# TFF1007HN

## Low phase noise LO generator for VSAT applications

Rev. 1 — 23 August 2012 Product data sheet

## 1. General description

The TFF1007HN is a frequency generator intended for low phase noise Local Oscillator (LO) circuits for $K_a$ band VSAT transmitters and transceivers. The specified phase noise complies with IESS-308 from Intelsat.

## 2. Features and benefits

- Phase noise compliant with IESS-308 (Intelsat)
- LO generator with VCO range from 14.62 GHz to 15.00 GHz
- Input signal 228.44 MHz to 234.38 MHz
- Divider setting 64
- Output level −4 dBm minimum
- Third or fourth order PLL
- Internally stabilized voltage reference for loop filter

## 3. Applications

- VSAT up converters
- Local oscillator signal generation

## 4. Quick reference data

**Table 1. Quick reference data**

$T_{case}$ = 25 °C.

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $V_{CC}$ | supply voltage | | 3.0 | 3.3 | 3.6 | V |
| $I_{CC}$ | supply current | | - | 116 | 130 | mA |
| $f_{o(RF)}$ | RF output frequency | in locked state | 14.62 | - | 15.00 | GHz |
| $\varphi_{n(synth)}$ | synthesizer phase noise | divider value = 64 with loop bandwidth = 2 MHz; reference phase noise = −150 dBc/Hz; at 100 kHz offset | - | −109 | −104 | dBc/Hz |
| $RL_{out}$ | output return loss | measured at demo board and de-embedded to footprint | - | −10 | - | dB |

## 5. Ordering information

**Table 2. Ordering information**

| Type number | Package | | |
|---|---|---|---|
| | Name | Description | Version |
| TFF1007HN | HVQFN24 | plastic thermal enhanced very thin quad flat package; no leads; 24 terminals; body 4 × 4 × 0.85 mm | SOT616-1 |

