



# Wireless Components

3-Band TV Tuner IC

TUA6030, TUA6032 Version 2.1

Specification July 2001

<b>Revision History: Current Version:</b> Preliminary Data Sheet, V1.1, August 2000		
Previous Version: Target Data Sheet, V1.0, November 1999		
Page (in previous Version)	Page (in current Version)	Subjects (major changes since last revision)
all	all	Version to V1.1, status to preliminary
Product Info	Product Info	Ordering code added.
4-2	4-2	Div. components changed.
4-3	4-3	Div. components changed.
5-2	5-2	Junction temperature and storage temperature +125 °C max.
5-5	5-5	Bus inputs SCL, SDA: $V_{IH} = 2.3$ V.
5-8, 5-9, 5-10	5-8, 5-9, 5-10	Input conductance, input capacitance corrected.
5-10	5-10	Phase noise @ $\pm 1$ kHz frequency offset deleted. Phase noise, LOW band oscillator: $\Phi_{OSC} = 92$ dBc/Hz min @ $\pm 10$ kHz. Phase noise, MID band oscillator: $\Phi_{OSC} = 92$ dBc/Hz min @ $\pm 10$ kHz.
5-11	5-11	Phase noise @ $\pm 1$ kHz frequency offset deleted. Phase noise, HIGH band oscillator: $\Phi_{OSC} = 87$ dBc/Hz min.
5-14	5-14	Table 5-5, Description of Symbols: CP and OS 'default' added
5-15	5-15	Table 5-5, Test Modes: Normal operation 'default' added.
5-14	5-14	Table 5-5, Description of Symbols: CP and OS 'default' added.
5-15	5-15	Table 5-5, Test Modes: Normal operation 'default' added.
5-16	5-16	Table 5-10, A to D converter levels, footnote 'No erratic codes in the transition' added, Table 5-1, Defaults at power-on reset, Auxiliary byte, bit5 = 1.
5-18, 5-19, 5-20	5-18, 5-19, 5-20	Smith charts added..
div	div	Tbf's replaced .
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4-2, 4-3	4-2, 4-3	Application circuits modified
5-2	5-2	New definition of thermal properties.
5-6	5-6, 5-7	Saturation Voltages for P0, 2, 3 added
5-11	5-11	AGC take-over point: Min/max values added. Mixer output impedance: Values added

<b>Revision History: Current Version:</b> Preliminary Data Sheet,V1.1, August 2000		
5-11, 5-12	5-11, 5-12	Phase noise corrected
5-16	5-16	Table 5-1, Defaults at power-on reset, Auxiliary byte, bit5 = 1.
5-18	5-18	More telegram examples
<b>Revision History: Current Version:</b> Data Sheet, V2.1, July 2001		
Previous Version:Preliminary Data Sheet, V2.0, March 2001		
all	all	Mirror imaged version TUA6032 added

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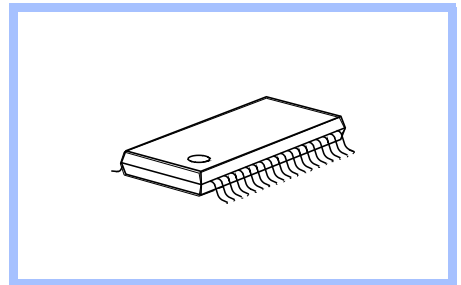
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## Product Info

**General Description** The **TUA6030, TUA6032** devices combine a mixer-oscillator block with a digitally programmable phase locked loop (PLL) for use in TV and VCR tuners.

### Package



### Features **General**

- Suitable for PAL/NTSC and **Digital Video Broadcasting**
- Wideband AGC detector for internal tuner AGC
  - 5 programmable take-over points
  - 2 programmable time constants
- Full ESD protection

### **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

### **IF-Amplifier**

- IF preamplifier with symmetrical 75  $\Omega$  output impedance able to drive a SAW filter (500  $\Omega$ /40 pF)

### **PLL**

- 4 independent I<sup>2</sup>C addresses
- I<sup>2</sup>C bus protocol compatible with 3.3 V and 5V micro-controllers up to 400 kHz
- Short lock-in time
- High voltage VCO tuning output
- 4 PNP ports
- 3 NPN ports
- 1 NPN port/ADC input
- Internal LOW/MID/HIGH band switch
- Lock-in flag
- Programmable reference divider ratio (24, 64, 80, 128)
- Programmable charge pump current

### **Application**

- The IC is suitable for PAL and NTSC tuners in TV- and VCR-sets or set-top receivers for analog TV and **Digital Video Broadcasting**.
- The AGC stage makes the tuner AGC independent of the Video-IF AGC.

### **Ordering Information**

Type	Ordering Code	Package
TUA6030	Q67037-A1146 (tape and reel)	P-TSSOP-38
TUA6032	Q67037-Axxxx (tape and reel)	P-TSSOP-38

# 1

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# 2 Product Description

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## 2.1 Overview

The **TUA6030, TUA6032** devices combine a mixer-oscillator block with a digitally programmable phase locked loop (PLL) for use in TV and VCR tuners.

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 IF amplifier, a reference voltage, and a band switch.

The PLL block with four independently selectable 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 or 166.7 kHz. The tuning process is controlled by a microprocessor via an I<sup>2</sup>C bus. The device has 8 output ports, one of them (P6) can also be used as ADC input port. 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.

## 2.2 Features

### General

- Suitable for PAL/NTSC and Digital Video Broadcasting
- Wideband AGC detector for internal tuner AGC
  - 5 programmable take-over points
  - 2 programmable time constants
- Full ESD protection

### 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

### IF-Amplifier

- IF preamplifier with symmetrical 75  $\Omega$  output impedance able to drive a SAW filter (500  $\Omega$ //40 pF)

### PLL

- 4 independent I<sup>2</sup>C addresses
- I<sup>2</sup>C bus protocol compatible with 3.3 V and 5V micro-controllers up to 400 kHz



- Short lock-in time
- High voltage VCO tuning output
- 4 PNP ports
- 3 NPN ports
- 1 NPN port/ADC input
- Internal LOW/MID/HIGH band switch
- Lock-in flag
- Programmable reference divider ratio (24, 64, 80, 128)
- Programmable charge pump current

## 2.3 Application

- The IC is suitable for PAL and NTSC tuners in TV- and VCR-sets or cable set-top receivers for analog TV and Digital Video Broadcasting.
- The AGC stage makes the tuner AGC independent of the Video-IF AGC.

Recommended band limits in MHz:

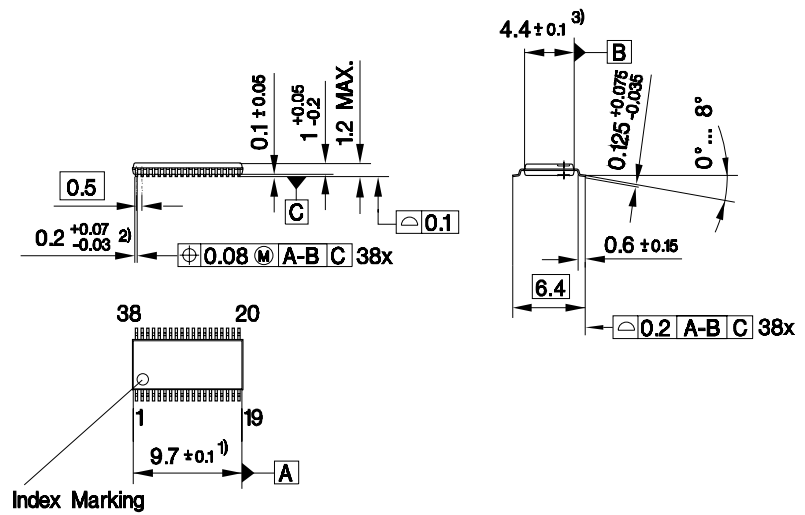
Table 2-1 NTSC tuners				
Band	RF input		Oscillator	
	min	max	min	max
LOW	55.25	127.25	101	173
MID	133.25	361.25	179	407
HIGH	367.25	801.25	413	847

Table 2-2 PAL tuners				
Band	RF input		Oscillator	
	min	max	min	max
LOW	44.25	154.25	83.15	193.15
MID	161.25	439.25	200.15	478.15
HIGH	447.25	863.25	486.15	902.15

Note: Tuning margin of  $\pm 3$  MHz not included.

## 2.4 Package Outlines

P-TSSOP-38



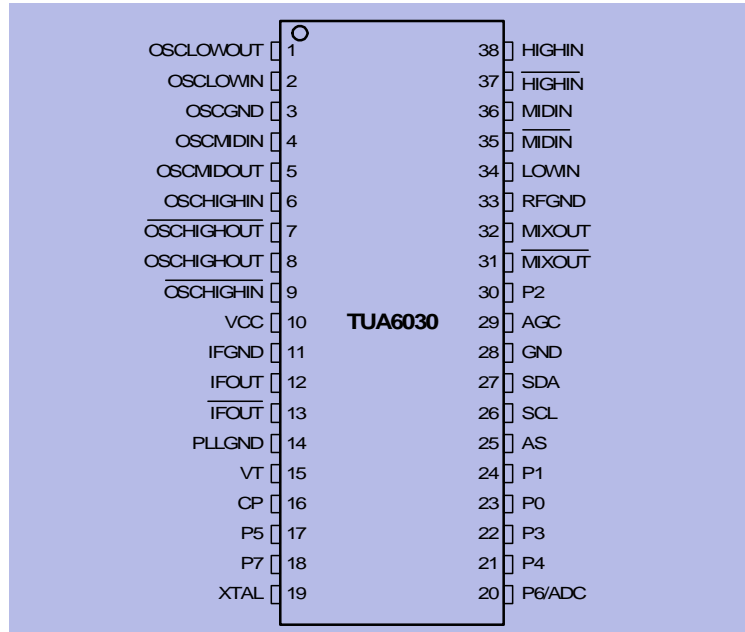
- 1) Does not include plastic or metal protrusion of 0.15 max. per side
- 2) Does not include dambar protrusion of 0.08 max. per side
- 3) Does not include plastic or metal protrusion of 0.25 max. per side

# 3 Functional Description

## Contents of this Chapter

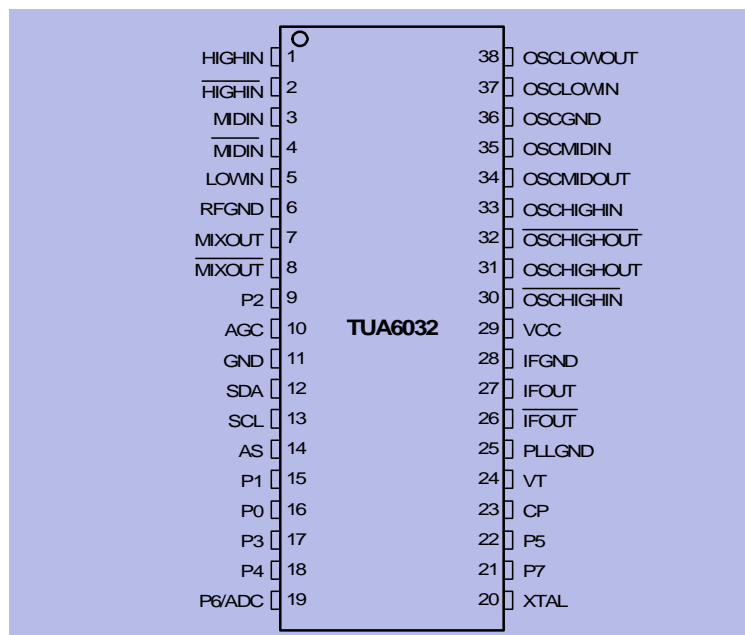
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### 3.1 Pin Configuration



