; use cross reference to refer to modified content>

17. Legal information

17.1 Data sheet status

Document status[1][2]	Product status[3]	Definition
Objective [short] data sheet	Development	This document contains data from the objective specification for product development.
Preliminary [short] data sheet	Qualification	This document contains data from the preliminary specification.
Product [short] data sheet	Production	This document contains the product specification.

[1] Please consult the most recently issued document before initiating or completing a design.

[2] The term 'short data sheet' is explained in section "Definitions".

[3] The product status of device(s) described in this document may have changed since this document was published and may differ in case of multiple devices. The latest product status information is available on the Internet at URL http://www.semiconductors.philips.com.

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