27MHz to 67MHz Low-RF Single-Conversion Superhet Receiver

1 The transformation of a high-RF double-conversion to a low-RF single-conversion superhet receiver

Receiver ICs with fully integrated VCOs are very welcome to the system designer because there is no need for external VCO components like varactor diodes or inductors. On the other hand, a fully integrated VCO typically has a limited LO frequency range that restricts the receiver's operating frequency range. The frequency translation scheme of a standard double-conversion superhet (DCSH) receiver follows the rule that the highest frequency of operation (high-RF) is down-converted by the first mixer to a lower frequency of operation (low-RF) that constitutes the first IF. Then a second mixer handles the next step of down-conversion to derive the second IF. It follows logically that the operating frequency range of a DCSH should be down-scalable if the first mixer could be bypassed to make the second mixer's input to be the terminal of the desired signal frequency (now the low-RF). Then the DCSH is transformed to a single-conversion superhet (SCSH) receiver.
The TH71102 block diagram, shown in Fig. 1, reveals that MIX1 ports IN_MIX1 and IF1 are fully accessible. This gives the chance to connect the LNA output directly to the input of MIX2. In this situation, MIX2 is the one and only mixer in the system, able to receive low-RF signals. Fig. 1 outlines how the transformation from DCSH to SCSH can be realized by using the TH71102. As it can be seen from the block diagram, port LO1 of MIX1 cannot be disconnected because it is internal to the IC. Furthermore the internal signal path from MIX1 to MIX2 is fixed. This implies to take care of two things:

- The input of MIX1 must be AC-grounded to prevent from picking up unwanted high-RF signals that could be down-converted and interfere with the desired low-RF
- The output of MIX2 must be matched to the desired low-RF signal to keep parasitic LO1 feed-through as low as possible.

Both demands can be easily met: first by applying a capacitor to pin IN_MIX1 that is well connected to ground, while second comes along because the LC tank at pins IF1P and IF1N is trimmed to the desired low-RF anyway. The following table summarizes the relationships between the different frequencies in the SCSH receiver chain.

Signal	low-side injection	high-side injection
REF (reference osc. freq.)	(RF – IF)/2	(RF + IF)/2
LO2	2 • REF	2 • REF
IF	RF – LO2	LO2 – RF

The specified LO1 frequency range of the TH71102 is 300 MHz to 450 MHz. This translates to an LO2 range of 37.5 MHz to 56.25 MHz which is the new LO frequency range of the receiver that has been derived by DCSH-to-SCSH transformation (LO2 of DCSH = LO of SCSH). The following table depicts the new operating frequency range (RF desired), the reference (REF), and the LO and image frequency (RF image) of the SCSH considering the example of an intermediate frequency of IF = 10.7 MHz.

Signal type	LO low-side injection	LO high-side injection
RF desired / MHz	48.2 to 66.95	26.8 to 45.55
REF / MHz	18.75 to 28.125	18.75 to 28.125
LO / MHz	37.5 to 56.25	37.5 to 56.25
RF image / MHz	26.8 to 45.55	48.2 to 66.95

According to CEPT/ERC recommendation 70-03, the following low-frequency services can be covered by the modified TH71102 application circuit.

Service	Frequency range	Channel spacing	Typical applications
non-specific SRDs	26.957 - 27.238 MHz 40.660 - 40.700 MHz	no channels specified	telemetry, telecommand, alarms, data in general and other similar applications
model control	26.995 - 27.195 MHz 34.995 - 35.225 MHz 40.665 - 40.695 MHz	10 kHz	controlling the movement of a model
inductive applications	26.957 - 27.283 MHz	no channels specified	car immobilizers, animal identification, alarm systems, personal identification, proximity sensors, anti-theft systems, automatic article identification
narrow-band audio	29.7 - 47.0 MHz	50 kHz	audio signal transmission

2 Measured data of the low-RF single-conversion superhet receiver

A test board has been setup to validate the theoretical approach of the DCSH-to-SCSH transformation. The board's circuit schematic corresponds to Fig. 2/3 with a receiving frequency of 40.68 MHz, the center frequency of one of the non-specific SRD bands. The most important parameters are summarized in the following table.

