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TDA7528

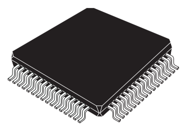
FM/AM car-radio receiver front-end for IF-sampling systems with fully integrated VCO

Features

- High-performance AM/FM front-end chip for IF-sampling car-radio tuners
- Compatible with AM(LW, MW, SW) / FM(EU, US, JAPAN, OIRT) / Weather Band / HD-Radio / DRM applications
- Ready for multi-tuner applications (phase diversity, background tuner)
- Dual input FM-mixer with high image rejection, specialized for different front-end circuits
- Integrated AM preamplifier and tank for lower-cost applications
- Fully integrated tuning PLL with two VCO's for diversity systems
- World tuning capable
- Integrated IF tank
- AGC controlled IF amplifier with four inputs for connection of up to four ceramic filters
- Fully electronically adjustable
- I^2C/SPI controlled

Description

The TDA7528 is a front-end module for use in car radio receivers with digital IF processing, using the STA3004, respectively the STA3005 backend IC.



LQFP64

Its field of use includes all the current radio broadcast services in the range of 50kHz to 163MHz for AM radio, FM radio and US weather band. Digital standards such as DRM and HD radio can also be handled. A single supterheterodyne architecture with 10.7 MHz IF-frequency provides high dynamic range.

The IMR mixer has separate input and output stages for AM frequency bands up to 30 MHz and for FM frequencies above 30 MHz.

The integrated AM-preamplifier and the fully integrated low-pass filter enable low cost applications. Two FM inputs with different noise / IP3 parameter, provide full flexibility for the pre-stage circuitry. Each mixer output is able to drive two IF-filters, which can be selected by the different IF-amplifier inputs.

The fast tuning PLL controls two different VCO, which are designed to operate without frequency overlap.

Table 1. Device summary

Order code	Package	Packing
TDA7528	LQFP64 exposed pad (10x10x1.4 mm)	Tray

Contents

List of tables

List of figures

1 Product description

1.1 Summary

The TDA7528 is a front-end module for use in car radio receivers on the 50 kHz - 108 MHz and 161 MHz - 163 MHz frequency bands. Its field of use includes all the current radio broadcast services worldwide on long, medium and short wave, CB radio, FM radio on the OIRT, Japanese and ITU frequency bands and the American weather band. Both analogue AM and FM and digital standards such as DRM and HD radio (IBOC) can be handled.

The receiver is designed as a single super-heterodyne with an intermediate frequency of 10.7 MHz. The IF signal is digitized, filtered and demodulated in the appropriate backend IC. The combination of two independently-operating front-ends with the backend makes phase diversity operation possible or the simultaneous reception of two freely-selectable frequencies with any combination of types of demodulation.

The TDA7528 IMR mixer has separate input- and output-stages for AM frequency bands up to 30 MHz (narrowband services) and for FM frequencies above 30 MHz (broadband signals).

As an option, the AM path can be operated with an integrated preamplifier stage and an integrated low-pass filter to reduce interfering input signals on the IF and image frequencies. The mixer has two FM inputs with different properties. The more sensitive (lower noise) input is intended for the use of a passive pre-selection stage and the high level, advanced IP3 input for an active preamplifier stage. The mixer outputs have a single ended low impedance design to drive one or two IF filters with different bandwidths. A switchable gain IF amplifier, independent IF AGC and an integrated anti-aliasing stage drive the IF A/D converter of the backend. Programmable RF AGCs to actuate adjustable preamplifier stages and two D/A converters for tuning external filter stages complete the reception path.

