



# **AK2400**

## **High integrated receiver for PMR/LMR**

### **Overview**

- Operating Supply Voltage : 2.7 to 5.5V
- Wide Operating Temperature Range : -40 to +85°C
- Delta-Sigma Fractional-N PLL with a frequency switching function : No glitch operation for AFC(Automatic Frequency Control) and DFM(Digital Frequency Modulation)
- High linearity RF Mixer(1st) and IF Mixer(2nd)
- IF Local frequency selectable as usage : 28.8MHz,45.9MHz,50.4MHz,57.6MHz
- Frequency tripler generates IF Local signal
- Built-in very narrow programmable bandwidth IF BPF (450kHz)
- PLL FM detector
- RSSI function
- Noise squelch circuit
- Built-in 12bits 1Msps SAR ADC
- Audio output signal S/N (Wide/Narrow) : 50dB / 46dB (Typ.) \*De-emphasis + BPF
- Compact packaging : 56pin-QFN (8 x 8 mm、 0.5 mm pitch)

### **Applications**

- Narrowband high performance professional digital wireless systems (Channel spacing for 6.25kHz,12.5kHz)
- Public safety and community wireless systems
- Marine / mobile communication systems
- Low power radio systems
- Monitoring and control telemeter systems

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# Block Diagram

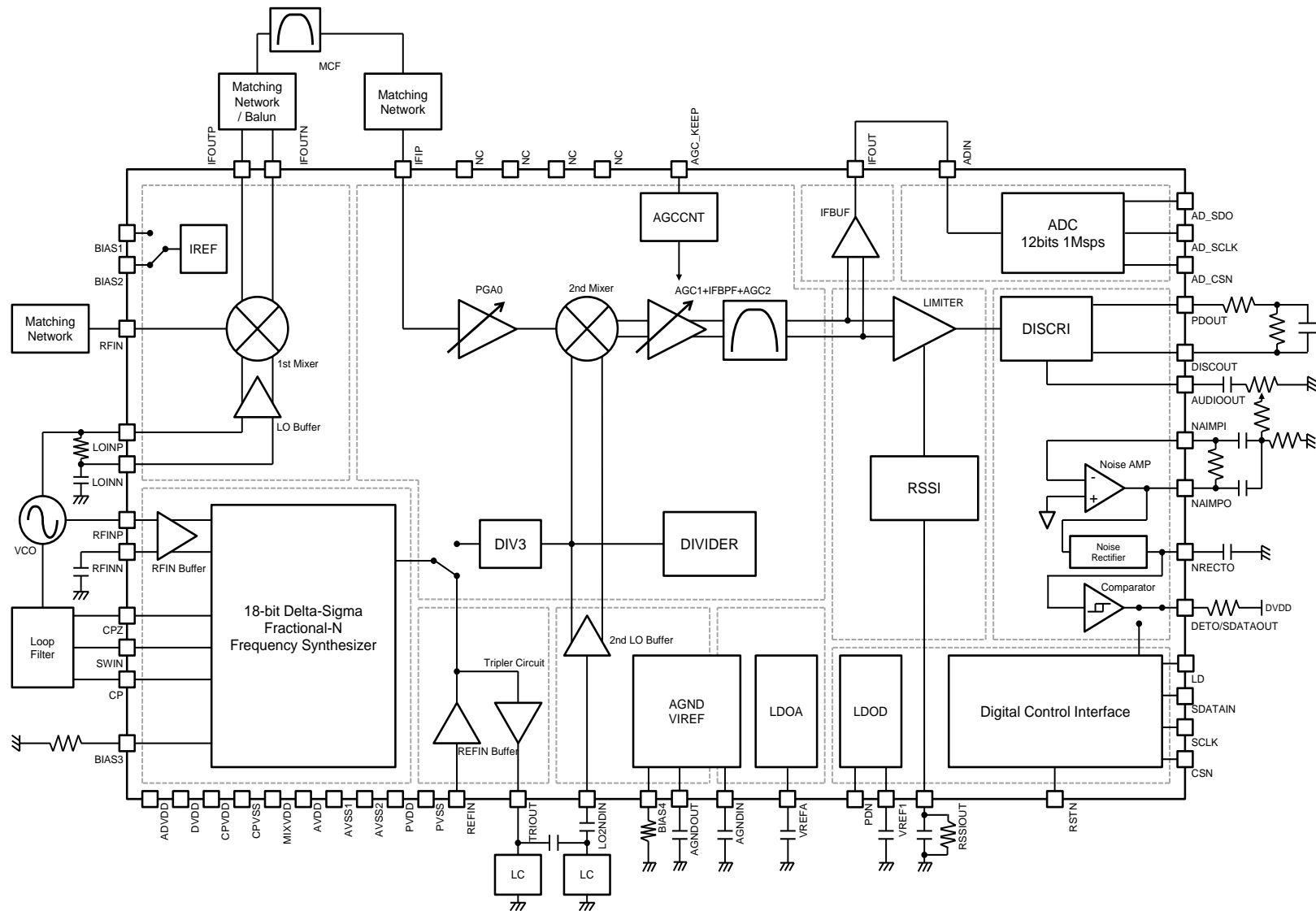


Figure 1 Block Diagram

## Function

| Block           | Description  |
|-----------------|--|
| PLL SYNTH       | The Delta-Sigma Fractional-N PLL (Phase Locked Loop) frequency synthesizer by the external VCO and the loop filter.  |
| 1stMIX          | 1st Mixer to convert the RFIN signal down to IF frequency by 1st LO signal.  |
| PGA0+2ndMIX     | 2nd Mixer to convert the IFIP signal down to 450kHz by 2ndLO signal.   |
| AGC+BPF         | The circuit composed of AGC and BPF, where the desired signal is amplified and spurious components included in the signal from the 2nd-mixer are eliminated. |
| IFBUF           | The circuit to output filtered signal by AGC+BPF.  |
| Divider         | The circuit to divide the signal from LO2NDIN pin.   |
| LIMITER         | The circuit to amplify the signal filtered at the AGC+BPF stage and generate rectangular wave.   |
| DISCRI          | The demodulator circuit with PLL FM detector, where the audio signal is recovered.   |
| Noise AMP       | The amplifiers to compose the Band-pass filter for noise squelch.  |
| Noise Rectifier | The rectification circuit to detect the noise level.   |
| Comparator      | The circuit to compare the noise level with reference voltage level.   |
| RSSI            | The circuit to indicate the Received Signal Strength Indicator (RSSI) by generating a DC voltage corresponding to the input level from Limiter.              |
| AGND+VIREF      | The circuit to generate internal reference voltage.  |
| Control Logic   | The control register controls the status of internal condition by serial data that consists of 1 instruction bit, 5 address bits and 18 data bits.           |
| ADC             | 12bits 1MSPS A/D converter.  |

