# 3-Channel GPS/GLONASS/Galileo/BeiDou/IRNSS/QZSS S/L1/L2/L3/L5 bands RF Front End

## SPECIFICATION

## 1 FEATURES

**Overall**

- 3 independent, fully customizable channels
- 3 coherent fractional-N PLLs with fully integrated VCOs and auto-tuning system
- Clock output for correlator with programmable frequency, amplitude and DC level
- Pass-through TCXO reference signal output
- I2C interface
- Embedded temperature sensor
- Few external components
- 12x12mm QFN108 package

**Channels #1 and #2 feature list:**

- Single conversion super heterodyne structure channels
- Integrated LNA
- Integrated active antenna input buffer including short-protected antenna supply circuit
- Tunable passband with auto-calibration system
- Output signal manual selection: complex or real with separate upper and lower sideband
- Analog differential output or 2-bit ADC digital output with programmable thresholds and output logic high level
- 3-wire SPI access to control registers

**Channel #3 feature list:**

- Direct conversion structure channel for S-band IRNSS reception
- Dual AGC system (RF + IF) or manually programmable gain
- Wide dynamic range with 1dB compression point up to +7 dBm
- Receiving RTK data over FM 65…110 MHz, VHF 160…240 MHz, UHF 470…862 MHz bands

## 2 APPLICATION

- Navigation systems
- Portable receivers
- Mobile communication
- Measuring equipment

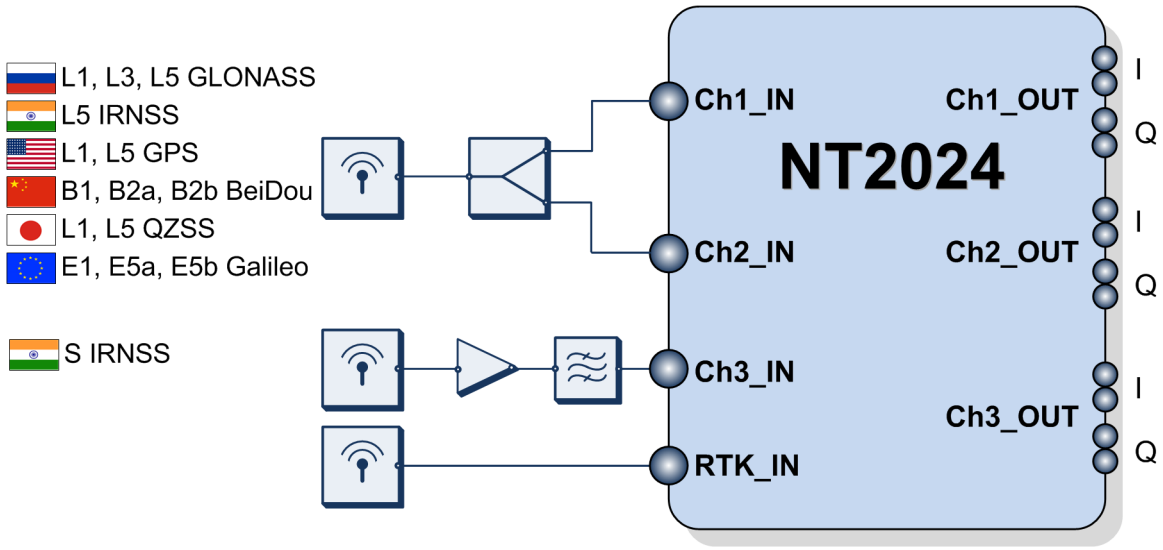
## 3 OVERVIEW

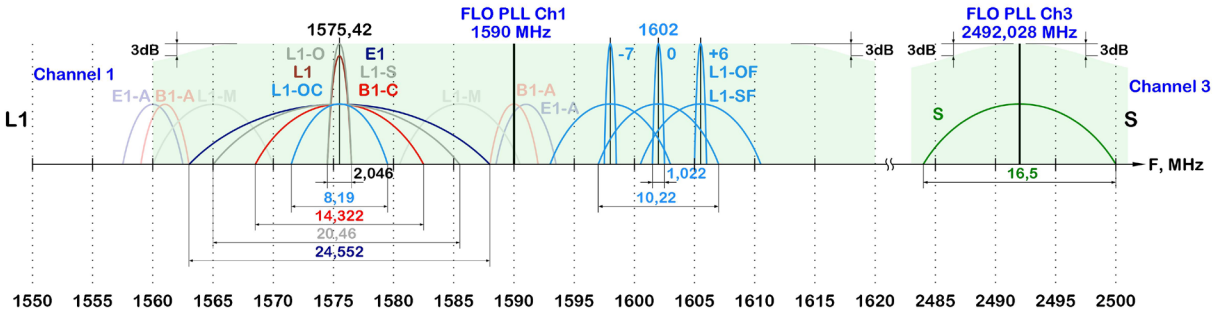
NT2024 is a 3-channel RF Front End that covers all GNSS (GLONASS, IRNSS, GPS, Galileo, BeiDou, QZSS) signals at all frequency bands. It makes possible to benefit from all the advantages of acquiring multiple systems. Channels #1 and #2 are designed with single conversion low-IF architecture, individually programmable and intended to receive either L1, E1, B1 or E6, B3, L2, L3, B2, L5, E5 in different combinations. IQ and image suppression modes are available, other options can be discovered in feature list. Channel #3 is dedicated to operate on S band of IRNSS and has zero-IF architecture. This special addition makes possible to effectively eliminate ionospheric distortion utilizing large signal base of IRNSS between L5

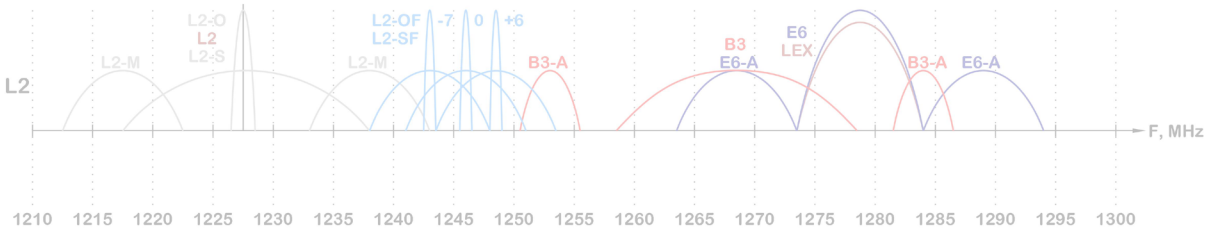
and S bands. As alternative, channel#3 can be software-reconfigured to receive real-time corrections data transmitted over FM, VHF and UHF bands.
NT2024 does also integrate 3 fractional-N synthesizers that have the common reference (TCXO) input making LO signals coherent in terms of frequency. Wide list of attractive features and high level of customization make NT2024 capable to meet a demand of researchers and OEM developers in special applications: high precision positioning, goniometric, driverless car systems, professional drones and related areas.

