

# TUA 6039F-2, TUA 6037F

3 Band Digital / Hybrid Tuner IC with  
integrated IF AGC amplifier

OmniTune™ TUA 6039F-2,

OmniTune™ TUA 6037F

Communication Solutions



Never stop thinking

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Page	Subjects (major changes since last revision)
all	Status "Preliminary" and "Confidential" removed. Formatting of document cross-references updated.
<a href="#">9, 11</a>	DMB-TH standard added.
<a href="#">23</a>	Functional Block Diagram of TUA 6037F added.
<a href="#">24 - 27</a>	Functional Description updated for PLL, Loop-Thru and added for ADC.
<a href="#">45 - 46</a>	Table footnotes updated.

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# 1 Product Info

## General Description

The **TUA 6039F-2, TUA 6037F** device combines a mixer-oscillator function and an IF AGC amplifier with a digitally programmable phase locked loop (PLL) for use in analog and digital terrestrial applications.

## Features

### General

- Supply voltage 5 Volt
- Narrowband RF AGC detector for internal tuner with
  - 5 programmable take over points
  - 2 programmable time constants
  - RF AGC buffer output
- Low phase noise
- Full ESD protection
- Qualified according to JEDEC for consumer applications

### Mixer/Oscillator

- Three band tuner
- Unbalanced highohmic LOW input
- Balanced lowohmic MID input
- Balanced lowohmic HIGH input
- Two pin oscillators for LOW/MID band
- Four pin oscillator for HIGH band

### SAW filter driver and IF-Amplifier

- 4 IF pins to connect a 2 pole bandpass
- Symmetrical SAW filter driver
- Fully balanced IF AGC amplifier

### PLL

- I<sup>2</sup>C bus
- 4 pin-programmable I<sup>2</sup>C addresses
- High voltage VCO tuning output
- 4 PNP ports, 1 NPN port/ADC input<sup>1)</sup>
- Internal LOW/MID/HIGH band switch
- X\_TAL 4 MHz, X\_TAL buffer output
- 6 reference divider ratios
- 4 charge pump currents

### Power management

- Bus controlled power down mode

### Application

- The IC is suitable for PAL, NTSC, SECAM, DVB-C, DVB-T, T-DMB, DMB-TH, DAB, ISDB-T, Open Cable and ATSC tuners.

1) ADC function is only available in TUA 6039F-2.

## Ordering Information

Type	Ordering Code	Package
TUA 6039F-2	SP000315897	PG-VQFN-48
TUA 6037F	SP000315896	PG-VQFN-48

## 2 Product Description

The TUA 6039F-2, TUA 6037F 'OmniTune™TUA 6039F-2, OmniTune™TUA 6037F' device combines a mixer-oscillator block with a digitally programmable phase locked loop (PLL) and a variable gain IF AGC amplifier for use in TV and VCR tuners, set-top-box and mobile applications. Integrated narrow band RF AGC functions with output buffer are provided.

The mixer-oscillator block includes three balanced mixers (one mixer with an unbalanced high-impedance input and two mixers with a balanced low-impedance input), two 2-pin asymmetrical oscillators for the LOW and the MID band, one 4-pin symmetrical oscillator for the HIGH band, a reference voltage and a band switch. The mixer output signal passes a SAW filter driver and an IF AGC amplifier to provide constant output level ready for A/D sampling.

The PLL block with four pin programmable chip addresses forms a digitally programmable phase locked loop. With a 4 MHz quartz crystal, the PLL permits precise setting of the frequency of the tuner oscillator up to 1024 MHz in increments of 31.25, 50, 62.5, 125, 142.86 or 166.7 kHz. The tuning process is controlled by a microprocessor via an I<sup>2</sup>C bus. A flag is set when the loop is locked. The lock flag can be read by the processor via the I<sup>2</sup>C bus. The device has 5 output ports and a X\_TAL output buffer. One of the ports (P4) can be also used as input for a 5-level A to D converter (only available in TUA 6039F-2).

### 2.1 Features

#### 2.1.1 General

- Supply voltage 5 Volt
- Narrowband RF AGC detector for internal tuner with
  - 5 programmable take over points
  - 2 programmable time constants
  - RF AGC buffer output
- Low phase noise
- Full ESD protection
- Qualified according to JEDEC for consumer applications

#### 2.1.2 Mixer/Oscillator

- High impedance mixer input (common emitter) for LOW band
- Low impedance mixer input (common base) for MID band
- Low impedance mixer input (common base) for HIGH band
- 2 pin oscillator for LOW band
- 2 pin oscillator for MID band
- 4 pin oscillator for HIGH band

### 2.1.3 SAW Filter Driver

- 4 IF pins to connect a 2 pole bandpass
- Symmetrical IF preamplifier with low output impedance able to drive a compensated SAW filter (500  $\Omega$ /40 pF)

### 2.1.4 IF AGC Amplifier

- Symmetrical variable gain IF output amplifier with low noise, high linearity, high dynamic range.

### 2.1.5 PLL

- 4 pin-programmable I<sup>2</sup>C addresses
- I<sup>2</sup>C bus protocol compatible with 3.3 V and 5 V micro-controllers up to 400 kHz
- High voltage VCO tuning output
- 4 PNP ports
- 1 NPN port/ADC input<sup>1)</sup>
- Power down mode
- Internal LOW/MID/HIGH band switch
- Lock-in flag
- 6 programmable reference divider ratios (24, 28, 32, 64, 80, 128)
- 4 programmable charge pump currents

## 2.2 Application

- The IC is suitable for PAL, NTSC, SECAM, DVB-C, DVB-T, T-DMB, DMB-TH, DAB, ISDB-T, Open Cable and ATSC tuners. The focus is on digital terrestrial.
- The AGC stage makes the tuner AGC independent of the Video-IF AGC.

### 2.2.1 Recommended band limits in MHz

**Table 1 ATSC tuners**

Band	RF input		Oscillator	
	min	max	min	max
LOW	55.25	157.25	101	203
MID	163.25	451.25	209	497
HIGH	457.25	861.25	503	907

1) ADC function is only available in TUA 6039F-2.

**Table 2 DVB-T and analog tuners**

	<b>RF input</b>		<b>Oscillator</b>	
<b>Band</b>	<b>min</b>	<b>max</b>	<b>min</b>	<b>max</b>
LOW	48.25	154.25	87.15	193.15
MID	161.25	439.25	200.15	478.15
HIGH	447.25	863.25	486.15	902.15

**Table 3 ISDB-T tuners**

	<b>RF input</b>		<b>Oscillator</b>	
<b>Band</b>	<b>min</b>	<b>max</b>	<b>min</b>	<b>max</b>
LOW	93	167	150	224
MID	173	467	230	524
HIGH	473	767	530	824

*Note: Tuning margin of 3 MHz not included.*

### 3 Functional Description

#### 3.1 Pin Configuration

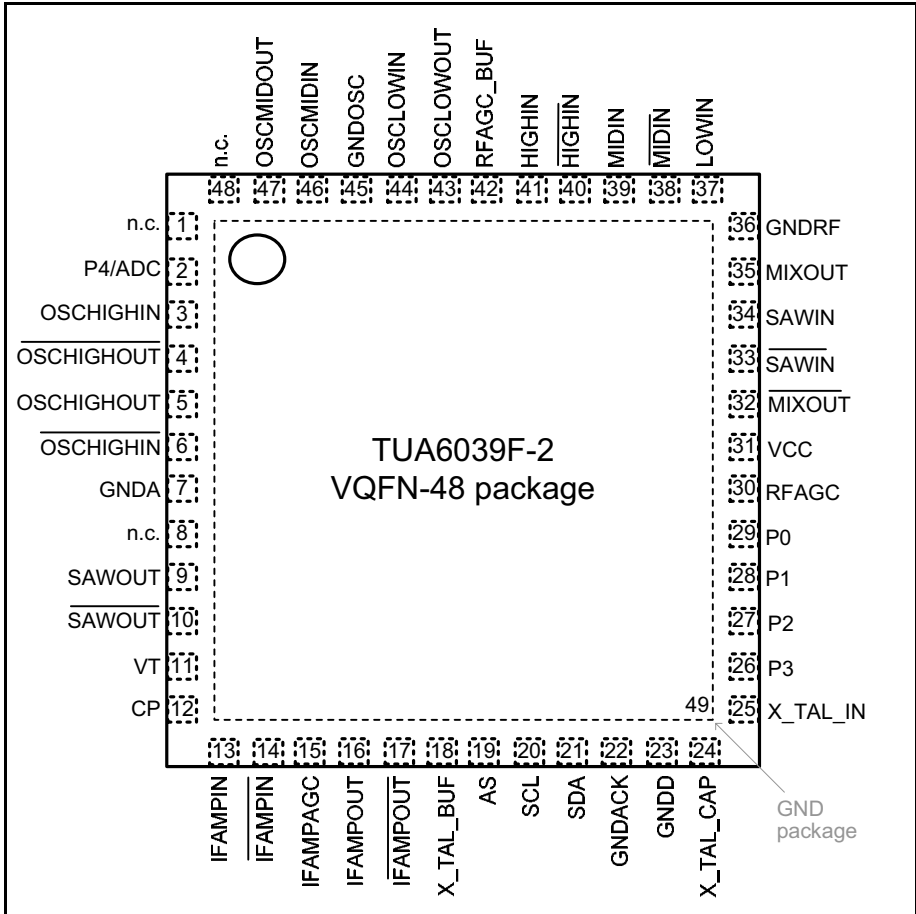


Figure 1 Pin Configuration of TUA 6039F-2

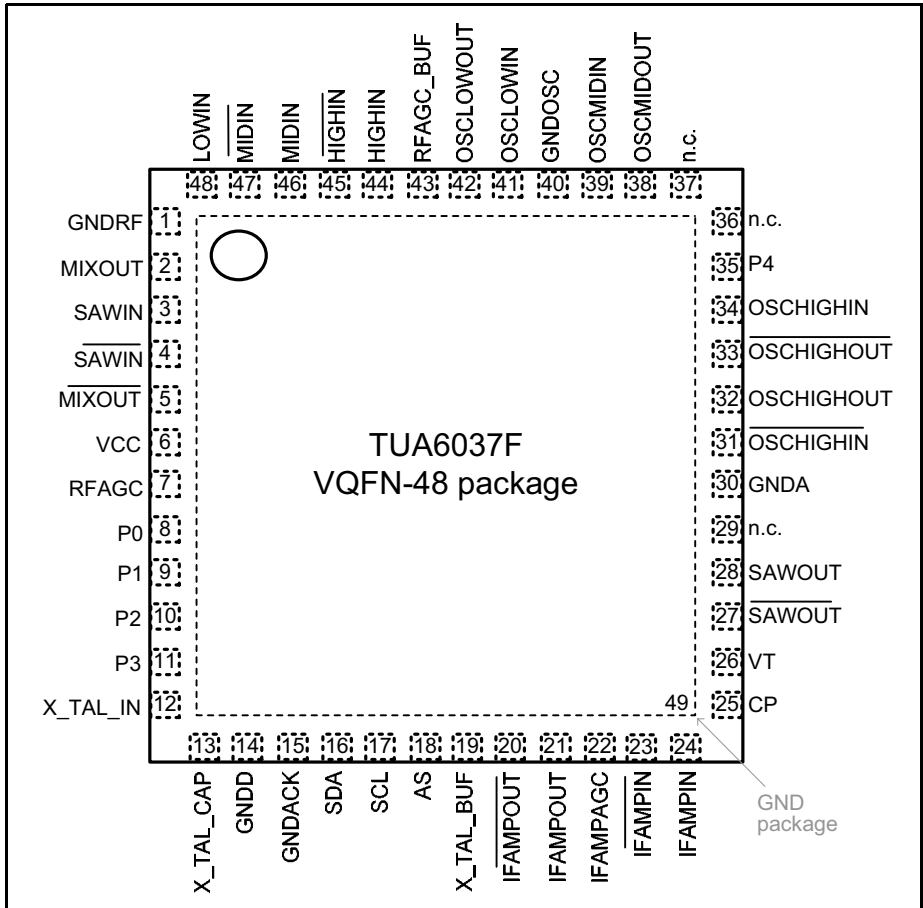
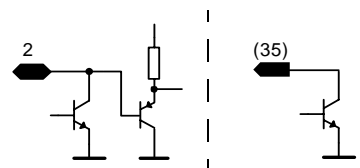
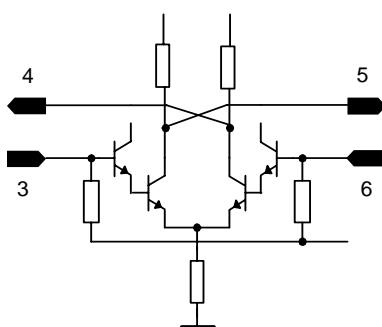
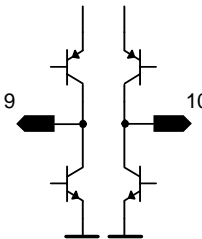


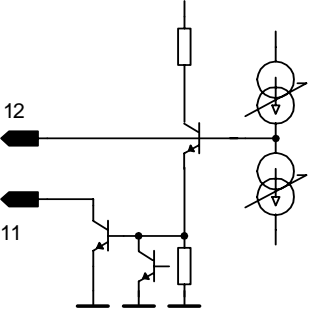
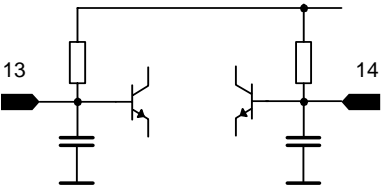
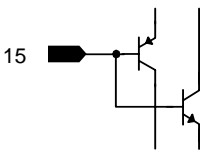
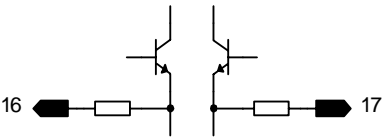
Figure 2 Pin Configuration of TUA 6037F