## 6. Block diagram

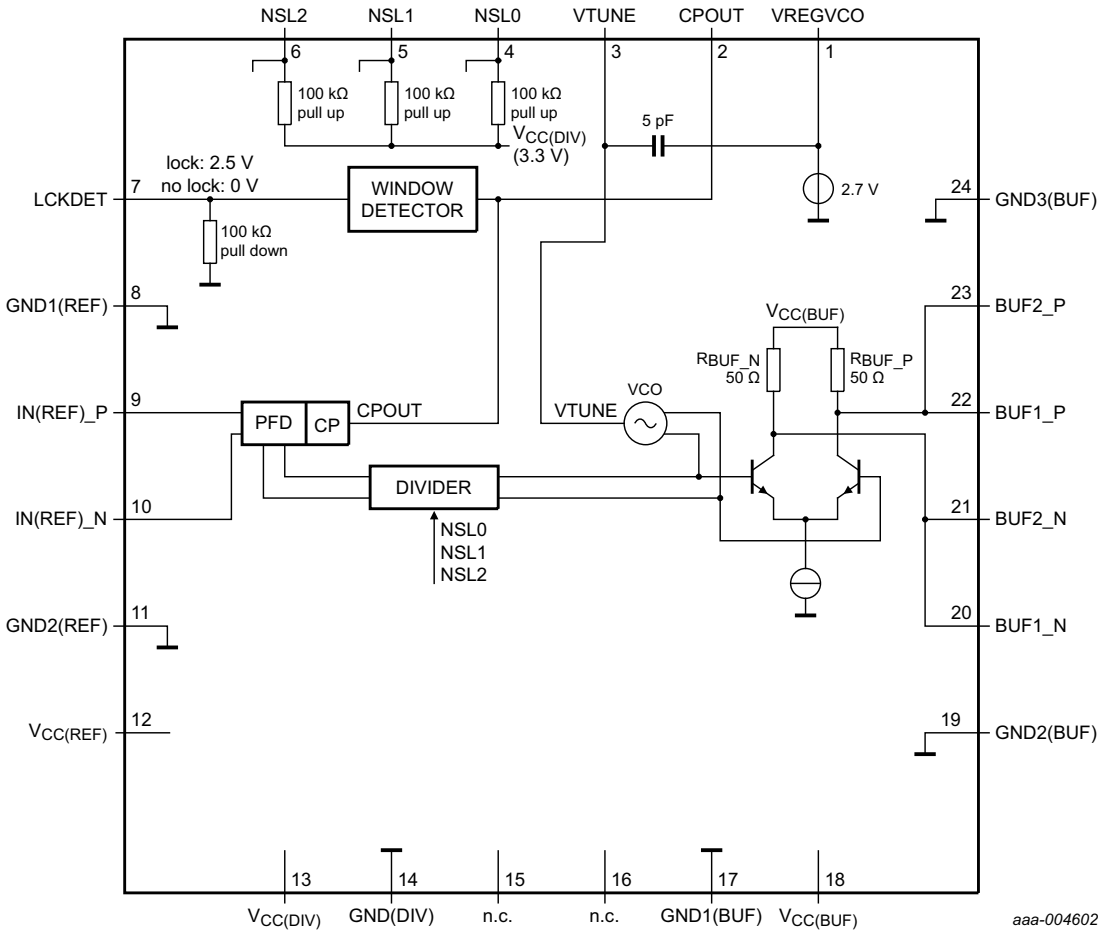



**Fig 1. Block diagram**

## 7. Functional diagram

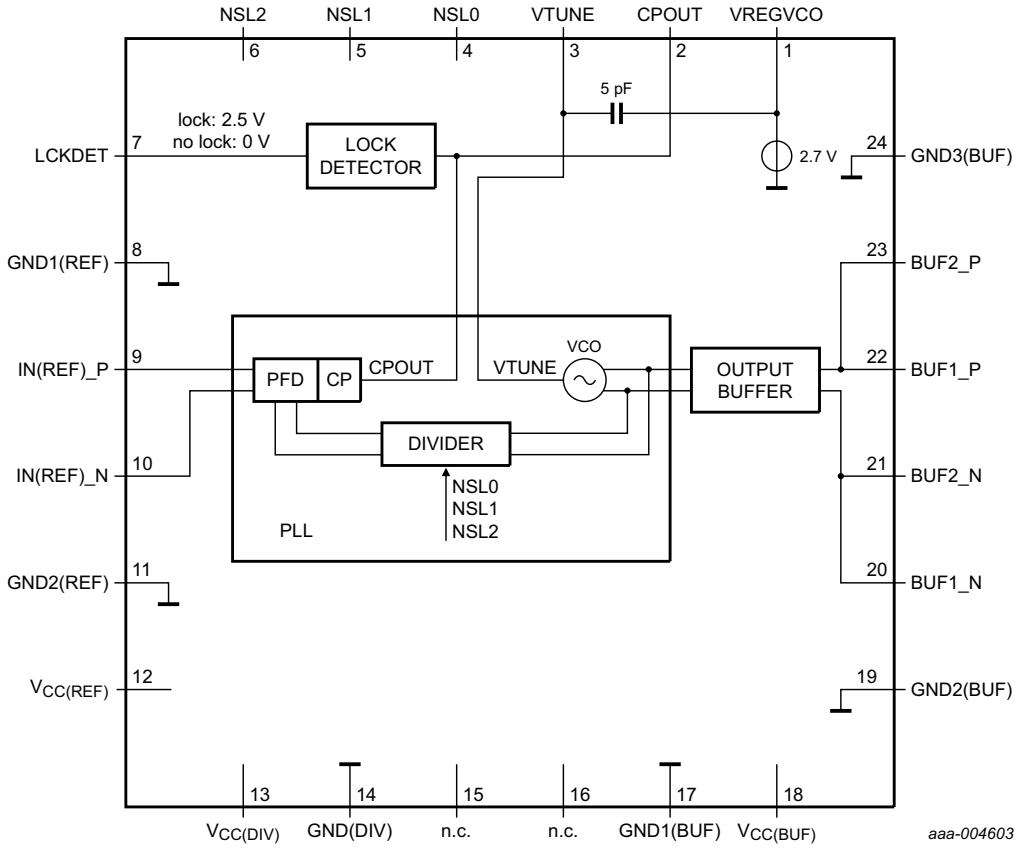



**Fig 2. Functional diagram**

# 8. Pinning information

## 8.1 Pinning

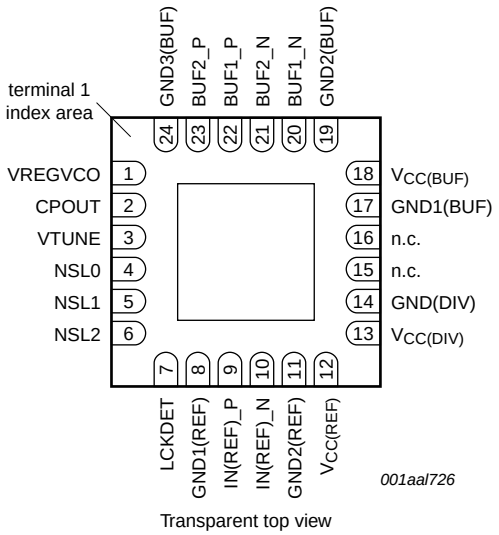



**Fig 3. Pin configuration for HVQFN24**

## 8.2 Pin description

**Table 3. Pin description**

| Symbol | Pin | Description |
|---|---|---|
| VREGVCO | 1 | Regulated output voltage for VCO loop filter. Connect loop filter to this pin. |
| CPOUT | 2 | Charge pump output. |
| VTUNE | 3 | Tuning voltage for VCO. |
| NSL0 | 4 | Divider setting, LSB. Leave open for “1”, connect to GND for “0”. See Table 6. |
| NSL1 | 5 | Divider setting. Leave open for “1”, connect to GND for “0”. See Table 6. |
| NSL2 | 6 | Divider setting, MSB. Leave open for “1”, connect to GND for “0”. See Table 6. |
| LCKDET | 7 | Lock detect. Lock = 2.5 V; out of lock = 0 V. See Table 4. |
| GND1(REF) | 8 | Ground for REF input. Connect this pin to the exposed diepad landing. |
| IN(REF)_P | 9 | Reference signal, non-inverting input. Couple this AC to the source. |
| IN(REF)_N | 10 | Reference signal, inverting input. Couple this AC to the source. |
| GND2(REF) | 11 | Ground for REF input. Connect this pin to the exposed diepad landing. |
| $V_{CC(REF)}$ | 12 | Supply of the internal regulated voltages. Decouple this pin against GND2(REF) (pin 11). |
| $V_{CC(DIV)}$ | 13 | Supply of the divider and PFD/CP. Decouple this pin against GND(DIV) (pin 14). |
| GND(DIV) | 14 | Ground of the divider. Connect this pin to the exposed diepad landing. |
| n.c. | 15 | not connected |
| n.c. | 16 | not connected |
| GND1(BUF) | 17 | Ground for RF output. Connect this pin to the exposed diepad landing. |