## Pin assignment

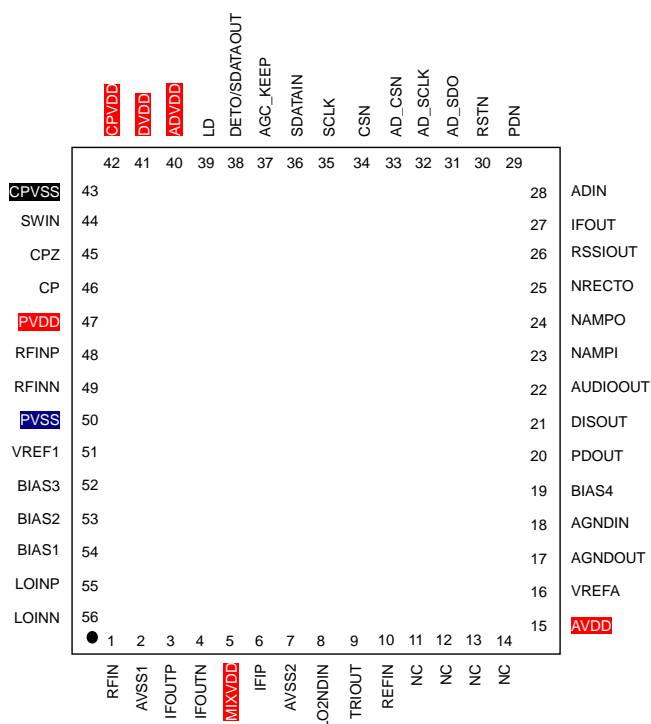


Figure 2 Pin assignment

Note) The exposed pad at the center of the backside should be connected to ground.

|                     |
|---------------------|
| <b>Pin/Function</b> |
|---------------------|

| No. | Name     | Type | Conditions at power down | Function  |
|-----|----------|------|--------------------------|---|
| 1   | RFIN     | AI   | -                        | RF signal input pin.<br>Connecting a inductor between this pin and ground.                    |
| 2   | AVSS1    | PWR  | -                        | Analog VSS power supply pin   |
| 3   | IFOUTP   | AO   | -                        | IF Output Positive .This pin is open drain output.<br>It needs power feeding via an inductor. |
| 4   | IFOUTN   | AO   | -                        | IF Output Negative .This pin is open drain output.<br>It needs power feeding via an inductor. |
| 5   | MIXVDD   | PWR  | -                        | Mixer VDD power supply pin  |
| 6   | IFIP     | AI   | -                        | IF signal input pin   |
| 7   | AVSS2    | PWR  | -                        | Analog VSS power supply pin   |
| 8   | LO2NDIN  | AI   | -                        | 2nd LO signal input pin   |
| 9   | TRIOUT   | AO   | -                        | Tripler circuit output pin  |
| 10  | REFIN    | AI   | -                        | Reference signal input pin  |
| 11  | NC       | -    | Hi-Z                     | This pin must be left open  |
| 12  | NC       | -    | Hi-Z                     | This pin must be left open  |
| 13  | NC       | -    | Hi-Z                     | This pin must be left open  |
| 14  | NC       | -    | Hi-Z                     | This pin must be left open  |
| 15  | AVDD     | PWR  | -                        | Analog VDD power supply pin   |
| 16  | VREFA    | AO   | -                        | LDO reference pin. Connect the capacitor to stabilize LDO reference voltage                   |
| 17  | AGNDOUT  | AO   | -                        | Analog ground output pin. Connect the capacitor to stabilize the analog ground level.         |
| 18  | AGNDIN   | AI   | -                        | Analog ground input pin. Connect the capacitor to stabilize the analog ground level.          |
| 19  | BIAS4    | AO   | -                        | Output pin to connect bias resistor for reference voltage                                     |
| 20  | PDOUT    | AO   | -                        | Pin1 for Discriminator Low-pass filter  |
| 21  | DISCOUT  | AO   | -                        | Pin2 for Discriminator Low-pass filter  |
| 22  | AUDIOOUT | AO   | -                        | Demodulated audio signal output pin   |
| 23  | NAMPI    | AI   | -                        | Input pin for noise squelch amplifier   |
| 24  | NAMPO    | AO   | -                        | Output pin for noise squelch amplifier  |
| 25  | NRECTO   | AO   | -                        | Output pin for the rectification circuit  |
| 26  | RSSIOUT  | AO   | -                        | Output pin to connect capacitor for Received Signal Strength Indicator(RSSI)                  |
| 27  | IFOUT    | AO   | -                        | Output pin for IFBUF  |
| 28  | ADIN     | AI   | -                        | Input pin for A/D converter   |
| 29  | PDN      | DI   | Hi-Z                     | Power down pin for LDO  |
| 30  | RSTN     | DI   | Hi-Z                     | Hardware reset pin  |
| 31  | AD_SDO   | DO   | -                        | A/D Converter data output pin for serial data   |
| 32  | AD_SCLK  | DI   | Hi-Z                     | A/D Converter clock input pin for serial data   |
| 33  | AD_CSN   | DI   | Hi-Z                     | A/D Converter chip select input pin for serial data   |
| 34  | CSN      | DI   | Hi-Z                     | Chip select input pin for serial data   |