### 3.2 Pin Definition and Functions

Table 4 Pin Definition and Functions

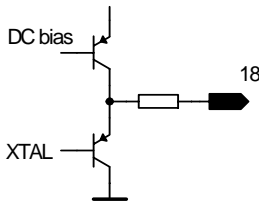
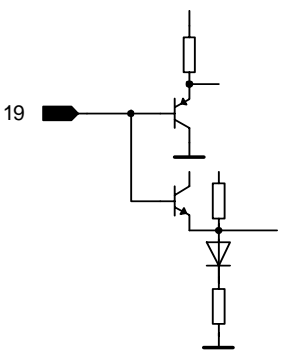
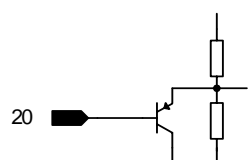
Pin No. <sup>1)</sup>	Symbol	Equivalent I/O Schematic	Average DC voltage at $V_{CC} = 5V$		
			LOW	MID	HIGH
1 (36)	n.c.				
2 (35)	P4/ADC input <sup>2)</sup> (P4)		$0V + V_{CE}$ or $V_{CC}$	$0V + V_{CE}$ or $V_{CC}$	$0V + V_{CE}$ or $V_{CC}$
3 (34)	OSCHIGHIN				2.3 V
4 (33)	OSCHIGHOUT				2.1 V
5 (32)	OSCHIGHOUT				2.1 V
6 (31)	OSCHIGHIN				2.3 V
7 (30)	GNDA		Analog ground	0 V	0 V
8 (29)	n.c.				
9 (28)	SAWOUT		2.5 V	2.5 V	2.5 V
10 (27)	SAWOUT		2.5 V	2.5 V	2.5 V

Functional Description

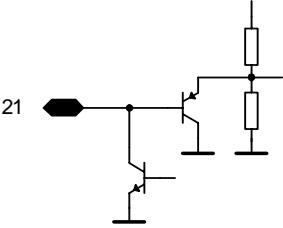
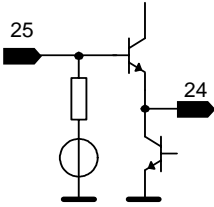
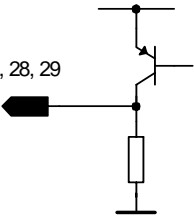
Pin No. <sup>1)</sup>	Symbol	Equivalent I/O Schematic	Average DC voltage at $V_{CC} = 5V$		
			LOW	MID	HIGH
11 (26)	VT		VT	VT	VT
12 (25)	CP		1.4 V	1.4 V	1.4 V
13 (24)	IFAMPIN		2.6 V	2.6 V	2.6 V
14 (23)	IFAMPIN		2.6 V	2.6 V	2.6 V
15 (22)	IFAMPAGC		n.a.	n.a.	n.a.
16 (21)	IFAMPOUT		3.3 V	3.3 V	3.3 V
17 (20)	IFAMPOUT		3.3 V	3.3 V	3.3 V



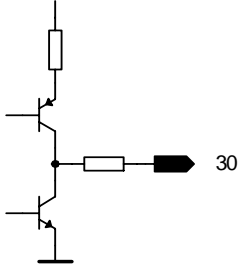
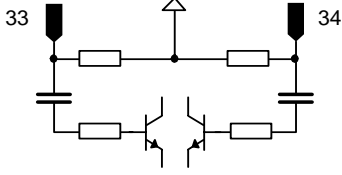
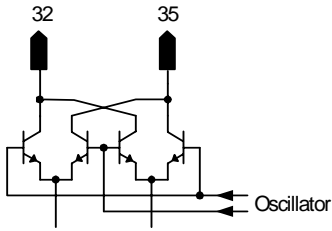
Functional Description

Pin No. <sup>1)</sup>	Symbol	Equivalent I/O Schematic	Average DC voltage at V <sub>CC</sub> = 5V		
			LOW	MID	HIGH
18 (19)	X_TAL_BUF		4 V	4 V	4 V
19 (18)	AS		n.a.	n.a.	n.a.
20 (17)	SCL		n.a.	n.a.	n.a.

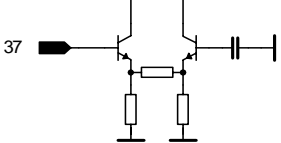
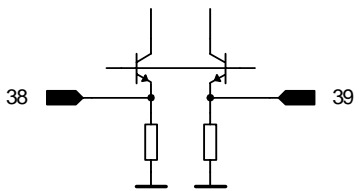
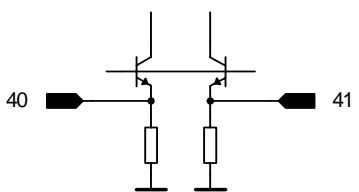
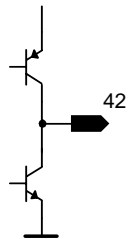
Functional Description

Pin No. <sup>1)</sup>	Symbol	Equivalent I/O Schematic	Average DC voltage at $V_{CC} = 5V$		
			LOW	MID	HIGH
21 (16)	SDA		n.a	n.a	n.a
22 (15)	GNDACK	Acknowledge ground	0	0	0
23 (14)	GNDD	Digital ground	0	0	0
24 (13)	X_TAL_CAP		0.6 V	0.6 V	0.6 V
25 (12)	X_TAL_IN		1.2 V	1.2 V	1.2 V
26 (11)	P3		0 V or $V_{CC} - V_{CE}$	0 V or $V_{CC} - V_{CE}$	0 V or $V_{CC} - V_{CE}$
27 (10)	P2		0 V or $V_{CC} - V_{CE}$	0 V or $V_{CC} - V_{CE}$	0 V or $V_{CC} - V_{CE}$
28 (9)	P1		0 V or $V_{CC} - V_{CE}$	0 V or $V_{CC} - V_{CE}$	0 V or $V_{CC} - V_{CE}$
29 (8)	P0		0 V or $V_{CC} - V_{CE}$	0 V or $V_{CC} - V_{CE}$	0 V or $V_{CC} - V_{CE}$

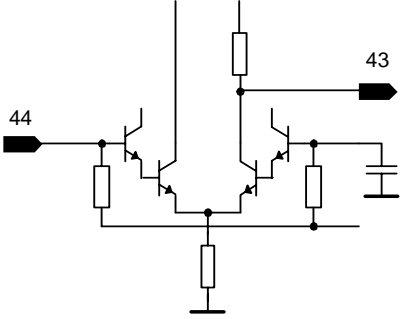
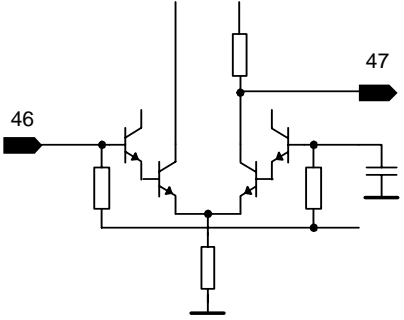
Functional Description

Pin No. <sup>1)</sup>	Symbol	Equivalent I/O Schematic	Average DC voltage at $V_{CC} = 5V$		
			LOW	MID	HIGH
30 (7)	RFAGC		$V_{RFAGC}$	$V_{RFAGC}$	$V_{RFAGC}$
31 (6)	VCC	supply voltage	$V_{CC}$	$V_{CC}$	$V_{CC}$
33 (4)	SAWIN		$V_{CC}$	$V_{CC}$	$V_{CC}$
34 (3)	SAWIN		$V_{CC}$	$V_{CC}$	$V_{CC}$
32 (5)	MIXOUT		$V_{CC}$	$V_{CC}$	$V_{CC}$
35 (2)	MIXOUT		$V_{CC}$	$V_{CC}$	$V_{CC}$
36 (1)	GNDRF	RF ground	0.0 V	0.0 V	0.0 V

Functional Description

Pin No. <sup>1)</sup>	Symbol	Equivalent I/O Schematic	Average DC voltage at $V_{CC} = 5V$		
			LOW	MID	HIGH
37 (48)	LOWIN		2 V		
38 (47)	MIDIN			1 V	
39 (46)	MIDIN			1 V	
40 (45)	HIGHIN				1 V
41 (44)	HIGHIN				1 V
42 (43)	RFAGC_BUF		$V_{RFAGC}$	$V_{RFAGC}$	$V_{RFAGC}$

**Functional Description**

Pin No. <sup>1)</sup>	Symbol	Equivalent I/O Schematic	Average DC voltage at $V_{CC} = 5V$		
			LOW	MID	HIGH
43 (42)	OSCLOWOUT		1.8 V		
44 (41)	OSCLOWIN		2.3 V		
45 (40)	GNDOSC	Oscillator ground	0.0 V	0.0 V	0.0 V
46 (39)	OSCMIDIN			2.3 V	
47 (38)	OSCMIDOUT		1.8 V		
48 (37)	n.c.				
49 (49)	GND package	Exposed pad ground	0.0 V	0.0 V	0.0 V

1) Pin numbering for TUA 6039F-2 (Pin numbering for TUA 6037F in parentheses).

2) ADC function is only available in TUA 6039F-2.

### 3.3 Functional Block Diagram

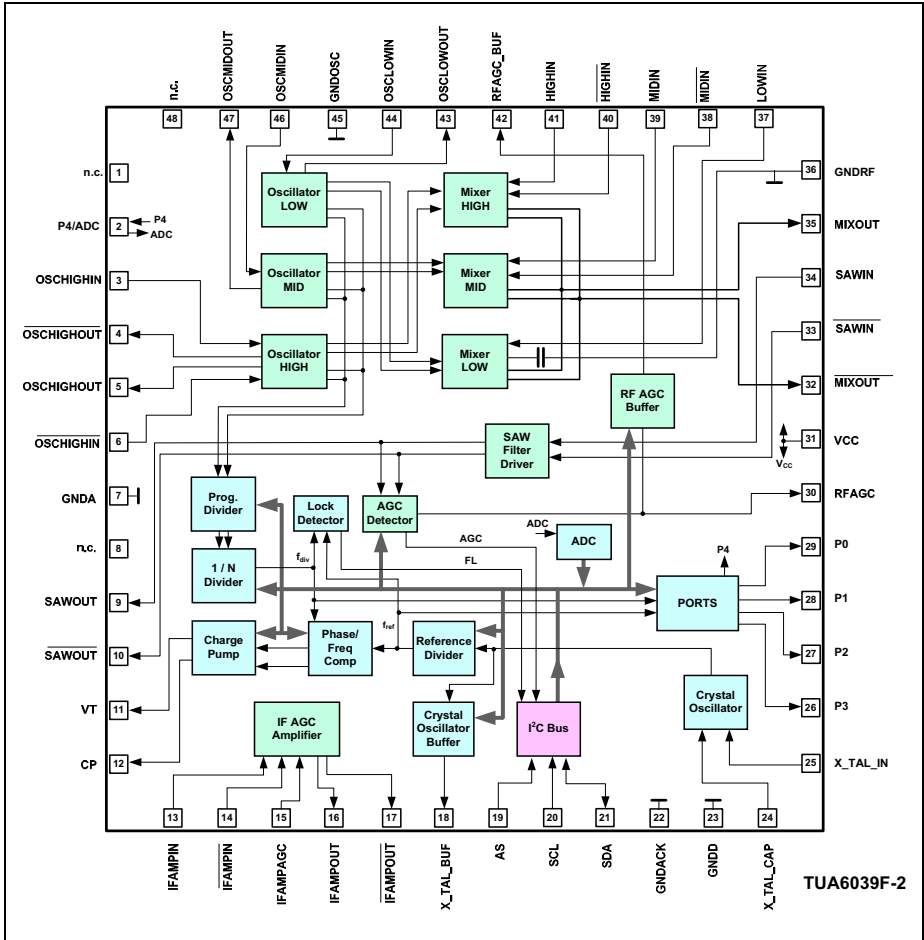


Figure 3 Functional Block Diagram of TUA 6039F-2

Functional Description

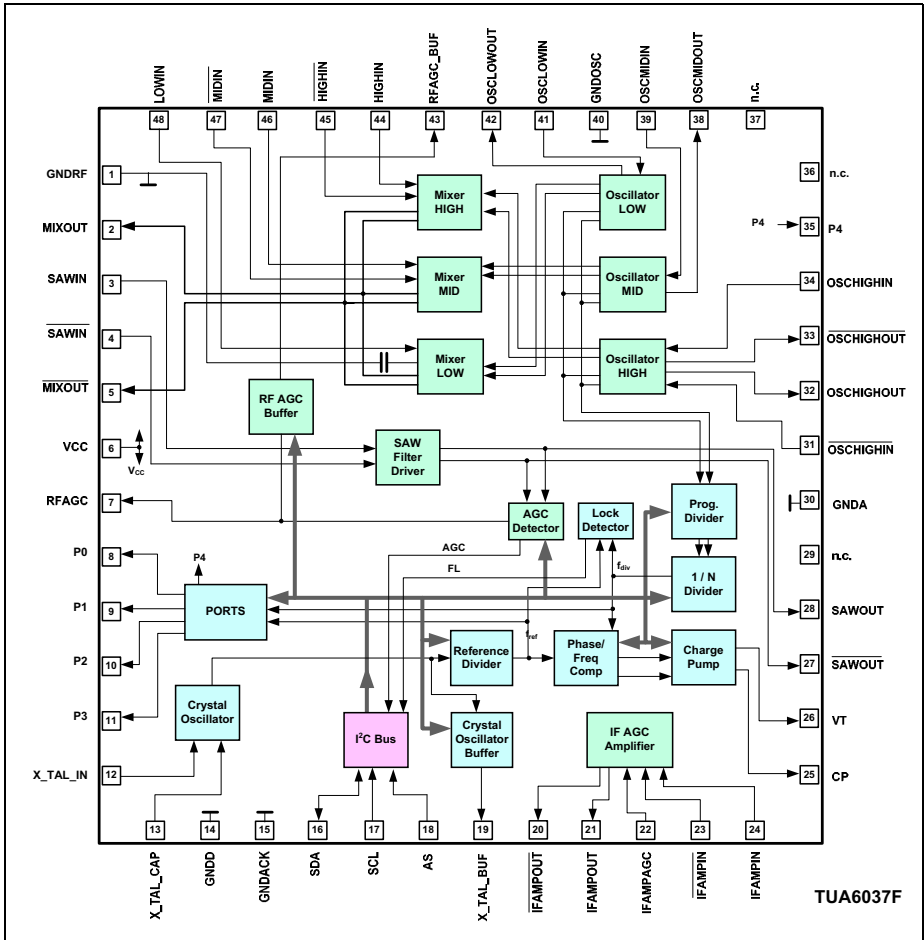


Figure 4 Functional Block Diagram of TUA 6037F

### 3.4 Circuit Description

#### 3.4.1 Mixer-Oscillator block with SAW filter driver

The mixer-oscillator block includes three balanced mixers (one mixer with an unbalanced high-impedance input and two mixers with a balanced low-impedance input), two 2-pin asymmetrical oscillators for the LOW and the MID band, one 4-pin symmetrical oscillator for the HIGH band, an SAW filter driver, a reference voltage and a band switch.

Filters between tuner input and IC separate the TV frequency signals into three bands. The band switching in the tuner front-end is done by using three PNP port outputs. In the selected band the signal passes a tuner input stage with a MOSFET amplifier, a double-tuned bandpass filter and is then fed to the mixer input of the IC which has in case of LOW band a high-impedance input and in case of MID or HIGH band a low-impedance input. The input signal is mixed there with the signal from the activated on chip oscillator to the IF frequency. The IF is filtered by means of an IF filter in between the 2 mixer output pins and the 2 input pins of the following SAW filter driver. The SAW filter driver has a low output impedance to drive the SAW filter directly.