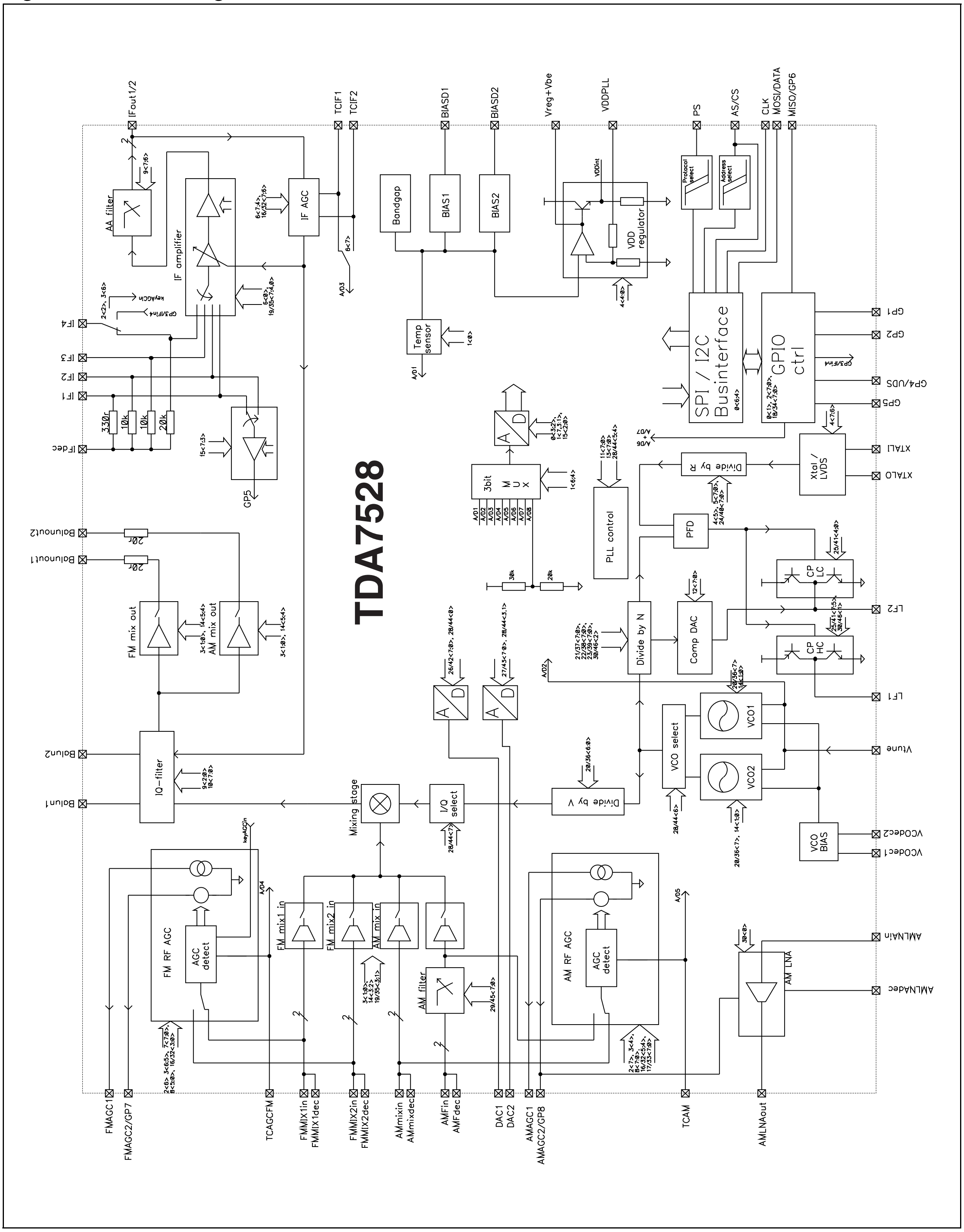
Two fully-integrated VCOs are included in the TDA7528, oscillating in a range around 3.7 GHz and 4.7 GHz respectively. The output signal of the selected VCO drives a programmable divider generating the LO signal for the mixer stage. The PLL, integrated with the exception of the loop filter, facilitates reception on all the above-mentioned frequencies, rapid frequency changes in the standard tuning steps of 50 kHz for FM, 9 or 10 kHz for LW and MW and 5 kHz for SW. The smallest available tuning steps are 12.5 kHz for FM and 1 kHz for all AM bands.

The TDA7528 is controlled by a serial command interface, switchable between SPI and I^2C protocol. The external reference source is typically 74.1 MHz. However, the TDA7528 also has its own reference oscillator.

All the necessary calibration steps can be carried out electronically during production. An integrated temperature sensor facilitates the adaptation of various parameters during operation, like IF gain or AGC threshold.

1.2 Block diagram

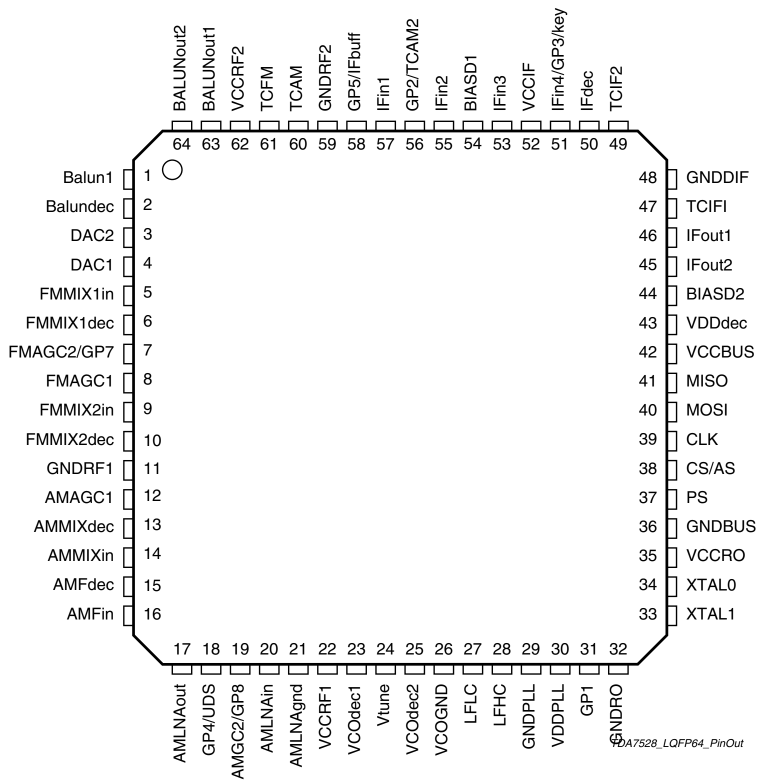
Figure 1. Block diagram



2 Pin description

2.1 Pin connection

Figure 2. Pinout diagram (top view)