TUA6030 Pin\_config

Figure 3-1 Pin Configuration TUA6030



TUA6032 Pin\_config

Figure 3-2 Pin Configuration TUA6032

### 3.2 Pin Definition and Function

Remark: First pin number refers to TUA6030, second to TUA6032

Table 3-1 Pin Definition and Function

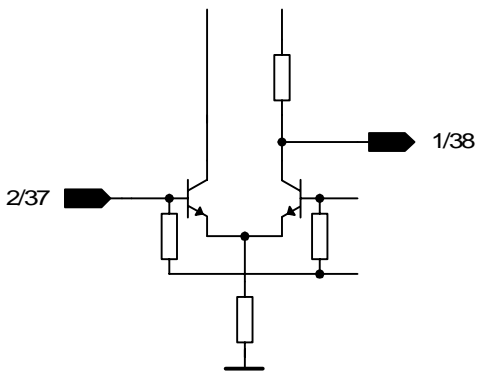
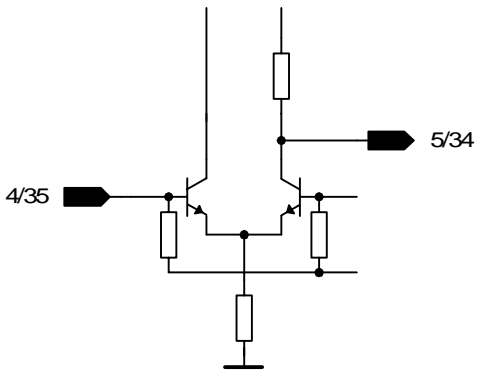
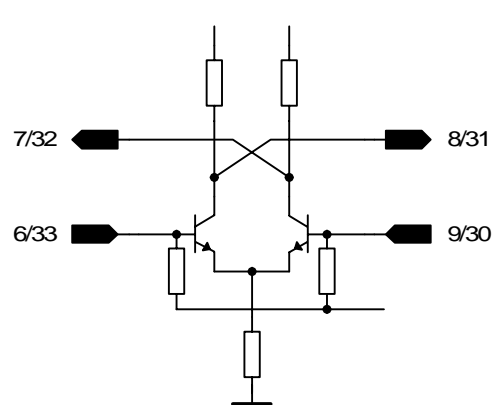
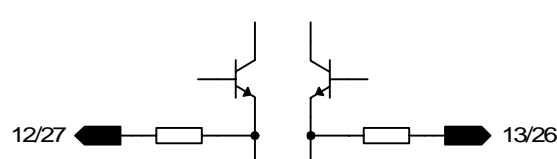
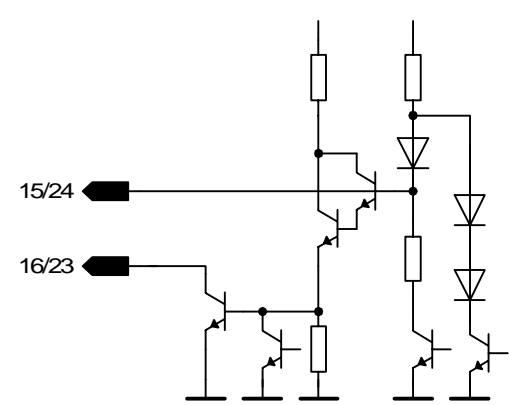
Pin No.	Symbol	Equivalent I/O-Schematic	Average DC voltage		
			LOW	MID	HIGH
1/38	OSCLOWOUT		2.2 V		
2/37	OSCLOWIN		1.5 V		
3/36	OSCGND	oscillator ground	0.0 V	0.0 V	0.0 V
4/35	OSCMIDIN			1.5 V	
5/34	OSCMIDOUT			2.2 V	

Table 3-1 Pin Definition and Function (continued)

Pin No.	Symbol	Equivalent I/O-Schematic	Average DC voltage		
			LOW	MID	HIGH
6/33	OSCHIGHIN				1.8 V
7/32	$\overline{\text{OSCHIGOUT}}$				2.2 V
8/31	OSCHIGOUT				2.2 V
9/30	$\overline{\text{OSCHIGHIN}}$				1.8 V
10/29	VCC	supply voltage	5.0 V	5.0 V	5.0 V
11/28	IFGND	IF ground	0.0 V	0.0 V	0.0 V
12/27	IFOUT		2.1 V	2.1 V	2.1 V
13/26	$\overline{\text{IFOUT}}$		2.1 V	2.1 V	2.1 V
14/25	PLLGND	PLL ground	0.0 V	0.0 V	0.0 V
15/24	VT		VT	VT	VT
16/23	CP		1.9 V	1.9 V	1.9 V

**Table 3-1 Pin Definition and Function (continued)**

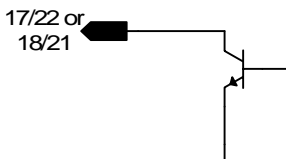

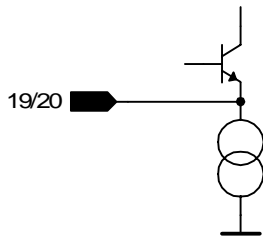
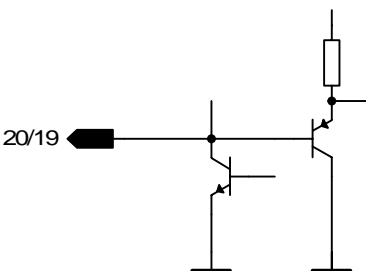
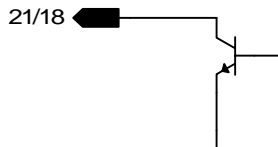
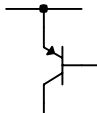
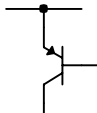

Pin No.	Symbol	Equivalent I/O-Schematic	Average DC voltage		
			LOW	MID	HIGH
17/22	P5		5 V or $V_{CE}$	5 V or $V_{CE}$	5 V or $V_{CE}$
18/21	P7		5 V or $V_{CE}$	5 V or $V_{CE}$	5 V or $V_{CE}$
19/20	XTAL		3.3 V	3.3 V	3.3 V
20/19	P6/ADC		5 V or $V_{CE}$	5 V or $V_{CE}$	5 V or $V_{CE}$
21/18	P4		5 V or $V_{CE}$	5 V or $V_{CE}$	5 V or $V_{CE}$
22/17	P3		n.a.	n.a.	0 V or $V_{CC} - V_{CE}$
23/16	P0		$V_{CC} - V_{CE}$	n.a.	n.a.
24/15	P1		n.a.	$V_{CC} - V_{CE}$	n.a.

Table 3-1 Pin Definition and Function (continued)

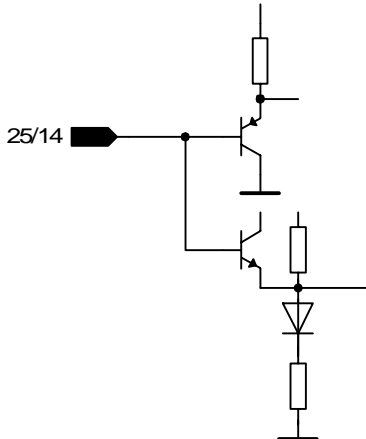
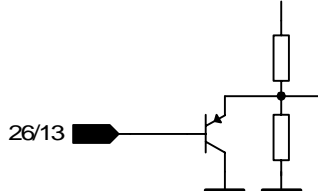
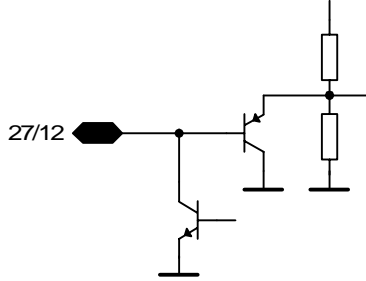
Pin No.	Symbol	Equivalent I/O-Schematic	Average DC voltage		
			LOW	MID	HIGH
25/14	AS		$V_{AS}$	$V_{AS}$	$V_{AS}$
26/13	SCL		n.a.	n.a.	n.a.
27/12	SDA		n.a.	n.a.	n.a.
28/11	GND	ground	0.0	0.0	0.0



Table 3-1 Pin Definition and Function (continued)

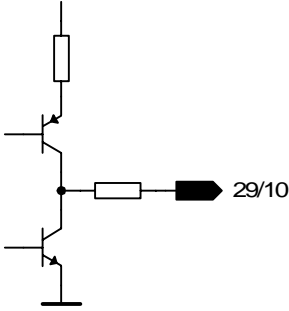
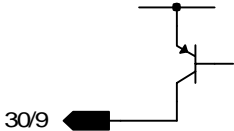
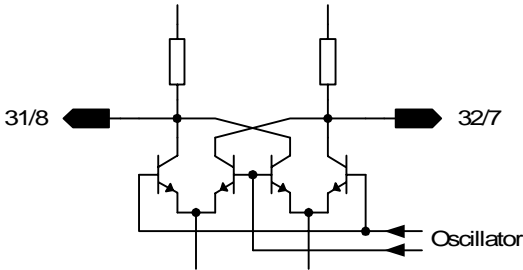
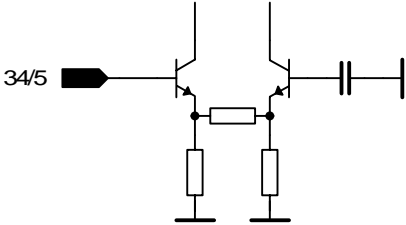
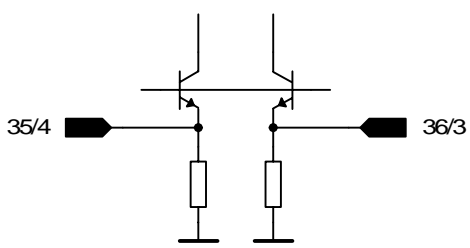
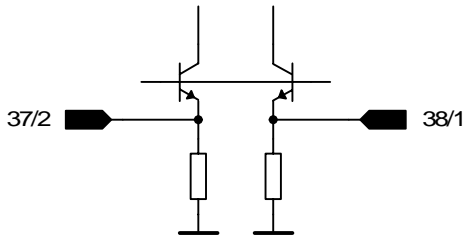
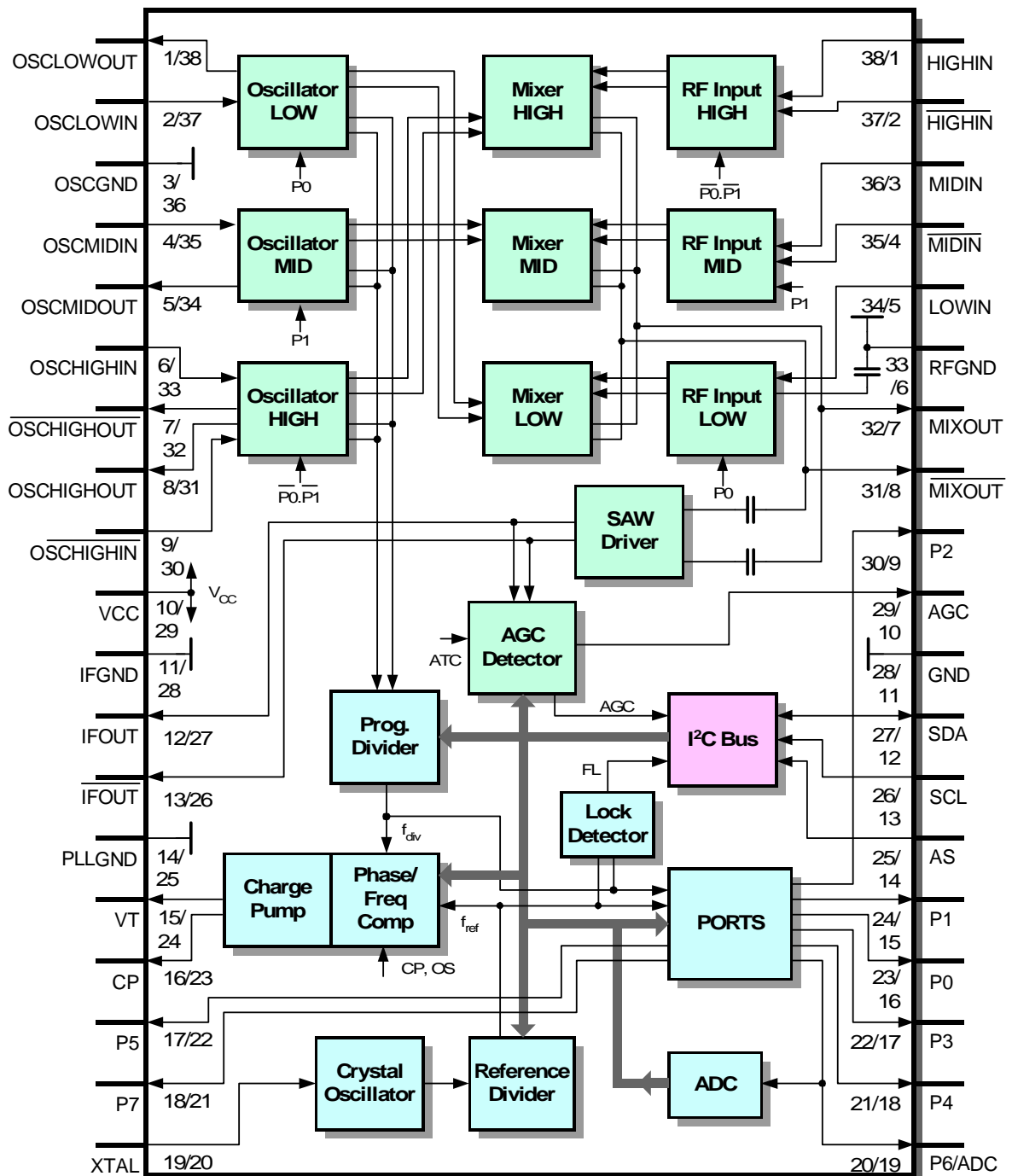
Pin No.	Symbol	Equivalent I/O-Schematic	Average DC voltage		
			LOW	MID	HIGH
29/10	AGC		3.0 V	3.0 V	3.0 V
30/9	P2		n.a.	n.a.	0 V or $V_{CC} - V_{CE}$
31/8	MIXOUT		4.0 V	4.0 V	4.0 V
32/7	MIXOUT		4.0 V	4.0 V	4.0 V
33/6	RFGND	IF ground	0.0 V	0.0 V	0.0 V
34/5	LOWIN		1.9 V		