#### 3.4.2 PLL block

The oscillator signal is internally DC-coupled as a differential signal to the programmable divider inputs. The signal subsequently passes through a programmable divider with ratio  $N = 256$  through 32767 and is then compared in a digital frequency/phase detector with a reference frequency  $f_{ref} = 31.25, 50, 62.5, 125, 142.86$  or  $166.67$  kHz. This frequency is derived from a low-impedance 4 MHz crystal oscillator (pins XTALIN, XTALCAP) divided by 128, 80, 64, 32, 28 or 24. The reference frequencies will be different with a quartz other than 4 MHz.

The phase detector has two outputs which drive four current sources of a charge pump. If the negative edge of the divided VCO signal appears prior to the negative edge of the reference signal, the positive current source pulses for the duration of the phase difference. In the reverse case the negative current source pulses. If the two signals are in phase, the charge pump output (CP) goes into the high-impedance state (PLL is locked). An active low-pass filter integrates the current pulses to generate the tuning voltage for the VCO (internal amplifier, external pull-up resistor at  $V_T$  and external RC circuitry). The charge pump output is also switched into the high-impedance state if the control bits  $T_2, T_1, T_0 = 0, 1, 0$ . Here it should be noted, however, that the tuning voltage can alter over a long period in the high impedance state as a result of self discharge in the peripheral circuitry.  $V_T$  may be switched off by the control bit OS to allow external adjustments.

If the VCO is not oscillating the PLL locks to a tuning voltage of 33V ( $V_{TH}$ ).

By means of control bits CP, T0, T1 and T2 the pump current can be switched between four values by software. This programmability permits alteration of the control response



**Functional Description**

of the PLL in the locked-in state. In this way different VCO gains can be compensated, for example. Furthermore, in order to obtain best results for phase noise, reference frequency rejection and PLL stability especially in a wideband system like a digital tuner, it is necessary to set the charge pump current to different values depending on the band and frequency used. This is to cope with the variations of the different parameters that set the bandwidth. The selection can be done in the application and requires for each frequency to program not only the divider ratios, but also the band and the best charge pump current.

The software controlled ports P0 to P4 are general purpose open-collector outputs. The test bits T2, T1, T0, OS = 0, 1, 0, 1 switch the test signals  $f_{div} / 2$  (divided input signal) and  $f_{ref}$  (i.e. 4 MHz / 64) to P0 and P1 respectively.

The lock detector resets the lock flag FL if the width of the charge pump current pulses is greater than the period of the crystal oscillator (i.e. 250 ns). Hence, if FL = 1, the maximum deviation of the input frequency from the programmed frequency is given by

$$\Delta f = \pm I_P * (K_{VCO} / f_{XTAL}) * (C1 + C2) / (C1 * C2)$$

where  $I_P$  is the charge pump current,  $K_{VCO}$  the VCO gain,  $f_{XTAL}$  the crystal oscillator frequency and  $C_1, C_2$  the capacitances in the loop filter (see [Section 4.2](#)). As the charge pump pulses at i.e. 62.5 kHz (=  $f_{ref}$ ), it takes a maximum of 16  $\mu$ s for FL to be reset after the loop has lost lock state.

Once FL has been reset, it is set only if the charge pump pulse width is less than 250 ns for eight consecutive  $f_{ref}$  periods. Therefore it takes between 128 and 144  $\mu$ s for FL to be set after the loop regains lock.

### 3.4.3 RF AGC

The RF AGC stage detects the level of the SAW filter driver output signal. If the detected level is below the RF AGC take-over point, an external capacity will be charged with the source current of 300 nA or 9  $\mu$ A (release current). If the detected level is above the RF AGC take-over point, the external capacity will be discharged with the sink current of 100  $\mu$ A (attack current). The integrated current generates the AGC voltage for gain control of the tuners input transistors. The RF AGC take-over and the time constant are selectable by the I<sup>2</sup>C bus (see [Table 13](#)).

An integrated RF AGC buffer allows to monitor the AGC voltage without any influence on the tuner gain control.

### 3.4.4 IF AGC amplifier

Coming out of the SAW filter the IF signal is sent through a VGA (Variable Gain Amplifier) which will set the differential IF output signal to the desired level (preferably 1 Vpp). The gain of the VGA is determined by the DC-voltage at pin IFAMPAGC

### 3.4.5 I<sup>2</sup>C-Bus Interface

Data is exchanged between the processor and the PLL via the I<sup>2</sup>C bus. The clock is generated by the processor (input SCL). Pin SDA functions as an input or output depending on the direction of the data (open collector, external pull-up resistor). Both inputs have a hysteresis and a low-pass characteristic, which enhance the noise immunity of the I<sup>2</sup>C bus.

The data from the processor pass through an I<sup>2</sup>C bus controller. Depending on their function the data are subsequently stored in registers. If the bus is free, both lines will be in the marking state (SDA, SCL are high). Each telegram begins with the start condition and ends with the stop condition. Start condition: SDA goes low, while SCL remains high. Stop condition: SDA goes high while SCL remains high. All further information transfer takes place during SCL = low, and the data is forwarded to the control logic on the positive clock edge.

The table 'Bit Allocation' (see [Table 8](#)) should be referred to for the following description. All telegrams are transmitted byte-by-byte, followed by a ninth clock pulse, during which the control logic returns the SDA line to low (acknowledge condition). The first byte is comprised of seven address bits. These are used by the processor to select the PLL from several peripheral components (address select). The LSB bit (R/W) determines whether data are written into (R/W = 0) or read from (R/W = 1) the PLL.

In the data portion of the telegram during a WRITE operation, the MSB bit of the first or third data byte determines whether a divider ratio or control information is to follow. In each case the second byte of the same data type has to follow the first byte. Appropriate setting of the test bits will decide whether the band-switch byte or the auxiliary byte will be transmitted (see [Table 11](#)).

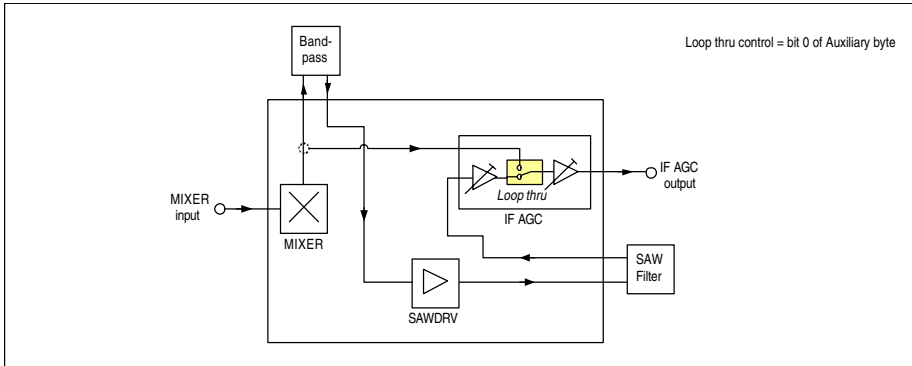
If the address byte indicates a READ operation, the PLL generates an acknowledge and then shifts out the status byte onto the SDA line. If the processor generates an acknowledge, a further status byte is output; otherwise the data line is released to allow the processor to generate a stop condition. The status word consists of three bits from the A/D converter, the lock flag and the power-on flag.

Four different chip addresses can be set by an appropriate DC level at pin AS (see [Table 10](#)).

While the supply voltage is applied, a power-on reset circuit prevents the PLL from setting the SDA line to low, which would block the bus. The power-on reset flag POR is set at power-on and if  $V_{CC}$  falls below 2 V. It will be reset at the end of a READ operation.

### 3.4.6 Loop thru

For the tuner prestage alignment a programmable switch is integrated to bypass the bandpass, the SAW filter driver and the SAW filter. If "Loop thru" is active the mixer output signal in front of the external bandpass is fed into the IF AGC amplifier as shown in [Figure 5](#).



**Figure 5 Functional Block Diagram of Loop thru**

This results in a flat frequency response from the mixer input to the IF amplifier output and allows tuner alignment without the need of an external resistor.

### 3.4.7 ADC<sup>1)</sup>

A built-in 5 level Analog to Digital converter is available on P4/ADC pin. This converter can be used to read out an external AFC information via the I2C-BUS interface. The relationship between the external voltage at P4/ADC pin and the bits A2, A1 and A0 is given in **Table 14**. P4 output port cannot be used and the corresponding bit needs to be programmed to logic 0 when the ADC is in use.

1) ADC function is only available in TUA 6039F-2.

## 4 Application

### 4.1 Tuner application block diagram

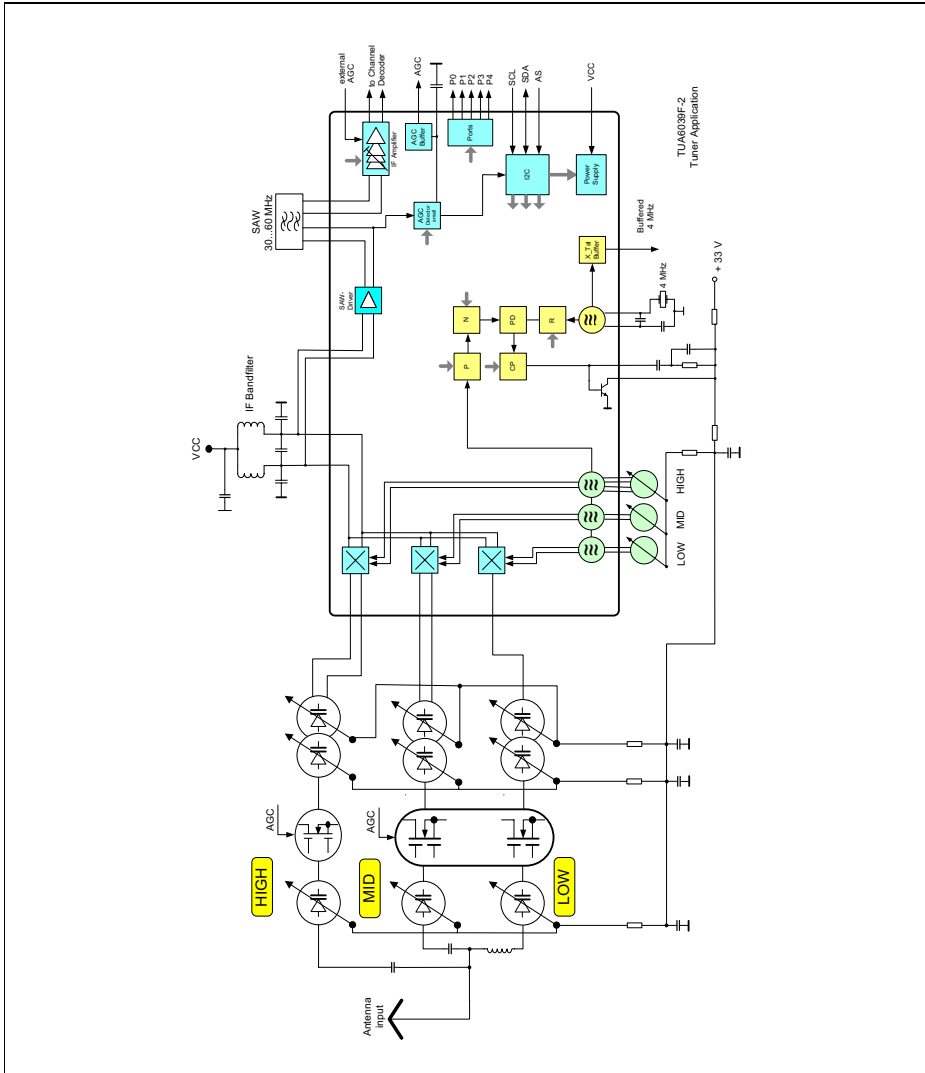
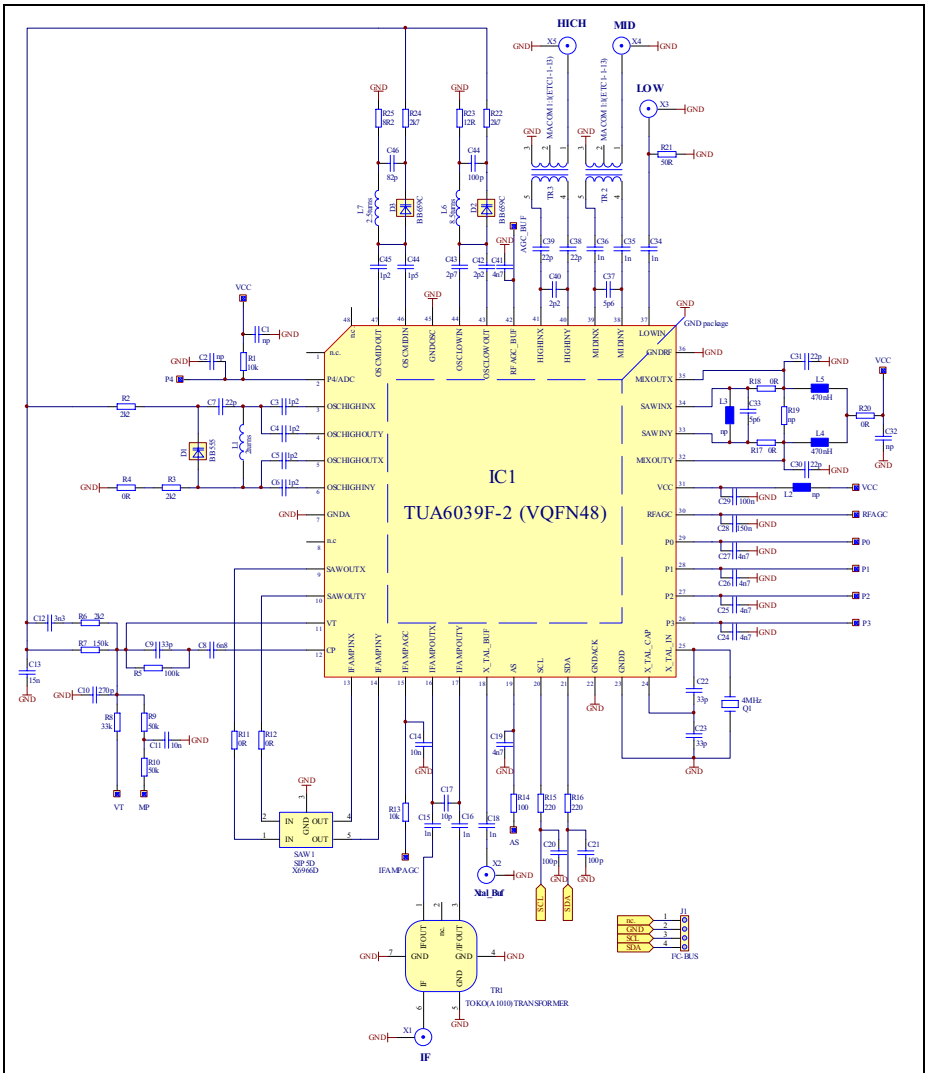