**Table 3. Pin description** *...continued*

| Symbol | Pin | Description |
|---|---|---|
| $V_{CC(BUF)}$ | 18 | Supply voltage for the RF output buffer. Decouple this pin against GND2(BUF) (pin 19). |
| GND2(BUF) | 19 | Ground for RF output. Connect this pin to the exposed diepad landing. |
| BUF1_N | 20 | RF output. |
| BUF2_N | 21 | RF output. |
| BUF1_P | 22 | RF output. |
| BUF2_P | 23 | RF output. |
| GND3(BUF) | 24 | Ground for RF output. Connect this pin to the exposed diepad landing. |

# 9. Functional description

The TFF1007HN consists of the following blocks:

- PLL
- Output buffer
- Lock detector
- Reference input
- Divider settings

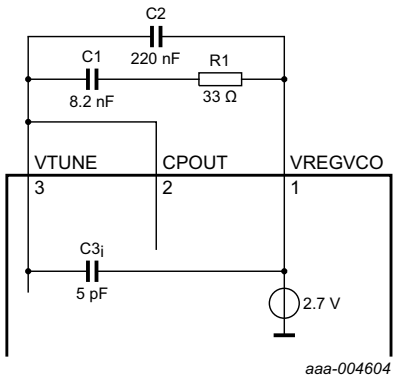
The functionality of the blocks will be discussed below.

## 9.1 PLL

The PLL is formed by the VCO, DIVIDER (possible settings: 16, 32, 64, 128 and 256 (see Table 6)) and a PFD/CP. The tune voltage is referred to the band gap regulated voltage: VREGVCO (pin 1).

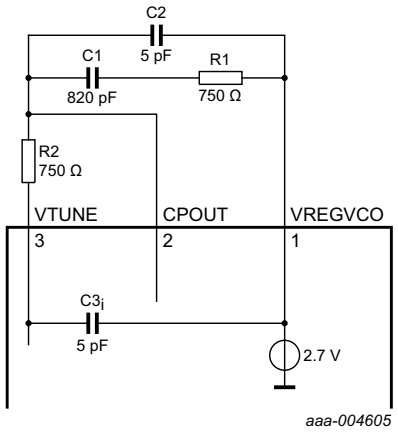
The loop filter can be set to type 2 or type 3. If a type 2 filter is used, the pins CPOUT (pin 2) and VTUNE (pin 3) must be interconnected. No capacitor is placed internally between CPOUT (pin 2) and VREGVCO (pin 1), and a 5 pF capacitor is placed between VTUNE (pin 3) and VREGVCO (pin 1). See Figure 4 and Figure 5. Type 3 filter has an extra pole formed by R2, leading to better spurious suppression.

The VCO input voltage range is between $0.1 \times V_{O(reg)VCO}$ and $0.9 \times V_{O(reg)VCO}$.




Minimal integrated phase noise at divider value = 64

**Fig 4. Type 2 loop filter**




Wide loop bandwidth

**Fig 5. Type 3 loop filter**

## 9.2 Output buffer

The output consists of a differential pair with 50 Ω collector resistors. If only one output is used, terminate the non used output with the same impedance as the load (see Figure 8)

## 9.3 Lock detector

The lock detector is the output of a window detector. The window detector compares the output voltage over the charge pump. This voltage is identical to VTUNE (pin 3) when a type 2 loop filter is used (see Figure 4). In case of a type 3 loop filter this voltage is filtered by R2/C3 (see Figure 5). Due to this filtering the attack and decay time will decrease.