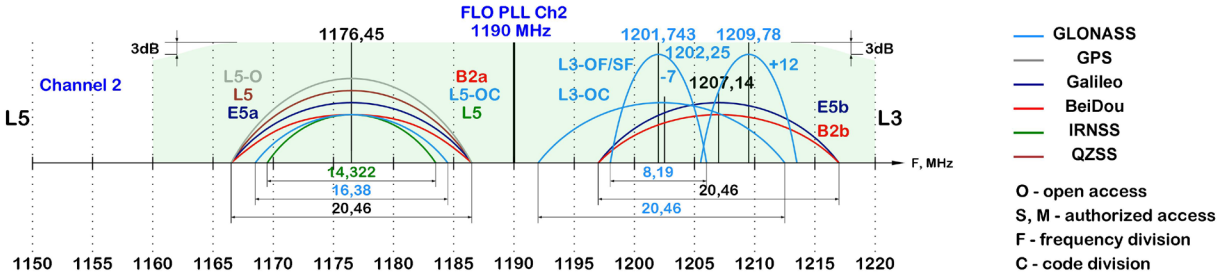
# 4 TYPICAL APPLICATION

## 4.1 APPLICATION EXAMPLE 1

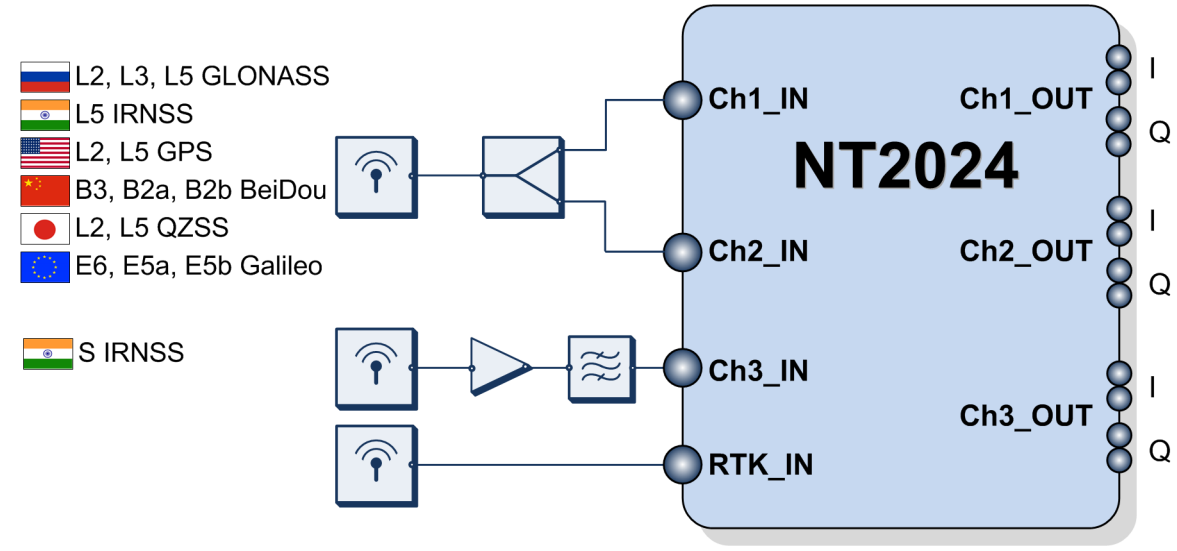


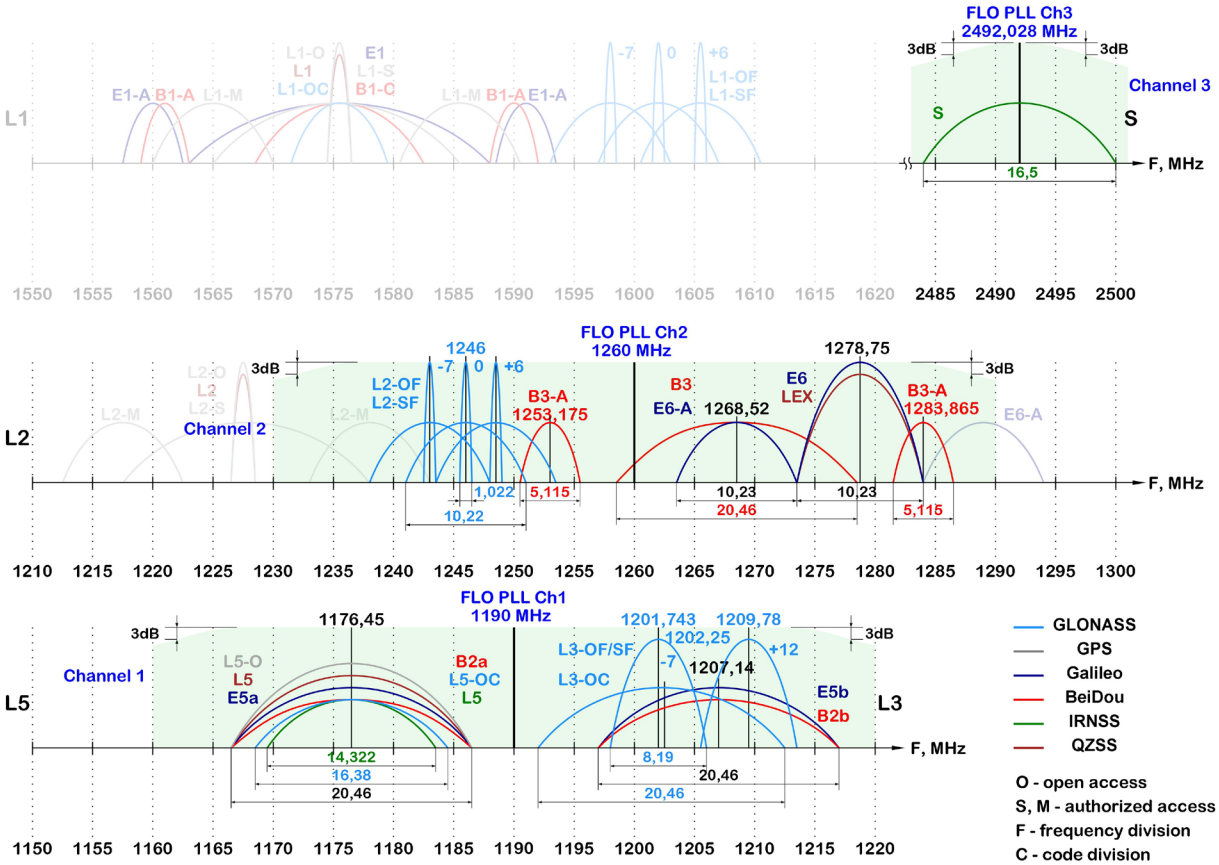



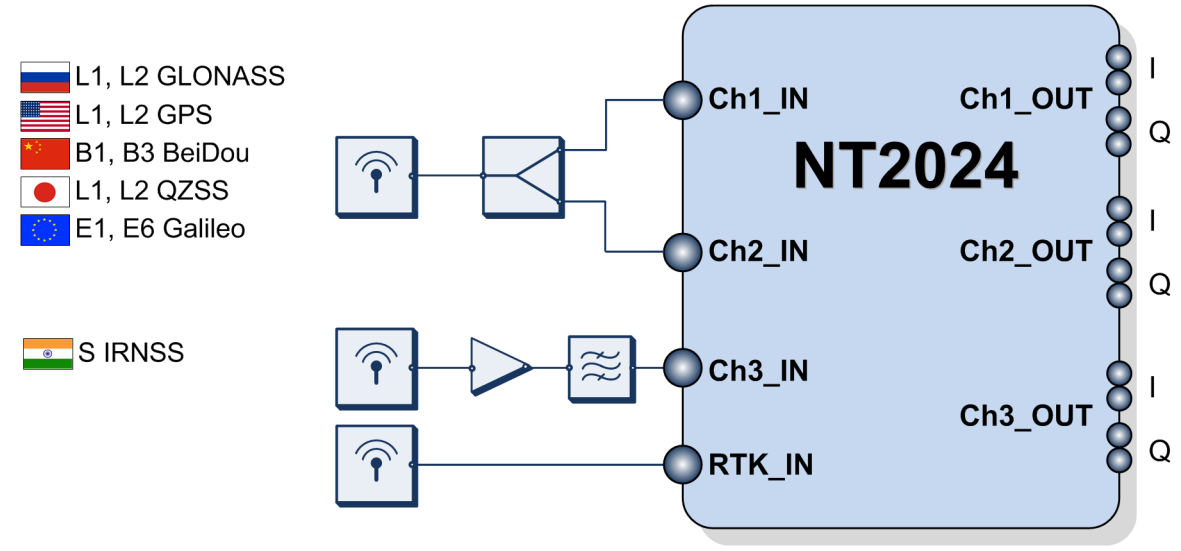