Table 3-1 Pin Definition and Function (continued)

Pin No.	Symbol	Equivalent I/O-Schematic	Average DC voltage		
			LOW	MID	HIGH
35/4	MIDIN			0.75 V	
36/3	MIDIN			0.75 V	
37/2	HIGHIN				0.75 V
38/1	HIGHIN				0.75 V

### 3.3 Block Diagram

Remark: First pin number refers to TUA6030, second to TUA6032



TUA6030\_1 BlockDiag

Figure 3-3 Block Diagram

## 3.4 Circuit Description

### 3.4.1 Mixer-Oscillator block

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 IF amplifier, 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 which is filtered out at the balanced mixer output pair by means of a parallel tuned circuit. The following IF amplifier is capacitively coupled to the mixer outputs and 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  $f_{ref} = 31.25, 50, 62.5$  or  $166.7$  kHz. This frequency is derived from an unbalanced, low-impedance 4 MHz crystal oscillator (pin XTAL) divided by 128, 80, 64 or 24. The reference frequencies will be different with a quartz other than 4 MHz.

The phase detector has two outputs which drive two 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 VT and external RC circuitry). The charge pump output is also switched into the high-impedance state if the control bits  $T2, T1, T0 = 0, 1, 0$ . 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. VT 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 bit CP the pump current can be switched between two values by software. This programmability permits alteration of the control response of the PLL in the locked-in state. In this way different VCO gains can be compensated, for example.

The software controlled ports P0 to P7 are general purpose open-collector outputs. The test bits T2, T1, T0 = 1, 0, 0 switch the test signals  $f_{div}$  (divided input signal) and  $f_{ref}$  (i.e. 4 MHz / 64) to P4 and P5 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 ([Chapter 4](#)). 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 AGC

The wide-band AGC stage detects the level of the IF output signal and generates an AGC voltage for gain control of the tuner input transistors. The AGC take-over and the time constant are selectable by the I<sup>2</sup>C bus.

### 3.4.4 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 5-4 Bit Allocation Read / Write on page 39](#)) 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 5-7 Test modes on page 40](#)).

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 5-6 Address selection on page 40](#)).

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 3.2 V. It will be reset at the end of a READ operation.

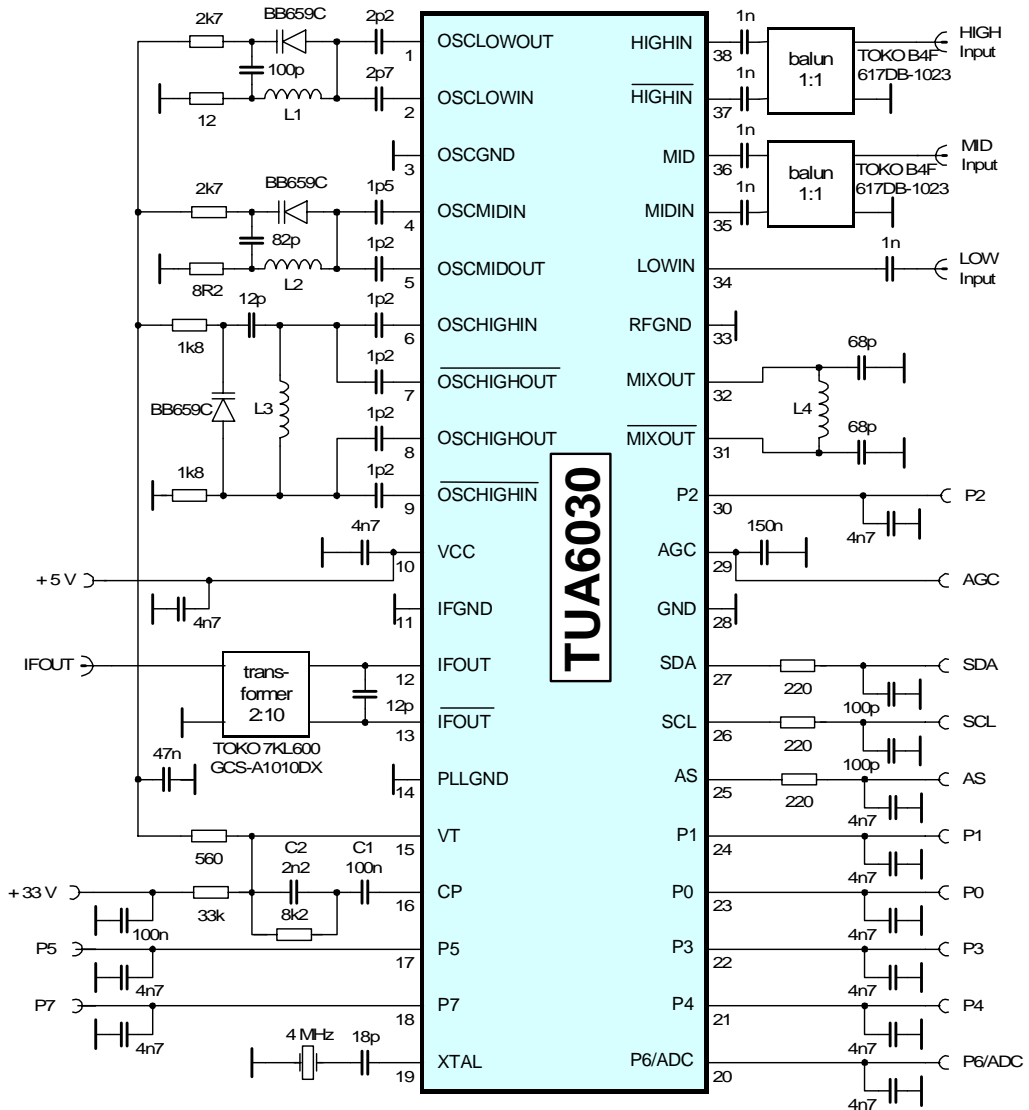
# 4 Applications

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### 4.1 Circuits

Remark: Pinning refers to TUA6030



App Circuit Ntsc

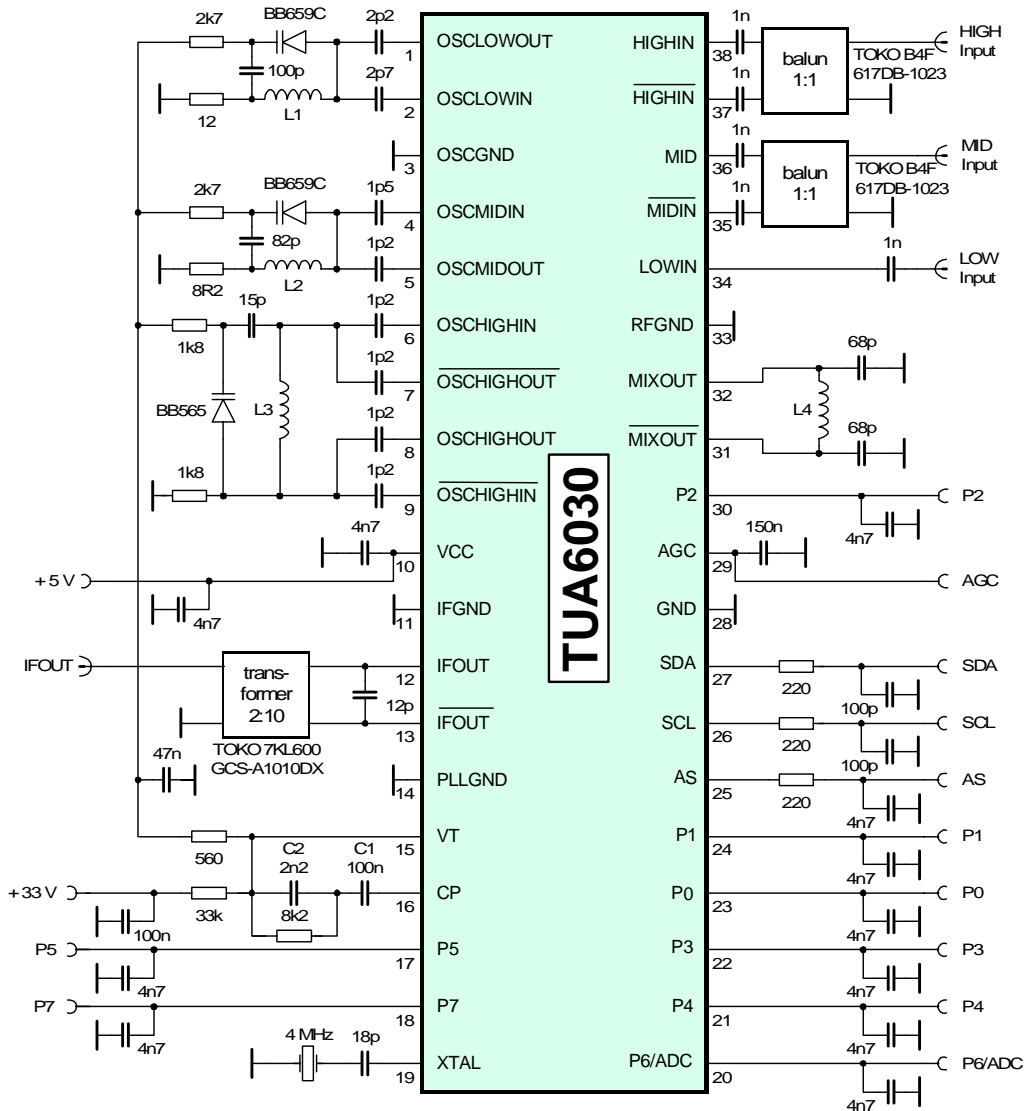
Figure 4-1 Application Circuit for NTSC

Recommended band limits in MHz				
	RF input		Oscillator	
	min	max	min	max
LOW	55.25	127.25	101	173
MID	133.25	361.25	179	407
HIGH	367.25	801.25	413	847

	Coils		
	turns	∅	wire ∅
L1	8.5	3.2 mm	0.5 mm
L2	3.5	2.5 mm	0.5 mm
L3	1.5	2.4 mm	0.5 mm
L4	12.5	3.5 mm	0.3 mm



Remark: Pinning refers to TUA6030



App Circuit PAL

Figure 4-2 Application Circuit for PAL

Recommended band limits in MHz				
	RF input		Oscillator	
	min	max	min	max
LOW	44.25	154.25	83.15	193.15
MID	161.25	439.25	200.15	478.15
HIGH	447.25	863.25	486.15	902.15

Coils			
	turns	∅	wire ∅
L1	8.5	3.2 mm	0.5 mm
L2	2.5	3 mm	0.5 mm
L3	1.5	2.4 mm	0.5 mm
L4	14.5	4 mm	0.3 mm