Figure 6 Tuner application block diagram

### 4.2 Application circuit for hybrid application



**Figure 7** Circuit diagram for hybrid application (DVB-T / PAL)

*Note: TUA 6037F has different pinning and no ADC function.*

### 4.3 Application circuit for ATSC

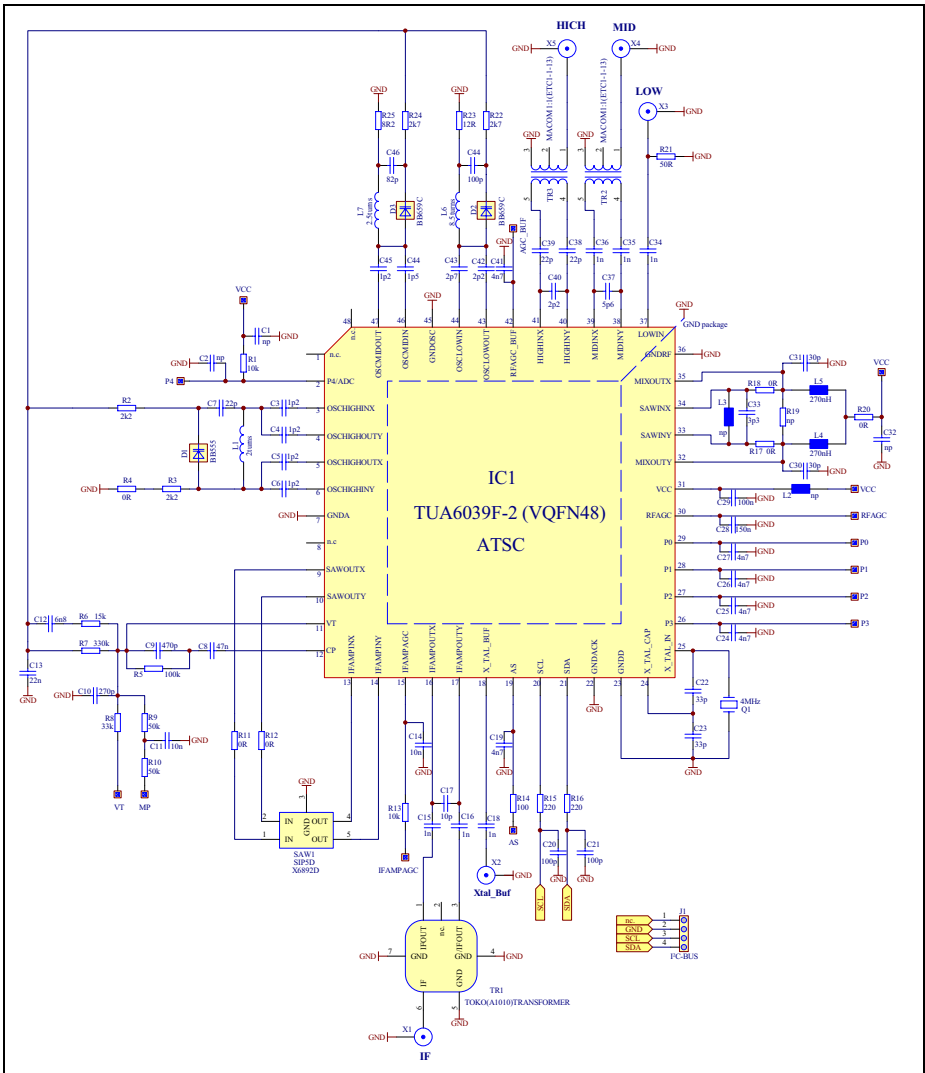


Figure 8 Circuit diagram for ATSC

Note: TUA 6037F has different pinning and no ADC function.

### 4.4 Application circuit for DVB-T

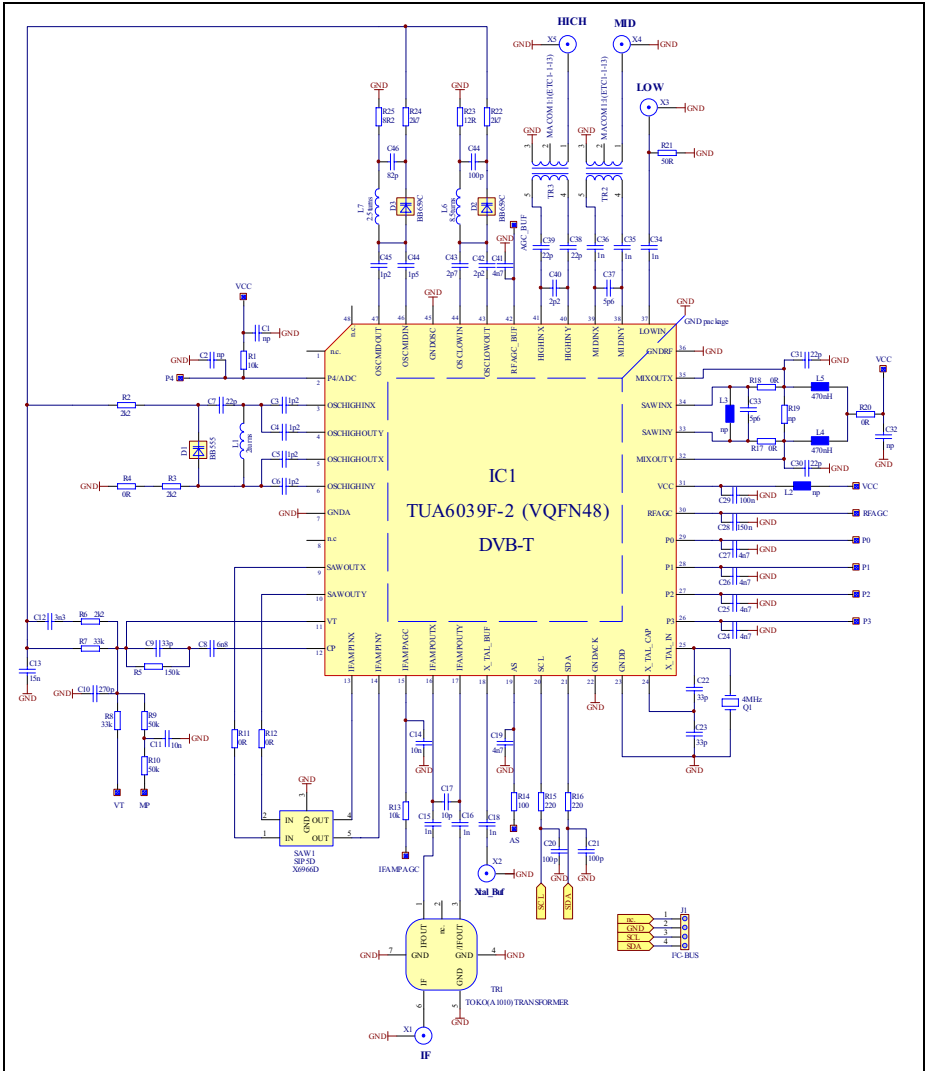


Figure 9 Circuit diagram for DVB-T

Note: TUA 6037F has different pinning and no ADC function.

### 4.5 Application circuit for ISDB-T

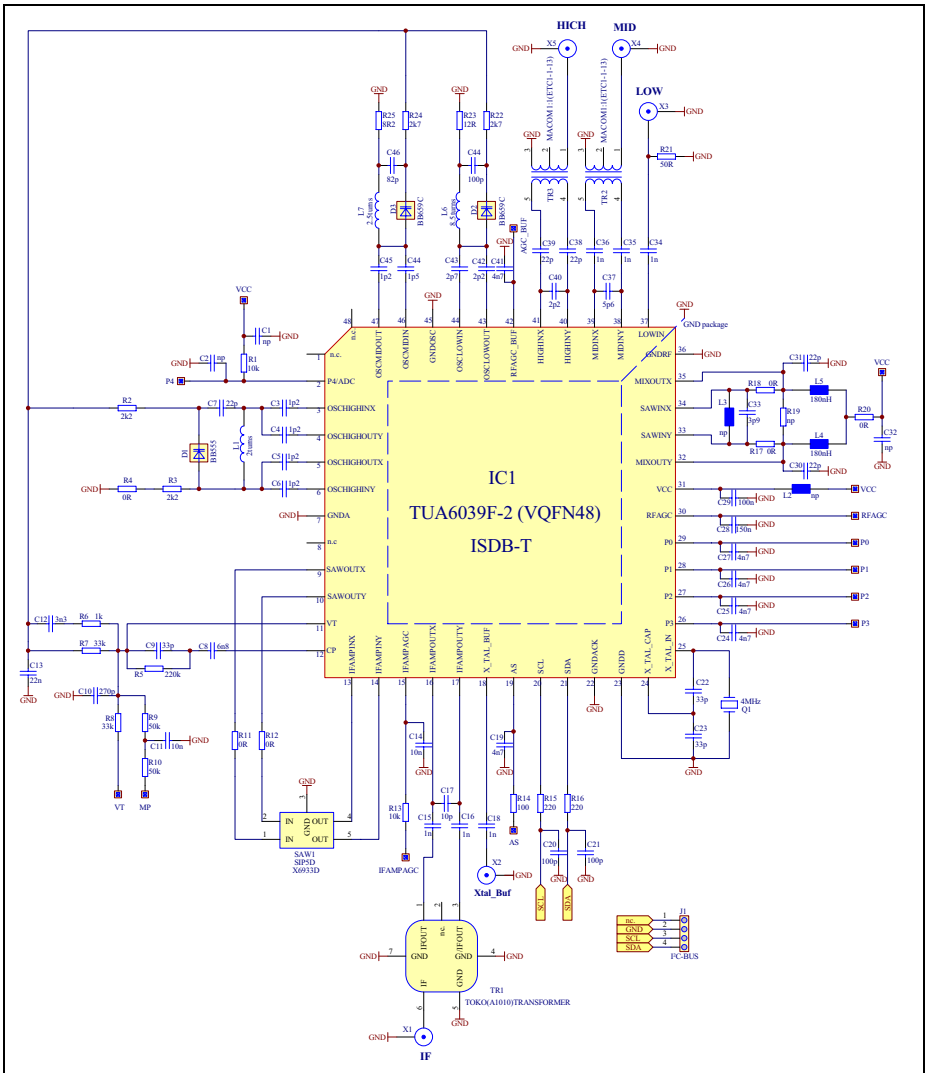


Figure 10 Circuit diagram for ISDB-T

Note: TUA 6037F has different pinning and no ADC function.



## 5 Reference

### 5.1 Electrical Data

#### 5.1.1 Absolute Maximum Ratings

**Attention:** The maximum ratings may not be exceeded under any circumstances, not even momentarily and individually, as permanent damage to the IC will result.

**Table 5 Absolute Maximum Ratings**

#	Parameter <sup>1)</sup>	Symbol	Limit Values		Unit	Remarks
			min.	max.		
1.	Supply voltage	$V_{CC}$	-0.3	6	V	
2.	Ambient temperature	$T_A$	-40	+85	°C	exposed GND pad soldered
3.	Junction temperature	$T_J$		+125	°C	
4.	Storage temperature	$T_{Stg}$	-40	+125	°C	
5.	Thermal resistance junction to ambient <sup>2)</sup>	$R_{THJA}$		39	K/W	exposed GND pad soldered
6.	Temperature difference junction to case <sup>3)</sup>	$T_{JC}$		3	K	exposed GND pad soldered
PLL						
7.	CP	$V_{CP}$	-0.3	3	V	
8.		$I_{CP}$		1	mA	
9.	Bus input/output SDA	$V_{SDA}$	-0.3	6	V	
10.	Bus output current SDA during acknowledge	$I_{SDA(L)}$		10	mA	open collector
11.	Bus input SCL	$V_{SCL}$	-0.3	6	V	
12.	Chip address switch AS	$V_{AS}$	-0.3	6	V	
13.	VCO tuning output (loop filter)	$V_{VT}$	-0.3	35	V	
14.	PNP port output current of P0,P1,P2,P3	$I_{PP}$	-5	0	mA	open collector
15.	Total port output current of PNP ports	$\Sigma I_{PP}$	-20	0	mA	$t_{max} = 0.1 \text{ s at } 5.5 \text{ V}$

#	Parameter <sup>1)</sup>	Symbol	Limit Values		Unit	Remarks
			min.	max.		
16.	NPN port output current of P4	$I_{PN}$	0	5	mA	open collector
<b>Mixer-Oscillator</b>						
17.	Mix inputs LOW band	$V_{LOW}$	-0.3	3	V	
18.	Mix inputs MID/HIGH	$V_{MID/HIGH}$	-0.3	2	V	
19.	band	$I_{MID/HIGH}$	-5	6	mA	
20.	VCO base voltage	$V_B$	-0.3	3	V	LOW, MID and HIGH band oscillators
21.	VCO collector voltage	$V_C$		6	V	LOW, MID and HIGH band oscillators
22.	RF AGC output	$V_{RFAGC}$	-0.3	4	V	
23.		$I_{RFAGC}$		1	mA	
24.	Voltage on all other input and output pins except GNDs	$V_{max}$	-0.3	$V_{CC}$	V	

**ESD-Protection<sup>4)</sup>**

25.	all pins	$V_{ESD}$		2	kV	
-----	----------	-----------	--	---	----	--

- 1) All values are referred to ground (pin), unless stated otherwise.  
Currents with a positive sign flow into the pin and currents with a negative sign flow out of pin.
- 2) Measured in a multi layer board as defined by JEDEC standard.  
The thermal resistance depends on the PCB board design.
- 3) Referred to top center of package in free air condition.
- 4) According to EIA/JESD22-A114-B (HBM incircuit test), as a single device incircuit contact discharge test.