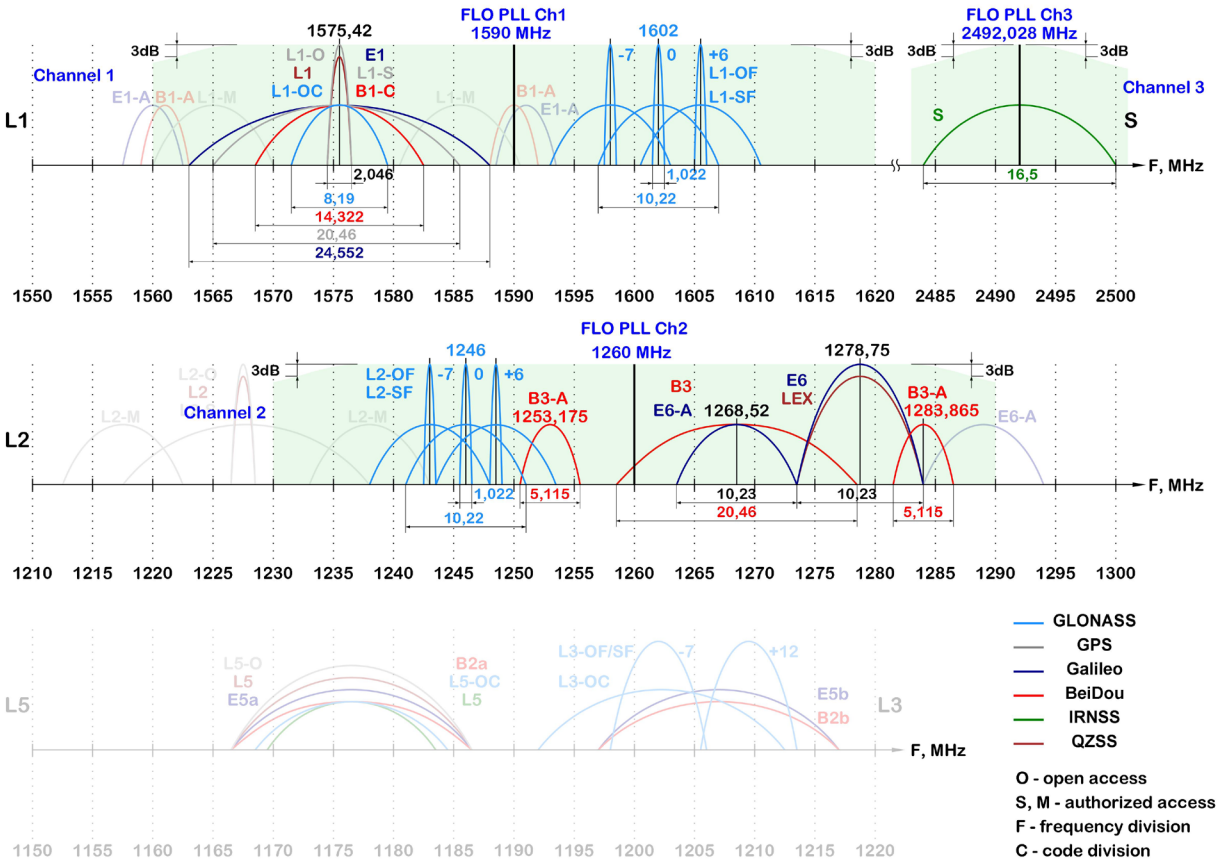
## 4.2 APPLICATION EXAMPLE 2



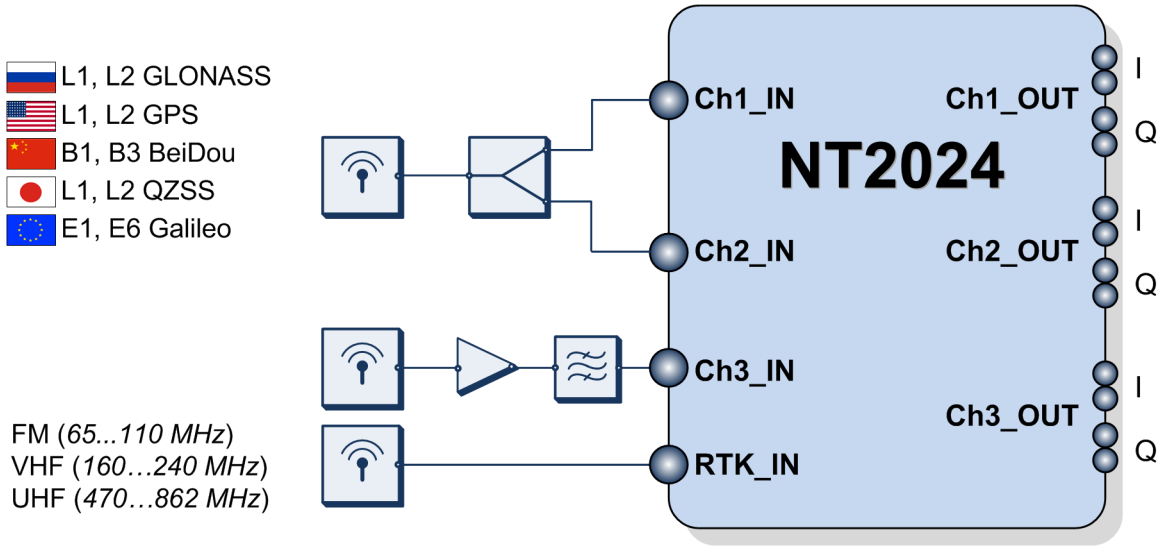



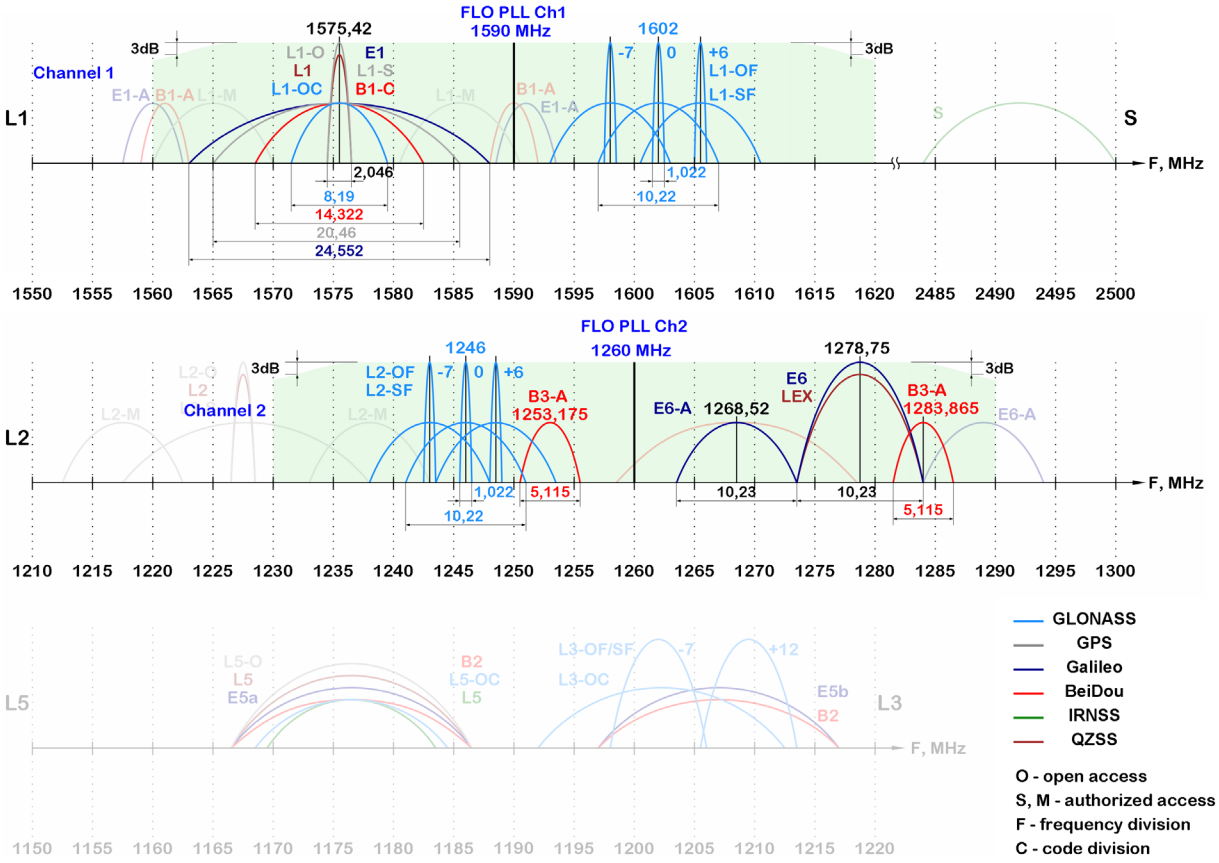
## 4.3 APPLICATION EXAMPLE 3



## 4.4 APPLICATION EXAMPLE 4



# 5 LAYOUT DESCRIPTION

IC dimensions are given in the table 2

Table 1: Block dimensions

| Dimension | Value | Unit |
|---|---|---|
| Height | 6 735 | um |
| Width | 6 445 | um |