# 5 Reference

## Contents of this Chapter

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## 5.1 Electrical Data

### 5.1.1 Absolute Maximum Ratings



#### WARNING

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

**Table 5-1 Absolute Maximum Ratings, ambient temperature  $T_{AMB} = -10^{\circ}\text{C} \dots T_{Amax}$**

Parameter <sup>1)</sup>	Symbol	Limit Values		Unit	Remarks
		min	max		
Supply voltage	$V_{CC}$	-0.3	6	V	
Ambient temperature	$T_A$	-10	$T_{Amax}$ 2).	$^{\circ}\text{C}$	
Storage temperature	$T_{Stg}$	-40	+125	$^{\circ}\text{C}$	
Junction temperature	$T_J$		+125	$^{\circ}\text{C}$	
Temperature difference junction to case <sup>3)</sup>	$T_{JC}$		2	K	
<b>PLL</b>					
CP	$V_{CP}$	-0.3	3	V	
	$I_{CP}$		1	mA	
Crystal oscillator pin XTAL	$V_Q$		6	V	
	$I_Q$	-5		mA	
Bus input/output SDA	$V_{SDA}$	-0.3	6	V	
Bus output current SDA	$I_{SDA(L)}$		10	mA	open collector
Bus input SCL	$V_{SCL}$	-0.3	6	V	
Chip address switch AS	$V_{AS}$	-0.3	6	V	
VCO tuning output (loop filter)	$V_{VT}$	-0.3	35	V	

**Table 5-1 Absolute Maximum Ratings, ambient temperature  $T_{AMB} = -10^{\circ}\text{C} \dots +85^{\circ}\text{C}$  (continued)**

Parameter 1.)	Symbol	Limit Values		Unit	Remarks
		min	max		
NPN port output voltage	$V_{P4, 5, 7}$	-0.3	6	V	open collector
NPN port output current	$I_{P4, 5, 7(L)}$	-1	10	mA	open collector, $t_{max} = 0.1$ sec. at 5.5 V
P6/ADC input/output voltage	$V_{P6/ADC}$	-0.3	6	V	
NPN port output current	$I_{P6/ADC(L)}$	-1	10	mA	open collector, $t_{max} = 0.1$ sec. at 5.5 V
PNP port output voltage	$V_{P0, 1, 2, 3}$	-0.3	6	V	open collector
PNP port output current	$I_{P1(L)}$	+1	-25	mA	open collector, $t_{max} = 0.1$ sec. at 5.5 V
PNP port output current	$I_{P0(L)}$	+1	-10	mA	open collector, $t_{max} = 0.1$ sec. at 5.5 V
PNP port output current	$I_{P2, 3(L)}$	+1	-5	mA	open collector, $t_{max} = 0.1$ sec. at 5.5 V
Total port output current of NPN ports	$\Sigma I_{P(L)}$		40	mA	$t_{max} = 0.1$ sec. at 5.5 V
Total port output current of PNP ports	$\Sigma I_{P(L)}$		-40	mA	$t_{max} = 0.1$ sec. at 5.5 V
<b>Mixer-Oscillator</b>					
Mix inputs LOW band	$V_{LOW}$	-0.3	3	V	
Mix inputs MID/HIGH band	$V_{MID/HIGH}$		2	V	
	$I_{MID/HIGH}$	-5	6	mA	
VCO base voltage	$V_B$	-0.3	3	V	LOW, MID and HIGH band oscillators
VCO collector voltage	$V_C$		6	V	LOW, MID and HIGH band oscillators
ESD-Protection 4).					
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). The maximum ambient temperature depends on the mounting conditions of the package. Any application mounting must guarantee not to exceed the maximum junction temperature of 125 °C. As reference the temperature difference junction to case is given.

3). Referred to top center of package.

4). According to EIA/JESD22-A114-B (HBM in-circuit test), as a single device in-circuit contact discharge test.

## 5.1.2 Operating Range

Within the operational range the IC operates as described in the circuit description. The AC / DC characteristic limits are not guaranteed.

**Table 5-2 Operating Range**

Parameter	Symbol	Limit Values		Unit	Test Conditions	L	Item
		min	max				
Supply voltage	$V_{CC}$	+4.5	+5.5	V			
Programmable divider factor	N	256	32767				
LOW mixer input frequency range	$f_{MIXV}$	30	200	MHz			
MID and HIGH band mixer input frequency range	$f_{MIXU}$	130	900	MHz			
LOW oscillator frequency range	$f_{OH}$	65	250	MHz			
MID band oscillator frequency range	$f_{OU}$	165	530	MHz			
HIGH band oscillator frequency range	$f_{OU}$	400	950	MHz			
Ambient temperature	$T_{AMB}$	-10	$T_{Amax}$ 1).	°C			

1). see 5.1.1 Absolute Maximum Ratings on page 27

### 5.1.3 AC/DC Characteristics

**Table 5-3 AC/DC Characteristics with  $T_{AMB} = 25\text{ }^{\circ}\text{C}$ ,  $V_{CC} = 5\text{ V}$** 

	Symbol	Limit Values			Unit	Test Conditions	L	Item
		min	typ	max				
<b>Supply</b>								
Supply voltage	$V_{CC}$	4.5	5	5.5	V			
Current consumption	$I_{VCC}$		73		mA	LOW band		
	$I_{VCC}$		75		mA	MID band		
	$I_{VCC}$	-	66		mA	HIGH band		
<b>Digital Part</b>								
<b>PLL</b>								
<b>Crystal oscillator connections XTAL</b>								
Crystal frequency	$f_{XTAL}$	3.2	4.0	4.48	MHz	series resonance		
Crystal resistance	$R_Q$	25		300	$\Omega$	series resonance		
Input impedance	$Z_Q$	-1000	-1200		$\Omega$	$f_{XTAL} = 4\text{ MHz}$		
<b>Charge pump output CP</b>								
High-level output current	$I_{CPH}$		$\pm 280$		$\mu\text{A}$	$CP = 1, V_{CP} = 2\text{ V}$		
Low-level output current	$I_{CPL}$		$\pm 60$		$\mu\text{A}$	$CP = 0, V_{CP} = 2\text{ V}$		
Tristate current	$I_{CPZ}$		+1		nA	$T2, T1, T0 = 0, 1, 0,$ $V_{CP} = 2\text{ V}$		
Output voltage	$V_{CP}$	1.0		2.5	V	loop closed		
<b>Tuning voltage output VT (open collector)</b>								
Leakage current	$I_{TH}$			10	$\mu\text{A}$	$V_{TH} = 33\text{ V}, OS = 1$		
Output voltage when the loop is closed, (test mode in normal operation)	$V_{TL}$	0.4		32.7	V	$OS=0, R_{Load} = 33\text{ k}\Omega,$ tuning supply = 33 V		
<b>I<sup>2</sup>C-Bus</b>								
<b>Bus inputs SCL, SDA</b>								
High-level input voltage	$V_{IH}$	2.3		5.5	V			
Low-level input voltage	$V_{IL}$	0		1.5	V			
High-level input current	$I_{IH}$			10	$\mu\text{A}$	$V_{bus} = 5.5\text{ V},$ $V_{CC} = 0\text{ V}$		
	$I_{IH}$			10	$\mu\text{A}$	$V_{bus} = 5.5\text{ V},$ $V_{CC} = 5.5\text{ V}$		

**Table 5-3 AC/DC Characteristics with  $T_{AMB} = 25\text{ }^{\circ}\text{C}$ ,  $V_{CC} = 5\text{ V}$  (continued)**

	Symbol	Limit Values			Unit	Test Conditions	L	Item
		min	typ	max				
Low-level input current	$I_{IL}$			10	$\mu\text{A}$	$V_{bus} = 1.5\text{ V}$ , $V_{CC} = 0\text{ V}$		
	$I_{IL}$	-10			$\mu\text{A}$	$V_{bus} = 0\text{ V}$ , $V_{CC} = 5.5\text{ V}$		
<b>Bus output SDA (open collector)</b>								
Leakage current	$I_{OH}$			10	$\mu\text{A}$	$V_{OH} = 5.5\text{ V}$		
Low-level output voltage	$V_{OL}$			0.4	V	$I_{OL} = 3\text{ mA}$		
Low-level output voltage	$V_{OL}$			0.6	V	$I_{OL} = 6\text{ mA}$ at 400 kHz		
<b>Edge speed SCL,SDA</b>								
Rise time	$t_r$			300	ns			
Fall time	$t_f$			300	ns			
<b>Clock timing SCL</b>								
Frequency	$f_{SCL}$	0	100	400	kHz			
High pulse width	$t_H$	0.6			$\mu\text{s}$			
Low pulse width	$t_L$	1.3			$\mu\text{s}$			
<b>Start condition</b>								
Set-up time	$t_{susta}$	0.6			$\mu\text{s}$			
Hold time	$t_{hsta}$	0.6			$\mu\text{s}$			
<b>Stop condition</b>								
Set up time	$t_{susto}$	0.6			$\mu\text{s}$			
Bus free	$t_{buf}$	1.3			$\mu\text{s}$			
<b>Data transfer</b>								
Set-up time	$t_{sudat}$	0.1			$\mu\text{s}$			
Hold time	$t_{hdat}$	0			$\mu\text{s}$			
Input hysteresis SCL, SDA	$V_{hys}$		200		mV			
Pulse width of spikes which are suppressed	$t_{sp}$	0		50	ns			
Capacitive load for each bus line	$C_L$			400	pF			
<b>PNP port outputs P0, P1, P2, P3 (open collector)</b>								
Output leakage current	$I_{POH0to3}$			-10	$\mu\text{A}$	$V_{CC} = 5.5\text{ V}$		
Output saturation voltage port 0	$V_{PL0}$		0.25	0.4	V	$I_{POL0} = 10\text{ mA}$		
Output saturation voltage port 1	$V_{PL1}$		0.25	0.4	V	$I_{POL1} = 15\text{ mA}$		

**Table 5-3 AC/DC Characteristics with  $T_{AMB} = 25\text{ }^{\circ}\text{C}$ ,  $V_{CC} = 5\text{V}$  (continued)**

	Symbol	Limit Values			Unit	Test Conditions	L	Item
		min	typ	max				
Output saturation voltage ports 2, 3	$V_{PL2,3}$		0.25	0.4	V	$I_{POL2,3} = 5\text{ mA}$		
<b>NPN port outputs P4, P5, P6, P7 (open collector)</b>								
Output leakage current	$I_{POH4to7}$			10	$\mu\text{A}$	$V_{CC} = 5.5$ , $V_{Pn4to7} = 6\text{ V}$		
Output saturation voltage	$V_{PL04to7}$		0.25	0.4	V	$I_{POL4to7} = 5\text{ mA}$		
<b>ADC input</b>								
ADC input voltage	$V_{ADC}$	0		5.5	V			
High-level input current	$I_{ADCH}$			10	$\mu\text{A}$			
Low-level input current	$I_{ADCL}$	-10			$\mu\text{A}$			
<b>Address selection input AS</b>								
High-level input current	$I_{ASH}$			50	$\mu\text{A}$	$V_{ASH} = 5.5\text{ V}$		
Low-level input current	$I_{ASL}$	-50			$\mu\text{A}$	$V_{ASL} = 0\text{ V}$		
<b>Analog Part</b>								
<b>LOW band mixer mode (P0 = 1, P1 = 0, including IF amplifier)</b>								
RF frequency	$f_{RF}$	44.25		170.25	MHz	picture carrier <sup>1)</sup> .		
Voltage gain	$G_V$	23.5	26	28.5	dB	$f_{RF} = 44.25\text{ MHz}$ , <a href="#">see 5.5.1 on page 46</a>		
	$G_V$	23.5	26	28.5	dB	$f_{RF} = 170.25\text{ MHz}$ , <a href="#">see 5.5.1 on page 46</a>		
Noise figure	NF		8	10	dB	$f_{RF} = 50\text{ MHz}$ , <a href="#">see 5.5.4 on page 47</a> , <a href="#">see 5.5.3 on page 47</a>		
Output voltage causing 0.3% of crossmodulation in channel	$V_O$	108	111		dB $\mu\text{V}$	$f_{RF} = 44.25\text{ MHz}$ , <a href="#">see 5.5.6 on page 48</a>		
	$V_O$	108	111		dB $\mu\text{V}$	$f_{RF} = 170.25\text{ MHz}$ , <a href="#">see 5.5.6 on page 48</a>		
Output voltage causing 1.1 kHz incidental FM	$V_O$	108	111		dB $\mu\text{V}$	$f_{RF} = 44.25\text{ MHz}$ <sup>2)</sup> .		
	$V_O$	108	111		dB $\mu\text{V}$	$f_{RF} = 170.25\text{ MHz}$ <sup>2)</sup> .		
Local oscillator FM caused by I <sup>2</sup> C communication	$FM_{I2C}$			2.12	kHz	$f_{RF} = 170.25\text{ MHz}$ <sup>3)</sup> .		
750 Hz Pulling	$V_i$	88			dB $\mu\text{V}$	$f_{RF} = 154.25\text{ MHz}$ <sup>4)</sup> .		
Channel S02 beat	$INT_{S02}$	57	60		dBc	$V_{RFpix} = 115\text{ dB}\mu\text{V}$ at IF output <sup>5)</sup> .		