### 5.1.2 Operating Range

**Table 6 Operating Range**

#	Parameter	Symbol	Limit Values		Unit	Remarks
			min.	max.		
1.	Supply voltage	$V_{CC}$	4.5	5.5	V	nominal 5 V
2.	Ambient temperature	$T_A$	-20	+85	°C	exposed GND pad soldered
3.	Programmable divider factor	N	256	32767		
4.	LOW mixer input frequency range	$f_{MIXV}$	30	200	MHz	
5.	MID and HIGH band mixer input frequency range	$f_{MIXU}$	130	1000	MHz	
6.	LOW oscillator frequency range	$f_{OH}$	65	250	MHz	
7.	MID band oscillator frequency range	$f_{OU}$	165	530	MHz	
8.	HIGH band oscillator frequency range	$f_{OU}$	400	950	MHz	

### 5.1.3 AC/DC Characteristics

**Table 7 AC/DC Characteristics,  $T_A = 25^\circ\text{C}$ ,  $V_{CC} = 5\text{ V}$** 

#	Parameter <sup>1)</sup>	Symbol	Limit Values			Unit	Test Conditions	■
			min.	typ.	max.			
Supply								
1.	Supply voltage	$V_{CC}$	4.5	5	5.5	V		
2.	Current	$I_{VCC}$	84	105	126	mA	LOW band	
3.	consumption in active mode	$I_{VCC}$	84	105	126	mA	MID band	
4.		$I_{VCC}$	84	105	126	mA	HIGH band	

#	Parameter <sup>1)</sup>	Symbol	Limit Values			Unit	Test Conditions	■
			min.	typ.	max.			
5.	Current consumption in power down mode	$I_{pd}$		12		mA		

**Digital Part**
**PLL**
**Crystal oscillator connections XTAL**

6.	Crystal frequency	$f_{XTAL}$	3.2	4.0	4.8	MHz		
7.	Crystal resistance	$R_{XTAL}$		30	300	$\Omega$		
8.	Crystal oscillator startup capability	$Z_{XTAL}$		-1000	-650	$\Omega$	$f_{XTAL} = 4$ MHz	
9.	XTAL Buffer output frequency	$f_{XTALIO}$		4.0		MHz	$f_{XTAL} = 4$ MHz	
10.	XTAL Buffer Signal voltage	$V_{AC}$		400		mV <sub>pp</sub>		

**Charge pump output CP**

11.	Output current,	$I_{CPDH}$	$\pm 455$	$\pm 650$	$\pm 845$	$\mu A$	$V_{CP} = 1.4$ V	
12.	see <b>Table 15</b>	$I_{CPH}$	$\pm 175$	$\pm 250$	$\pm 325$	$\mu A$	$V_{CP} = 1.4$ V	
13.		$I_{CPDL}$	$\pm 87$	$\pm 125$	$\pm 163$	$\mu A$	$V_{CP} = 1.4$ V	
14.		$I_{CPL}$	$\pm 35$	$\pm 50$	$\pm 65$	$\mu A$	$V_{CP} = 1.4$ V	
15.	Tristate current	$I_{CPZ}$			$\pm 10$	nA	$V_{CP} = 1.4$ V, T2,T1,OS = 1,0,1	
16.	Output voltage	$V_{CP}$	0.9	1.4	1.9	V	loop locked	

**Tuning voltage output VT (open collector)**

17.	Leakage current	$I_{TH}$			10	$\mu A$	$V_{TH} = 33$ V, T2,T1,OS = 0,0,1	
18.	Output voltage when the loop is closed, (test mode in normal operation)	$V_{TL}$	0.4		32.7	V	OS = 0, $R_{Load} = 33$ k $\Omega$ , tuning supply = 33 V	

**I<sup>2</sup>C-Bus**
**Bus inputs SCL, SDA**

#	Parameter <sup>1)</sup>	Symbol	Limit Values			Unit	Test Conditions	■
			min.	typ.	max.			
19.	High-level input voltage	$V_{IH}$	2.5		5.5	V	$V_{CC} = 4.5$ to $5.5$ V	
20.	Low-level input voltage	$V_{IL}$	0		1	V	$V_{CC} = 4.5$ to $5.5$ V	
21.	High-level input current	$I_{IH}$			10	$\mu$ A	$V_{bus} = 5.5$ V, $V_{CC} = 0$ V	
22.		$I_{IH}$			10	$\mu$ A	$V_{bus} = 5.5$ V, $V_{CC} = 5.5$ V	
23.	Low-level input current	$I_{IL}$			10	$\mu$ A	$V_{bus} = 1.5$ V, $V_{CC} = 0$ V	
24.		$I_{IL}$	-10			$\mu$ A	$V_{bus} = 0$ V, $V_{CC} = 5.5$ V	

**Bus output SDA (open collector)**

25.	Leakage current	$I_{OH}$			10	$\mu$ A	$V_{OH} = 5.5$ V	
26.	Low-level output voltage	$V_{OL}$			0.4	V	$I_{OL} = 3$ mA	

**Edge speed SCL,SDA**

27.	Rise time	$t_r$			300	ns		
28.	Fall time	$t_f$			300	ns		

**Clock timing SCL**

29.	Frequency	$f_{SCL}$	0	100	400	kHz		
30.	High pulse width	$t_H$	0.6			$\mu$ s		
31.	Low pulse width	$t_L$	1.3			$\mu$ s		

**Start condition**

32.	Set-up time	$t_{susta}$	0.6			$\mu$ s		
33.	Hold time	$t_{hsta}$	0.6			$\mu$ s		

**Stop condition**

34.	Set up time	$t_{susto}$	0.6			$\mu$ s		
35.	Bus free time between a STOP and START condition	$t_{buf}$	1.3			$\mu$ s		

**Data transfer**

#	Parameter <sup>1)</sup>	Symbol	Limit Values			Unit	Test Conditions	■
			min.	typ.	max.			
36.	Set-up time	$t_{\text{sudat}}$	0.1			$\mu\text{s}$		
37.	Hold time	$t_{\text{hdat}}$	0			$\mu\text{s}$		
38.	Input hysteresis SCL, SDA	$V_{\text{hys}}$		200		mV		
39.	Pulse width of spikes which are suppressed	$t_{\text{sp}}$	0		50	ns		
40.	Capacitive load for each bus line	$C_{\text{L}}$			400	pF		

**Ports**

41.	PNP Output saturation voltage	$V_{\text{PP,sat}} =$ $V_{\text{CC}} -$ $V_{\text{CE,sat}}$		0.25	0.4	V	$I_{\text{PP}} = 5 \text{ mA}$	
42.	NPN Output saturation voltage	$V_{\text{PN,sat}}$		0.25	0.4	V	$I_{\text{PN}} = 5 \text{ mA}$	
43.	Port Output leakage current	$I_{\text{LEAK,Port}}$			10	$\mu\text{A}$		

**ADC input (only available in TUA 6039F-2)**

44.	ADC input voltage	$V_{\text{ADC}}$	0		$V_{\text{CC}}$	V		
45.	High-level input current	$I_{\text{ADCH}}$			10	$\mu\text{A}$		
46.	Low-level input current	$I_{\text{ADCL}}$	-10			$\mu\text{A}$		

**Analog Part**
**LOW band mixer and SAW filter driver**

47.	RF frequency	$f_{\text{RF}}$	44.25		170.25	MHz	picture carrier <sup>2)</sup>	
48.	Voltage gain	$G_{\text{V}}$	21	24	27	dB	$f_{\text{RF}} = 48.25 \text{ MHz}$ to 154.25 MHz see <a href="#">Section 5.5.1</a>	
49.	Noise figure	NF		8	12	dB	$f_{\text{RF}} = 48.25 \text{ MHz}$ to 154.25 MHz see <a href="#">Section 5.5.4</a>	

#	Parameter <sup>1)</sup>	Symbol	Limit Values			Unit	Test Conditions	■
			min.	typ.	max.			
50.	SAWOUT output voltage causing 0.8% of crossmodulation in channel	$V_o$		120		dB $\mu$ V	$f_{RF} = 48.25$ MHz to 154.25 MHz see <a href="#">Section 5.5.6</a>	
51.	Input IP3	IIP3		117		dB $\mu$ V	$f_{RF1} = 48.25$ MHz, $f_{RF2} = 49.25$ MHz, $P_{RF1} = P_{RF2}$	
52.		IIP3		117		dB $\mu$ V	$f_{RF1} = 154.25$ MHz, $f_{RF2} = 155.25$ MHz, $P_{RF1} = P_{RF2}$	
53.	Local oscillator FM caused by I <sup>2</sup> C communication	$FM_{I2C}$			2.12	kHz	$f_{RF} = 154.25$ MHz <sup>3)</sup>	
54.	(N+5) - 1 MHz pulling	N+5 - 1 MHz	77	80		dB $\mu$ V	$f_{RFW} = 69.25$ MHz, $f_{OSC} = 108.15$ MHz, $f_{RFU} = 108.25$ MHz <sup>4)</sup>	
55.	Input impedance	$R_p$		1		k $\Omega$	parallel equivalent circuit at 100 MHz <sup>5)</sup> see <a href="#">Section 5.4.1</a>	
56.	$Z_i = (R_p \parallel 1/j\omega C_p)$	$C_p$		2		pF		

**Mid band mixer and SAW filter driver**

57.	RF frequency	$f_{RF}$	154.25		454.25	MHz	picture carrier <sup>2)</sup>	
58.	Voltage gain	$G_V$	31	34	37	dB	$f_{RF} = 161.25$ MHz to 439.25 MHz see <a href="#">Section 5.5.2</a>	
59.	Noise figure (not corrected for image)	NF		6	10	dB	$f_{RF} = 161.25$ MHz to 439.25 MHz see <a href="#">Section 5.5.5</a>	
60.	SAWOUT output voltage causing 0.8% of crossmodulation in channel	$V_o$		120		dB $\mu$ V	$f_{RF} = 161.25$ MHz to 439.25 MHz see <a href="#">Section 5.5.7</a>	

#	Parameter <sup>1)</sup>	Symbol	Limit Values			Unit	Test Conditions	■
			min.	typ.	max.			
61.	Input IP3	IIP3		106		dBμV	$f_{RF1} = 161.25 \text{ MHz}$ $f_{RF2} = 162.25 \text{ MHz}$ , $P_{RF1} = P_{RF2}$	
62.		IIP3		105		dBμV	$f_{RF1} = 439.25 \text{ MHz}$ $f_{RF2} = 440.25 \text{ MHz}$ , $P_{RF1} = P_{RF2}$	
63.	Local oscillator FM caused by I <sup>2</sup> C communication	FM <sub>I2C</sub>			2.12	kHz	$f_{RF} = 439.25 \text{ MHz}^{3)}$	
64.	(N+5) - 1 MHz pulling	N+5 - 1 MHz	77	80		dBμV	$f_{RFW} = 359.25 \text{ MHz}$ , $f_{OSC} = 398.15 \text{ MHz}$ , $f_{RFU} = 398.25 \text{ MHz}^{4)}$	
65.	Input impedance	R <sub>s</sub>		22		Ω	series equivalent circuit at 300 MHz <sup>5)</sup>	
66.	Z <sub>i</sub> = (R <sub>s</sub> + jωL <sub>s</sub> )	L <sub>s</sub>		2.7		nH	see <a href="#">Section 5.4.2</a>	

**HIGH band mixer and SAW filter driver**

67.	RF frequency	f <sub>RF</sub>	399.25		863.25	MHz	picture carrier <sup>2)</sup>	
68.	Voltage gain	G <sub>V</sub>	31	34	37	dB	$f_{RF} = 447.25 \text{ MHz}$ to 863.25 MHz see <a href="#">Section 5.5.2</a>	
69.	Noise figure (not corrected for image)	NF		6	10	dB	$f_{RF} = 447.25 \text{ MHz}$ to 863.25 MHz see <a href="#">Section 5.5.5</a>	
70.	SAWOUT output voltage causing 0.8% of crossmodulation in channel	V <sub>o</sub>		120		dBμV	$f_{RF} = 447.25 \text{ MHz}$ to 863.25 MHz see <a href="#">Section 5.5.7</a>	
71.	Input IP3	IIP3		105		dBμV	$f_{RF1} = 447.25 \text{ MHz}$ $f_{RF2} = 448.25 \text{ MHz}$ $P_{RF1} = P_{RF2}$	
72.		IIP3		105		dBμV	$f_{RF1} = 863.25 \text{ MHz}$ $f_{RF2} = 864.25 \text{ MHz}$ $P_{RF1} = P_{RF2}$	



#	Parameter <sup>1)</sup>	Symbol	Limit Values			Unit	Test Conditions	■
			min.	typ.	max.			
73.	Local oscillator FM caused by I <sup>2</sup> C communication	FM <sub>I2C</sub>			2.12	kHz	f <sub>RF</sub> = 863.25 MHz <sup>3)</sup>	
74.	(N+5) - 1 MHz pulling	N+5 - 1 MHz	77	80		dBμV	f <sub>RFw</sub> = 823.25 MHz, f <sub>OSC</sub> = 862.15 MHz, f <sub>RFu</sub> = 862.25 MHz <sup>4)</sup>	
75.	Input impedance	R <sub>s</sub>		25		Ω	series equivalent circuit at 650 MHz <sup>5)</sup> see <a href="#">Section 5.4.3</a>	
76.	Z <sub>i</sub> = (R <sub>s</sub> + jωL <sub>s</sub> )	L <sub>s</sub>		2.5		nH		

**LOW band oscillator**

77.	Oscillator frequency	f <sub>OSC</sub>	80		210	MHz	<sup>6)</sup>		
78.	Phase noise, carrier to noise sideband	Φ <sub>OSC</sub>		-85	-77	dBc/Hz	±1 kHz frequency offset, worst case in the frequency range <sup>7)</sup>		
79.				-92	-88	dBc/Hz		±10 kHz frequency offset, worst case in the frequency range <sup>8)</sup>	
80.				-112	-108	dBc/Hz		±100 kHz frequency offset, worst case in the frequency range	
81.	Ripple susceptibility of V <sub>p</sub>	RSC		-50		dBc	V <sub>Ripple</sub> = 20 mVpp, f <sub>Ripple</sub> = 100 kHz <sup>9)</sup>		

**MID band oscillator**

82.	Oscillator frequency	f <sub>OSC</sub>	201		493	MHz	<sup>6)</sup>	
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#	Parameter <sup>1)</sup>	Symbol	Limit Values			Unit	Test Conditions	■		
			min.	typ.	max.					
83.	Phase noise, carrier to noise sideband	$\Phi_{\text{OSC}}$		-80	-73	dBc/Hz	$\pm 1$ kHz frequency offset, worst case in the frequency range <sup>7)</sup>			
84.				-92	-88				dBc/Hz	$\pm 10$ kHz frequency offset, worst case in the frequency range <sup>8)</sup>
85.				-112	-108					
86.	Ripple susceptibility of $V_P$	RSC		-60		dBc	$V_{\text{Ripple}} = 20$ mVpp, $f_{\text{Ripple}} = 100$ kHz <sup>9)</sup>			
<b>HIGH band oscillator</b>										
87.	Oscillator frequency	$f_{\text{OSC}}$	435		905	MHz	6)			
88.	Phase noise, carrier to noise sideband	$\Phi_{\text{OSC}}$		-77	-70				dBc/Hz	$\pm 1$ kHz frequency offset, worst case in the frequency range <sup>7)</sup>
89.				-90	-86	dBc/Hz	$\pm 10$ kHz frequency offset, worst case in the frequency range <sup>8)</sup>			
90.				-110	-106			dBc/Hz		
91.	Ripple susceptibility of $V_P$	RSC		-60		dBc	$V_{\text{Ripple}} = 20$ mVpp, $f_{\text{Ripple}} = 100$ kHz <sup>9)</sup>			
<b>SAW filter driver</b>										
92.	Voltage gain	$G_V$		20		dB	$f_{\text{IF}} = 36$ MHz to 54 MHz			