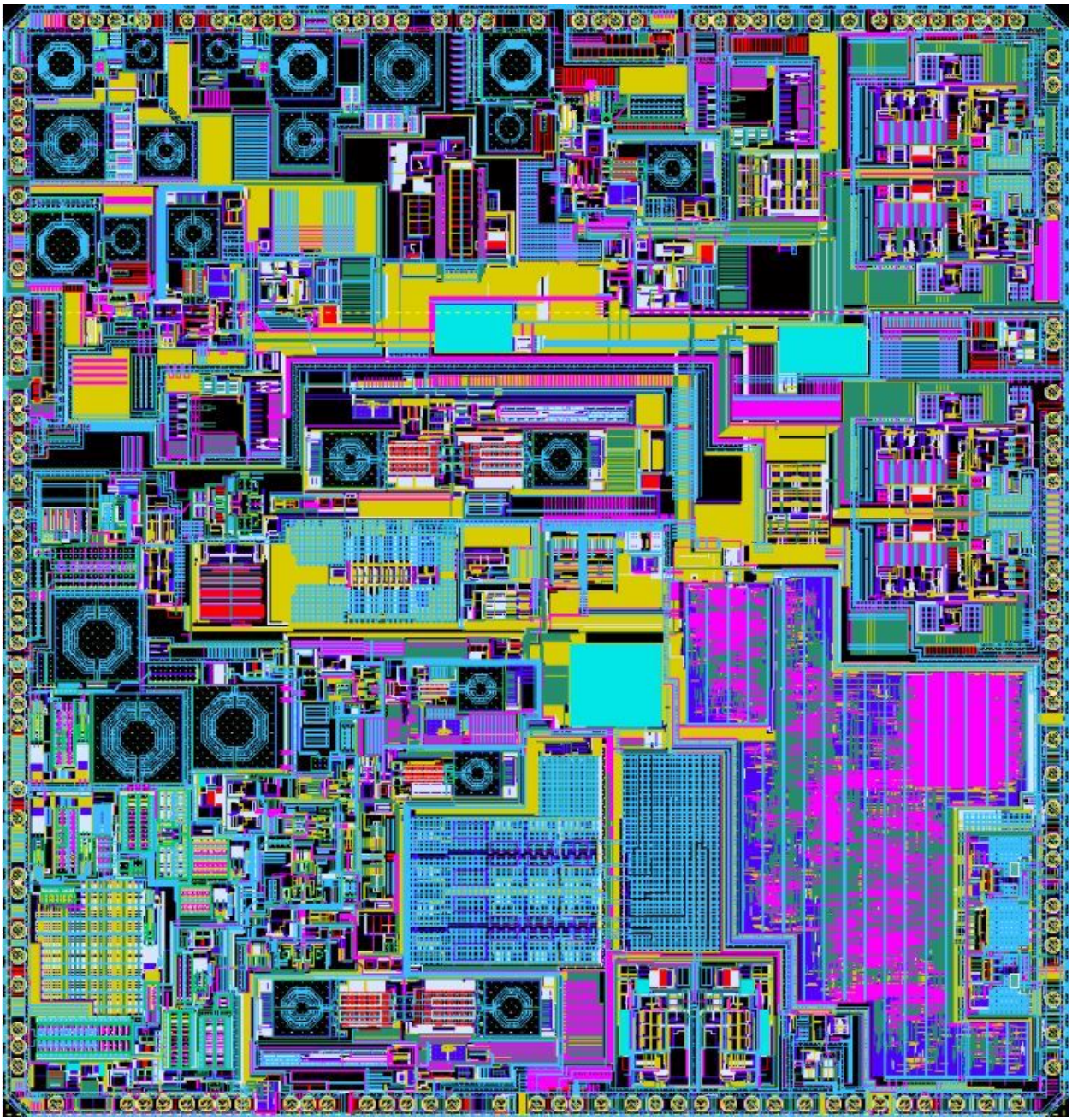


Figure 1: Block layout

# 6 OPERATING CHARACTERISTICS

## 6.1 TECHNICAL CHARACTERISTICS

Technology _____ TSMC BiCMOS 0.18 um
Status _____ silicon proven
Area _____ 43.5 $mm^2$

## 6.2 DC ELECTRICAL CHARACTERISTICS

The values of electrical characteristics are specified for $V_{cc}$ = 2.8 V to 3.6V, $T_a$ =-40…+85°C. Typical values are at $V_{cc}$ = 3.0 V, $T_a$ =+27°C, unless otherwise specified.

| Parameter | Symbol | Condition | Value | | | Unit |
|---|---|---|---|---|---|---|
| | | | min | typ. | max | |
| **Overall** | | | | | | |
| Supply voltage | $V_{cc}$ | - | 2.8 | 3.0 | 3.6 | V |
| Current consumption | $I_{cc}$ | Mode 1 | - | 62 | - | mA |
| | | Mode 2 | - | 144 | - | |
| | | Mode 3 | - | 137 | - | |
| | | Mode 4 | - | 31 | - | |
| | | Mode 5 | - | 33 | - | |
| | | Mode 6 | - | 82 | - | |
| | $I_{stb}$ | Stand-by mode | - | - | 2.0 | uA |
| Die temperature measurement range | $T_j$ | - | -40 | 27 | +100 | °C |
| Die temperature measurement accuracy | $\Delta T_j$ | - | - | - | ±5 | °C |
| Temperature sensor DAC resolution | K | - | - | 10 | - | bit |
| Input logic-level high | $V_{IL}$ | - | -0.25 | - | 0.3 | V |
| Input logic-level low | $V_{IH}$ | - | 0.7$V_{cc}$ | - | $V_{cc}$ +0.25 | V |
| **Channels #1 and #2** | | | | | | |
| AA output voltage drop | $\Delta V_{AA}$ | From supply voltage $V_{cc}$. Nominal value. Note 1 | - | 0.16 | - | V |
| Short-circuit protection current | $I_{AS}$ | Nominal value. Note 2 | - | 16.0 | - | mA |
| AA detection current | $I_{AW}$ | Nominal value. Note 3 | - | 1.8 | - | mA |
| IFA output DC level | $V_{IFA\_dif\_ch1\&2}$ | - | - | $V_{cc}$-1.17 | - | V |
| | | - | - | $V_{cc}$-1.36 | - | |
| Output logic-level high (digital output) | $V_{OH\_dig}$ | For outputs ch1_Ip (Sign), ch1_In (Magn), ch2_Ip (Sign), ch2_In (Magn). Load current 2 mA | $V_{cc}$-0.5 | $V_{cc}$-0.2 | $V_{cc}$ | V |
| Output logic-level low (digital output) | $V_{OL\_dig}$ | | 0 | 0.04 | 0.2 | V |
| Clock output DC level | $V_{DC\_CLK\_ch1\&2}$ | Preset1 | - | 1.16 - $V_{clk\_ch1\&2}/4^*$ | - | V |
| | | Preset2 | - | 1.74 - $V_{clk\_ch1\&2}/4^*$ | - | |
| | | Preset3 | - | 2.32 - $V_{clk\_ch1\&2}/4^*$ | - | |
| | | Preset4 | - | $V_{cc}$ - $V_{clk\_ch1\&2}/4^*$ | - | |
| **Channel #3** | | | | | | |
| IFA output DC level | $V_{IFA\_dif\_ch3}$ | Preset1 | - | $V_{cc}$–1.25 | - | V |
| | | Preset2 | - | $V_{cc}$–1.35 | - | |
| | | Preset3 | - | $V_{cc}$–1.50 | - | |
| | | Preset4 | - | $V_{cc}$–1.65 | - | |
| LNA AGC control voltage | $V_{AGCLNA}$ | Maximum gain | - | $V_{cc}$ | - | V |
| | | Minimum gain | - | 0 | - | |