|    |                    |     |         |   |
|----|--------------------|-----|---------|---|
| 35 | SCLK               | DI  | Hi-Z    | Clock input pin for serial data   |
| 36 | SDATAIN            | DI  | Hi-Z    | Data input pin for serial data  |
| 37 | AGC_KEEP           | DI  | Hi-Z    | Input pin for AGC_KEEP function   |
| 38 | DETO /<br>SDATAOUT | DO  | Hi-Z    | Signal detect output pin/<br>Data output pin for serial data                |
| 39 | LD                 | DO  | Low     | Lock detect output pin for PLL  |
| 40 | ADVDD              | PWR | -       | AD VDD power supply pin   |
| 41 | DVDD               | PWR | -       | Digital VDD power supply pin  |
| 42 | CPVDD              | PWR | -       | Charge pump VDD power supply pin  |
| 43 | CPVSS              | PWR | -       | Charge pump VSS power supply pin  |
| 44 | SWIN               | AI  | Note1,2 | Connect to resistance pin for fast lock up                                  |
| 45 | CPZ                | AI  | Note1,2 | Connect to the loop filter capacitor  |
| 46 | CP                 | AO  | Hi-Z    | Charge pump output pin  |
| 47 | PVDD               | PWR | -       | PLL VDD power supply pin  |
| 48 | RFINP              | AI  | -       | Prescaler input positive  |
| 49 | RFINN              | AI  | -       | Prescaler input negative  |
| 50 | PVSS               | PWR | -       | PLL VSS power supply pin  |
| 51 | VREF1              | AO  | -       | LDO reference pin. Connect the capacitor to stabilize LDO reference voltage |
| 52 | BIAS3              | AO  | -       | Resistance pin for setting charge pump output current                       |
| 53 | BIAS2              | AIO | -       | Resistance pin for current adjustment for 1st Mixer                         |
| 54 | BIAS1              | AIO | -       | Resistance pin for current adjustment for 1st Mixer                         |
| 55 | LOINP              | AI  | -       | Lo input positive   |
| 56 | LOINN              | AI  | -       | Lo input negative   |

AI: Analog input pin

AO: Analog output pin

AIO: Analog I/O pin

PWR: Power supply pin

DI: Digital input pin

DO: Digital output pin

Note1) When [PDN]="0", {PDSYNTH\_N}="0", or [PDN]="1", {PDSYNTH\_N}="0", the state of the switch of loop filter selection is ON.

Note2) Power down refers to the state where [PDN]="0" after power-on.

[CPZ] pin should be connected to R2 and C2, which are intermediate nodes, even if the Fast Lockup feature is not used. For the output destination from [CPZ] pin, see "Charge Pump and Loop Filter" on page 36.

## Absolute Maximum Ratings

| Parameter                                  | Symbol           | Min. | Max.                                | Unit | Remarks |
|--|------------------|------|-------------------------------------|------|---------|
| Supply Voltage                             | VDD1             | -0.3 | 6.5                                 | V    | Note 1  |
|  | CPVDD            | -0.3 | 6.5                                 | V    |         |
|  | MIXVDD           | -0.3 | 5.5                                 | V    |         |
|  | DVDD             | -0.3 | 6.5                                 | V    |         |
| Ground level                               | VSS              | 0    | 0                                   | V    |         |
| Analog Input Voltage                       | V <sub>AIN</sub> | -0.3 | VDD1+0.3<br>CPVDD+0.3<br>MIXVDD+0.3 | V    | Note 1  |
| Digital Input Voltage                      | V <sub>DIN</sub> | -0.3 | DVDD+0.3                            | V    |         |
| Input Current<br>(Except power supply pin) | I <sub>IN</sub>  | -10  | +10                                 | mA   |         |
| RF Input Power                             | RFPOW            |      | 12                                  | dBm  |         |
| LO Input Power                             | LOPOW            |      | 12                                  | dBm  |         |
| Storage Temperature                        | T <sub>stg</sub> | -55  | 125                                 | °C   |         |

Note 1 VDD1 is applied to PVDD, AVDD, ADVDD pins

Note 2 All voltages are relative to the VSS pin.

Note 3 Exceeding these maximum ratings may result in damage to the AK2400. Normal operation is not guaranteed at these extremes.

## Recommended Operating Conditions

| Parameter                | Symbol         | Conditions        | Min. | Typ.     | Max. | Unit |
|--------------------------|----------------|-------------------|------|----------|------|------|
| Operating Temperature    | T <sub>a</sub> |                   | -40  |          | 85   | °C   |
| Power Supply voltage     | VDD1           | PVDD, AVDD, ADVDD | DVDD | 3.0      | 5.5  | V    |
|                          | CPVDD          |                   | VDD1 | 5.0      | 5.5  | V    |
|                          | MIXVDD         |                   | VDD1 | 5.0      | 5.5  | V    |
|                          | DVDD           |                   | 2.7  | 3.0      | 5.5  | V    |
| Analog Reference Voltage | AGND           | AGNDOUT           |      | 1/2VREFA |      | V    |

Note ) All voltages are relative to the VSS pin.

## Digital DC Characteristics

| Parameter                 | Symbol   | Conditions  | Min.     | Typ. | Max.    | Unit    |
|---------------------------|----------|---|----------|------|---------|---------|
| High level input voltage  | $V_{IH}$ | RSTN, SCLK, SDATAIN,<br>CSN, PDN, AD_CSN,<br>AD_SCLK, AGC_KEEP                  | 0.8DVDD  |      |         | V       |
| Low level input voltage   | $V_{IL}$ | RSTN, SCLK, SDATAIN,<br>CSN, PDN, AD_CSN,<br>AD_SCLK, AGC_KEEP                  |          |      | 0.2DVDD | V       |
| High level input current  | $I_{IH}$ | $V_{IH}=DVDD$<br>RSTN, SCLK, SDATAIN,<br>CSN, PDN, AD_CSN,<br>AD_SCLK, AGC_KEEP |          |      | 10      | $\mu A$ |
| Low level input current   | $I_{IL}$ | $V_{IL}=0V$<br>RSTN, SCLK, SDATAIN,<br>CSN, PDN, AD_CSN,<br>AD_SCLK, AGC_KEEP   | -10      |      |         | $\mu A$ |
| High level output voltage | $V_{OH}$ | $I_{OH}=+0.2mA$<br>LD, AD_SDO,<br>DETO/SDATAOUT                                 | DVDD-0.4 |      | DVDD    | V       |
| Low level output voltage  | $V_{OL}$ | $I_{OL}=-0.4mA$<br>LD, AD_SDO,<br>DETO/SDATAOUT                                 | 0.0      |      | 0.4     | V       |