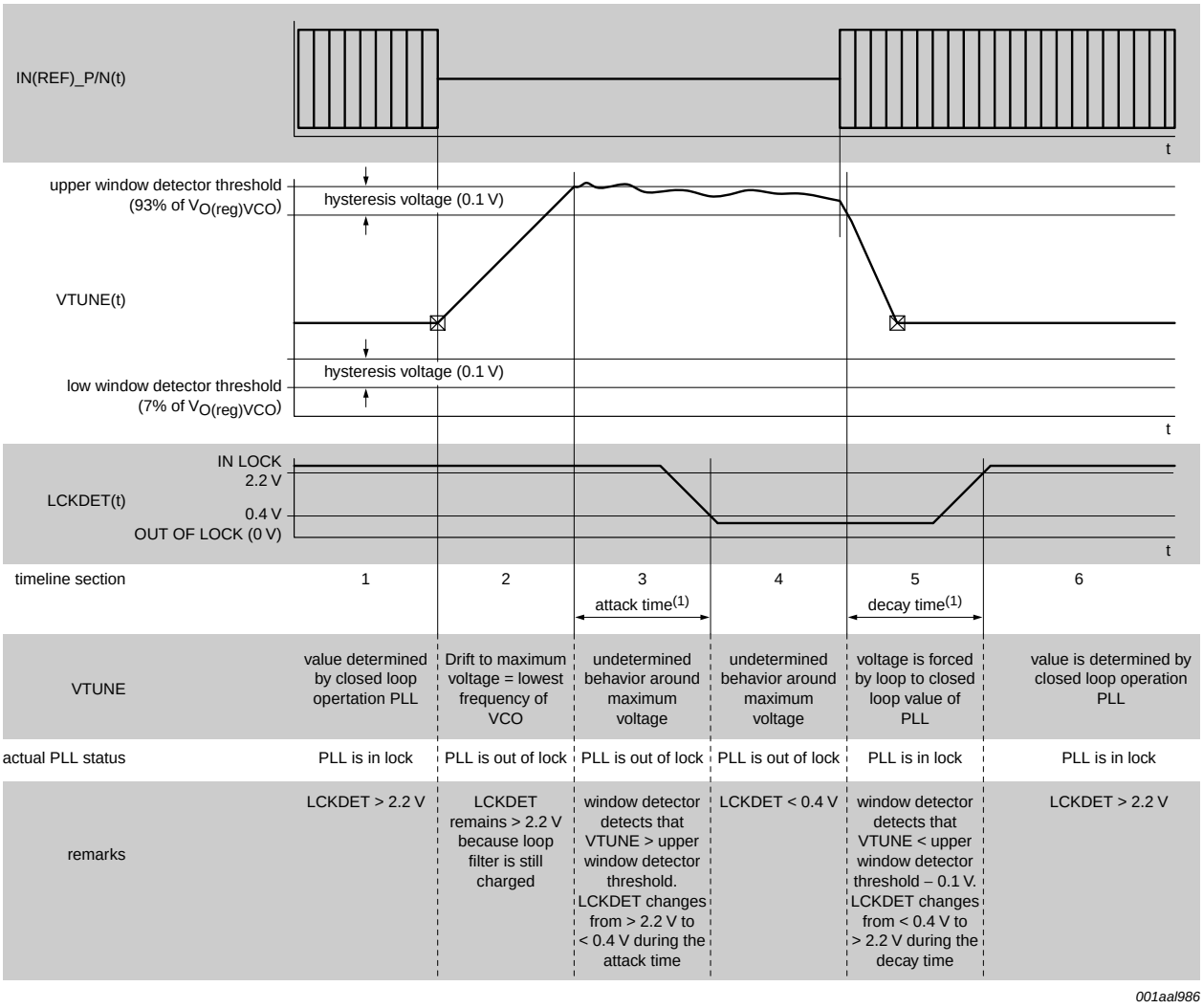
The lower window detector threshold voltage is 7 % of the output voltage on pin VREGVCO (pin 1), the upper window detector threshold voltage is 93 % of the output voltage on pin VREGVCO (pin 1). The hysteresis is 0.1 V. The output is 2.5 V CMOS compliant. The values are shown in Table 4. The timing diagram is shown in Figure 6.

At start-up the LCKDET (pin 7) will be low until the circuit has acquired lock.

**Table 4. Logical value and physical value for lock detect (LCKDET)**

| Logical value | Physical value | Lock detect state |
|---|---|---|
| 0 | 0 V | out of lock |
| 1 | 2.5 V | lock |

LCKDET (pin 7) has a pull-down resistor of 100 kΩ to GND1(REF) (pin 8).




(1) The attack time and decay time are typically 10 μs and are mainly depending on the drift of the VCO tuning voltage.

**Fig 6. Timing diagram lock detector**

## 9.4 Reference input (IN(REF)_P, IN(REF)_N)

The reference input is a differential pair and is internally biased. The input is high ohmic. The input signal must be AC coupled. If used in a single ended mode, the not used input must be terminated with the same impedance as the driving source.

An example of the differential source and two single ended loads are shown in Figure 7. An example of a single ended application is shown in Figure 8.

Note that the phase noise of the output signal is also determined by the phase noise of the reference signal. The reference frequency range is equal to the output frequency / division value. Note that the output frequency is guaranteed from 14.62 GHz to 15.00 GHz.

### 9.5 Divider setting (NSL2, NSL1, NSL0)

The divider is optimized for divider value 64. The other values (16, 32, 128 and 256) can be used, but performance for these values is not included in this data sheet (see Table 6). The logic levels for NSL0 (pin 4), NSL1 (pin 5) and NSL2 (pin 6) are given in Table 5.

The pins have a pull-up resistor of 100 kΩ to $V_{CC(DIV)}$ (pin 13).

The device is only guaranteed when NSL2, NSL1 and NSL0 are predefined at start-up (no change of divider value is allowed during operation).

**Table 5. Logical and physical value for divider setting (NSL2, NSL1, NSL0)**

| Logical value | Physical value |
|---|---|
| 0 | GND |
| 1 | open or $V_{CC}$ |

The truth table is shown in Table 6.