**Table 5-3 AC/DC Characteristics with  $T_{AMB} = 25\text{ }^{\circ}\text{C}$ ,  $V_{CC} = 5\text{V}$  (continued)**

	Symbol	Limit Values			Unit	Test Conditions	L	Item
		min	typ	max				
Channel A-5 beat	$INT_{A-5}$	57	60		dBc	$V_{RFpix} = 115\text{ dB}\mu\text{V}$ at IF output <sup>6)</sup> .		
Channel CH6 color beat	$INT_{CH6}$	63	66		dBc	$V_{RFpix} = 80\text{ dB}\mu\text{V}$ $V_{RFsnd} = 80\text{ dB}\mu\text{V}$ <sup>7)</sup> .		
RF input level without lock-out	$V_i$			120	dB $\mu\text{V}$	<sup>8)</sup> .		
Input conductance	$g_i$		1		mS	$f_{RF} = 44.25\text{ MHz}$ , see 5.4.1 on page 43		
	$g_i$		1		mS	$f_{RF} = 170.25\text{ MHz}$ , see 5.4.1 on page 43		
Input capacitance	$C_{MixV}$		1		pF	$f_{RF} = 44.25$ to $170.25\text{ MHz}$ , see 5.4.1 on page 43		
<b>Mid band mixer mode (<math>P0 = 0</math>, <math>P1 = 1</math>, including IF amplifier)</b>								
RF frequency	$f_{RF}$	154.25		454.25		picture carrier <sup>1.)</sup>		
Voltage gain	$G_V$	33	36	39	dB	$f_{RF} = 154.25\text{ MHz}$ , see 5.5.2 on page 46		
	$G_V$	33	36	39	dB	$f_{RF} = 454.25\text{ MHz}$ , see 5.5.2 on page 46		
Noise figure (not corrected for image)	NF		6	8	dB	$f_{RF} = 154.25\text{ MHz}$ , see 5.5.5 on page 48		
	NF		6	8	dB	$f_{RF} = 300\text{ MHz}$ , see 5.5.5 on page 48		
Output voltage causing 0.3% of crossmodulation in channel	$V_O$	108	111		dB $\mu\text{V}$	$f_{RF} = 154.25\text{ MHz}$ , see 5.5.7 on page 49		
	$V_O$	108	111		dB $\mu\text{V}$	$f_{RF} = 454.25\text{ MHz}$ , see 5.5.7 on page 49		
Output voltage causing 1.1 kHz incidental FM	$V_O$	108	111		dB $\mu\text{V}$	$f_{RF} = 154.25\text{ MHz}$ <sup>2.)</sup>		
	$V_O$	108	111		dB $\mu\text{V}$	$f_{RF} = 454.25\text{ MHz}$ <sup>2.)</sup>		
Local oscillator FM caused by I <sup>2</sup> C communication	$FM_{I2C}$			2.12	kHz	$f_{RF} = 454.25\text{ MHz}$ <sup>3.)</sup>		
N+5 - 1 MHz pulling	N+5 - 1 MHz	77	80		dB $\mu\text{V}$	$f_{RFw} = 359.25\text{ MHz}$ , $f_{OSC} = 398.15\text{ MHz}$ , $f_{RFu} = 399.25\text{ MHz}$ <sup>9)</sup> .		

**Table 5-3 AC/DC Characteristics with  $T_{AMB} = 25\text{ }^{\circ}\text{C}$ ,  $V_{CC} = 5\text{V}$  (continued)**

	Symbol	Limit Values			Unit	Test Conditions	L	Item
		min	typ	max				
750 Hz Pulling	$V_i$	78			dB $\mu$ V	$f_{RF} = 439.25\text{ MHz}$ <sup>4.)</sup>		
RF input level without lock-out	$V_i$			120	dB $\mu$ V	8.)		
Input impedance $Z_i = (R_s + j\omega L_s)$	$R_s$		35		$\Omega$	$f_{RF} = 154.25.25\text{ MHz}$ , <a href="#">see 5.4.2 on page 43</a>		
	$R_s$		30		$\Omega$	$f_{RF} = 454.25\text{ MHz}$ , <a href="#">see 5.4.2 on page 43</a>		
	$L_s$		5		nH	$f_{RF} = 154.25.25\text{ MHz}$ , <a href="#">see 5.4.2 on page 43</a>		
	$L_s$		4.5		nH	$f_{RF} = 454.25\text{ MHz}$ , <a href="#">see 5.4.2 on page 43</a>		
<b>HIGH band mixer mode (<math>P_0 = 0</math>, <math>P_1 = 0</math>, including IF amplifier)</b>								
RF frequency	$f_{RF}$	399.25		863.25		picture carrier <sup>1.)</sup>		
Voltage gain	$G_V$	33	36	39	dB	$f_{RF} = 407.25\text{ MHz}$ , <a href="#">see 5.5.2 on page 46</a>		
	$G_V$	33	36	39	dB	$f_{RF} = 863.25\text{ MHz}$ , <a href="#">see 5.5.2 on page 46</a>		
Noise figure (not corrected for image)	NF		6	8	dB	$f_{RF} = 407.25\text{ MHz}$ , <a href="#">see 5.5.5 on page 48</a>		
	NF		7	9	dB	$f_{RF} = 863.25\text{ MHz}$ , <a href="#">see 5.5.5 on page 48</a>		
Output voltage causing 0.3% of crossmodulation in channel	$V_O$	108	111		dB $\mu$ V	$f_{RF} = 407.25\text{ MHz}$ , <a href="#">see 5.5.7 on page 49</a>		
	$V_O$	108	111		dB $\mu$ V	$f_{RF} = 863.25\text{ MHz}$ , <a href="#">see 5.5.7 on page 49</a>		
Output voltage causing 1.1 kHz incidental FM	$V_O$	108	111		dB $\mu$ V	$f_{RF} = 407.25\text{ MHz}$ <sup>2.)</sup>		
	$V_O$	108	111		dB $\mu$ V	$f_{RF} = 454.25\text{ MHz}$ <sup>2.)</sup>		
Local oscillator FM caused by I <sup>2</sup> C communication	$FM_{I2C}$			2.12	kHz	$f_{RF} = 863.25\text{ MHz}$ <sup>3.)</sup>		
N+5 - 1 MHz pulling	N+5 - 1 MHz	77	80		dB $\mu$ V	$f_{RFw} = 823.25\text{ MHz}$ , $f_{OSC} = 862.15\text{ MHz}$ , $f_{RFu} = 862.25\text{ MHz}$ <sup>9.)</sup>		
750 Hz Pulling	$V_i$	78			dB $\mu$ V	$f_{RF} = 855.25\text{ MHz}$ <sup>4.)</sup>		

**Table 5-3 AC/DC Characteristics with  $T_{AMB} = 25\text{ }^{\circ}\text{C}$ ,  $V_{CC} = 5\text{ V}$  (continued)**

	Symbol	Limit Values			Unit	Test Conditions	L	Item
		min	typ	max				
RF input level without lock-out	$V_i$			120	dB $\mu$ V	8.)		
Input impedance $Z_i = (R_s + j\omega L_s)$	$R_s$		35		$\Omega$	$f_{RF} = 407.25\text{ MHz}$ , see 5.4.3 on page 44		
	$R_s$		30		$\Omega$	$f_{RF} = 863.25\text{ MHz}$ , see 5.4.3 on page 44		
	$L_s$		5		nH	$f_{RF} = 407.25\text{ MHz}$ , see 5.4.3 on page 44		
	$L_s$		4.5		nH	$f_{RF} = 863.25\text{ MHz}$ , see 5.4.3 on page 44		
<b>LOW band oscillator, Chapter 4</b>								
Oscillator frequency	$f_{OSC}$	80		210	MHz	10.)		
Oscillator frequency shift	$\Delta f_{OSC(V)}$		20	70	kHz	$\Delta V_{CC} = 5\% \text{ }^{11)}$		
	$\Delta f_{OSC(V)}$		110		kHz	$\Delta V_{CC} = 10\% \text{ }^{11)}$		
Oscillator frequency drift	$\Delta f_{OSC(T)}$		300	500	kHz	$\Delta T = 25\text{ }^{\circ}\text{C}$ , with compensation 12.)		
Oscillator frequency drift	$\Delta f_{OSC(t)}$		150	250	kHz	5 s to 15 min after switch on <sup>13)</sup>		
Phase noise, carrier to noise sideband	$\Phi_{OSC}$	88	92		dBc/ Hz	$\pm 10\text{ kHz}$ frequency offset, worst case in frequency range		
Ripple susceptibility of $V_P$	RSC	15	20		mV	$4.75\text{ V} < V_P < 5.25\text{ V}$ , worst case in fre- quency range, ripple frequency 500 kHz 14.)		
<b>MID band oscillator, Chapter 4</b>								
Oscillator frequency	$f_{OSC}$	201		493	MHz	10.)		
Oscillator frequency shift	$\Delta f_{OSC(V)}$		20	70	kHz	$\Delta V_{CC} = 5\% \text{ }^{11)}$		
	$\Delta f_{OSC(V)}$		110		kHz	$\Delta V_{CC} = 10\% \text{ }^{11)}$		
Oscillator frequency drift	$\Delta f_{OSC(T)}$		500	750	kHz	$\Delta T = 25\text{ }^{\circ}\text{C}$ ; with com- pensation <sup>12)</sup>		
Oscillator frequency drift	$\Delta f_{OSC(t)}$		250	500	kHz	5 s to 15 min after switch on <sup>13)</sup>		
Phase noise, carrier to noise sideband	$\Phi_{OSC}$	86	92		dBc/ Hz	$\pm 10\text{ kHz}$ frequency offset, worst case in frequency range		

**Table 5-3 AC/DC Characteristics with  $T_{AMB} = 25\text{ }^{\circ}\text{C}$ ,  $V_{CC} = 5\text{V}$  (continued)**

	Symbol	Limit Values			Unit	Test Conditions	L	Item
		min	typ	max				
Ripple susceptibility of $V_P$	RSC	15	20		mV	4.75 < $V_P$ < 5.25 V, worst case in frequency range, ripple frequency 500 kHz 14.)		
<b>HIGH band oscillator, Chapter 4</b>								
Oscillator frequency	$f_{OSC}$	435		905	MHz	10.)		
Oscillator frequency shift	$\Delta f_{OSC(V)}$		20	70	kHz	$\Delta V_{CC} = 5\%$ 11.)		
	$\Delta f_{OSC(V)}$		300		kHz	$\Delta V_{CC} = 10\%$ 11.)		
Oscillator frequency drift	$\Delta f_{OSC(T)}$		600	1000	kHz	$\Delta T = 25\text{ }^{\circ}\text{C}$ ; with compensation 12.)		
Oscillator frequency drift	$\Delta f_{OSC(t)}$		250	500	kHz	5 s to 15 min after switch on 13.)		
Phase noise, carrier to noise sideband	$\Phi_{OSC}$	86	90		dBc/Hz	$\pm 10$ kHz frequency offset, worst case in frequency range		
Ripple susceptibility of $V_P$	RSC	15	20		mV	4.75 < $V_P$ < 5.25 V, worst case in frequency range, ripple frequency 500 kHz 14.)		
<b>IF amplifier</b>								
Mixer output impedance $Y_o = G_s + j\omega C_s$	$G_p$		3		mS	at 36 MHz, see 5.4.4 on page 44		
	$C_p$		4		pF	at 36 MHz, see 5.4.4 on page 44		
IF amplifier output impedance $Z_o = R_s + j\omega L_s$	$R_s$		65		$\Omega$	at 36 MHz, see 5.4.5 on page 45		
	$L_s$		20		nH	at 36 MHz, see 5.4.5 on page 45		
<b>Rejection at the IF outputs</b>								
Level of divider interferences in the IF signal	$INT_{DIV}$			20	dB $\mu$ V	15)., worst case		
Crystal oscillator interferences rejection	$INT_{XTAL}$	60	66		dBc	$V_{IF} = 100$ dB $\mu$ V, worst case in frequency range 16).		
Reference frequency rejection	$INT_{REF}$	60	66		dBc	$V_{IF} = 100$ dB $\mu$ V, worst case in frequency range 17).		
<b>AGC output</b>								
AGC take-over point	$AGC_{TOP}$	111	112	113	dB $\mu$ V	AL2, AL1, AL0 = 0, 1, 0		