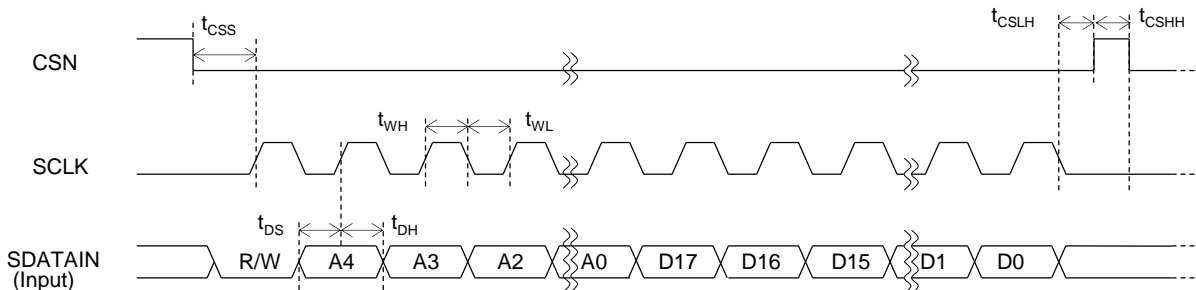
## Digital AC Timing

### 1) Serial Interface Timing

AK2400 is connected to a CPU by three-wired interface through CSN, SCLK, SDATAIN and SDATAOUT pins, which can make reading and writing data for control registers.

Serial data named SDATAIN is consist of 1-bit read and write instruction(R/W), 5-bit address (A4 to A0) and 18-bit data(D17 to D0) in one frame.

#### Write mode



#### Read mode

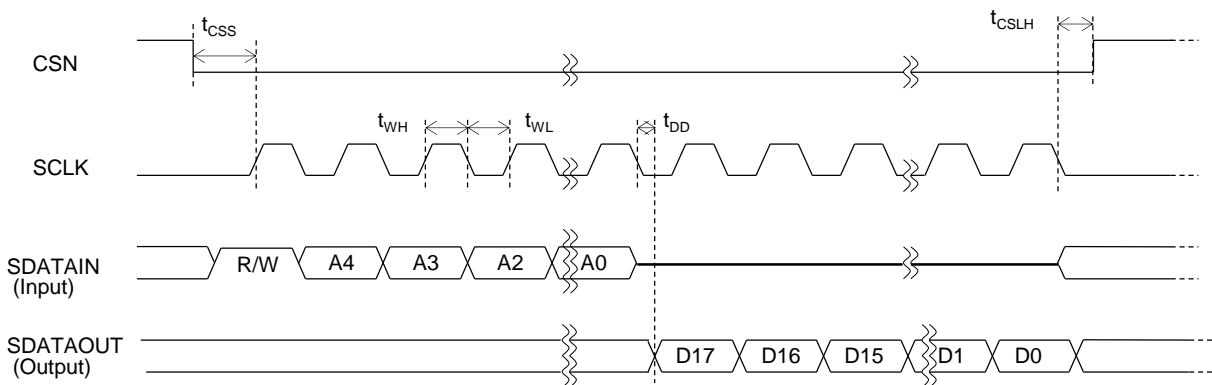


Figure 3 Serial Interface Timing

R/W : Instruction bit controls to write data to AK2400 or read back from it.  
When set to low, AK2400 is in write mode. When set to high, AK2400 is in read mode.

A4 to A0 : Register address to be accessed.  
D17 to D0 : Write or read data to be accessed.

- <1> CSN(Chip select) is normally selected high for disable.  
When CSN is set to low, serial interface becomes active.
- <2> In write mode, instruction, address and data input from SDATAIN pin are synchronized and latched with the rising edge of 24 iterations of SCLK clock. Set to low between address A0 and data D17. Input data is fixed synchronized with the rising edge of 24th clock. Note that if CSN become "H" before 24th clock, setting data becomes invalid. During the period when CSN is set to "L", consecutive writing is available.
- <3> In read mode, instruction and address are synchronized and latched with the rising edge of 6 iterations of SCLK clock. And the register data are output from SDATAIN pin synchronized with the falling edge of 18 iterations of SCLK clock.  
CSN to "H" once reading is completed because consecutive reading is not valid.  
Also, in read mode DETO/SDATAOUT pin should be set to SDATAOUT by {SDATAOUT\_OE}="1".

| Parameter                       | Symbol     | Conditions | Min. | Typ. | Max. | Unit |
|---------------------------------|------------|------------|------|------|------|------|
| CSN setup time                  | $t_{CSS}$  |            | 40   |      |      | ns   |
| SDATAIN setup time              | $t_{DS}$   |            | 20   |      |      | ns   |
| SDATAIN hold time               | $t_{DH}$   |            | 20   |      |      | ns   |
| SCLK high time                  | $t_{WH}$   |            | 40   |      |      | ns   |
| SCLK low time                   | $t_{WL}$   |            | 40   |      |      | ns   |
| CSN low hold time               | $t_{CSLH}$ |            | 20   |      |      | ns   |
| CSN high hold time              | $t_{CSHH}$ |            | 40   |      |      | ns   |
| SCLK to SDATA output delay time | $t_{DD}$   | 20pF load  |      |      | 40   | ns   |

Note) Digital input and output timing is relative to 0.5DVDD of rising signal and falling signal.

## ADC AC Timing

At first, set {PDADC\_N}="1" to operate the A/D Converter. A/D conversion cycle is started by the falling edge of AD\_CSN. AD\_SDO outputs "0" synchronized with the falling edge of AD\_CSN. AD\_SDO outputs "0" until the third falling edge of AD\_SCLK. From the fourth falling edge, the results of 12 bits A/D conversion are output with MSB first during the 16th edge. A/D conversion cycle is ended on the 16th falling edge, AD\_SDO becomes Hi-Z. After the 16th edge, set AD\_CSN = "1". Since A/D converter becomes acquisition phase after the 16th falling edge of AD\_SCLK, AD\_CSN pin must keep "1" during the end of "tq" time after AD\_SDO became Hi-Z. It is possible to get the available conversion results from the next cycle, since the first A/D conversion result is the dummy cycle (unavailable result).