**Table 6. Divider setting as function of NSL2, NSL1 and NSL0**

| Setting number | NSL2 | NSL1 | NSL0 | Divider value |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 16 [1] |
| 1 | 0 | 0 | 1 | 32 [1] |
| 2 | 0 | 1 | 0 | 64 |
| 3 | 0 | 1 | 1 | 128 [1] |
| 4 | 1 | 0 | 0 | 256 [1] |
| 5 | 1 | 0 | 1 | [2] |
| 6 | 1 | 1 | 0 | [2] |
| 7 | 1 | 1 | 1 | [2] |

[1] Test mode.

[2] Test mode, divider output will be disabled.

## 10. Limiting values

**Table 7. Limiting values**

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

| Symbol | Parameter | Conditions | Min | Max | Unit |
|---|---|---|---|---|---|
| $V_I$ | input voltage | on pin NSL0 | –0.5 | +5 | V |
| | | on pin NSL1 | –0.5 | +5 | V |
| | | on pin NSL2 | –0.5 | +5 | V |
| | | on pin IN(REF)_P | –0.5 | +5 | V |
| | | on pin IN(REF)_N | –0.5 | +5 | V |
| | | on pin $V_{CC(REF)}$ | –0.5 | +5 | V |
| | | on pin $V_{CC(DIV)}$ | –0.5 | +5 | V |
| | | on pin $V_{CC(BUF)}$ | –0.5 | +5 | V |
| $P_i$ | input power | on pin IN(REF)_P | –4 | +10 | dBm |
| | | on pin IN(REF)_N | –4 | +10 | dBm |
| $T_j$ | junction temperature | | –40 | +125 | °C |

**Table 7. Limiting values** *...continued*

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

| Symbol | Parameter | Conditions | Min | Max | Unit |
|---|---|---|---|---|---|
| $T_{stg}$ | storage temperature | | –40 | +125 | °C |
| $V_{ESD}$ | electrostatic discharge voltage | Human Body Model (HBM); According JEDEC standard 22-A114E | - | 2.5 | kV |
| | | Charged Device Model (CDM); According to JEDEC standard 22-C101B | - | 1 | kV |

## 11. Recommended operating conditions

**Table 8. Operating conditions**

*NSL0 (pin 4), NSL1 (pin 5) and NSL2 (Pin 6) not changed during operation.*

| Symbol | Parameter | Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| $T_{amb}$ | ambient temperature | | | –40 | +25 | +85 | °C |
| $Z_0$ | characteristic impedance | | | - | 50 | - | Ω |
| $\varphi_{n(ref)}$ | reference phase noise | divider value = 64 | [1] | - | - | –150 | dBc/Hz |
| $f_{i(ref)}$ | reference input frequency | $f_{i(ref)} = f_{o(RF)}$ / divider value | | 228.44 | - | 234.38 | MHz |
| $P_{i(ref)}$ | reference input power | | | –4 | - | +4 | dBm |

[1] Required reference phase noise is set 10 dB below equivalent input phase noise.

## 12. Thermal characteristics

**Table 9. Thermal characteristics**

| Symbol | Parameter | Conditions | Typ | Unit |
|---|---|---|---|---|
| $R_{th(j-sp)}$ | thermal resistance from junction to solder point | | 25 | K/W |

## 13. Characteristics

**Table 10. Characteristics**

*3.0 < $V_{CC}$ < 3.6 V; Operating conditions of Table 8 apply.*

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $V_{CC}$ | supply voltage | | 3.0 | 3.3 | 3.6 | V |
| $I_{CC}$ | supply current | | - | 116 | 130 | mA |
| **PLL** | | | | | | |
| $f_{o(RF)}$ | RF output frequency | In locked state | 14.62 | - | 15.00 | GHz |
| $V_{O(reg)VCO}$ | VCO regulator output voltage | | 2.5 | 2.7 | 2.9 | V |
| $I_{cp}$ | charge pump current | | - | 2 | - | mA |
| $K_O$ | VCO steepness | | - | 0.75 | - | GHz/V |
| $I_{cp} \times K_O$ | charge pump current and VCO steepness product | | 0.8 | 1.5 | 2.4 | mA·GHz/V |