#	Parameter <sup>1)</sup>	Symbol	Limit Values			Unit	Test Conditions	■
			min.	typ.	max.			
93.	Output voltage causing 1 dB compression	$V_o$		126		dB $\mu$ V		
94.	Input impedance	$R_p$		470		$\Omega$	parallel equivalent circuit at 36 MHz <sup>5)</sup> see <a href="#">Section 5.4.5</a>	
95.	$Z_i = (R_p \parallel 1/j\omega C_p)$	$C_p$		6		pF		
96.	Output impedance	$R_s$		25		$\Omega$	series equivalent circuit at 36 MHz <sup>5)</sup> see <a href="#">Section 5.4.6</a>	
97.	$Z_o = (R_s + j\omega L_s)$	$L_s$		50		nH		

**Rejection at the SAW driver outputs**

98.	Level of divider interferences in the IF signal	$INT_{DIV}$		-66	-60	dBc	$V_{OUT} = 100 \text{ dB}\mu\text{V}^{10)}$	
99.	Crystal oscillator interferences rejection	$INT_{XTAL}$		-66	-60	dBc	$V_{OUT} = 100 \text{ dB}\mu\text{V}^{11)}$	
100.	Reference frequency rejection	$INT_{REF}$		-66	-60	dBc	$V_{OUT} = 100 \text{ dB}\mu\text{V}^{12)}$	
101.	Channel S02 beat	$INT_{S02}$		-66	-60	dBc	$f_{RFpix} = 76.25 \text{ MHz}$ , $V_{RFpix} = 80 \text{ dB}\mu\text{V}$ , $f_{IF} = 38.9 \text{ MHz}^{13)}$	

**RF AGC output**

102.	RF AGC output	$AGC_{TOP}$ narrow	103		115	dB $\mu$ V		
103.	Source current 1	$I_{AGCfast}$		9.0		$\mu$ A		
104.	Source current 2	$I_{AGCslow}$		300		nA		
105.	Peak sink to ground	$I_{AGCpeak}$		100		$\mu$ A		
106.	RF AGC output voltage	$V_{AGCmax}$		3.7		V	maximum level, $I_{AGC} = 9 \mu\text{A}$	
107.		$V_{AGCmin}$	0		0.25	V	minimum level	
108.	RF voltage range to switch the AGC from active to inactive mode	$AGC_{SLIP}$			0.5	dB		

#	Parameter <sup>1)</sup>	Symbol	Limit Values			Unit	Test Conditions	■
			min.	typ.	max.			
109.	RF AGC leakage current	$AGC_{LEAK}$	-50		50	nA	$0 < V_{AGC} < V_{CC}$ , AL2, AL1, AL0 = 1, 1, 0	
110.	RF AGC output voltage	$AGC_{OFF}$		3.7		V	AGC is disabled, $I_{AGC} = 9 \mu A$	
<b>RF AGC buffer</b>								
111.	RF AGC buffer output current	$I_{max}$			1	mA		
112.	RF AGC buffer output saturation voltage low	$V_{low}$		120	200	mV	$I_{load} = 1 \text{ mA}$	
113.	RF AGC buffer output saturation voltage high	$V_{CC} - V_{high}$		170	300	mV	$I_{load} = 1 \text{ mA}$	
<b>IF AGC amplifier</b>								
114.	Voltage gain	$G_{max}$		65		dB	$V_{IFAGC} \geq 2.0 \text{ V}$	
115.		$G_{min}$		9		dB	$V_{IFAGC} \leq 0.2 \text{ V}$	
116.	Maximum IF input level	$V_{IF/IF}$		102		d $\mu$ V	min. gain, $f_{IF/IF} = 36 \text{ MHz}$ (sine), $V_{IFAGC} = 0.2 \text{ V}$ , $V_{OUT/OUT} = 1 \text{ V}_{pp}$	
117.	Minimum IF input level	$V_{IF/IF}$		46			max. gain, $f_{IF/IF} = 36 \text{ MHz}$ (sine), $V_{IFAGC} = 2 \text{ V}$ , $V_{OUT/OUT} = 1 \text{ V}_{pp}$	
118.	Input impedance	$R_{IF/IF}$		2		k $\Omega$	parallel equivalent circuit at 36 MHz <sup>5)</sup> see <a href="#">Section 5.4.7</a>	
119.	$Z_i = (R_{IF/IF} \parallel 1/j\omega C_{IF/IF})$	$C_{IF/IF}$		1.5		pF		
120.	Low end cutoff frequency (-1 dB)	$f_L$			25	MHz	$V_{IF/IF} = 60 \text{ dB}\mu\text{V}$ , $R_{LOAD} \geq 5 \text{ k}\Omega$ , $C_{LOAD} \leq 1.5 \text{ pF}$ , $V_{OUT/OUT} = 1 \text{ V}_{pp}$ at $f_{IF/IF} = 36 \text{ MHz}$ (sine)	
121.	High end cutoff frequency (-1 dB)	$f_H$	65			MHz		

#	Parameter <sup>1)</sup>	Symbol	Limit Values			Unit	Test Conditions	■
			min.	typ.	max.			
122.	Intermodulation	C/IM3		-56		dBc	$f_{IF/IF1} = 37 \text{ MHz}$ , $f_{IF/IF2} = 38 \text{ MHz}$ , $V_{IF/IF1} = 90 \text{ dB}\mu\text{V}$ , $V_{IF/IF2} = 90 \text{ dB}\mu\text{V}$ , $R_{LOAD} \geq 5 \text{ k}\Omega$ , $C_{LOAD} \leq 10 \text{ pF}$ , $V_{OUT/OUT} = 1 \text{ V}_{pp}$	
123.	Third order output intercept point	OIP3		138		$\text{dB}\mu\text{V}$	$f_{IF/IF1} = 37 \text{ MHz}$ , $f_{IF/IF2} = 38 \text{ MHz}$ , $V_{IF/IF1} = 90 \text{ dB}\mu\text{V}$ , $V_{IF/IF2} = 90 \text{ dB}\mu\text{V}$ , $R_{LOAD} \geq 5 \text{ k}\Omega$ , $C_{LOAD} \leq 10 \text{ pF}$ , $V_{OUT/OUT} = 1 \text{ V}_{pp}$	
124.	Signal to noise ratio	SNR		43		dB	$f_{IF/IF} = 36 \text{ MHz}$ (sine), $V_{IF/IF} = 60 \text{ dB}\mu\text{V}$ , $V_{OUT/OUT} = 1 \text{ V}_{pp}$ , $BW = 8 \text{ MHz}$	
125.	Noise figure			9		dB	max. gain	
126.	Output impedance	$R_{IF/IF}$		90	150	$\Omega$	series equivalent circuit at 36 MHz <sup>5)</sup> see <a href="#">Section 5.4.8</a>	
127.	$Z_o = (R_{IF/IF} + j\omega L_{IF/IF})$	$L_{IF/IF}$		120		nH		

- 1) Values are referred to the application given in [Figure 7](#) and  $f_{IF} = 36 \text{ MHz}$ , unless stated otherwise.
- 2) The RF frequency range is defined by the oscillator frequency range and the intermediate frequency (IF).
- 3) Local oscillator FM modulation resulting from I<sup>2</sup>C communication is measured at the IF output using a modulation analyzer with a peak to peak detector  $((P_+ + P_-) / 2)$  and a post detection filter 20 Hz - 100 kHz. The I<sup>2</sup>C messages are sent to the tuner in such a way that the tuner is addressed but the content of the PLL registers are not altered. The refresh interval between each data set shall be 20 ms to 1 s.
- 4) (N+5) -1 MHz is defined as the input level of channel N+5, at frequency 1 MHz lower, causing 100 kHz FM sidebands 30 dB below the wanted carrier.
- 5) Impedance measured with differential 2-port measurement at input or output. Input and output pins directly connected to measurement equipment with 50  $\Omega$  strip lines.
- 6) Limits are related to the tank circuit used in the application board (see [Figure 7](#)). Frequency bands may be adjusted by the choice of external components.
- 7) For wide loop filter application (see [Figure 9](#)).
- 8) For narrow loop filter application (see [Figure 8](#)).

- 9) The supply ripple susceptibility is a sideband measurement using a spectrum analyzer connected to the IF output. An unmodulated RF signal with a level of 80 dB $\mu$ V is applied to the test board RF input. A sinewave signal with a defined frequency is superposed onto the supply voltage (see [Figure 19](#)). The specified value is the worst case in the frequency range.
- 10) This is the level of divider interferences close to the IF frequency. For example channel S3:  $f_{OSC} = 158.15$  MHz,  $1/4 f_{OSC} = 39.5375$  MHz. The rejection has to be better than 60 dB for a SAW driver output level of 100 dB $\mu$ V.
- 11) Crystal oscillator interference means the 4 MHz sidebands caused by the crystal oscillator. The rejection has to be better than 60 dB for a SAW driver output level of 100 dB $\mu$ V.
- 12) The reference frequency rejection is the level of reference frequency sidebands according to the application circuit (166.67 kHz for DVB-T standard, 142.86 kHz for ISDB-T standard or 62.5 kHz for ATSC standard) related to the carrier. The rejection has to be better than 60 dB for a SAW driver output level of 100 dB $\mu$ V. In hybrid application the rejection is valid for the digital reference frequency (166.67 kHz for DVB-T/PAL standard, or 142.86 kHz for ISDB-T/NTSC standard), but any lower analog reference frequency may reduce this rejection.
- 13) Channel S02 beat is the interfering product of  $f_{RFpix}$ ,  $f_{IF}$  and  $f_{OSC}$  of channel S02,  $f_{BEAT} = 37.35$  MHz. The possible mechanisms are  $f_{OSC} - 2 \times f_{IF}$  or  $2 \times f_{RFpix} - f_{OSC}$ .

## 5.2 Bus Interface

**Table 8 Bit Allocation Read/Write**

Name	Byte	Bits								Ack
		MSB	bit6	bit5	bit4	bit3	bit2	bit1	LSB	
Write Data (for TUA 6039F-2 and for TUA 6037F)										
Address Byte	ADB	1	1	0	0	0	MA1	MA0	R/W=0	A
Divider Byte 1	DB1	0	N14	N13	N12	N11	N10	N9	N8	A
Divider Byte 2	DB2	N7	N6	N5	N4	N3	N2	N1	N0	A
Control byte	CB	1	CP	T2	T1	T0	RSA	RSB	OS	A
Bandswitch byte	BB	XTB			P4	P3	P2	P1	P0	A
Auxiliary byte <sup>1)</sup>	AB	ATC	AL2	AL1	AL0	0	0	0	LP	A
Read data (for TUA 6039F-2)										
Address byte	ADB	1	1	0	0	0	MA1	MA0	R/W=1	A
Status byte	SB	POR	FL	1	NBD	AGC	A2	A1	A0	A
Read data (for TUA 6037F)										
Address byte	ADB	1	1	0	0	0	MA1	MA0	R/W=1	A
Status byte	SB	POR	FL	1	1	AGC	NBD	1	1	A

1) AB replaces BB when T2, T1, T0 = 0, 1, 1, see [Table 11](#).

**Table 9 Description of Symbols**

<b>Symbol</b>	<b>Description</b>
A	Acknowledge
MA0, MA1	Address selection bits, see <a href="#">Table 10</a>
N14 to N0	programmable divider bits: $N = 2^{14} \times N14 + 2^{13} \times N13 + \dots + 2^3 \times N3 + 2^2 \times N2 + 2^1 \times N1 + N0$
CP	charge pump current bit: bit = 0: charge pump current = 50 $\mu$ A or 125 $\mu$ A bit = 1: charge pump current = 250 $\mu$ A (default) or 650 $\mu$ A, see <a href="#">Table 15</a>
T0, T1, T2	test bits, <a href="#">Table 11</a>
RSA, RSB	reference divider bits, see <a href="#">Table 12</a>
OS	tuning amplifier control bit: bit = 0: enable $V_T$ ; bit = 1: disable $V_T$ (default)
XTB	disable XTAL buffer control bit: bit = 0: enable XTAL buffer (default); bit = 1: disable XTAL buffer
P0, P1, P2, P3	PNP ports control bits: bit = 0: Port is inactive, high impedance state (default) bit = 1: Port is active, $V_{OUT} = V_{CC} - V_{CE,sat}$
P4	NPN port control bit: bit = 0: Port is inactive, high impedance state (default) bit = 1: Port is active, $V_{OUT} = V_{CE,sat}$
ATC	RF AGC time constant bit: bit = 0: $I_{AGC} = 300$ nA; $\Delta t = 2$ s with C = 160 nF (default) bit = 1: $I_{AGC} = 9$ $\mu$ A; $\Delta t = 50$ ms with C = 160 nF
AL0, AL1, AL2	RF AGC take-over point bits, see <a href="#">Table 13</a>
LP	Loop through: bit = 0: disable loop through (default); bit = 1: enable loop through
POR	Power-on reset flag, bit = 1 at power-on
FL	PLL lock flag, bit = 1: loop is locked
NBD	Narrow Band detector flag, bit =1 when SAWOUT level is above RF AGC take-over point
AGC	internal AGC flag, bit = 1 when internal AGC is active (level below 3V)
A0, A1, A2	digital output of the 5-level ADC (only available in TUA 6039F-2)

**Table 10 Address selection**

Voltage at AS	MA1	MA0
$(0 \text{ to } 0.1) \times V_{CC}$	0	0
open circuit or $(0.2 \text{ to } 0.3) \times V_{CC}$	0	1
$(0.4 \text{ to } 0.6) \times V_{CC}$	1	0
$(0.9 \text{ to } 1) \times V_{CC}$	1	1

**Table 11 Test modes**

Mode	T2	T1	T0	OS
Normal mode (XMODE = 0 <sup>1)</sup> , charge pump currents 50 $\mu$ A and 250 $\mu$ A selectable	0	0	0	0
Normal mode (XMODE = 0), charge pump currents 50 $\mu$ A and 250 $\mu$ A selectable (default)	0	0	1	0
Normal mode (XMODE = 0), CP test tristate, CP currents off, $V_T$ disabled	0	0	x	1
Port test output: P0 = NB	0	1	0	0
Port test output: P0 = $f_{div} / 2$ , P1 = $f_{ref}$	0	1	0	1
byte AB will follow (otherwise byte BB will follow)	0	1	1	0
byte AB will follow (otherwise byte BB will follow), CP test tristate, CP currents off, $V_T$ disabled	0	1	1	1
CP test sink	1	0	0	0
CP test source	1	0	1	0
CP test tristate, CP currents off, $V_T$ active	1	0	x	1
Extended mode (XMODE = 1), charge pump currents 50 $\mu$ A and 250 $\mu$ A selectable	1	1	0	0
Extended mode (XMODE = 1), charge pump currents 125 $\mu$ A and 650 $\mu$ A selectable	1	1	1	0
Extended mode (XMODE = 1), CP test tristate, CP currents off, $V_T$ disabled	1	1	x	1

1) XMODE = internal flag for extended mode



**Table 12 Reference divider ratios**

Reference divider ratio	$f_{ref}^{1)}$	Mode	T2	T1	RSA	RSB
80	50 kHz	normal	0	0	0	0
128	31.25 kHz	normal	0	0	0	1
24	166.67 kHz	x	x	x	1	0
64	62.5 kHz	x	x	x	1	1
32	125 kHz	extended	1	1	0	0
28	142.86 kHz	extended	1	1	0	1

1) With a 4 MHz quartz.