**Table 5-3 AC/DC Characteristics with  $T_{AMB} = 25\text{ }^{\circ}\text{C}$ ,  $V_{CC} = 5V_C$  (continued)**

	Symbol	Limit Values			Unit	Test Conditions	L	Item
		min	typ	max				
Source current 1	$AGC_{fast}$	7.2	9.0	10.8	$\mu\text{A}$			
Source current 2	$AGC_{slow}$	185	220	264	nA			
Peak sink to ground	$AGC_{peak}$	80	100	120	$\mu\text{A}$			
AGC output voltage	$V_{AGCmax}$	3.3	3.5	3.7	V	maximum level		
AGC output voltage	$V_{AGCmin}$	0		0.25	V	minimum level		
RF voltage range to switch the AGC from active to inactive mode	$AGC_{SLIP}$			0.5	dB			
AGC output voltage	$AGC_{RML}$	0		2.9	V	AGC bit high or AGC active		
AGC output voltage	$AGC_{RMH}$	3	3.5	$V_{CC} - 0.5$ or 4	V	AGC bit low or AGC inactive		
AGC leakage current	$AGC_{LEAK}$	-50		50	nA	AL2, AL1, AL0 = 1,1,0 $0 < V_{AGC} < V_{CC}$		
AGC output voltage	$AGC_{OFF}$	3.3	3.5	$V_{CC} - 0.5$ or 4	V	AL2, AL1, AL0 = 1,1,1 AGC is disabled		

■ This value is only guaranteed in lab.

- 1). The RF frequency range is defined by the oscillator frequency range and the intermediate frequency (IF).
- 2). This is the level of the RF unwanted signal (50% amplitude modulated with 1kHz) that causes a 1.1 kHz FM modulation of the local oscillator and thus of the wanted signal;  $V_{wanted} = 100\text{ dB}\mu\text{V}$ ;  $f_{unwanted} = f_{wanted} + 5.5\text{ MHz}$ .
- 3). Local oscillator FM modulation resulting from I<sup>2</sup>C communication is measured at the IF output using a modulation analyser with a peak to peak detector ( $(P_+ + P_-)/2$ ) and a post detection filter 30 Hz - 200 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 1s.
- 4). This is the level of the RF signal (100% amplitude modulated with 11.89 kHz) that causes a 750 Hz frequency deviation on the oscillator signal producing sidebands 30 dB below the level of the oscillator signal.
- 5). Channel S02 beat is the interfering product of  $f_{RFpix}$ ,  $f_{IF}$  and  $f_{OSC}$  of channel S02,  $f_{BEAT} = 37.35\text{ MHz}$ . The possible mechanisms are  $f_{OSC} - 2 \times f_{IF}$  or  $2 \times f_{RFpix} - f_{OSC}$ .
- 6). Channel A-5 beat is the interfering product of  $f_{RFpix}$ ,  $f_{IF}$  and  $f_{OSC}$  of channel A-5;  $f_{BEAT} = 45.5\text{ MHz}$ . The possible mechanisms are:  $f_{OSC} - 2 \times f_{IF}$  or  $2 \times f_{RFpix} - f_{OSC}$ .
- 7). Channel 6 beat is the interfering product of  $f_{RFpix} + f_{RFsnd} - f_{OSC}$  of channel 6 at 42 MHz.
- 8). The IF output signal stays stable within the range of the  $f_{ref}$  step for a low level RF input up to 120 dB $\mu\text{V}$ .
- 9). N+5 -1 MHz is defined as the input level of channel N+5, at frequency 1 MHz lower, causing FM sidebands 30 dB below the wanted carrier.
- 10). Limits are related to the tank circuit used in the application board (Chapter 4). Frequency bands may be adjusted by the choice of external components.
- 11). The frequency shift is defined as a change in oscillator frequency when the supply voltage varies from  $V_{CC} = 5$  to 4.75 V (4.5 V) or from  $V_{CC} = 5$  to 5.25 V (5.5 V). The oscillator is free running during this measurement.
- 12). The frequency drift is defined as a change in oscillator frequency if the ambient temperature varies from  $T_{amb} = 25$  to 50  $^{\circ}\text{C}$  or from  $T_{amb} = 25$  to 0  $^{\circ}\text{C}$ . The oscillator is free running during this measurement.

13). The switch-on drift is defined as a change in oscillator frequency between 5 s and 15 min after switch-on. The oscillator is free running during this measurement.

14). The supply ripple susceptibility is measured in the application board (Chapter 4), using a spectrum analyser connected to the IF output. An unmodulated RF signal is applied to the test board RF input. A sinewave signal with a frequency of 500 kHz is superposed onto the supply voltage (see 5.5.8 on page 49). The amplitude of this ripple is adjusted to bring the 500 kHz sidebands around the IF carrier to a level of 53.5 dBc referred to the carrier.

15). 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. Divider interference is measured with the application board (Chapter 4). All ground pins are connected to a single ground plane under the IC. The LOWIN input must be left open (i.e. not connected to any load or cable). The MIDIN and HIGHIN inputs are connected to a hybrid. The measured level of divider interference are influenced by layout, grounding and port decoupling. The measurement results between various applications and the reference board could vary as much as 10 dB.

16). Crystal oscillator interference means the 4 MHz sidebands caused by the crystal oscillator. The rejection has to be greater than 60 dB for an IF output of 100 dB $\mu$ V.

17). The reference frequency rejection is the level of reference frequency sidebands (e.g. 62.5 kHz) related to the carrier. The rejection has to be greater than 60 dB for an IF output of 100 dB $\mu$ V.

## 5.2 Programming

**Table 5-4 Bit Allocation Read / Write**

Name	Byte	Bits								Ack
		MSB	bit6	bit5	bit4	bit3	bit2	bit1	LSB	
Write Data										
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	P7	P6	P5	P4	P3	P2	P1	P0	A
Auxiliary byte <sup>1)</sup>	AB	ATC	AL2	AL1	AL0	0	0	0	0	A
Read data										
Address byte	ADB	1	1	0	0	0	MA1	MA0	R/ W=1	A
Status byte	SB	POR	FL	1	1	AGC	A2	A1	A0	A

1). AB replaces BB when T2, T1, T0 = 0, 1, 1, see [Table 5-7 Test modes on page 40](#)

**Table 5-5 Description of Symbols**

Symbol	Description
A	Acknowledge
MA0, MA1	Address selection bits, see <a href="#">Table 5-6 Address selection on page 40</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 = 60 $\mu$ A bit = 1: charge pump current = 280 $\mu$ A (default)
T0, T1, T2	test bits, see <a href="#">Table 5-7 Test modes on page 40</a>
RSA, RSB	reference divider bits, see <a href="#">Table 5-8 Reference divider ratios on page 40</a>
OS	tuning amplifier control bit: bit = 0: enable $V_T$ bit = 1: disable $V_T$ (default)
P0, P1, P2, P3	PNP ports control bits bit = 0: Port is inactive, high impedance state (default) bit = 1: Port is active, $V_{OUT} = V_{CC} - V_{CESAT}$
P4, P5, P6, P7	NPN ports control bits bit = 0: Port is inactive, high impedance state (default) bit = 1: Port is active, $V_{OUT} = V_{CESAT}$
ATC	AGC time constant bit bit = 0: $I_{AGC} = 220\text{nA}$ ; $\Delta t = 2\text{s}$ with $C = 160\text{nF}$ (default) bit = 1: $I_{AGC} = 9\mu\text{A}$ ; $\Delta t = 50\text{ms}$ with $C = 160\text{nF}$

**Table 5-5 Description of Symbols**

AL0, AL1, AL2	AGC take-over point bits
POR	Power-on reset flag; POR =1 at power-on
FL	PLL lock flag bit = 1: loop is locked
AGC	internal AGC flag. AGC=1 when internal AGC is active (level below 3V)
A0, A1, A2	digital output of the 5-level ADC

**Table 5-6 Address selection**

Voltage at AS	MA1	MA0
(0 to 0.1) * V <sub>CC</sub>	0	0
open circuit	0	1
(0.4 to 0.6) * V <sub>CC</sub>	1	0
(0.9 to 1) * V <sub>CC</sub>	1	1

**Table 5-7 Test modes**

Mode	T2	T1	T0
Normal operation	0	0	0
Normal operation (default)	0	0	1
CP is in high-impedance state	0	1	0
byte AB will follow (otherwise byte BB will follow)	0	1	1
P4 = f <sub>div</sub> output, P5 = f <sub>ref</sub> output	1	0	0
not in use	1	0	1
not in use	1	1	0
not in use	1	1	1

**Table 5-8 Reference divider ratios**

Reference divider ratio	f <sub>ref</sub> <sup>1)</sup>	RSA	RSB
80	50 kHz	0	0
128	31.25 kHz	0	1
24	166.7 kHz	1	0
64	62.5 kHz	1	1

1). With a 4 MHz quartz

**Table 5-9 AGC take-over point**

IF 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



**Table 5-9 AGC take-over point**

103 dB $\mu$ V		1	0	1
I <sub>AGC</sub> = 0	External AGC <sup>1)</sup> .	1	1	0
3.5 V	Disabled <sup>2)</sup> .	1	1	1

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

2). The AGC detector is disabled and I<sub>AGC</sub> = 9  $\mu$ A.

**Table 5-10 A to D converter levels <sup>1)</sup>.**

Voltage at ADC	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 5-11 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	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	X	X	1
Bandswitch byte	BB	0	0	0	0	0	0	0	0
Auxiliary byte	AB	0	0	1	0				

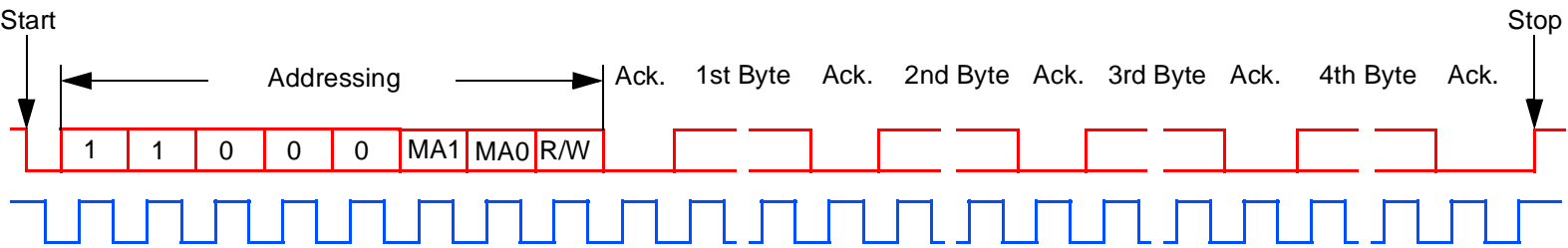
**Table 5-12 Internal band selection**

Band	Mixer	Oscillator
LOW	P0. $\overline{P1}$ <sup>1)</sup> .	P0. $\overline{P1}$
MID	P1. $\overline{P0}$	P1. $\overline{P0}$
HIGH <sup>2)</sup> .	$\overline{P0.P1}$	$\overline{P0.P1}$