V_{cc} = 3.0 V, T_a = 23 °C, RF = 40.68 MHz, IF = 10.7 MHz, B_{IF} = 150 kHz, Δf_{FSK} = ±30 kHz, M_{ASK} = 100 %, data rate = 4 kbit/s NRZ, BER < $3{\cdot}10^{-3}$

Parameter	Condition	Value	Unit
stand-by current	ENRX at 0 V	<100	nA
current consumption at LNA high gain	GAIN_LNA at 0 V	7.7	mA
current consumption at LNA low gain	GAIN_LNA open	6.3	mA
FSK input sensitivity at LNA high gain	GAIN_LNA at 0 V	-108	dBm
FSK input sensitivity at LNA low gain	GAIN_LNA open	-70	dBm
FSK maximum input signal at LNA high gain	GAIN_LNA at 0 V	-10	dBm
FSK maximum input signal at LNA low gain	GAIN_LNA open	0	dBm
ASK input sensitivity at LNA high gain	GAIN_LNA at 0 V	-110	dBm
ASK input sensitivity at LNA low gain	GAIN_LNA open	-72	dBm
ASK maximum input signal at LNA high gain	GAIN_LNA at 0 V	-24	dBm
ASK maximum input signal at LNA low gain	GAIN_LNA open	-5	dBm
image rejection	GAIN_LNA at 0 V	36	dB
rejection of undesired double-conversion RF at 451.72 MHz	GAIN_LNA at 0 V	77	dB
rejection of undesired double-conversion RF at 370.36 MHz	GAIN_LNA at 0 V	65	dB
spurious emission	GAIN_LNA at 0 V	< -104	dBm