Table “DC electrical characteristics” (continue)

| Parameter | Symbol | Condition | Value | | | Unit |
|---|---|---|---|---|---|---|
| | | | min | typ. | max | |
| MIX AGC control voltage | $V_{AGCMix}$ | Maximum gain | - | $V_{cc}$ | - | V |
| | | Minimum gain | - | 0 | - | |
| IF AGC control voltage | $V_{AGCIF}$ | Maximum gain | - | $V_{cc}$–0.1 | - | V |
| | | Minimum gain | - | 0.1 | - | |
| Clock output DC level | $V_{DC\_CLK\_ch3}$ | Preset1 | - | 1.10 – $V_{clk\_ch3}/2^{**}$ | - | V |
| | | Preset2 | - | 1.65 - $V_{clk\_ch3}/2^{**}$ | - | |
| | | Preset3 | - | 2.25 - $V_{clk\_ch3}/2^{**}$ | - | |
| | | Preset4 | - | $V_{cc}$ - $V_{clk\_ch3}/2^{**}$ | - | |

**Notes:**

*- $V_{clk\_ch1\&2}$ refer to table «AC electrical characteristics» on page 16

**- $V_{clk\_ch3}$ refer to table «AC electrical characteristics» on page 18

Notes:

1. Voltage drop value is evaluated from the equation $\Delta V = 0.1V + (2\Omega \times IAA)$, where IAA is active antenna current.
2. Current IAS = Imax, where Imax is active antenna maximal current
3. Current IAW = Imin, where Imin is active antenna minimal current

**Modes:**

1. **Channel 1:** L1 band, IQ GNSS, analog differential output, $V_{out\_p\text{-}p}$ = 230 mV
   **Channel 2:** L2 band, IQ GNSS, analog differential output, $V_{out\_p\text{-}p}$ = 230 mV
   **Channel 3:** disable.
2. **Channel 1:** L1 band, IQ GNSS, analog differential output, $V_{out\_p\text{-}p}$ = 230 mV
   **Channel 2:** L2 band, IQ GNSS, analog differential output, $V_{out\_p\text{-}p}$ = 230 mV
   **Channel 3:** S band, IQ IRNSS, analog differential output, $V_{out\_p\text{-}p}$ = 430 mV
3. **Channel 1:** L1 band, IQ GNSS, analog differential output, $V_{out\_p\text{-}p}$ = 230 mV
   **Channel 2:** L2 band, IQ GNSS, analog differential output, $V_{out\_p\text{-}p}$ = 230 mV
   **Channel 3:** RTK.
4. **Channel 1:** L1 band, IQ GNSS, analog differential output, $V_{out\_p\text{-}p}$ = 230 mV
   **Channel 2:** disabled;
   **Channel 3:** disabled.
5. **Channel 1:** disable;
   **Channel 2:** L2 band, IQ GNSS, analog differential output, $V_{out\_p\text{-}p}$ = 230 mV
   **Channel 3:** disable.
6. **Channel 1:** disabled;
   **Channel 2:** disabled;
   **Channel 3:** S band, IQ IRNSS, analog differential output, $V_{out\_p\text{-}p}$ = 430 mV

## 6.3 AC ELECTRICAL CHARACTERISTICS

The values of electrical characteristics are specified for $V_{cc}$ = 2.8 V to 3.6V, $T_a$ =-40…+85°C. Typical values are at $V_{cc}$ = 3.0 V, $T_a$ =+27°C, unless otherwise specified.