2.2 Pin description

Table 2. Pin function description

Pin #	Pin name	Description
1	BALUN1	Active balun input 1
2	BALUNdec	Active balun input 2 (decoupling)
3	DAC2	Tuning DAC 2 output
4	DAC1	Tuning DAC 1 output
5	FMMIX1in	FM mixer input – high gain stage = mode 1
6	FMMIX1dec	FM mixer decouple
7	FMAGC2/GP7	FM AGC voltage output / alternative GP7 output
8	FMAGC1	FM AGC current output for PIN diode
9	FMMIX2in	FM Mixer input – low gain stage = mode2

Table 2. Pin function description (continued)

Pin #	Pin name	Description
10	FMMIX2dec	FM Mixer decouple
11	GNDRF1	GND RF1 section
12	AMAGC1	AMAGC PIN diode driver output
13	AMMIXdec	AM mixer decouple
14	AMMIXin	AM mixer input
15	AMFdec	Decoupling of AM filter
16	AMFin	Input of AM filter
17	AMLNAout	AM LNA output
18	GP4/UDS	GPIO 4 / UDS input
19	AMAGC2/GP8	AM AGC voltage output / alternative GP8 output
20	AMLNAin	AM LNA input
21	AMLNAGND	AM LNA Ground
22	VCCRF1	Supply RF1 section
23	VCOdec1	BIAS decouple for VCO
24	Vtune	VCO tuning voltage
25	VCOdec2	BIAS decouple for VCO
26	GNDVCO	VCO Ground
27	LFLC	Loop filter low current output
28	LFHC	Loop filter high current output
29	GNDPLL	PLL Ground
30	VDDPLL	Supply PLL
31	GP1	GPIO 1
32	GNDRO	Ground PLL digital part
33	XTALI	Reference oscillator input
34	XTALO	Reference oscillator output
35	VCCRO	Supply PLL digital part
36	BUSGND	BUS interface Ground
37	PS	Protocol Select
38	CS/AS	Chip select / Address select
39	CLK	SPI / I2C clock
40	MOSI	SPI data input / I2C Data
41	MISO	SPI data output / GP6
42	VCCBUS	Supply of BUS interface
43	VDDdec	Decouple of internal 3.3V (=3,3V + Vbe)
44	BIASD2	Decoupling for biasing

Table 2. Pin function description (continued)

Pin #	Pin name	Description
45	IFout2	Differential IF output 2
46	IFout1	Differential IF output 1
47	TCIF1	time constant IF AGC for AM
48	GNDIF	ground IF section
49	TCIF2	time constant IF AGC for FM
50	IFdec	Decouple of IF amplifier
51	IFin4 / GP3	IF input 4 (= AM IBOC input) / GPIO 3
52	VCCIF	Supply IF section
53	IFin3	IF input 3 (= AM analog input)
54	BIASD1	Decoupling for biasing
55	IFin2	IF input 2 (= FM IBOC input)
56	GP2/TCAM2	GPIO 2 / input for 2nd order time constant of AM AGC
57	IFin1	IF input 1 (= FM analog input)
58	GP5/IFbuff	GPIO 5 / IF buffer amplifier output
59	GNDRF2	GND RF2 section = active balun GND
60	TCAM	AM AGC time constant
61	TCFM	FM AGC time constant
62	VCCRF2	Supply voltage RF2 section
63	Balunout1	Active balun output 1 = FM output
64	Balunout2	Active balun output 2 = AM output

3 Electrical characteristics

3.1 Absolute maximum ratings

Table 3. Absolute maximum ratings

Symbol	Parameter	Value	Unit
V_{CC}	Supply voltage	5.5	V
V_{DD}	Supply voltage	3.6	V
T_{amb}	Ambient temperature range	-40 to 125	°C
T_s	Storage temperature	-55 to 150	°C
T_j	Max. junction temperature	150	°C

Operating temperature and supply voltage range: -40 °C to 105 °C; 4.7 V to 5.35 V.
All specification parameter are fulfilled in this temperature and supply voltage range, unless otherwise specified. Typical values reflect average measurement at T_{amb} = 25 °C, V_{CC} = 5.0 V and V_{DD} = 3.3 V.

3.2 General parameters

Table 4. General parameters electrical characteristics

Symbol	Parameter	Test conditions	Min.	Typ	Max	Unit
V_{CC}	5V supply voltage	Full performance	4.7	5	5.35	V
		Fully functional but with reduced performance	4.6	-	4.7	V
V_{DD}	3.3V supply voltage	When used with external 3.3 V power supply regulator	3.1	3.3	3.5	V
	V_{CC} slew rate range	-	0.01	-	1000	V/ms
I_{CC}	Supply current @5V typ	FM typical application	-	160	200	mA
		AM external pre-stage	-	160	200	mA
		AM integrated pre-stage	-	175	215	mA
I_{CCmax}	Max supply current	FM, max application, (FM typ + Xtal, IF-buffer, AMAGC)	-	170	215	mA
I_{CC_pwd}	Supply current @5V in power down mode	-	-	7	11	mA
P_{max}	Power dissipation	FM typical application	-	650	950	mW
		AM external pre-stage	-	650	950	mW
		AM integrated pre-stage		710	1015	mW
T_{amb}	Ambient temperature range	Full performance, unless otherwise specified	-40	-	105	°C
T_{extend}	Extended ambient temperature range	Signal path functional with reduced performance	105	-	125	°C

3.3 Power management and voltage regulator

The TDA7528 has a single 5 V supply. The 3.3 V supply for the VCO must be derived from an external NPN transistor controlled by the internal voltage regulator. It is also possible to use an external 3.3 V regulator. In this case, special care has to be taken on this 3.3V .