**Table 13 RF AGC take-over point**

SAW driver output level, symmetrical mode	Remark	AL2	AL1	AL0
115 dB $\mu$ V		0	0	0
115 dB $\mu$ V		0	0	1
112 dB $\mu$ V	default mode at POR	0	1	0
109 dB $\mu$ V		0	1	1
106 dB $\mu$ V		1	0	0
103 dB $\mu$ V		1	0	1
$I_{RFAGC} = 0$	External RF AGC <sup>1)</sup> Disable RF AGC buffer	1	1	0
$V_{RFAGC} = \text{high}$	Disabled <sup>2)</sup>	1	1	1

1) The RF AGC detector is disabled. Both the sinking and sourcing current from the IC is disabled. The RF AGC output goes into a high impedance state and an external RF AGC source can be connected in parallel and will not be influenced. The RF AGC buffer is disabled.

2) The RF AGC detector is disabled,  $V_{RFAGC}$  is set to high voltage  $V_{RFAGC} = 3.7$  V.

**Table 14 A to D converter levels<sup>1)</sup>**

Voltage at ADC <sup>1)</sup>	A2	A1	A0
(0 to 0.15) * V <sub>CC</sub>	0	0	0
(0.15 to 0.3) * V <sub>CC</sub>	0	0	1
(0.3 to 0.45) * V <sub>CC</sub>	0	1	0
(0.45 to 0.6) * V <sub>CC</sub>	0	1	1
(0.6 to 1) * V <sub>CC</sub>	1	0	0

1) No erratic codes in the transition.

**Table 15 Charge pump current**

Charge pump current	Mode	CP	T2	T1	T0
50 µA	normal	0	0	0	x <sup>1)</sup>
250 µA (default)		1			x
50 µA	extended	0	1	1	0
125 µA		0			1
250 µA		1			0
650 µA		1			1

1) x = don't care.

**Table 16 Internal band selection**

Band	Mixer	Oscillator
LOW	P0, $\overline{P1}$ <sup>1)</sup>	P0, $\overline{P1}$
MID	P1, $\overline{P0}$	P1, $\overline{P0}$
HIGH (default)	$\overline{P0}$ , $\overline{P1}$	$\overline{P0}$ , $\overline{P1}$
Power down mode	P0, P1	P0, P1

1) Means: (P0 AND NOT P1); that is: LOW mixer is switched on if (P0 = 1 and P1 = 0).

1) ADC function is only available in TUA 6039F-2.

**Table 17 Defaults at power-on reset**

Name	Byte	Bits							
		MSB	bit6	bit5	bit4	bit3	bit2	bit1	LSB
Write Data									
Address Byte	ADB	1	1	0	0	0	MA1	MA0	R/W=0
Divider byte 1	DB1	0	x <sup>1)</sup>	x	x	x	x	x	x
Divider byte 2	DB2	x	x	x	x	x	x	x	x
Control byte	CB	1	1	0	0	1	0	0	1
Bandswitch byte	BB	0	0	0	0	0	0	0	0
Auxiliary byte	AB	0	0	1	0	0	0	0	0

1) x = don't care.

**Table 18 Description of modes**

Mode	Description
normal	Reference divider ratios 24, 64, <b>80</b> , <b>128</b> selectable. Charge pump currents 50, 250 $\mu$ A selectable. Auxiliary byte to follow Control byte (T2 = 0, T1 = 1, T0 = 1), otherwise Bandswitch byte to follow Control byte.
extended	Reference divider ratios 24, <b>28</b> , <b>32</b> , 64 selectable. Charge pump currents 50, <b>125</b> , 250, <b>650</b> $\mu$ A selectable. Auxiliary byte to follow Control byte (T2 = 0, T1 = 1, T0 = 1), otherwise Bandswitch byte to follow Control byte.

### 5.3 I<sup>2</sup>C Bus Timing Diagram

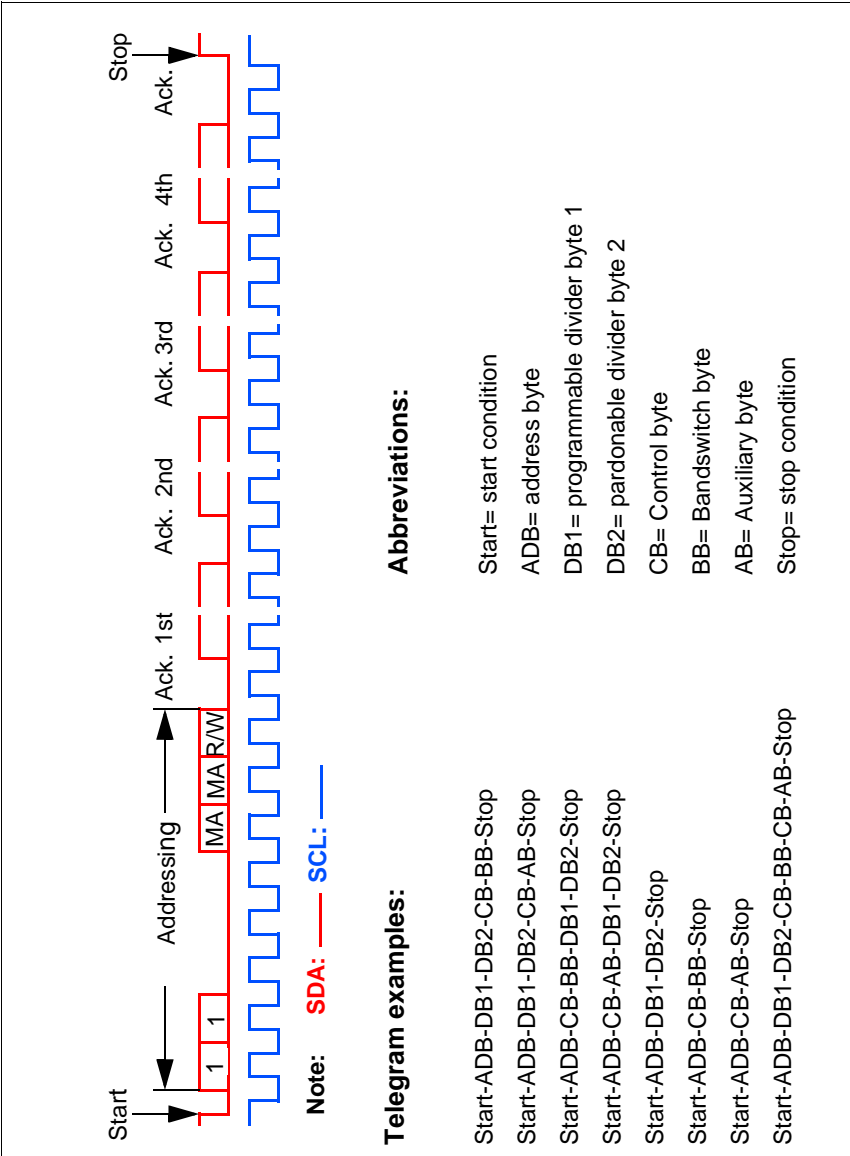
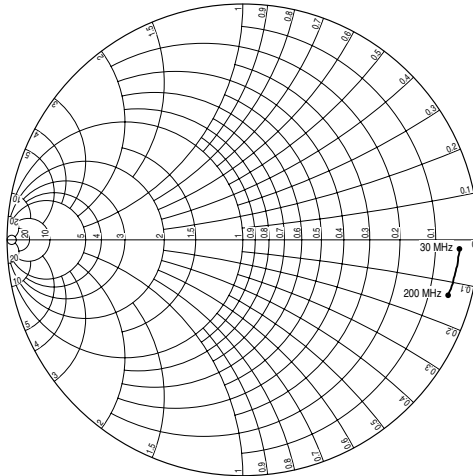


Figure 11 I<sup>2</sup>C Bus Timing Diagram

## 5.4 Electrical Diagrams

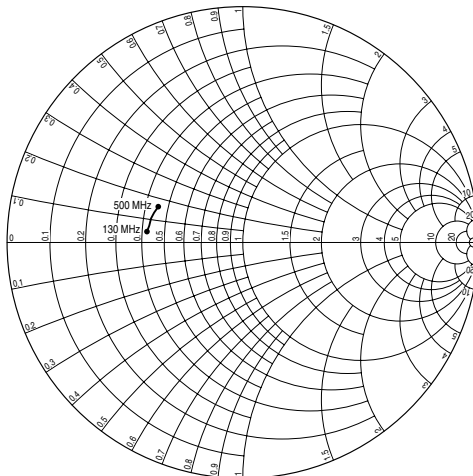
### 5.4.1 Input admittance (S11) of the LOW band mixer (30 to 200 MHz)

$Y_0 = 20 \text{ mA/V}$



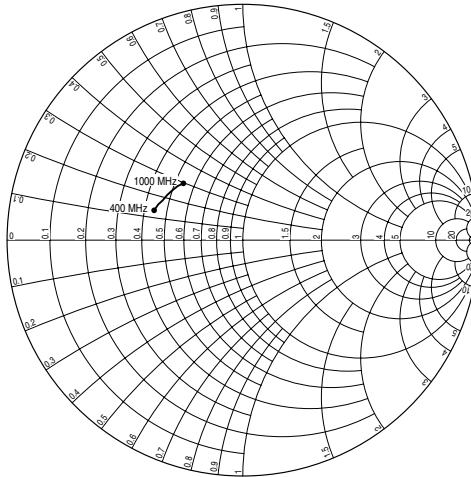
### 5.4.2 Input impedance (S11) of the MID band mixer (130 to 500 MHz)

$Z_0 = 50 \Omega$



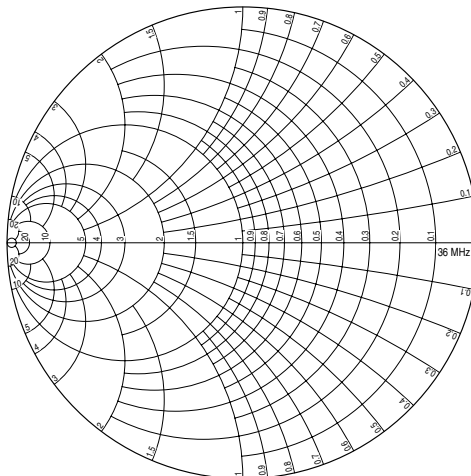
**5.4.3 Input impedance (S11) of the HIGH band mixer (400 to 1000 MHz)**

$Z_0 = 50 \Omega$



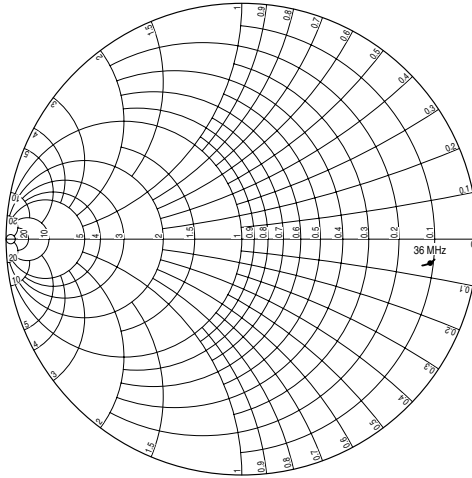
**5.4.4 Output admittance (S22) of the of the mixers (30 to 60 MHz)**

$Y_0 = 20 \text{ mA/V}$



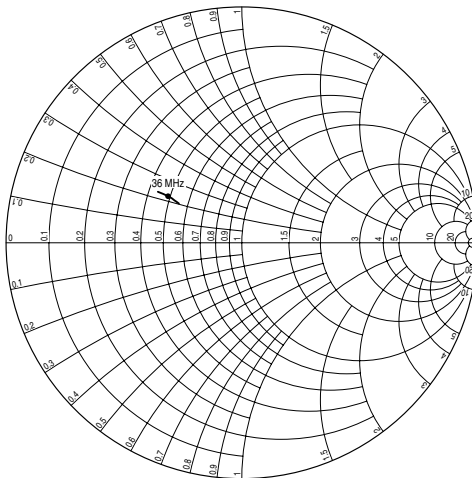
**5.4.5 Input admittance (S11) of the SAW filter driver (30 to 60 MHz)**

$Y_0 = 20 \text{ mA/V}$



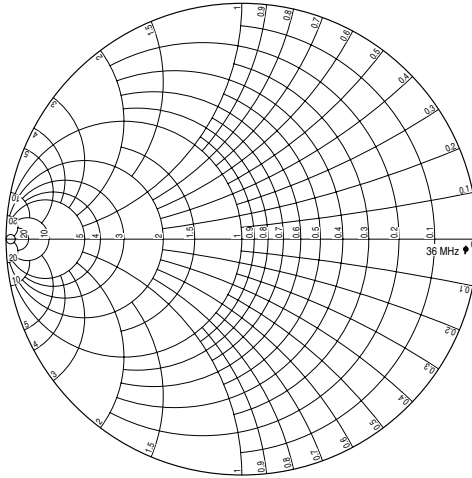
**5.4.6 Output impedance (S22) of the SAW filter driver (30 to 60 MHz)**