**Table 10. Characteristics** *...continued*

*3.0 < $V_{CC}$ < 3.6 V; Operating conditions of Table 8 apply.*

| Symbol | Parameter | Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| $\varphi_{n(VCO)}$ | VCO phase noise | at 1MHz offset | | –117 | –109 | –101 | dBc/Hz |
| $\varphi_{n(synth)}$ | synthesizer phase noise | divider value = 64 with loop bandwidth = 2 MHz; reference phase noise = –150 dBc/Hz | | | | | |
| | | at 30 kHz offset | | - | –108 | –103 | dBc/Hz |
| | | at 100 kHz offset | | - | –109 | –104 | dBc/Hz |
| | | at 1 MHz offset | | - | –109 | –104 | dBc/Hz |
| **Output buffer** | | | | | | | |
| $P_o$ | output power | measured single ended | [1] | –4 | –2 | 0 | dBm |
| $RL_{out}$ | output return loss | measured at demo board and de-embedded to footprint | | - | –10 | - | dB |
| $\alpha_{sup(sp)}$ | spurious suppression | within ± 1 MHz | | - | - | –60 | dBc |
| $\alpha_{sup(sp)ref}$ | reference spurious suppression | measured at divider value = 64 | [2] | - | - | –60 | dBc |
| $\alpha_{H(LO)}$ | LO harmonic rejection | | | - | –10 | - | dBc |
| **Lock detector** | | | | | | | |
| $V_{OL}$ | LOW-level output voltage | $I_O$ = 100 μA | | - | - | 0.4 | V |
| $V_{OH}$ | HIGH-level output voltage | $I_O$ = –100 μA | | 2.2 | - | - | V |
| $R_{pd}$ | pull-down resistance | | | 70 | 100 | 130 | kΩ |
| **Divider setting (NSL0, NSL1, NSL2)** | | | | | | | |
| $R_{pu}$ | pull-up resistance | | | 70 | 100 | 130 | kΩ |
| $V_{IL}$ | LOW-level input voltage | | | - | - | 0.8 | V |
| $V_{IH}$ | HIGH-level input voltage | | | 2.0 | - | - | V |

[1] Output stage is a differential pair with 50 Ω collector impedances.
Output power is measured per output pin for the fundamental tone only.
Output is DC coupled and is AC coupled in on-board.

[2] Loop filter components dimensioned to achieve a –1 dB PLL loop bandwidth ($B_{PLL(loop)}$) of 2 MHz under worst case conditions (minimum $K_O$ gain, minimum $I_{cp}$ and maximum value of loop filter components).
Loop filter components spread of 10 % taken into account.

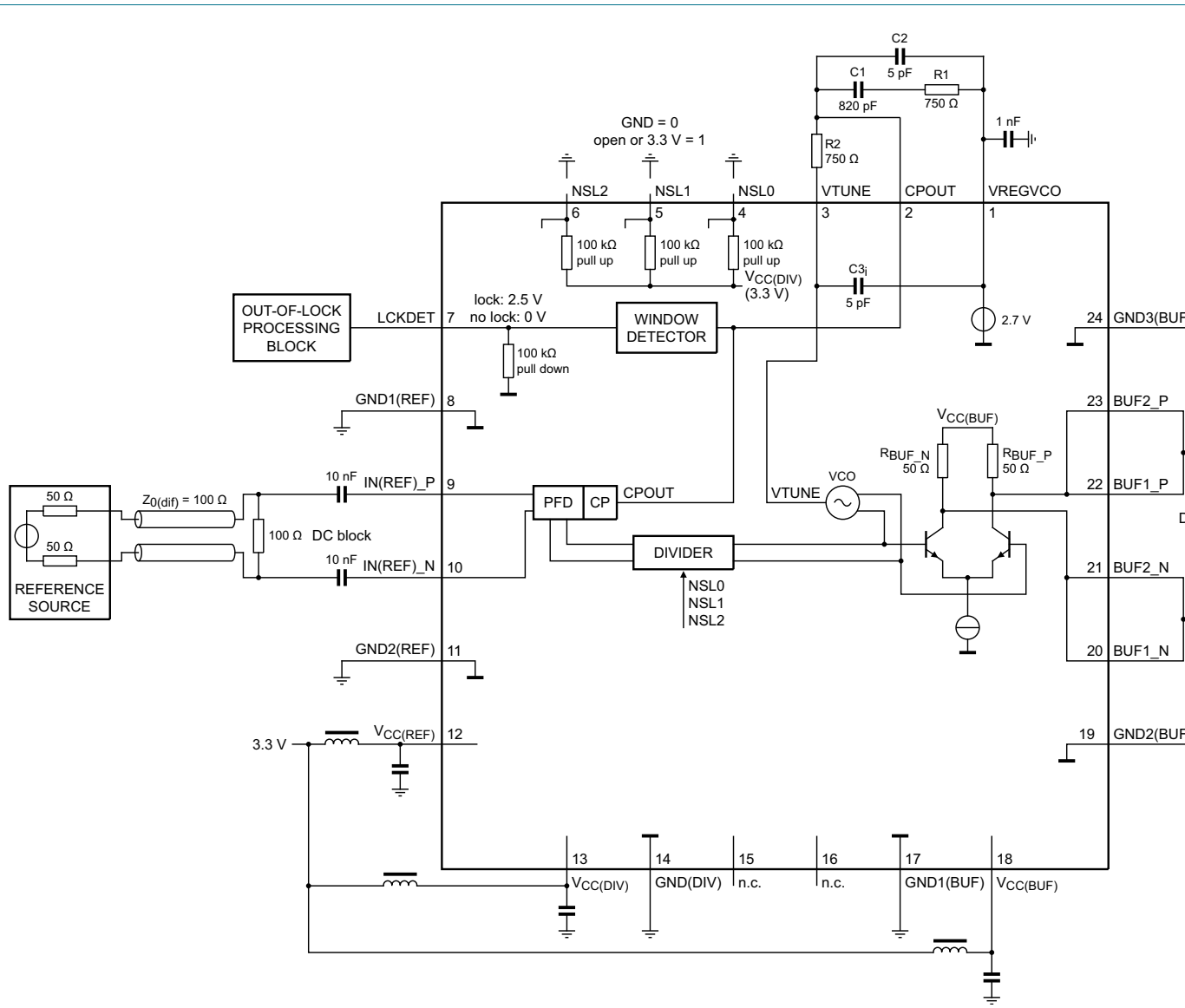



**Fig 7. Application diagram with differential source for IN(REF) and both outputs driving a load, loop filter is type 3**