3.3.1 Power management

The TDA7528 detects whether all the voltages are high enough and stable when the operating power supply is applied. The power-on reset is tripped and all the control registers are set to "low" if this condition is not met.

As long as the voltages remain within the permissible range, the SPI/I^{2}C interface is active (in the I^{2}C mode this can be detected by the μP through the acknowledge signal on every communication with the bus master).

The SPI-/I^{2}C interface is in power-on mode when the operating voltage is applied to the TDA7528.

The following function groups can be switched on/off via SPI/I^{2}C:

- PLL {divider R, N and V, PFD, charge pump, VCO1 (3,7 GHz-VCO) or VCO2 (4,7 GHz-VCO), Reference-Oscillator or LVDS input buffer}
- FM/AM-mixer and active balun, FM-AGC
- D/A-converter_1
- D/A-converter_2
- AM-LNA
- AM-low pass filter
- AM-AGC
- IF-section {IF-amplifier, anti-aliasing-filter, IF-AGC}
- GPIO
- temperature-sensor,
- Sensor ADC

3.3.2 Power-on circuit and low supply voltage detector

Power-on circuit:

The power-on circuit produces a reset whenever one of the following voltages is below it's POR level. (BIASD1, BIASD2 < 1.2 V; VDDPLL < 2.4V; VCCIF < 3.8 V)

Low supply voltage detector:

The "PWR_STABLE_read" status bit has the value "0" after power on. This bit is set to "1" by an SPI/I2C write command from the microcontroller in initialization communication to the "PWR_STABLE_write" bit. The microcontroller cannot reset the "PWR_STABLE_read" bit. A "0" transmitted in the "PWR_STABLE_write" bit has no effect.

If the power supply falls below the programmed threshold all registers are set to their power-on default, including that the "PWR_STABLE_read" bit is set to "0". By this the microcontroller can verify at any time whether a critical drop in voltage (value "0") has taken place since the last TDA7528 read out of this bit. The threshold voltage can be calibrated indirect by measuring the DAC1 (9 bit) output voltage for DAC1=0x200 or the DAC2 (8 bit) output voltage for DAC2=0x100).

The PWR_STABLE functionality can be switched on/off. The default value is the switched off mode.

Table 5. Voltage sag detection electrical characteristics

Symbol	Parameter	Test conditions	Min.	Typ	Max	Unit
V_{STHmin}	Min. supply voltage threshold	-40 to 150 °C, $T_j \leq 150$ °C	4.1	4.3	4.5	V
V_{STHmax}	Max supply voltage threshold	-	4.4	4.6	4.9	V
-	Step size	-	-	100	-	mV
t_c	Time constant	-	-	1	-	µs

3.3.3 Voltage regulator

The internal voltage regulator drives the external transistor for the 3.3V supply of the VCO and PLL. The 3.3 V voltage regulator for the bus interface and the reference oscillator is fully integrated.

Table 6. Voltage regulator electrical characteristics

Symbol	Parameter	Test conditions	Min.	Typ	Max	Unit
V_{DD}	3.3V supply voltage	Internal voltage regulator with external power transistor	3.1	3.3	3.5	V
I_{DD}	current of external V_{DD}	Current through external transistor or from external 3.3 V supply	-	60	80	mA

When an external 3.3 V supply is used for the VCO and PLL supply, special care has to be taken on the supply voltages during the ramp-up phase:

- the 3.3 V supply must never be higher than the 5 V supply;
- the difference between 5 V and 3.3 V must never exceed 3.6 V.

The second prerequisite is automatically met using a 3.3 V Z-diode between the 5 V and the 3.3 V supplies.

3.4 FM - Section

3.4.1 IMR and active balun

The IMR mixer has two software-selectable FM inputs (referred to as mode 1 and mode 2). These inputs are implemented with different gains, noise figures, IIP3, maximum input signal.

There are two single ended outputs of the IMR mixer. One is dedicated to FM (Balunout1) and the other to AM (Balunout2). It is not recommended to use both outputs in parallel.

Table 7. IMR and active balun electrical characteristics
(All parameter are referred to Balunout1, unless otherwise specified)