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

2). The HIGH band is selected by default

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



**Telegram examples:**

- Start-ADB-DB1-DB2-CB-BB-Stop
- Start-ADB-DB1-DB2-CB-AB-Stop
- Start-ADB-CB-BB-DB1-DB2-Stop
- Start-ADB-CB-AB-DB1-DB2-Stop
- Start-ADB-DB1-DB2-DB1-DB2-Stop
- Start-ADB-DB1-DB2-Stop
- Start-ADB-CB-BB-Stop
- Start-ADB-CB-AB-Stop
- Start-ADB-CB-BB-CB-AB-Stop
- Start-ADB-CB-AB-CB-BB-Stop

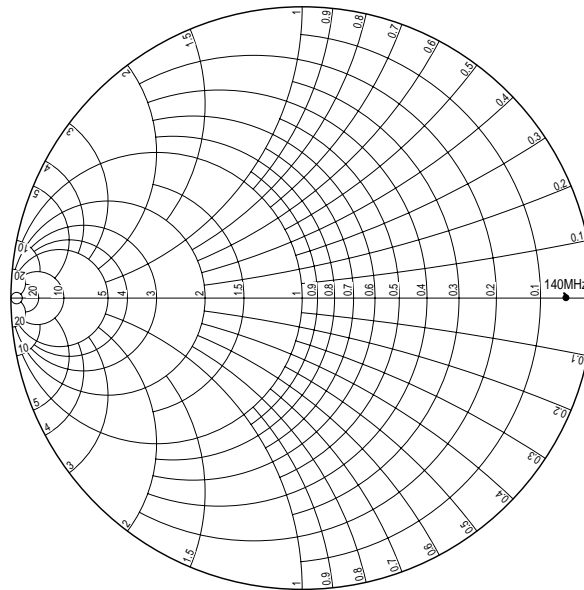
**Abbreviations:**

- Start= start condition
- ADB= address byte
- DB1= prog. divider byte 1
- DB2= prog. divider byte 2
- CB= Control byte
- BB= Bandswitch byte
- AB= Auxiliary byte
- Stop= stop condition

## 5.4 Electrical Diagrams

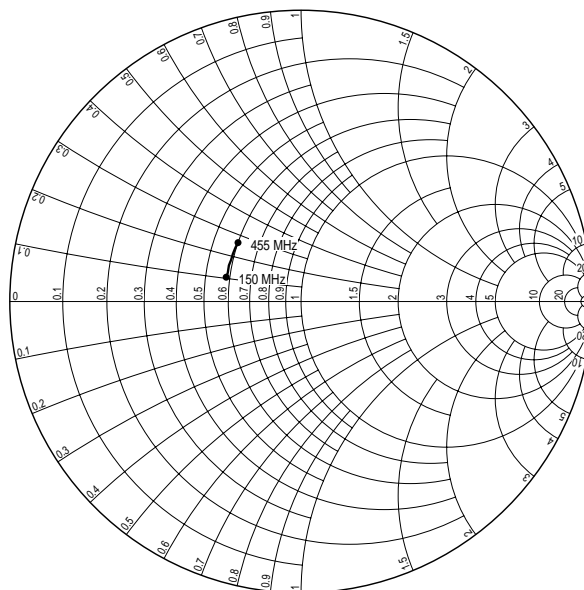
### 5.4.1 Input admittance (S11) of the LOW band mixer (40 to 140 MHz)

$$Y_0 = 20\text{mS}$$



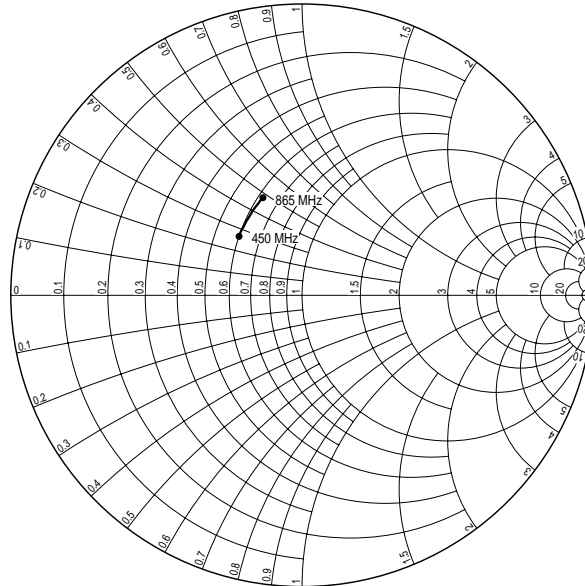
### 5.4.2 Input impedance (S11) of the MID band mixer (150 to 455 MHz)

$$Z_0 = 50 \Omega$$



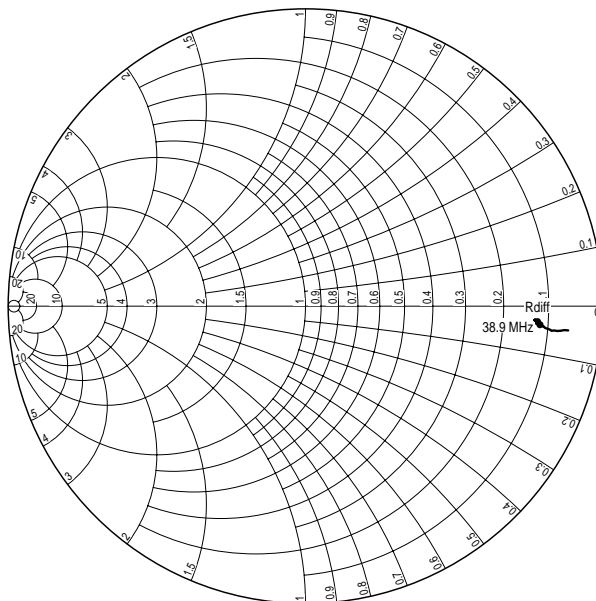
**5.4.3 Input impedance (S11) of the HIGH band mixer (450 to 865 MHz)**

$Z_0 = 50 \Omega$



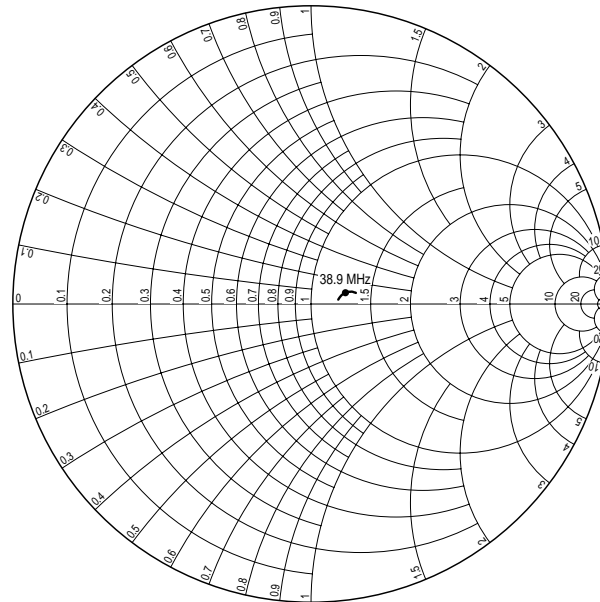
**5.4.4 Output admittance (S22) of the of the Mixer output (30 to 50 MHz)**

$Y_0 = 20\text{mS}$



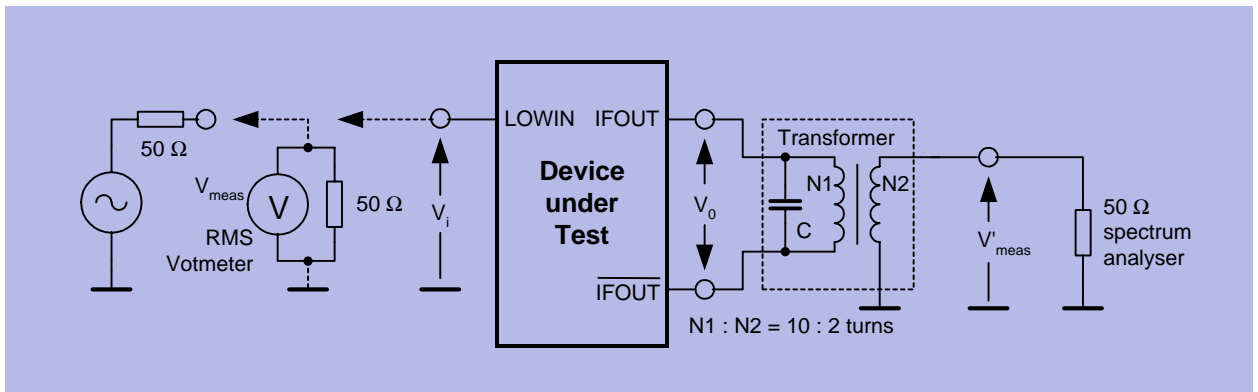
### 5.4.5 Output impedance (S22) of the IF amplifier (30 to 50 MHz)

$$Z_0 = 50 \Omega$$



## 5.5 Measurement Circuits

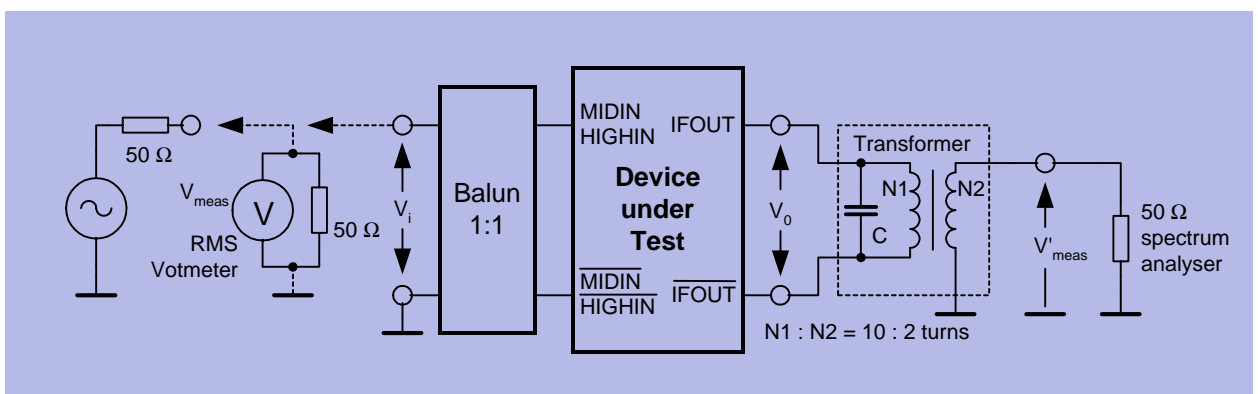
### 5.5.1 Gain ( $G_V$ ) measurement in LOW band



GVHF

- $Z_i \gg 50 \Omega \Rightarrow V_i = 2 \times V_{meas} = 80 \text{ dB}\mu\text{V}$
- $V_i = V_{meas} + 6\text{dB} = 80 \text{ dB}\mu\text{V}$
- $V_0 = V'_{meas} + 16 \text{ dB}$  (transformer ratio  $N1:N2$  and transformer loss)
- $G_V = 20 \log(V_0 / V_i)$

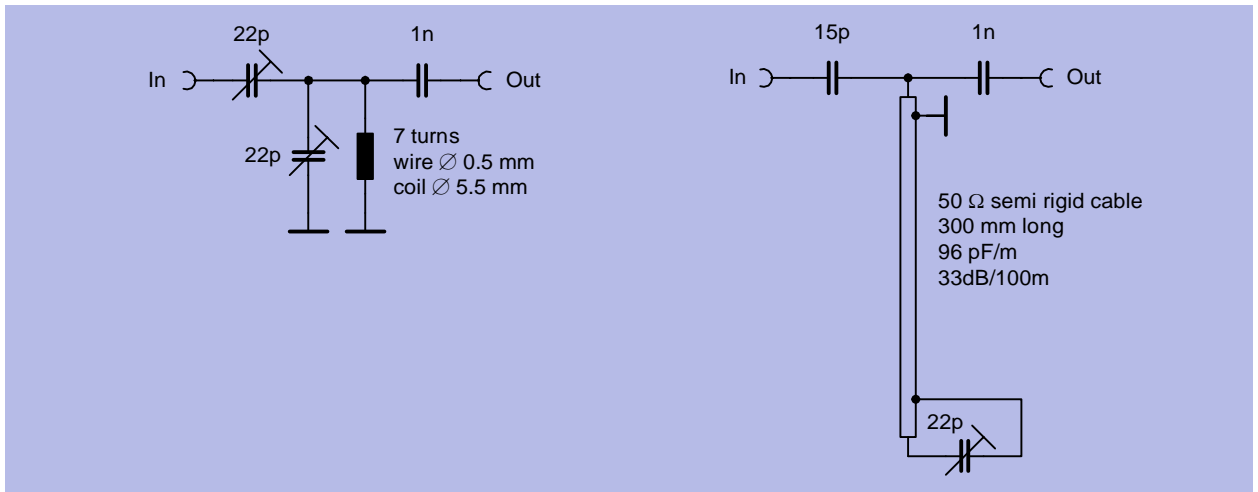
### 5.5.2 Gain ( $G_V$ ) measurement in MID and HIGH bands