| Parameter | Symbol | Condition | Value | | | Unit |
|---|---|---|---|---|---|---|
| | | | min | typ. | max | |
| **Overall** | | | | | | |
| Reference frequency range | $F_{REF}$ | - | 1 | 24.84 | 30 | MHz |
| Reference input level | $REF_{IN}$ | - | 0.8 | 1 | 2 | V |
| **Channels #1 and #2** | | | | | | |
| **Overall** | | | | | | |
| Input frequency range | $F_{IN}$ | L1 band | 1530 | - | 1610 | MHz |
| | | L2, L3 or L5 band | 1164 | - | 1300 | |
| Noise figure referred to LNA1 input | $NF_{IN\_LNA1}$ | $G_{IF}$ > 45 dB | - | 2.3 | - | dB |
| 1dB compression point referred to LNA1 input | $P_{1dB\_LNA1}$ | $G_{IFA}$ = min. | - | -51 | - | dBm |
| Intercept point 3rd order referred to LNA1 input | $IIP3_{LNA1}$ | $G_{IFA}$ = min. | - | -40 | - | dBm |
| Noise figure referred to LNA2 input | $NF_{IN\_LNA2}$ | $G_{IFA}$ = min. | - | 6.8 | - | dB |
| 1dB compression point referred to LNA2 input | $P_{1dB\_LNA2}$ | $G_{IFA}$ = min. | - | -34 | - | dBm |
| Intercept point 3rd order referred to LNA2 input | $IIP3_{LNA2}$ | $G_{IFA}$ = min. | - | -23 | - | dBm |
| Noise figure referred to mixer input | $NF_{IN\_MIX}$ | $G_{IF}$ > 45 dB | - | 8 | - | dB |
| 1dB compression point referred to mixer input | $P_{1dB\_MIX}$ | $G_{IFA}$ = min. | - | -37 | - | dBm |
| Intercept point 3rd order referred to mixer input | $IIP3_{MIX}$ | $G_{IFA}$ = min. | - | -28 | - | dBm |
| **LNA1** | | | | | | |
| LNA1 noise figure | $NF_{LNA1}$ | L1 band | - | 2.0 | - | dB |
| | | L2, L3 or L5 band | - | 1.8 | - | |
| LNA1 gain | $G_{LNA1}$ | L1 band | - | 14.3 | - | dB |
| | | L2, L3 or L5 band | - | 14 | - | |
| LNA1 input VSWR | $VSWR_{LNA1\_in}$ | 50 Ω, L1 band | - | 1.5 | - | - |
| | | 50 Ω, L2, L3 or L5 band | - | 1.4 | - | |
| LNA1 output VSWR | $VSWR_{LNA1\_out}$ | 50 Ω, L1 band | - | 1.8 | - | - |
| | | 50 Ω, L2, L3 or L5 band | - | 2 | - | |
| LNA1 input 1dB compression point | $P_{1dB\_LNA1}$ | L1 band | - | -21 | - | dBm |
| | | L2, L3 or L5 band | - | -25 | - | |
| LNA1 intercept point 3rd order | $IIP3_{LNA1}$ | L1 band | - | -10 | - | dBm |
| | | L2, L3 or L5 band | - | -9 | - | |
| Input impedance | $R_{in\_LNA1}$ | - | - | 50 | - | Ω |
| Output impedance | $R_{out\_LNA1}$ | - | - | 50 | - | Ω |
| **LNA2** | | | | | | |
| LNA2 noise figure | $NF_{LNA2}$ | L1 band | - | 5.8 | - | dB |
| | | L2, L3 or L5 band | - | 5.3 | - | |
| LNA2 gain | $G_{LNA2}$ | L1 band | - | 1.29 | - | dB |
| | | L2, L3 or L5 band | - | 2.1 | - | |
| LNA2 input VSWR | $VSWR_{LNA2\_in}$ | 50 Ω, L1 band | - | 1.6 | - | - |
| | | 50 Ω, L2, L3 or L5 band | - | 1.22 | - | |
| LNA2 output VSWR | $VSWR_{LNA2\_out}$ | 50 Ω, L1 band | - | 1.8 | - | - |
| | | 50 Ω, L2, L3 or L5 band | - | 1.65 | - | |
| LNA2 input 1dB compression point | $P_{1dB\ LNA2}$ | L1 band | - | -4 | - | dBm |
| | | L2, L3 or L5 band | - | -3.7 | - | |

Table “AC electrical characteristics” (continue)

| Parameter | Symbol | Condition | Value | | | Unit |
|---|---|---|---|---|---|---|
| | | | min | typ. | max | |
| LNA2 intercept point 3rd order | $IIP3_{LNA2}$ | L1 band | - | 3.6 | - | |
| | | L2, L3 or L5 band | - | 3.6 | - | |
| Input impedance | $R_{in\ LNA2}$ | - | - | 50 | - | Ω |
| Output impedance | $R_{out\ LNA2}$ | - | - | 50 | - | Ω |
| **Mixer** | | | | | | |
| Mixer input VSWR | $VSWR_{IN\_MIX}$ | L1 band, 50 Ω, F = 1589.76 MHz | - | 2 | - | - |
| | | L2, L3 or L5 band, 50 Ω, F = 1217.16 MHz | - | 2 | - | |
| **PPF** | | | | | | |
| Image rejection | IR | L1 band | - | 28 | - | dB |
| | | L2, L3 or L5 band | - | 30 | - | |
| **LPF&IFA** | | | | | | |
| Sinusoidal/noise signal peak-to-peak voltage at the differential linear outputs | $V_{p-p}$ | 510 Ohm load resistance | - | 200/480 | - | mV |
| Gain | G | Minimal | - | 10 | - | dB |
| | | Maximal | - | 58 | - | |
| AGC range | ΔG | - | 48 | - | - | dB |
| **Synthesizer** | | | | | | |
| LO frequency | $F_{LO}$ | Adjustable | 1165 | - | 1606 | MHz |
| LO phase noise | $PN_{LO}$ | At 10 kHz frequency offset, $F_{REF}$ = 24.84 MHz, L1 band | - | -89 | - | dBc/Hz |
| | | At 10 kHz frequency offset, $F_{REF}$ = 24.84 MHz, L2, L3 or L5 band | - | -89 | - | |
| | | At 100 kHz frequency offset, $F_{REF}$ = 24.84 MHz, L1 band | - | -91.5 | - | |
| | | At 100 kHz frequency offset, $F_{REF}$ = 24.84 MHz, L2, L3 or L5 band | - | -89 | - | |
| | | At 1 MHz frequency offset, $F_{REF}$ = 24.84 MHz, L1 band | - | -111 | - | |
| | | At 1 MHz frequency offset, $F_{REF}$ = 24.84 MHz, L2, L3 or L5 band | - | -116 | - | |
| Clock frequency | $F_{CLK}$ | $F_{LO}$/R, where R = CDIV<9:0> | 1.55 | - | 198.72 | MHz |
| Peak-to-peak voltage at the clock output at typical frequency | $V_{clk\_ch1\&2}$ | Preset1, ECL | - | 0.50 | - | V |
| | | Preset2, ECL | | 0.72 | | |
| | | Preset3, ECL | | 0.91 | | |
| | | Preset4, ECL | | 1.07 | | |
| | | Preset5, CMOS | - | 0.91 | - | |
| | | Preset6, CMOS | | 1.60 | | |
| | | Preset7, CMOS | | 2.28 | | |
| | | Preset8, CMOS | | 2.95 | | |
| **Channel #3** | | | | | | |
| **Overall** | | | | | | |
| Input frequency range | $F_{IN\_ch3}$ | IRNSS S-band | 2170 | - | 2500 | MHz |
| | | FM | 65 | - | 110 | |
| | | VHF | 160 | - | 240 | |
| | | UHF | 470 | - | 862 | |
| Noise figure | $NF_{ch3}$ | IRNSS S-band | - | 7.1 | - | dB |
| | | FM | - | 4.5 | - | |
| | | VHF | - | 4.5 | - | |
| | | UHF | - | 4.0 | - | |
| Input VSWR | $VSWR_{IN\_ch3}$ | 50 Ω, IRNSS S-band | - | 4.0 | - | - |
| | | 50 Ω, FM | - | 1.8 | - | |
| | | 50 Ω, VHF | - | 2.0 | - | |
| | | 50 Ω, UHF | - | 2.0 | - | |