Symbol	Parameter	Test condition	Min.	Typ	Max	Units
G_{mix1} G_{mix2}	Gain vs. Balunout1 Gain vs. Balunout1	Mode 1 (unloaded gain) Mode 2 (unloaded gain)	20 13	22 15	24 17	dB
G_{mix1} G_{mix2}	Gain vs. Balunout2 Gain vs. Balunout2	Mode 1 (unloaded gain) Mode 2 (unloaded gain)	16 9	18 11	20 13	dB
-	Absolute gain error	@ 100 MHz @ 25°C	-	-	± 1.0	dB
-	Gain error vs. frequency	Freq. range @ 25°C 47,0 to 74,0 MHz 76,0 to 90,0 MHz 87,5 to 108,0 MHz 30,0 to 170,0 MHz	-	-	± 0,5 ± 0,5 ± 0,5 ± 2,0	dB
-	Gain error vs. temperature	-40 °C to 105 °C	-	-	± 2,0	dB
-	Gain attenuation range	Controlled by IF-AGC	17.5	20	-	dB
-	Input impedance	Mode 1 Mode 2	5 5	-	-	kΩ
-	Input resistance	Mode 1 Mode 2	30 9.5	50 12.5	19.5	kΩ
-	Output impedance	Active balun	15	20	30	Ω
-	External load	Full current: reg14[5] = 0 Red. current: reg14[5] = 1	320 600	-	-	Ω Ω
V_{out_max}	Max. output voltage	1dB below 1dB compression point	121	123	-	dBμV
V_{in_max}	Max. input voltage	Mode 1 Mode 2 1dB below 1dB compression point	100 108	-	-	dBμV
V_{noise}(1)	Input noise voltage – mode1 Input noise voltage – mode2	Rsource=1.5 kΩ, noiseless in 65 MHz-170 MHz range Rsource = 800 Ω, noiseless in 65 MHz-170 MHz range	-	3.1 5	3.7 6	nV/√ Hz
d_{noise}	vnoise*atten*dnoise	AGC noise behavior @ 6 dB attenuation	-	6	-	dB

Table 7. IMR and active balun electrical characteristics (continued)
(All parameter are referred to Balunout1, unless otherwise specified)

Symbol	Parameter	Test condition	Min.	Typ	Max	Units
IIP3[1]	3rd order intercept point Reg9[5:4]=00	Mode 1 up to Vin/tone = 90 dBμV Mode 2 up to Vin/tone = 98 dBμV up to 95 °C junction temperature	123 126 130	125 133	-	dBμV
	3rd order intercept point in reduced current mode	Mode 1; reg14[3:2]=01	-	120	-	dBμV
		Mode 2; reg14[3:2]=01 60 °C up to 125 °C junction temperature	130	132	-	
		Mode 1; reg14[3:2]=10	-	117	-	
		Mode 2; reg14[3:2]=10 junction temperature > 90 °C	129	130	-	
IIP2[1]	2nd order intercept point	Mode 1 Mode 2	144 157	-	-	dBμV
IFattn	IF- output attenuation (without external circuitry)	@ 26.35 MHz @ 100 MHz	1 9	2	-	dB
-	IF rejection	-	38	-	-	dB
V_{LO_IN}	LO signal @ mixer input	R_{source} =1.5 kΩ @ fundamental LO freq. @ LO harmonics	-	-	10 40	dBμV
V_{LO_OUT}	LO signal @ balun output	Incl. LC-tank with Q=2, R_{load} = 1.0 kΩ @ fundamental LO freq. @ LO harmonics	-	-	66 60	dBμV
I_{QG}	I/Q gain adjust Min. Max.	4bit	-	-0.7 0.7	-	dB
-	gain step	-	-	0.1	-	dB
P_{IQ}	I/Q phase adjust Min. Max.	4bit	-	-1.2 1.2	-	°
-	Phase step	-	-	0.2	-	°
-	Center frequency adjust Min. Max.	3bit	-	-2.4 2.4	-	MHz
-	Frequency step	-	-	0.6	-	MHz
IRR	Image rejection ratio	without gain/phase adjust	30	45	-	dB
		with freq/gain adjust @ 25°C	45	-	-	
		with freq/gain/phase adjust vs. complete temp. range	40	-	-	

1. Parameter not guaranteed by production test

3.4.2 FM AGC

The time constant of the FM AGC is defined by an external capacitor and the programmable internal currents (details given in the *Table 8*). The currents can be selected independently for AGC attack and decay. By this a symmetrical behavior rather than a 2...250 times faster attack behavior can be programmed.

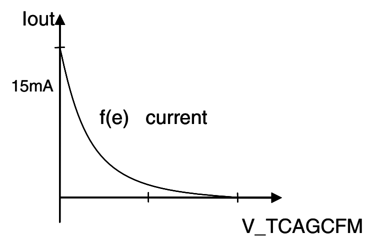
Control behavior:

The FM-RF-AGC is realized with two output pins which control the gain of the corresponding pre-stage.

The control behavior can be programmed to the following modes:

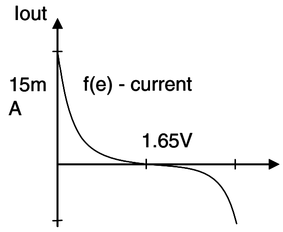
1. **Controlled current output mode 1**
   data byte FMAGC[3:0] = 1000
   positive current I = f(e): after reaching the AGC threshold voltage the current output delivers a current I = f(e) up to -15 mA in a voltage range from 0.2V up to V_{CC}-1.5 V.

Figure 3. FM AGC - Controlled current output mode 1



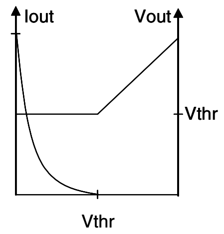
2. **Controlled current output mode 2**
   data byte FMAGC[3:0] = 1100
   Below the AGC threshold voltage the AGC output sinks a constant current of 5 mA. When the RF input level crosses the AGC threshold voltage the current is reduced down to 0mA with a quasi-log. behavior. At half control voltage the current becomes positive and reaches up to -15 mA following an exponential function.