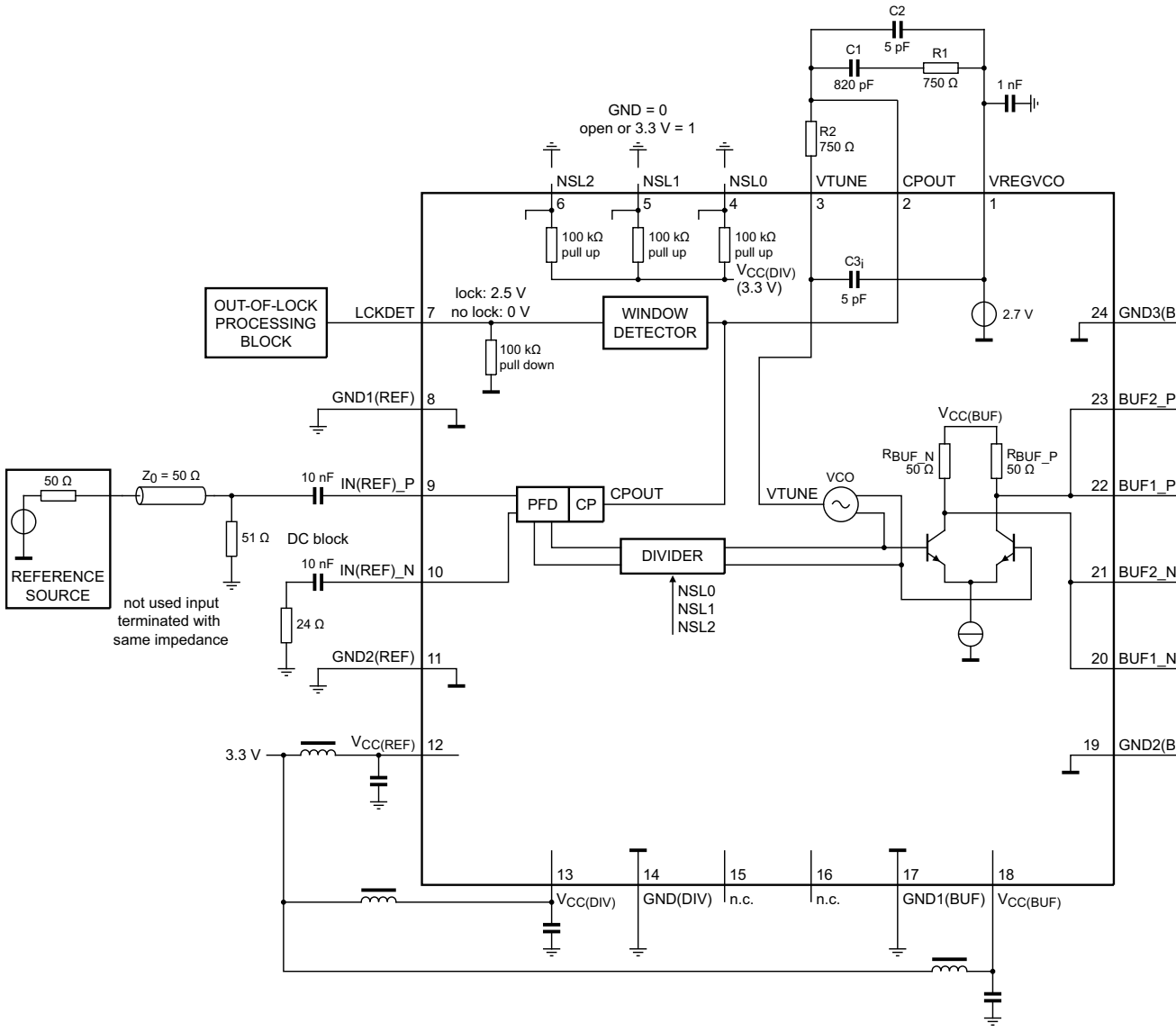
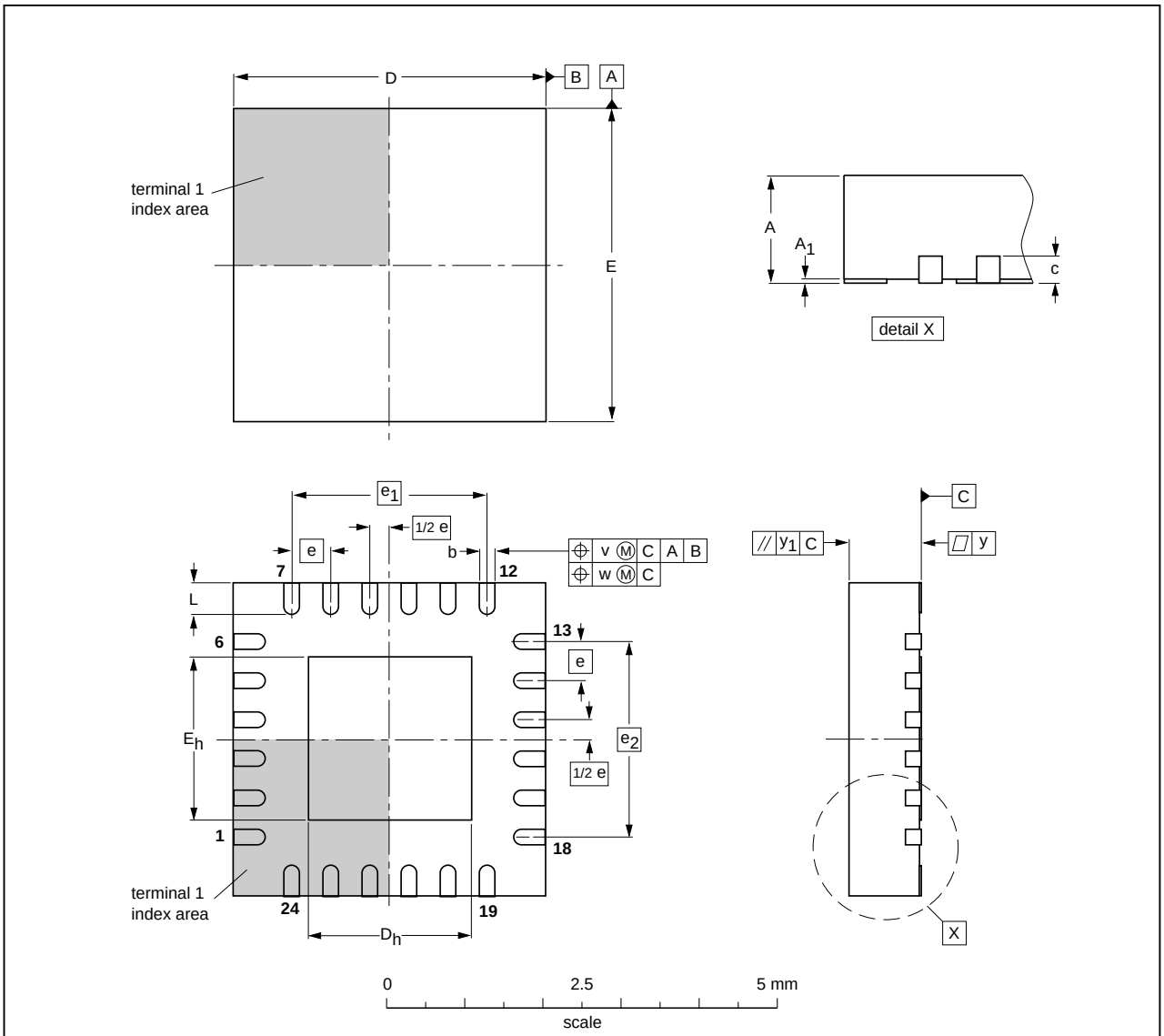