Table "AC electrical characteristics" (continue)

| Parameter | Symbol | Condition | | Value | | | Unit |
|---|---|---|---|---|---|---|---|
| | | | | min | typ. | max | |
| Input 1dB compression point | $P_{1dBRF\_ch3}$ | IRNSS S-band | $G_{RF}$ = max, $G_{IF}$ =min | - | -17 | - | dBm |
| | | | $G_{RF}$ = min, $G_{IF}$ =min | | 13 | | |
| | | FM, VHF, UHF | $G_{RF}$ = max, $G_{IF}$ =min | - | -28 | - | |
| | | | $G_{RF}$ = min, $G_{IF}$ =min | | 10 | | |
| Intercept point 3rd order | $IIP3_{RF\_ch3}$ | IRNSS S-band | $G_{RF}$ = max, $G_{IF}$ =min | - | -9 | - | dBm |
| | | | $G_{RF}$ = min, $G_{IF}$ =min | | 22 | | |
| | | FM, VHF, UHF | $G_{RF}$ = max, $G_{IF}$ =min | - | -20 | - | |
| | | | $G_{RF}$ = min, $G_{IF}$ =min | | 20 | | |
| Overall voltage gain | $G_{ch3}$ | - | | - | 90 | - | dB |
| IQ phase accuracy | $\Delta\varphi_{ch3}$ | I/Q phase error at 1 MHz | | -3 | - | +3 | degrees |
| LNA AGC range | $\Delta G_{LNA\_ch3}$ | IRNSS S-band | G = max | - | 16.4 | - | dB |
| | | | G = min | | -11.7 | | |
| | | FM, VHF, UHF | G = max | - | 18.1 | - | |
| | | | G = min | | -17 | | |
| MIX AGC range | $\Delta G_{Mix\_ch3}$ | IRNSS S-band | G = max | - | 7.0 | - | dB |
| | | | G = min | | 3.0 | | |
| | | FM, VHF, UHF | G = max | - | 11.6 | - | |
| | | | G = min | | 3.0 | | |
| IFA AGC range | $\Delta G_{IFA}$ | G = max | | - | -7 | - | dB |
| | | G = min | | | 73 | | |
| **IFA&LPF** | | | | | | | |
| Nominal output voltage | $V_{out\_ch3}$ | Minimal | | - | 150 | - | mV |
| | | Default | | - | 430 | - | |
| | | Maximal | | - | 1500 | - | |
| IQ amplitude output voltage accuracy | $\Delta A_{ch3}$ | - | | - | 28.5 | - | mV |
| Stopband attenuation | $S_A$ | $F_{cut\_LPF}$ = 3.80 MHz | F = 6 MHz | - | 20 | - | dB |
| | | | F = 8 MHz | - | 39 | - | |
| Output impedance | $R_{out}$ | Differential | | - | 1.5 | - | kΩ |
| LPF bandwidth | $BW_{LPF}$ | $F_{cut\_LPF}$ = 1.60 MHz | | - | 1.6 | - | MHz |
| | | $F_{cut\_LPF}$ = 3.80 MHz | | - | 3.8 | - | |
| | | $F_{cut\_LPF}$ = 4.90 MHz | | - | 4.9 | - | |
| **Synthesizer** | | | | | | | |
| LO phase noise | $PN_{LO\_ch3}$ | At 10 kHz frequency offset, $F_{REF}$ = 24.84 MHz | IRNSS S-band | - | -85 | - | dBc/Hz |
| | | | FM | - | -108 | - | |
| | | | VHF | - | -103 | - | |
| | | | UHF | - | -95 | - | |
| | | At 100 kHz frequency offset, $F_{REF}$ = 24.84 MHz | IRNSS S-band | - | -87 | - | |
| | | | FM | - | -110 | - | |
| | | | VHF | - | -105 | - | |
| | | | UHF | - | -98 | - | |
| | | At 1 MHz frequency offset, $F_{REF}$ = 24.84 MHz | IRNSS S-band | - | -115 | - | |
| | | | FM | - | -130 | - | |
| | | | VHF | - | -128 | - | |
| | | | UHF | - | -117 | - | |
| N divider ratio | N | IRNSS S-band | | 56 | - | 2047 | - |
| | | FM | | 16 | - | 1023 | |
| Fractional-N resolution | Res | - | | - | 24 | - | bit |
| R divider ratio | R | - | | 1 | - | 31 | - |

Table “AC electrical characteristics” (continue)

| Parameter | Symbol | Condition | Value | | | Unit |
|---|---|---|---|---|---|---|
| | | | min | typ. | max | |
| VCO frequency range | $F_{VCO}$ | VCO 1 | 900 | - | 1300 | MHz |
| | | VCO 2 | 1250 | - | 1820 | |
| | | VCO 3 | 4340 | - | 5000 | |
| Comparison frequency | $F_{CPC}$ | - | 1 | 24.84 | 30 | MHz |
| Peak-to-peak voltage at the clock output at typical frequency | $V_{clk\_ch3}$ | Preset1, ECL | - | 0.57 | - | V |
| | | Preset2, ECL | - | 0.85 | - | |
| | | Preset3, ECL | - | 1.14 | - | |
| | | Preset4, ECL | - | 1.38 | - | |
| | | Preset5, CMOS | - | 1.12 | - | |
| | | Preset6, CMOS | - | 1.70 | - | |
| | | Preset7, CMOS | - | 2.25 | - | |
| | | Preset8, CMOS | - | Vcc | - | |

# 7 DELIVERABLES

IP contents:

- Datasheet
- Layout View (GDSII)
- Evaluation kit based on packaged IC
- Characterization Report
- Behavioral Model
- SPICE netlist (.cdl)
- Integration Support