Figure 4. FM AGC - Controlled current output mode 2



3. **Constant current mode**
   data byte FMAGC[3:0] = 0100
   The output current can be set to 2 mA source current. The AGC detector is in power-down mode and only the pin diode driver is active.
4. **Controlled Voltage / current output**
   data byte FMAGC[3:0] = 1011
   voltage and current mode with hand-over: the Vthr level is programmable in the range of 0.2 V to 2.6 V.

Figure 5. FM AGC - Controlled Voltage / current output



5. **Calibration mode**
   data byte FMAGC[3:0] = 0010
   calibration mode for voltage output: The voltage Vthr can be switched directly to the voltage output pin.

All other possible bit combinations of data byte FMAGC[3:0] are not recommended.

The voltage output can be configured as GPO.

The FMAGC2 output (voltage output) is short-circuit protected by a current limiter. The FMAGC1 output (current output) needs an external resistor for current limitation. The current output is voltage-tolerant up to V_{CC}, the voltage output up to V_{DD}.

The microcontroller can read the voltage at the AGC capacitor via the serial control interface. On request of the microcontroller the measurement is done by applying the time constant capacitor voltage to the central ADC (specified in chapter *3.10*) and gives information to calculate the AGC-attenuation.

The FM AGC system is controlled by a peak detector.

The Key AGC function is controlled by a D/A converter in the backend.

Table 8. FM-AGC electrical characteristics

Symbol	Parameter	Test condition	Min.	Typ	Max	Units
Lthr	Threshold RF level Min. Threshold	Referred to mixer input	-	-	-	-
		Mode 1 - high gain mixer	-	86	-	dBµV
		Mode 2 – low gain mixer	-	92	-	
	Max Threshold	Mode 1 - high gain mixer	-	100	-	
		Mode 2 – low gain mixer	-	106	-	
-	Threshold steps	4 bit control	0.5	1	1.5	dB
-	Threshold error	30 to170 MHz @ 25 °C	-1.5	-	1,5	dB
-	Total threshold error	30.0 to 170.0 MHz	-3	-	3	dB
-	Temperature behavior of AGC thresholds	-	-	0.011	-	dB/°C
-	Frequency range	-	30	-	170	MHz
-	Pin diode source current ($I \approx -1.5$ mA * (exp(V_{DD}-V_{AGCTC})-1))	$V_{AGCTC} < 1V$ (due to exponential behavior, external resistor needed)	-	-	-10	mA
-	Pin diode sink current ($I \approx 1$ mA * (exp(V_{AGCTC}-1.65V)-1))	$V_{AGCTC} = V_{DD}$ (due to exponential behavior, external resistor needed)	3	-	-	mA

Table 8. FM-AGC electrical characteristics (continued)

Symbol	Parameter	Test condition	Min.	Typ	Max	Units
-	Pin diode source current in constant current mode	-	-	-2	-1	mA
-	Min. voltage	AGC control pin 1 @ positive current mode @ pos/neg current mode	-	-	0.2 0.4	V
-	Max. voltage	AGC control pin 1	V_{CC}-1.5	V_{CC}-1.3	-	V
-	Max. source current	AGC control pin 2; voltage output	1	-	-	mA
-	Min. sink current	AGC control pin 2; voltage output	-	-100	-	µA
-	Max. output voltage in analog voltage mode (follower mode)	AGC control pin 2 @ I_{load} = 1 mA	V_{DD}-0.3	-	V_{DD}	V
-	Min. output voltage in analog voltage mode	AGC control pin 2 @ I_{load} = -50 µA	-	-	1	V
$Vthr_{min}$	Vthr_min	-	0.1	0.2	0.3	V
$Vthr_{max}$	Vthr_max	-	2.4	2.6	2.8	V
-	Step size of Vthr	6bit	-	40	-	mV
DNL	nonlinearity of Vthr	-	-0.5		0.5	LSB
-	I attack for 6dB control error	Mode A1 Mode A2 Mode A3	30 150 0.75	50 250 1.25	80 400 2.0	µA
-	I decay max	Mode D1 Mode D2 Mode D3	-6 -30 -150	-4 -20 -100	-2.5 -12 -60	µA
-	Typical AGC time constant for attack(1)	C_{AGCTC} = 1 µF, mode A2 AGC conductance versus V_{AGCTC}= 20 dB/V	-	0.5	-	ms
-	Typical AGC time constant for decay(1)	C_{AGCTC} = 1 µF, mode D2 AGC conductance versus V_{AGCTC}= 20 dB/V	-	15	-	ms
-	Threshold shift keyed AGC	Control input range = 0.2 to 1 V	-	19	-	dB/V
-	Keyed AGC range	-	10	-	-	dB