GUHF3

- $V_i = V_{meas} = 70 \text{ dB}\mu\text{V}$
- $V_0 = V'_{meas} + 16 \text{ dB}$  (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



NFM

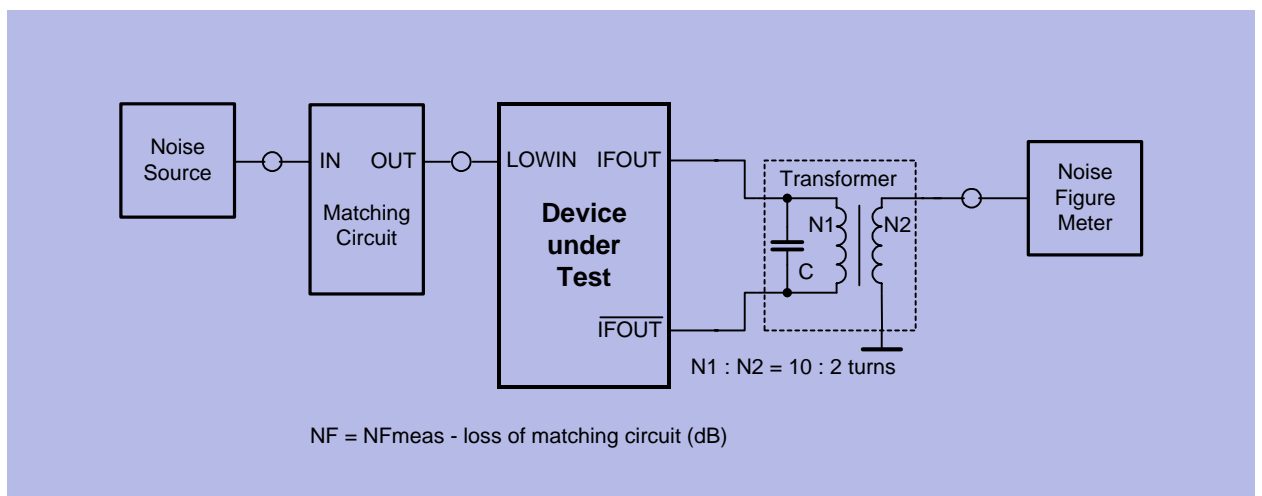
For  $f_{RF} = 50$  MHz

- loss = 0 dB
- image suppression = 16 dB

For  $f_{RF} = 150$  MHz

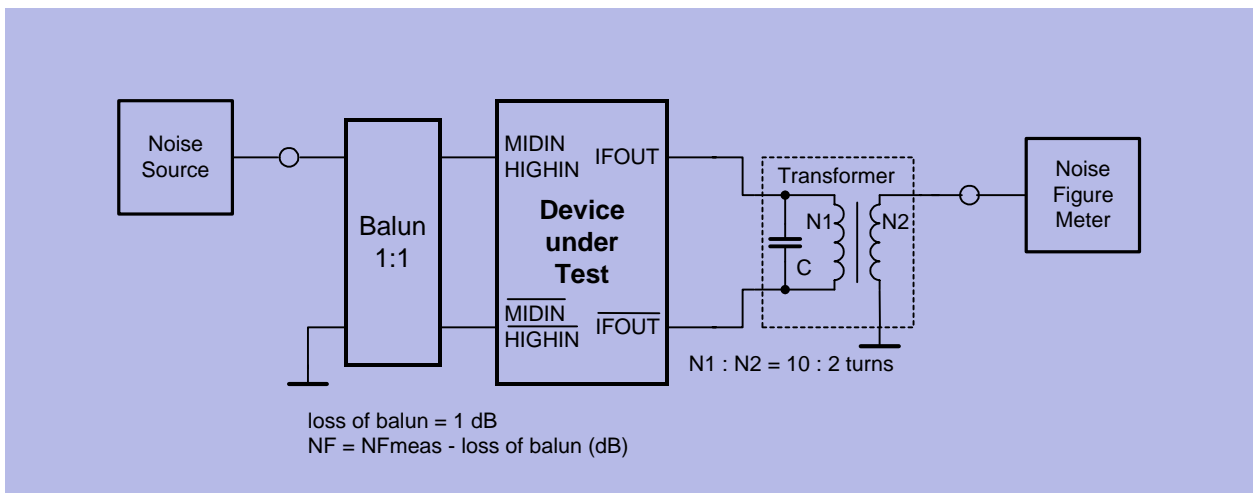
- loss = 1.3 dB
- image suppression = 13 dB

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



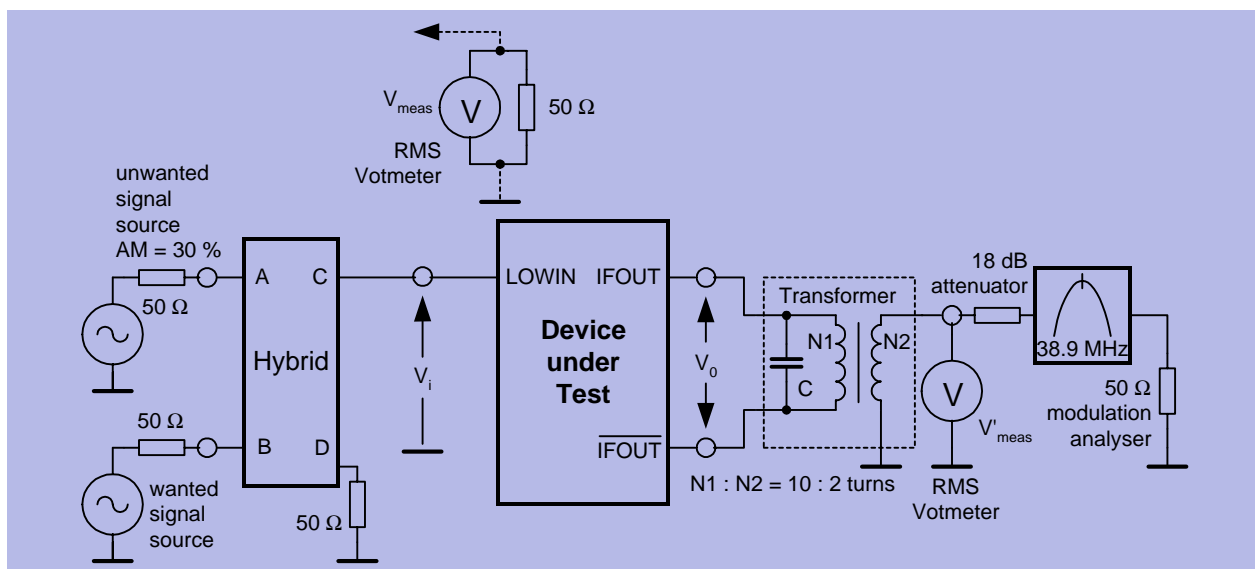
NFVHF

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



NFUHF3

### 5.5.6 Cross modulation measurement in LOW band

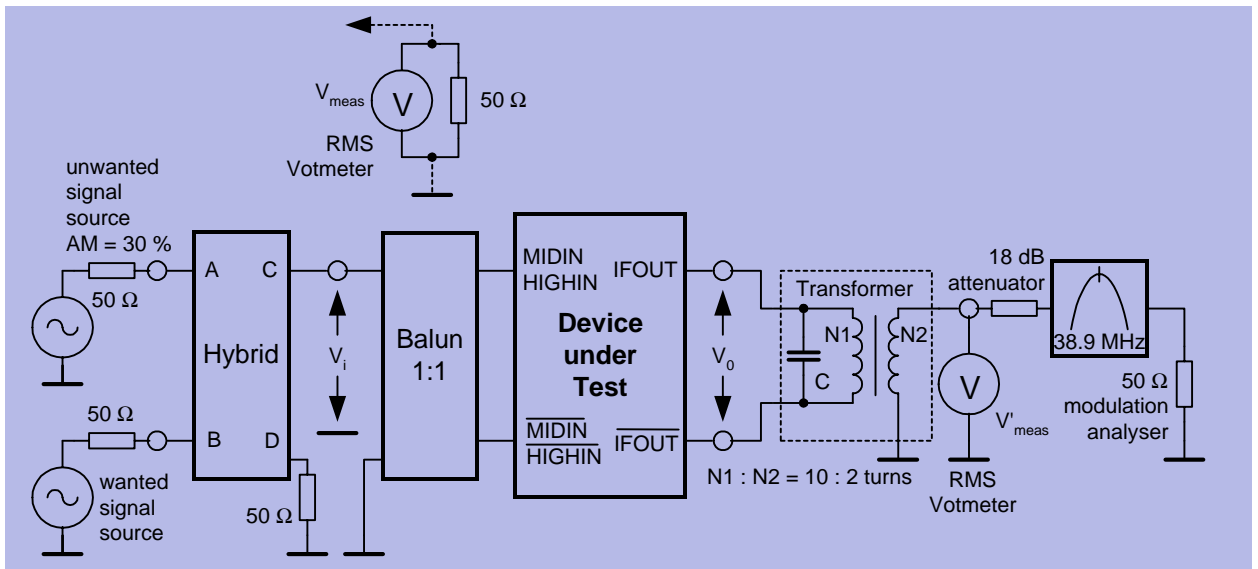


XVHF

- $Z_i \gg 50 \Omega \Rightarrow V_i = 2 \times V_{meas}$
- $V'_{meas} = V_0 - 16 \text{ dB}$  (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  $f_{snd}$



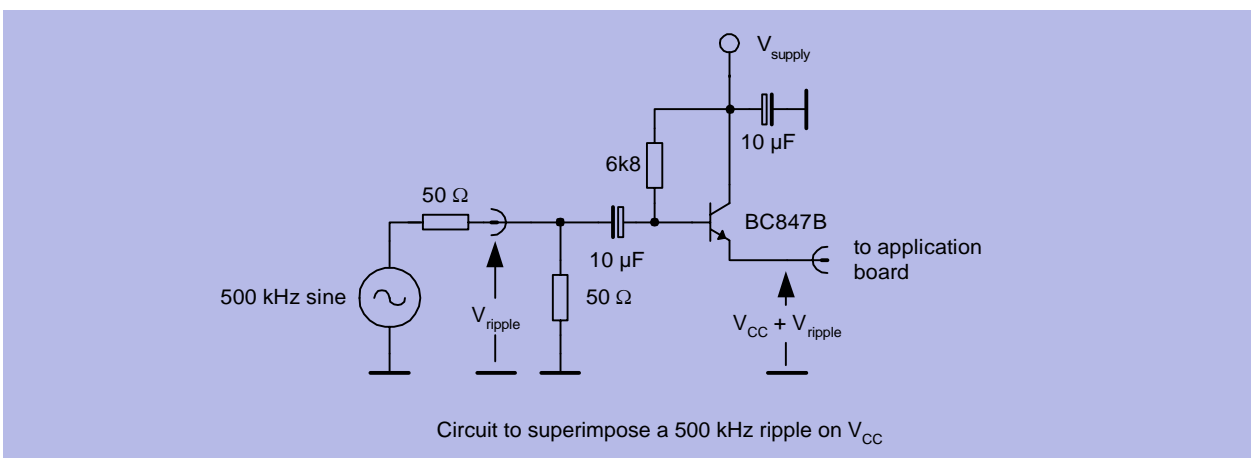
### 5.5.7 Cross modulation measurement in MID and HIGH bands



XUHF3

- $V'_{meas} = V_0 - 16 \text{ dB}$  (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  $f_{snd}$

### 5.5.8 Ripple susceptibility measurement



RIP