**Fig 8. Application diagram with single ended source for IN(REF) and single ended load, loop filter is type 3**

## 15. Package outline

**HVQFN24: plastic thermal enhanced very thin quad flat package; no leads; 24 terminals; body 4 x 4 x 0.85 mm** **SOT616-1**




**DIMENSIONS (mm are the original dimensions)**

| UNIT | $A^{(1)}$ max. | $A_1$ | b | c | $D^{(1)}$ | $D_h$ | $E^{(1)}$ | $E_h$ | e | $e_1$ | $e_2$ | L | v | w | y | $y_1$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| mm | 1 | 0.05<br>0.00 | 0.30<br>0.18 | 0.2 | 4.1<br>3.9 | 2.25<br>1.95 | 4.1<br>3.9 | 2.25<br>1.95 | 0.5 | 2.5 | 2.5 | 0.5<br>0.3 | 0.1 | 0.05 | 0.05 | 0.1 |

**Note**

1. Plastic or metal protrusions of 0.075 mm maximum per side are not included.

| OUTLINE VERSION | REFERENCES | | | | EUROPEAN PROJECTION | ISSUE DATE |
|---|---|---|---|---|---|---|
| | IEC | JEDEC | JEITA | | | |
| SOT616-1 | - - - | MO-220 | - - - | | | ~~01-08-08~~<br>02-10-22 |

**Fig 9. Package outline SOT616-1 (HVQFN24)**

# 16. Abbreviations

**Table 11. Abbreviations**

| Acronym | Description |
|---|---|
| CMOS | Complementary Metal Oxide Semiconductor |
| CP | Charge Pump |
| $K_a$ band | K-above band |
| LSB | Least Significant Bit |
| MSB | Most Significant Bit |
| PFD | Phase Frequency Detector |
| PLL | Phase-Locked Loop |
| VCO | Voltage Controlled Oscillator |
| VSAT | Very Small Aperture Terminal |

# 17. Revision history

**Table 12. Revision history**

| Document ID | Release date | Data sheet status | Change notice | Supersedes |
|---|---|---|---|---|
| TFF1007HN v.1 | 20120823 | Product data sheet | - | - |

# 18. Legal information

## 18.1 Data sheet status

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

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

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## 20. Contents





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**Date of release: 23 August 2012**
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