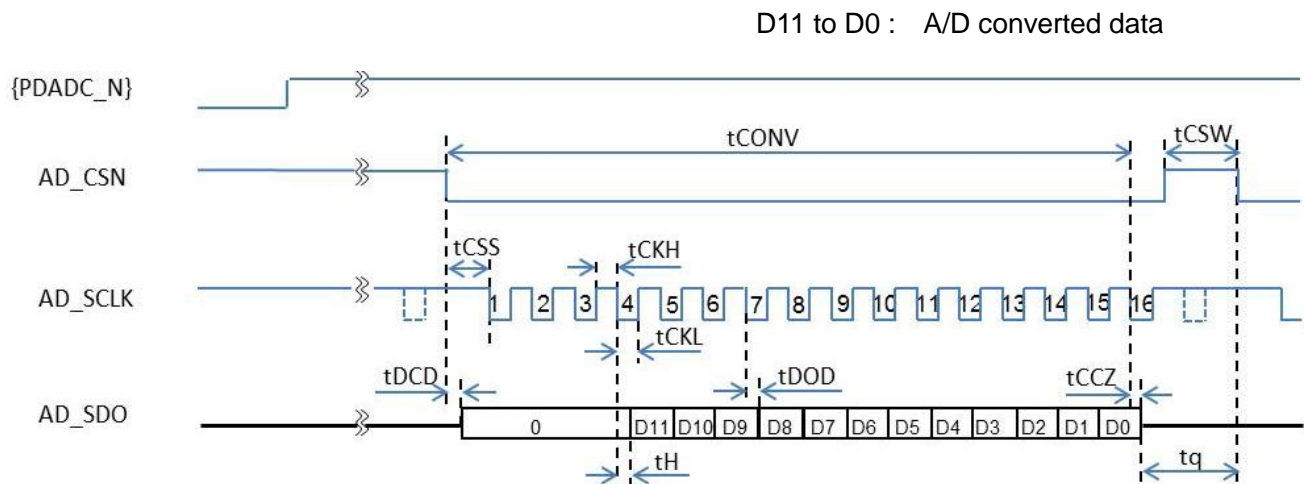


Figure 4 ADC Timing

| Parameter   | Symbol  | Conditions | Min.            | Typ. | Max. | Unit |
|---|---------|------------|-----------------|------|------|------|
| AD_SCLK frequency   | fADSCLK |            |                 |      | 20   | MHz  |
| Minimum quiet time required between bus relinquish and start of next conversion | Tq      |            | 40              |      |      | ns   |
| AD_CSN Falling to First SCLK Falling time                                       | tCSS    |            | 10              |      |      | ns   |
| AD_CSN edge to AD_SDO Tri-State Disabled  | tDCD    |            |                 |      | 25   | ns   |
| AD_SCLK Falling to AD_SDO Output Delay time                                     | tDOD    | 15pF load  |                 |      | 25   | ns   |
| AD_SCLK High Pulse Width  | tCKH    |            | 0.4×tA<br>DSCLK |      |      | ns   |
| AD_SCLK Low Pulse Width   | tCKL    |            | 0.4×tA<br>DSCLK |      |      | ns   |
| 16th AD_SCLK Falling to AD_SDO Hi-Z State Delay time                            | tCCZ    |            |                 |      | 25   | ns   |
| Minimum AD_CSN Pulse Width  | tCSW    |            | 25              |      |      | ns   |

Note) Digital input and output timing is relative to 0.5DVDD of rising signal and falling signal.

## Power-up sequence

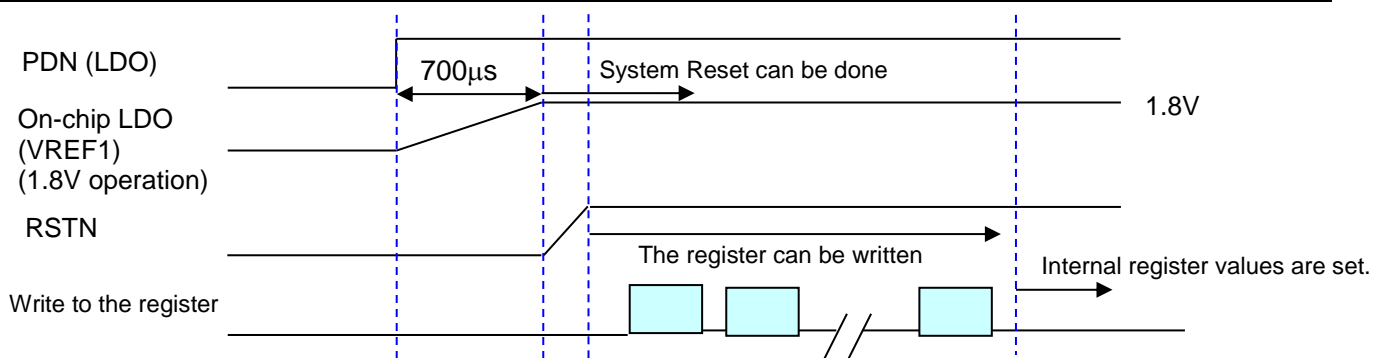


Figure 5 power-up sequence

Note) Power-up sequence assumes VDD ON.

After PDN is set to “High”, registers remain undefined. In order to initialize them, RSTN is set to “High”

## System Reset

| Parameter                         | Symbol     | Conditions    | Min. | Typ. | Max. | Unit          | Remarks |
|-----------------------------------|------------|---------------|------|------|------|---------------|---------|
| Hardware reset signal input width | $t_{RSTN}$ | RSTN pin      | 1    |      |      | $\mu\text{s}$ | Note 1) |
| Software reset                    |            | SRST register |      |      |      |               | Note 2) |

Note1) After power-on, be sure to perform a hardware reset operation (register initialization). The system is reset by a Low input of 1us (min.) and enters the normal operation state.

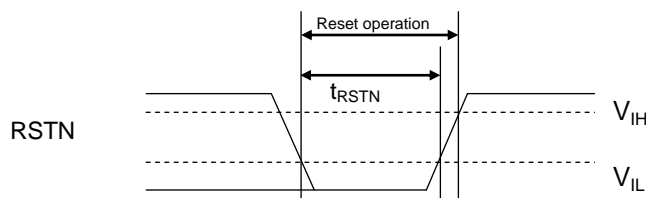


Figure 6 System Reset

During the reset operation, SCLK, SDATAIN and CSN pin should be keep to Low or High.

Ex) SCLK:Low, SDATAIN:Low, CSN:High

Note2) When data 0x09:10101010 is written to the SRST[7:0] register, software reset is performed. This setting initializes the registers and the operation mode is set to mode 2 (Standby 2). After software reset is completed, this register comes to “0”.