1. The time constant is defined as the 1τ value after a 6 dB level step

3.5 AM - Section

3.5.1 AM LNA

Table 9. AM LNA electrical characteristics

Symbol	Parameter	Test condition	Min.	Typ	Max	Units
gm	Transconductance	@ 25°C	10	15	20	mS
-	Gain error vs. frequency	Freq. range 150 to 350 kHz 520 to 1710 kHz 2.0 to 30.0 MHz 0.05 to 30.0 MHz	-	-	± 0.5 ± 0.5 ± 1.0 ± 2.5	dB
-	Input impedance	-	500	1000		kΩ
vnoise(1)	Input noise voltage	@ 1 MHz @ 150 kHz	-	1.7 2.6	2	nV/√ Hz
IIP3(1)	3^{rd} order intercept point	@ gain 20 dB	123	128	-	dBµV
IIP2	2^{nd} order intercept point	@ gain 20 dB	127	132	-	dBµV
AGC	AGC range	-	8	-	-	dB

1. Parameter not guaranteed by production test

3.5.2 Switchable LPF 4^{th} order

Table 10. Switchable LPF 4^{th} order electrical characteristics

Symbol	Parameter	Test condition	Min.	Typ	Max	Units
f_{LP1}	LP corner frequency 1	Mode 1(1)	1.71	-	1.95	MHz
f_{LP2}	LP corner frequency 2	Mode 2(1)	6.2	-	7.1	MHz
f_{LP3}	LP corner frequency 3	Mode 3(1)	14.0	-	16.0	MHz
f_{LP4}	LP corner frequency 4	Mode 4(1)	22.0	-	25.5	MHz
f_{LP5}	LP corner frequency 5	Mode 5(1)	26.1	-	31.0	MHz
G	Gain incl. mix vs. Balunout1	-	3	4.5	6	dB
G	Gain incl. mix vs. Balunout2	-	-1	0.5	2	dB
-	Passband ripple(2)	-	-	-	-	-
-	Stop band attenuation	Mode=1 @ 10.7 MHz (LW+MW) @ >22MHz Mode=2 @ >28 MHz (KW low) @ >87.5 MHz Mode=3 @ >43 MHz (KW mid) @ >87.5 MHz Mode=4 @ >74 MHz (KW high) @ >87.5 MHz Mode=5 @ >74 MHz (11m) @ >87.5 MHz	40 60 30 60 20 45 25 30 20 25	-	-	dB

Table 10. Switchable LPF 4th order electrical characteristics (continued)

Symbol	Parameter	Test condition	Min.	Typ	Max	Units
Vnoise(2)	Input noise voltage incl. IMR noise	@ 1 to 30 MHz, @ 25°C @ 0.15 to 1 MHz, @ 25°C	-	30 33	34 37	nV/√ Hz
IIP3	3rd order intercept point	Up to 10 MHz input frequency	137	140	-	dBµV
IIP2(2)	2nd order intercept point	Up to 10 MHz input frequency	160	-	-	dBµV

1. Corner frequency needs calibration
2. Parameter not guaranteed by production test

3.5.3 IMR and active balun

All parameter are referred to Balunout2, unless otherwise specified

Table 11. IMR and active balun electrical characteristics

Symbol	Parameter	Test condition	Min.	Typ	Max	Units
G	Gain	vs. Balunout2	7	9	11	dB
		vs. Balunout1	11	13	15	dB
-	Gain error	@ 1 MHz --> 10.7MHz	-	-	± 1.0	dB
-	Gain Error vs. frequency	freq. range 150 to 350 kHz 520 to 1710 kHz 2.0 to 30.0 MHz 0.05 to 30.0 MHz	-	-	± 0,5 ± 0,5 ± 1.0 ± 2,0	dB
-	Gain error vs. temperature	–40°C to 105 °C	-	-	± 2,0	dB
-	Gain attenuation range	IFAGC controlled	17.5	20		dB
-	Input impedance	For ext. LNA input	9.2	11.8	17.2	kΩ
-	Output impedance	-	15	20	30	Ω
-	Max. external load	-	400	-	-	Ω
Vmax	Max. output voltage	1 dB below 1 dB compression point	121	123	-	dBµV
Vin_max	Max. input voltage	Single tone two tone	101 98	-	-	dBµV dBµV
Vin_max	Max. input voltage	@4.6 V-4.7 V single tone two tone	99 96	-	-	dBµV dBµV
vnoise(1)	Input noise voltage	@ full gain 150 kHz-30 MHz		5.8	7.0	nV/√ Hz
IIP3(1)	3rd order intercept point	@ full gain Reg14[5:4] = 00 up to 95 °C junction temperature	128 131	134	-	dBµV

Table 11. IMR and active balun electrical characteristics (continued)

Symbol	Parameter	Test condition	Min.	Typ	Max	Units
-	3rd order intercept point in reduced current mode	Reg14[5:4] = 01 60 °C up to 125 °C junction temperature	131	133	-	dBµV
		Reg14[5:4] = 10 junction temperature > 90 °C	131	132	-	dBµV
IIP2(1)	2nd order intercept point	-	159	-	-	dBµV
-	IF-output attenuation	@ 26.35 MHz	1	-	-	dB
-	IF rejection	-	40	48	-	dB
V_{LO_IN}(1)	LO signal @ mixer input	R_{source} =1.5 kΩ @ fundamental LO freq @ harmonics of LO freq.	-	-	10 30	dBµV
V_{LO_OUT}	LO signal @ balun output using mixer input	Incl. LC-tank with Q=2, R_{load} = 1.0 kΩ @ fundamental LO freq. with 1 kΩ input termination resistor (1) @ harmonics of LO freq.	-	-	95 80 66	dBµV
	LO signal @ balun output, using low pass filter	Incl. LC-tank with Q=2, Rload=1.0 kΩ @ fundamental LO freq. @ harmonics of LO freq.	-	-	85 66	
I_{QG}	I/Q gain adjust Min. Max.	4 bit	-	-0.7 0.7	-	dB
-	Gain step	-	-	0.1	-	dB
PIQ	I/Q phase adjust Min. Max.	4bit	-	-0.25 0.25	-	°
-	phase step	-	-	0.25	-	°
-	Center frequency adjust Min. Max.	3bit	-	-2.4 2.4	-	MHz
-	Frequency step	-	-	0.6	-	MHz
IRR	Image rejection ratio	Without gain/phase adjust	30	45	-	dB
IRR	Image rejection ratio	With gain/phase adjust @ 25°C	45	-	-	dB
IRR	Image rejection ratio	With gain/phase adjust vs. complete temp. range	40	-	-	dB