3 Bock Diagram

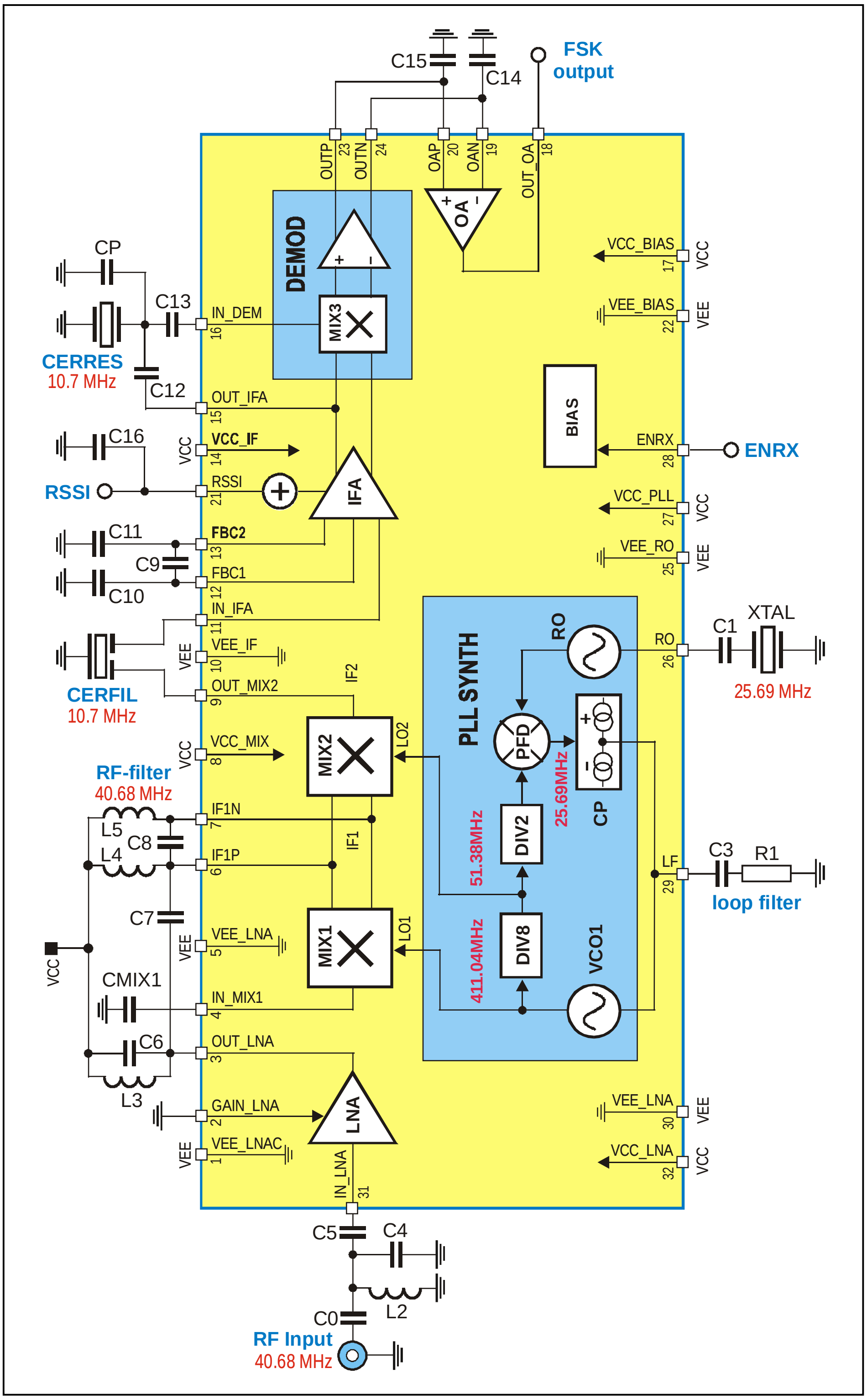

Fig. 1 TH71102 block diagram with external components for FSK reception

4 FSK Application Circuit

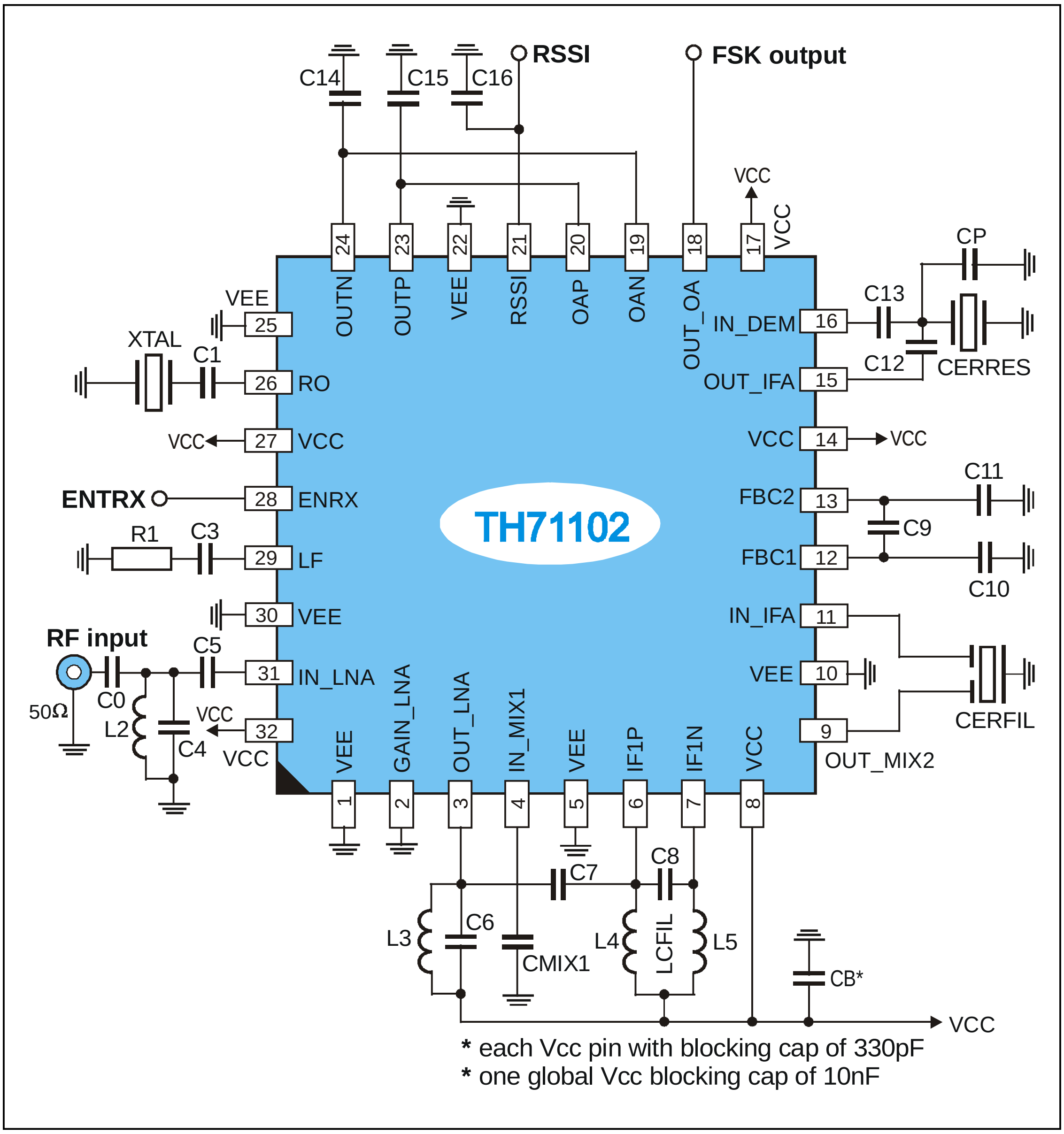

Fig. 2 Circuit diagram for FSK reception

4.1 Board Component Values for FSK (Fig. 2)

Part	Size	Value @ 40.68 MHz	Tolerance	Description
C0	0805	100 pF	±10%	capacitor
C1	0805	15 pF	±10%	crystal series capacitor
C3	0805	1 nF	±10%	loop filter capacitor
C4	0603	120 pF	±5%	capacitor
C5	0603	100 pF	±5%	capacitor
C6	0603	150 pf	±5%	LNA output tank capacitor
C7	0603	22 pF	±5%	capacitor
CMIX1	0805	2.2nF	±10%	capacitor
C8	0603	68 pF	±5%	RF tank capacitor
C9	0805	33 nF	±10%	IFA feedback capacitor
C10	0603	1 nF	±10%	IFA feedback capacitor
C11	0603	1 nF	±10%	IFA feedback capacitor
C12	0603	1.5 pF	±5%	DEMOD phase-shift capacitor
C13	0603	680 pF	±10%	DEMOD coupling capacitor
C14	0805	10 – 47 pF	±5%	demodulator output low-pass capacitor, depending on data rate
C15	0805	10 – 47 pF	±5%	demodulator output low-pass capacitor, depending on data rate
C16	0603	1.5 nF	±10%	RSSI output low-pass capacitor
CP	0805	10 – 12 pF	±5%	CERRES parallel capacitor
R1	0805	10 kΩ	±10%	loop filter resistor
L2	0603	100 nH	±5%	inductor
L3	0603	100 nH	±5%	LNA output tank inductor
L4	0805	100 nH	±5%	RF tank inductor
L5	0805	100 nH	±5%	RF tank inductor
XTAL	HC49 SMD	±25ppm calibration ±30ppm temperature		fundamental-mode crystal, C_{load} = 10 pF to 15pF, $C_{0,\,max}$ = 7 pF, $R_{m,\,max}$ = 50 Ω
CERFIL	SMD type	SFECV10M7JA00 (SFECV10.7MJS) @ B_{IF2} = 150 kHz, ±40kHz		ceramic filter from Murata, or equivalent part from different vendor
CERRES	SMD type	CDSCB10M7GA130 (CDACV10.7MG18)		ceramic resonator from Murata, or equivalent part from different vendor