## Analog Characteristics (PLL SYNTH)

Unless otherwise noted VDD=2.7 to 5.5V, Ta=-40°C to 85°C.

| Parameter   | Min | Typ.                 | Max  | Unit | Remarks                                     |
|---|-----|----------------------|------|------|---|
| RF Characteristics                                |     |                      |      |      |   |
| Input Sensitivity                                 | -10 |                      | 5    | dBm  |   |
| Input Frequency                                   | 40  |                      | 500  | MHz  | Prescaler 4/5                               |
|   | 40  |                      | 1000 | MHz  | Prescaler 8/9,16/17                         |
| REFIN Characteristics                             |     |                      |      |      |   |
| Input Sensitivity                                 | 0.4 |                      | 2    | Vpp  |   |
| Input Frequency                                   |     | 15.3<br>16.8<br>19.2 |      | MHz  | Note 1)                                     |
| Phase Frequency Detector                          |     |                      |      |      |   |
| Phase Detector Frequency                          |     |                      | 6.4  | MHz  |   |
| Charge Pump                                       |     |                      |      |      |   |
| Charge Pump 1 Maximum Value                       |     | 168.9                |      | μA   | BIAS3=27kΩ, Note 2)                         |
| Charge Pump 1 Minimum Value                       |     | 21.1                 |      | μA   | BIAS3=27kΩ, Note 2)                         |
| Charge Pump 2 Maximum Value                       |     | 2.32                 |      | mA   | BIAS3=27kΩ, Note 3)                         |
| Charge Pump 2 Minimum Value                       |     | 0.84                 |      | mA   | BIAS3=27kΩ, Note 3)                         |
| Icp TRI-STATE Leak Current                        |     | 1                    |      | nA   | 0.6≤Vcpo≤CPVDD-0.7<br>(Vcpo:CP pin voltage) |
| Mismatch between Source and Sink Currents Note 4) |     |                      | 10   | %    | Vcpo= CPVDD/2<br>Ta=25°C                    |
| Icp vs. Vcpo Note 5)                              |     |                      | 15   | %    | 0.5≤Vcpo≤CPVDD-0.5<br>Ta=25°C               |
| Current Consumption                               |     |                      |      |      |   |
| IDD_SYN1  |     |                      | 10   | μA   | PDN=0                                       |
| IDD_SYN2  |     | 2.4                  | 3.6  | mA   | Note 6)                                     |
| IDD_SYN3  |     | 0.17                 |      | mA   | Note 7)                                     |

Note 1) REFIN pin is input one third of the 2nd LO input frequency.

Note 2) Charge pump 1 current is determined by the setting in {CP1[2:0]} which is described on page 22.

Note 3) Charge pump 2 current is determined by the setting in {CP2[2:0]} which is described on page 23.

Note 4) Mismatch between Source and Sink Currents:  $\frac{(|I_{sink}| - |I_{source}|)}{(|I_{sink}| + |I_{source}|)/2} \times 100$  [%]

Note 5) Icp vs. Vcpo:  $\frac{\{1/2 \times (|I_1| - |I_2|)\}}{\{1/2 \times (|I_1| + |I_2|)\}} \times 100$  [%]

Note 6) [PDN]="High", {PDSYNTH\_N}="High" IDD for [PVDD]

Note 7) [PDN]="High", {PDSYNTH\_N}="High" IDD for [CPVDD]

IDD does not include the operation current in fast lockup mode.

Note ) [PDN]="High", {PDSYNTH\_N}="High", the total current consumption = IDD\_SYN2+IDD\_SYN3

Note ) In the shipment test, the exposed pad on the center of the back of the package is connected to ground.

Note ) When 2nd LO input frequency is used 28.8MHz, set {PDTRI\_N}=0 and input the 2nd LO signal(28.8MHz) from LO2NDIN pin. Then REFIN Frequency is set 28.8MHz/3=9.6MHz.

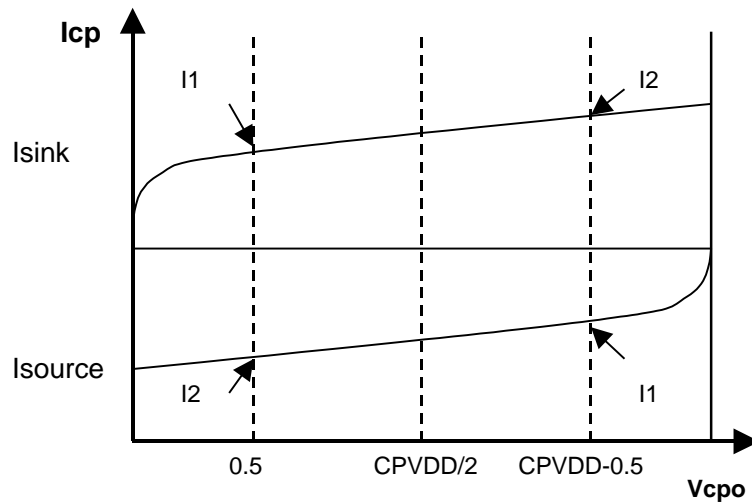


Figure 7 Charge Pump Characteristics - Voltage vs. Current

### Analog Characteristics (1st MIXER)

Unless otherwise noted IF output=50MHz, Lo Input Level=-10dBm to +5dBm, {FMIX\_HV}=0, {FMIX\_IP3}=0, Output Load Resistor (R<sub>Load</sub>)=2.2kΩ, VDD=2.7 to 5.5V, Ta=-40°C to 85°C, Test circuit is shown on page 41.