$Z_0 = 50 \Omega$



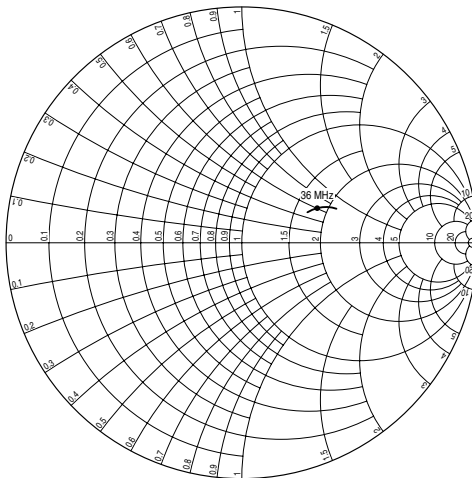
**5.4.7 Input admittance (S11) of the IF AGC amplifier (30 to 60 MHz)**

$Y_0 = 20 \text{ mA/V}$



**5.4.8 Output impedance (S22) of the IF AGC amplifier (30 to 60 MHz)**

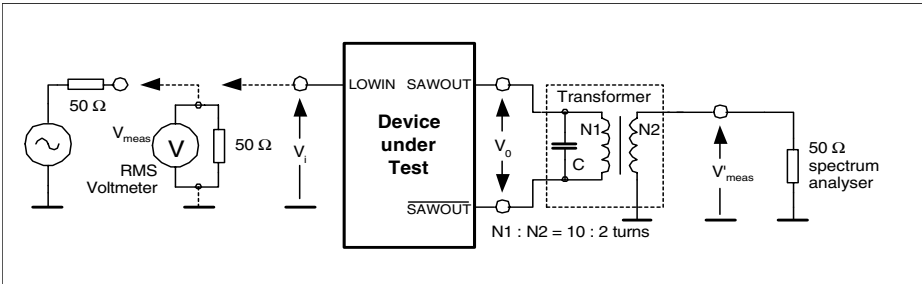
$Z_0 = 50 \Omega$





## 5.5 Measurement Circuits

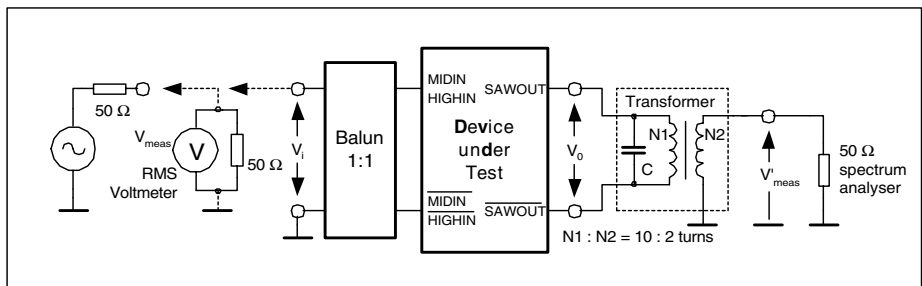
### 5.5.1 Gain ( $G_V$ ) measurement in LOW band



**Figure 12 Gain ( $G_V$ ) measurement in LOW band**

- $Z_i \gg 50 \Omega \Rightarrow V_i = 2 \times V_{\text{meas}} = 80 \text{ dB}\mu\text{V}$
- $V_i = V_{\text{meas}} + 6\text{dB} = 80 \text{ dB}\mu\text{V}$
- $V_0 = V'_{\text{meas}} + 17 \text{ dB}$  (transformer ratio  $N1:N2$  and transformer loss)
- $G_V = 20 \log(V_0 / V_i)$

### 5.5.2 Gain ( $G_V$ ) measurement in MID and HIGH bands



**Figure 13 Gain ( $G_V$ ) measurement in MID and HIGH bands**

- $V_i = V_{\text{meas}} = 70 \text{ dB}\mu\text{V}$
- $V_0 = V'_{\text{meas}} + 17 \text{ dB}$  (transformer ratio  $N1:N2$  and transformer loss)
- $G_V = 20 \log(V_0 / V_i) + 1 \text{ dB}$  (1 dB = insertion loss of balun)

### 5.5.3 Matching circuit for optimum noise figure in LOW band

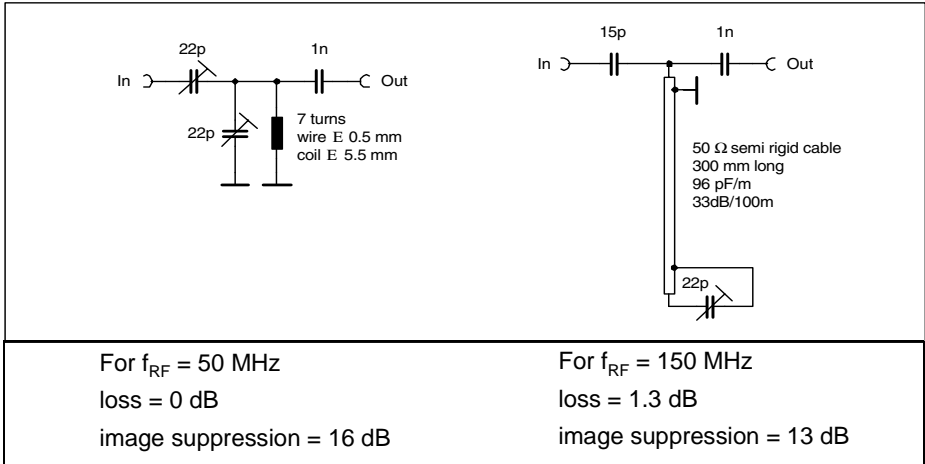


Figure 14 Matching circuit for optimum noise figure in LOW band

### 5.5.4 Noise figure (NF) measurement in LOW band

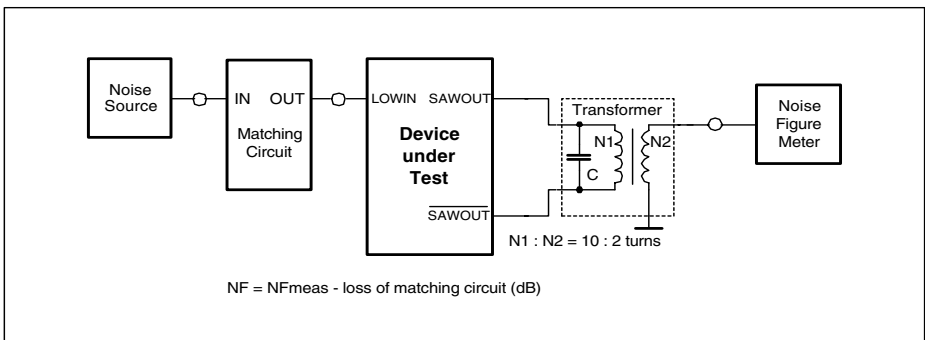


Figure 15 Noise figure (NF) measurement in LOW band

### 5.5.5 Noise figure (NF) measurement in MID and HIGH bands

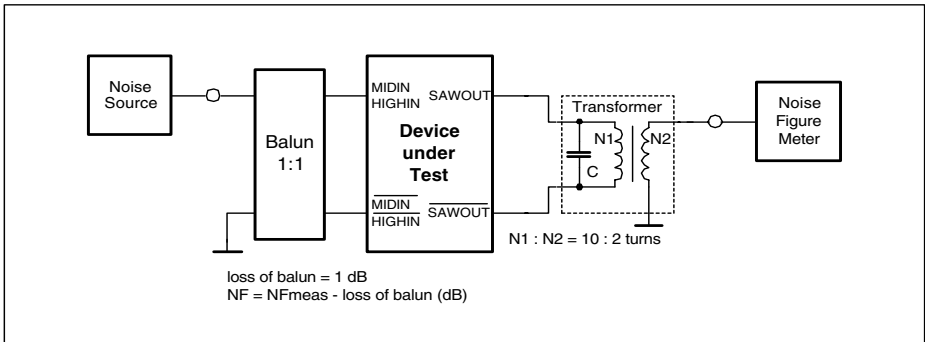


Figure 16 Noise figure (NF) measurement in MID and HIGH bands

### 5.5.6 Cross modulation measurement in LOW band

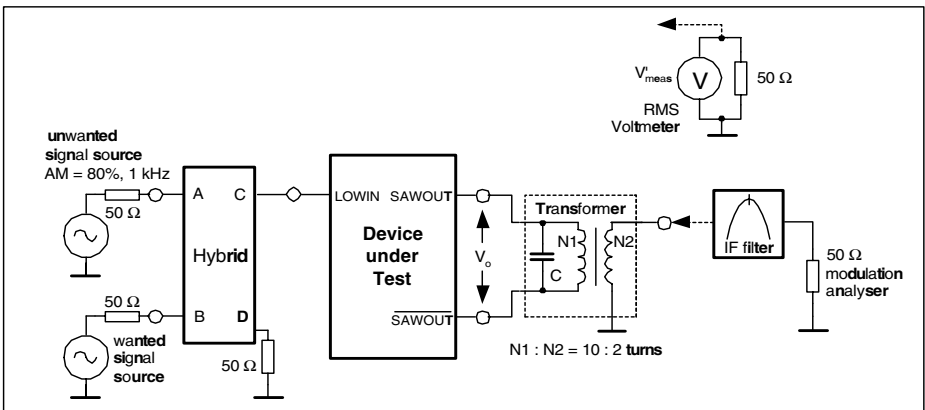
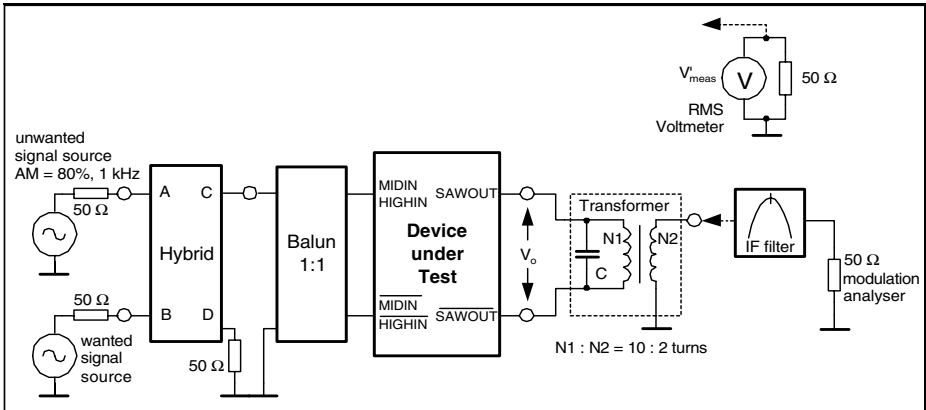


Figure 17 Cross modulation measurement in LOW band

- $V'_{meas} = V_0 - 17 \text{ dB}$  (transformer ratio  $N1:N2$  and transformer loss)
- wanted output signal at  $f_{pix}$ ,  $V_0 = 100 \text{ dB}\mu\text{V}$
- unwanted output signal at  $f_{snd}$

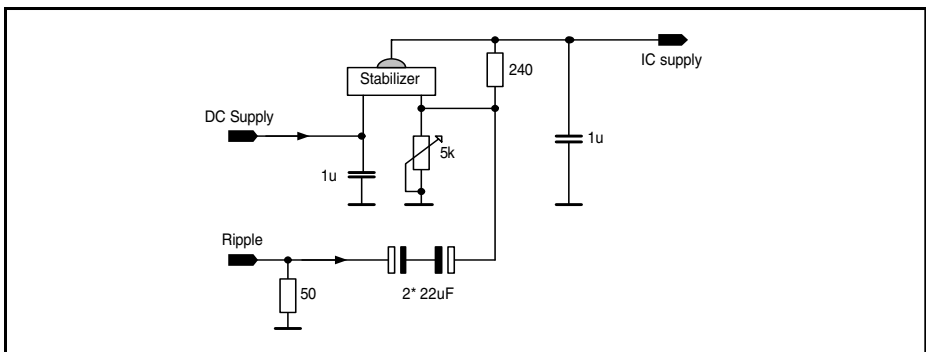
### 5.5.7 Cross modulation measurement in MID and HIGH bands



**Figure 18 Cross modulation measurement in MID and HIGH bands**

- $V'_{meas} = V_o - 17 \text{ dB}$  (transformer ratio  $N1:N2$  and transformer loss)
- wanted output signal at  $f_{pix}$ ,  $V_o = 100 \text{ dB}\mu\text{V}$
- unwanted output signal at  $f_{snd}$

### 5.5.8 Ripple susceptibility (RSC) measurement



**Figure 19 Ripple susceptibility measurement**

## 6 Package VQFN-48

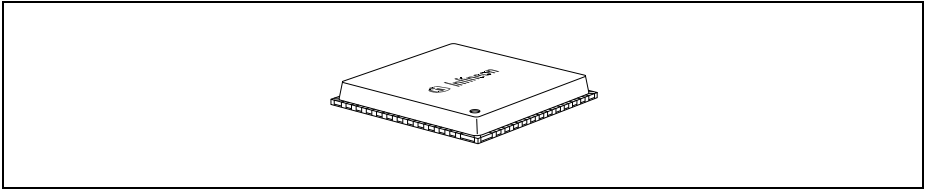


Figure 20 PG-VQFN-48 Vignette

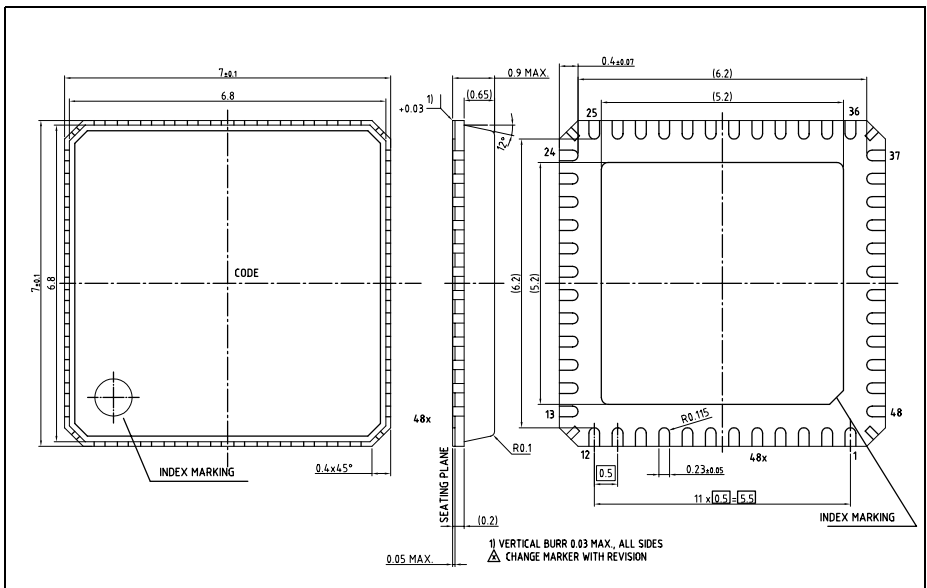


Figure 21 PG-VQFN-48 Outline Drawing

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