1. Parameter not guaranteed by production test

3.5.4 AM AGC

The time constant of the AM AGC is defined by an external capacitor and the programmable internal currents (details given in the *Table 12*).

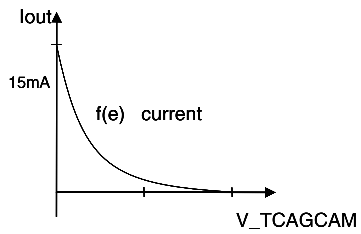
Control behavior:

The AM RF AGC is realized with two output pins which controls the gain of the corresponding pre-stage.

The control behavior can be programmed to the following modes:

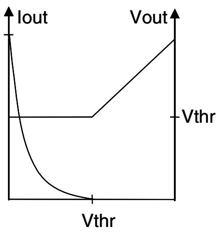
1. **Controlled current output mode 1**
   data byte AMAGC[3:0] = 1000
   positive current I = f(e): after reaching the AGC threshold voltage the current output delivers a current I = f(e) up to 15 mA in a voltage range from 0.1 V up to V_{CC}-1.5 V.

Figure 6. AM AGC - Controlled current output mode 1



2. **Constant current mode**
   data byte AMAGC[3:0] = 0100
   constant current mode: the output current can be set to 2 mA source current. The AGC detector is in power-down mode and only the pin diode driver is active.
3. **Voltage and current mode with hand-over**
   a) internal feedback
   data byte AMAGC[3:0] = 1001
   voltage and current mode with hand-over: the Vthr level is programmable in the range 1 V to 2.6 V.
   This mode can be used in combination with both the internal and the external LNA. In combination with the internal AM LNA, the maximum output voltage is limited to 2.7 V.

Figure 7. AM AGC - Voltage and current mode with hand-over



   b) external feedback
   data byte AMAGC[3:0] = 1011
   Voltage and current mode with hand-over: the Vthr level is programmable in the range 0.2 to 2.6 V. The voltage Vthr is the internal reference voltage for the

external feedback to pin GP4/UDS. This mode can only be used with an external LNA.

4. **Calibration mode for voltage output**

a) internal feedback
data byte AMAGC[3:0] = 1110
calibration mode for voltage output (mode 3.a.): the voltage Vthr can be switched directly to the voltage output pin. The reference voltage is programmable in the range described in 3.a.

b) external feedback
data byte AMAGC[3:0] = 0010
calibration mode for external feedback (mode 3.b.): the output voltage is set to a value, that the feedback on GP4(UDS is equal to Vthr. The reference voltage is programmable in the range described in 3.b.

All other possible bit combinations of data byte AMAGC[3:0] are prohibited.

The voltage output can be configured as GPO.

The AMAGC2 output (voltage output) is short-circuit protected by a current limiter. The AMAGC1 output (current output) needs an external resistor. The current output is voltage-tolerant up to VCC, the voltage output up to VDD.

The microcontroller (STA3005 backend) can read the voltage at the AGC capacitor via the serial control interface. On the microcontroller request, the measurement is done by connecting the time constant capacitor to the central ADC (specified in chapter *3.10*); the information can be used to calculate the AGC attenuation.

The AM AGC system is controlled by an average detector.

The AM AGC can be enabled independently in AM and FM mode

Table 12. AM-AGC electrical characteristics

Symbol	Parameter	Test condition	Min.	Typ	Max	Units
Lthr	Threshold RF level Min. Threshold	Referred to mixer input	-	-	-	-
		AM mixer input	-	89	-	dBµV
		AM filter input	-	94	-	dBµV
	Max Threshold	AM mixer input	-	101.5	-	dBµV
		AM filter input	-	106.5	-	dBµV
-	Threshold steps	4 bit control	0.4	0.9	1.4	dB
-	Absolute threshold error	0.5 to 30.0 MHz @ 25 °C	-1	-	2	dB
-	Total threshold error	0.5 to 30.0 MHz	-2	-	3	dB
-	Absolute threshold error	0.1 to 0.5 MHz @ 25 °C	-0.5	-	3	dB
-	Total threshold error	0.1 to 0.5 MHz	-2	-	3.5	dB
-	Temperature drift of AGC thresholds	-	-	0.011	-	dB/°C
-	Frequency range	Reduced performance	0.05	-	0.1	MHz
-	frequency range	-	0.1	-	30	MHz