| Parameter   | Min. | Typ. | Max. | Unit | Remarks                                     |
|---|------|------|------|------|---|
| RF Input Frequency  | 10   |      | 2000 | MHz  |   |
| Lo Input Frequency  | 10   |      | 2000 | MHz  |   |
| IF output Frequency   | 20   |      | 100  | MHz  |   |
| Lo Input Power  | -10  | 0    | +5   | dBm  |   |
| Current Adjustment Resistor(BIAS) ({FMIX_HV}=0)                 | 39   |      | 100  | kΩ   | Vdd=2.7 to 5.5V                             |
| Current Adjustment Resistor(BIAS) ({FMIX_HV}=1)                 | 18   |      | 39   | kΩ   | Vdd=4.5 to 5.5V                             |
| IDD(BIAS=18kΩ, {FMIX_HV}=1)                                     |      | 24   |      | mA   | The total current of MIXVDD,IFOUTP, IFOUTN. |
| IDD(BIAS=47kΩ)  |      | 9    | 13   | mA   |   |
| IDD({PDFSTMIX_N}=0)   |      | 1    | 10   | uA   |   |
| RFIN=600MHz, LOIN=550MHz(0dBm), BIAS=47kΩ, Vdd=3V               |      |      |      |      |   |
| Conversion Gain   | 0.5  | 3    | 5    | dB   |   |
| SSB Noise Figure  |      | 8.5  | 11   | dB   | Design guarantee value                      |
| IP1dB   | -3   | 1    |      | dBm  |   |
| IIP3  | 7    | 11   |      | dBm  |   |
| RFIN=600MHz, LOIN=550MHz(0dBm), BIAS=18kΩ, {FMIX_HV}=1,Vdd=5V   |      |      |      |      |   |
| Conversion Gain   |      | 5    |      | dB   |   |
| SSB Noise Figure  |      | 8.5  |      | dB   | Design guarantee value                      |
| IP1dB   |      | 0    |      | dBm  |   |
| IIP3  |      | 16   |      | dBm  | Design guarantee value                      |
| RFIN=600MHz, LOIN=550MHz(0dBm), BIAS=47kΩ, Vdd=3V, {FMIX_IP3}=1 |      |      |      |      |   |
| Conversion Gain   |      | 3    |      | dB   |   |
| SSB Noise Figure  |      | 10   |      | dB   | Design guarantee value                      |
| IP1dB   |      | 0    |      | dBm  |   |
| IIP3  |      | 14   |      | dBm  | Design guarantee value                      |
| IDD   |      | 7    |      | mA   |   |

## Analog Characteristics (2nd IF)

Unless otherwise noted VDD=2.7 to 5.5V, Ta=-40°C to 85°C.

Mode 6, LO2NDIN=50.4MHz, IFIP=50.85MHz,  $\Delta f = \pm 1.5\text{kHz}$ , fmod=1kHz, AGC+BPF=F2, {AGC\_OFF}=0, {AGC\_KEEP\_SEL}=0, {AGC\_KEEP}=0, PGA0[2:0]=011. {SDATAOUT\_OE}=0. The exposure back pad of the package is connected to VSS. Test circuit is shown on page 45.

### 1) 2nd LO input

| Parameter       | Symbol   | Conditions | Min. | Typ.                         | Max. | Unit     | Remarks |
|-----------------|----------|------------|------|------------------------------|------|----------|---------|
| Parameter       | $F_{LO}$ | LO2NDIN    |      | 28.8<br>45.9<br>50.4<br>57.6 |      | MHz      |         |
| Local Frequency | $V_{LO}$ | LO2NDIN    | 0.2  |                              | 2.0  | $V_{PP}$ | Note    |

Note) Input from LO2NDIN pin through DC cut

### 2) PGA0+2nd Mixer

Analog Characteristics (2nd IF) are included the circuit of IFIP input pin.

The input impedance of 2nd IF\_INPUT is 50Ω typ. (See Figure 8 for input matching network)

| Parameter       | Conditions | Min. | Typ.                   | Max. | Unit | Remarks |
|-----------------|------------|------|------------------------|------|------|---------|
| Input Impedance |            |      | 50                     |      | Ω    |         |
| Input Frequency |            |      | $F_{LO}$<br>$\pm 0.45$ |      | MHz  |         |
| Voltage Gain    |            |      | 48                     |      | dB   |         |

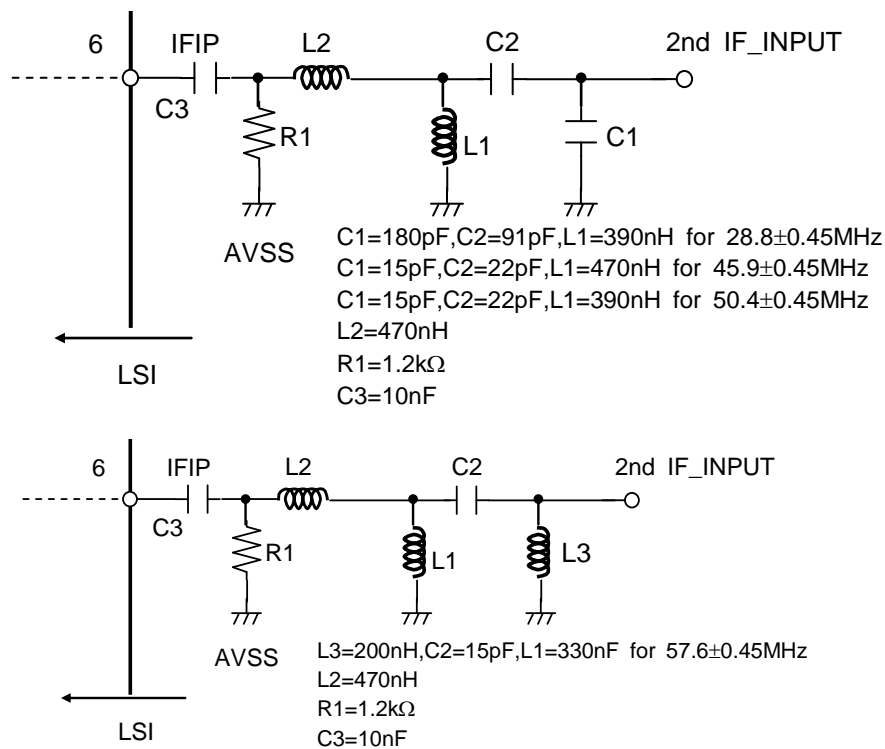


Figure 8 Test circuit of IFIP Input pin (2nd IF)