5 ASK Application Circuit

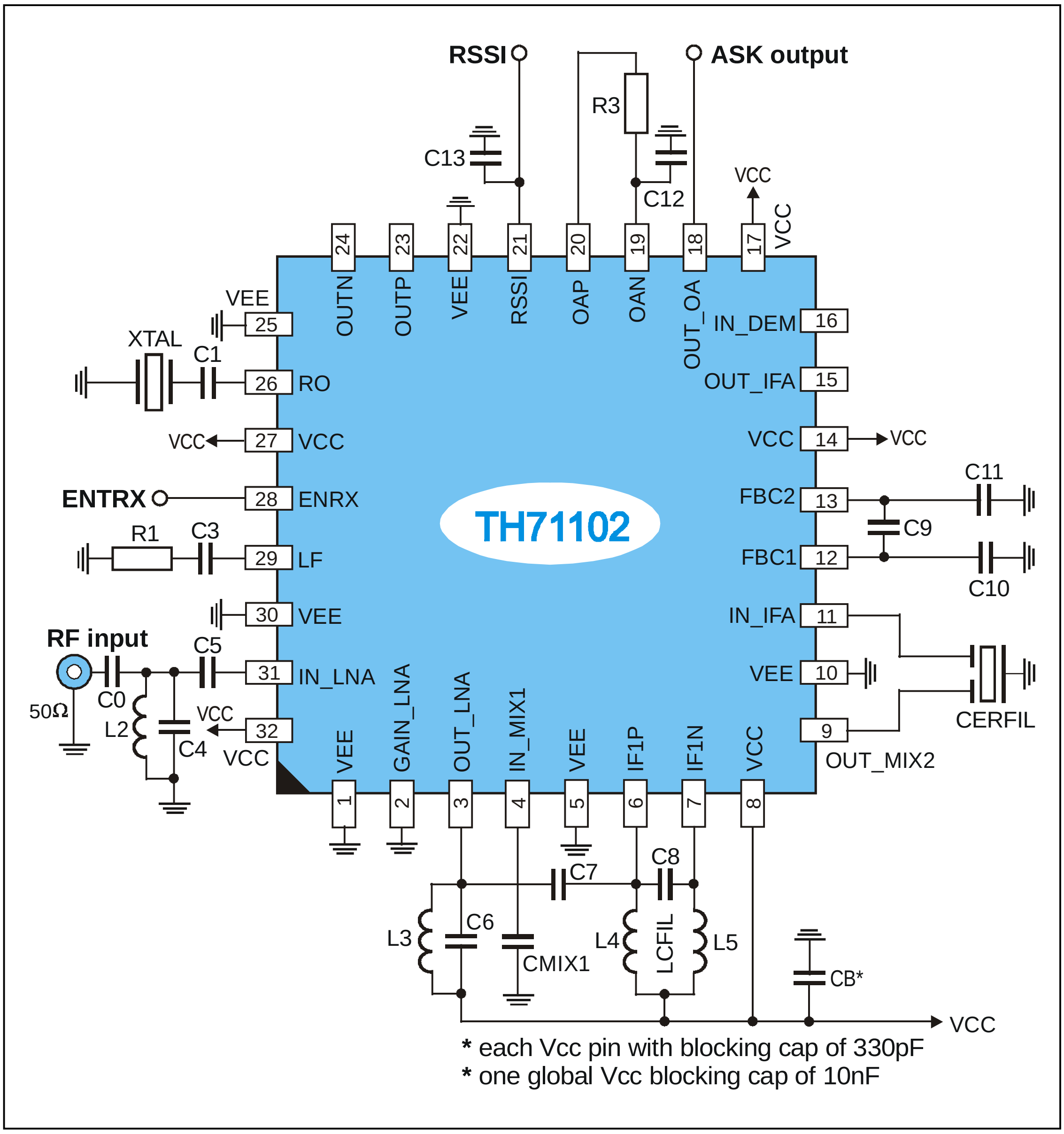

Fig. 3 Circuit diagram for ASK reception

5.1 Board Component Values for ASK (Fig. 3)

Part	Size	Value @ 40.68 MHz	Tolerance	Description
C0	0805	100 pF	±10%	capacitor
C1	0805	15 pF	±10%	crystal series capacitor
C3	0805	1 nF	±10%	loop filter capacitor
C4	0603	120 pF	±5%	capacitor
C5	0603	100 pF	±5%	capacitor
C6	0603	150 pf	±5%	LNA output tank capacitor
C7	0603	22 pF	±5%	capacitor
CMIX1	0805	2.2nF	±10%	capacitor
C8	0805	68 pF	±5%	IF1 tank capacitor
C9	0805	33 nF	±10%	IFA feedback capacitor
C10	0603	1 nF	±10%	IFA feedback capacitor
C11	0603	1 nF	±10%	IFA feedback capacitor
C12	0805	1 nF to 100 nF	±10%	ASK data slicer capacitor, depending on data rate
C13	0603	1.5 nF	±10%	RSSI output low-pass capacitor
R1	0805	10 kΩ	±10%	loop filter resistor
R3	0603	100 kΩ	±5%	ASK data slicer resistor, depending on data rate
L2	0603	100 nH	±5%	inductor
L3	0603	100 nH	±5%	LNA output tank inductor
L4	0805	100 nH	±5%	RF tank inductor
L5	0805	100 nH	±5%	RF tank inductor
XTAL	HC49 SMD	±25ppm calibration ±30ppm temperature		fundamental-mode crystal, C_{load} = 10 pF to 15pF, $C_{0, max}$ = 7 pF, $R_{m, max}$ = 50 Ω
CERFIL	SMD type	SFECV10M7JA00 (SFECV10.7MJS) @ B_{IF2} = 150 kHz, ±40kHz		ceramic filter from Murata, or equivalent part from different vendor

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