## 3) 2nd IF RX overall characteristics

| Parameter                          | Conditions   | Min. | Typ. | Max. | Unit  | Remarks |
|------------------------------------|--|------|------|------|-------|---------|
| 12dB SINAD                         | Note 1)  |      | -112 |      | dBm   |         |
| 2nd IF block<br>Total Gain         | Mode 5<br>Maximum gain setting for AGC<br>IFIP to IFOUT<br>{IFOG[2:0]}=001   |      | 101  |      | dB    |         |
|                                    | Mode 5<br>Minimum gain setting for AGC<br>IFIP to IFOUT<br>{IFOG[2:0]}=001   |      | 49   |      | dB    |         |
| NF                                 | Mode 5, BPF=F3<br>Maximum gain setting for AGC<br>IFIP to IFOUT<br>{IFOG[2:0]}=001                                     |      | 8    |      | dB    |         |
| IIP3                               | Maximum gain setting for AGC<br>IFIP=50.8635MHz&50.876MHz<br>{IFOG[2:0]}=001   |      | -37  |      | dBm   |         |
| IP1dB                              | Minimum gain setting for AGC<br>{IFOG[2:0]}=001  |      | -40  |      | dBm   |         |
| Demodulation<br>Output<br>Level    | $\Delta f=\pm 3.0\text{kHz}$ , fmod=1kHz,<br>AGC+BPF=F1, {DISLPF_G[2:0]}=101   | 70   | 100  | 130  | mVrms |         |
|                                    | $\Delta f=\pm 1.5\text{kHz}$ , fmod=1kHz,<br>AGC+BPF=F2, {DISLPF_G[2:0]}=001   | 70   | 100  | 130  | mVrms |         |
| S/N Ratio                          | $\Delta f=\pm 3.0\text{kHz}$ , fmod=1kHz, Vin=-47dBm<br>AGC+BPF=F1,<br>{DISLPF_G[2:0]}=101 Note 1)                     | 42   | 50   |      | dB    |         |
|                                    | $\Delta f=\pm 1.5\text{kHz}$ , fmod=1kHz, Vin=-47dBm<br>AGC+BPF=F2,<br>{DISLPF_G[2:0]}=001 Note 1)                     | 36   | 46   |      | dB    |         |
| Audio Frequency<br>characteristics | $\Delta f=\pm 0.5\text{kHz}$ , fmod=3kHz, Vin=-47dBm<br>AGC+BPF=F3,<br>IFIP to AUDIOOUT<br>{DISLPF_G[2:0]}=001 Note 2) | -4.3 | -3.5 |      | dB    |         |

Note 1) With De-emphasis+BPF(0.3 to 3kHz)

Note 2) relative to the output level at fmod=1kHz

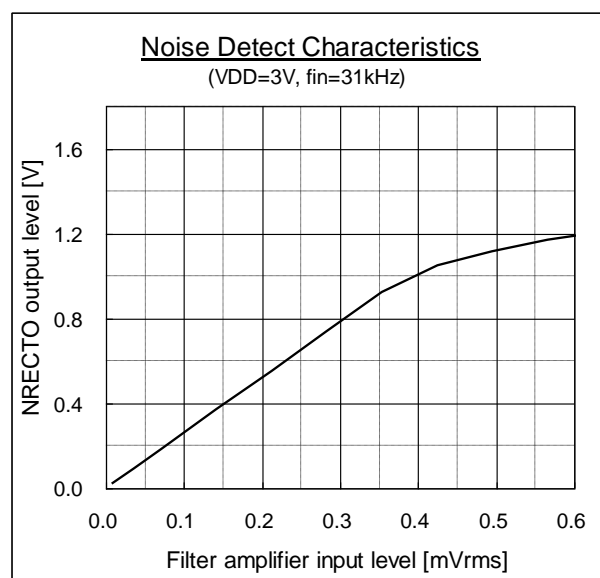
## 4) RSSI Characteristics

| Parameter           | Conditions   | Min. | Typ. | Max. | Unit | Remarks |
|---------------------|--|------|------|------|------|---------|
| RSSI output voltage | IFIP→RSSIOUT,<br>{AGC_OFF}=0<br>IFIP=-115dBm input |      | 0.6  |      | V    |         |
|                     | IFIP→RSSIOUT,<br>{AGC_OFF}=0<br>IFIP=-45dBm input  |      | 2.2  |      | V    |         |



## 5) Noise Squelch Characteristics

| Parameter                       | Conditions                               | Min. | Typ. | Max. | Unit | Remarks |
|---------------------------------|--|------|------|------|------|---------|
| Noise Detection Level           | NRECTO→DETO<br>Detect High               |      | 0.5  | 0.7  | V    |         |
|                                 | NRECTO→DETO<br>Detect Low                | 0.3  | 0.4  |      | V    |         |
| Noise Detection Characteristics | NAMPI→NRECTO<br>Input : 31kHz, 0.1mVrms  |      | 0.3  |      | V    |         |
|                                 | NAMPI→NRECTO<br>Input : 31kHz, 0.25mVrms |      | 0.65 |      | V    |         |



## 6) AGC+BPF

## 6.1) F0 (E type)

| Parameter   | Conditions      | Min. | Typ. | Max. | Unit | Remarks |
|---|-----------------|------|------|------|------|---------|
| Attenuation Characteristics<br>(relative to the gain at 450kHz) | 435kHz          |      |      | -50  | dB   |         |
|   | 442.5kHz        | -6   |      |      | dB   |         |
|   | 457.5kHz        | -6   |      |      | dB   |         |
|   | 465kHz          |      |      | -50  | dB   |         |
| Gain ripple   | Within 450±5kHz |      |      | 3    | dB   |         |

## 6.2) F1 (F type)

| Parameter   | Conditions      | Min. | Typ. | Max. | Unit | Remarks |
|---|-----------------|------|------|------|------|---------|
| Attenuation Characteristics<br>(relative to the gain at 450kHz) | 437.5kHz        |      |      | -50  | dB   |         |
|   | 444kHz          | -6   |      |      | dB   |         |
|   | 456kHz          | -6   |      |      | dB   |         |
|   | 462.5kHz        |      |      | -50  | dB   |         |
| Gain ripple   | Within 450±4kHz |      |      | 3    | dB   |         |

## 6.3) F2 (G type)

| Parameter   | Conditions      | Min. | Typ. | Max. | Unit | Remarks |
|---|-----------------|------|------|------|------|---------|
| Attenuation Characteristics<br>(relative to the gain at 450kHz) | 439kHz          |      |      | -50  | dB   |         |
|   | 445.5kHz        | -6   |      |      | dB   |         |
|   | 454.5kHz        | -6   |      |      | dB   |         |
|   | 461kHz          |      |      | -50  | dB   |         |
| Gain ripple   | Within 450±3kHz |      |      | 3    | dB   |         |

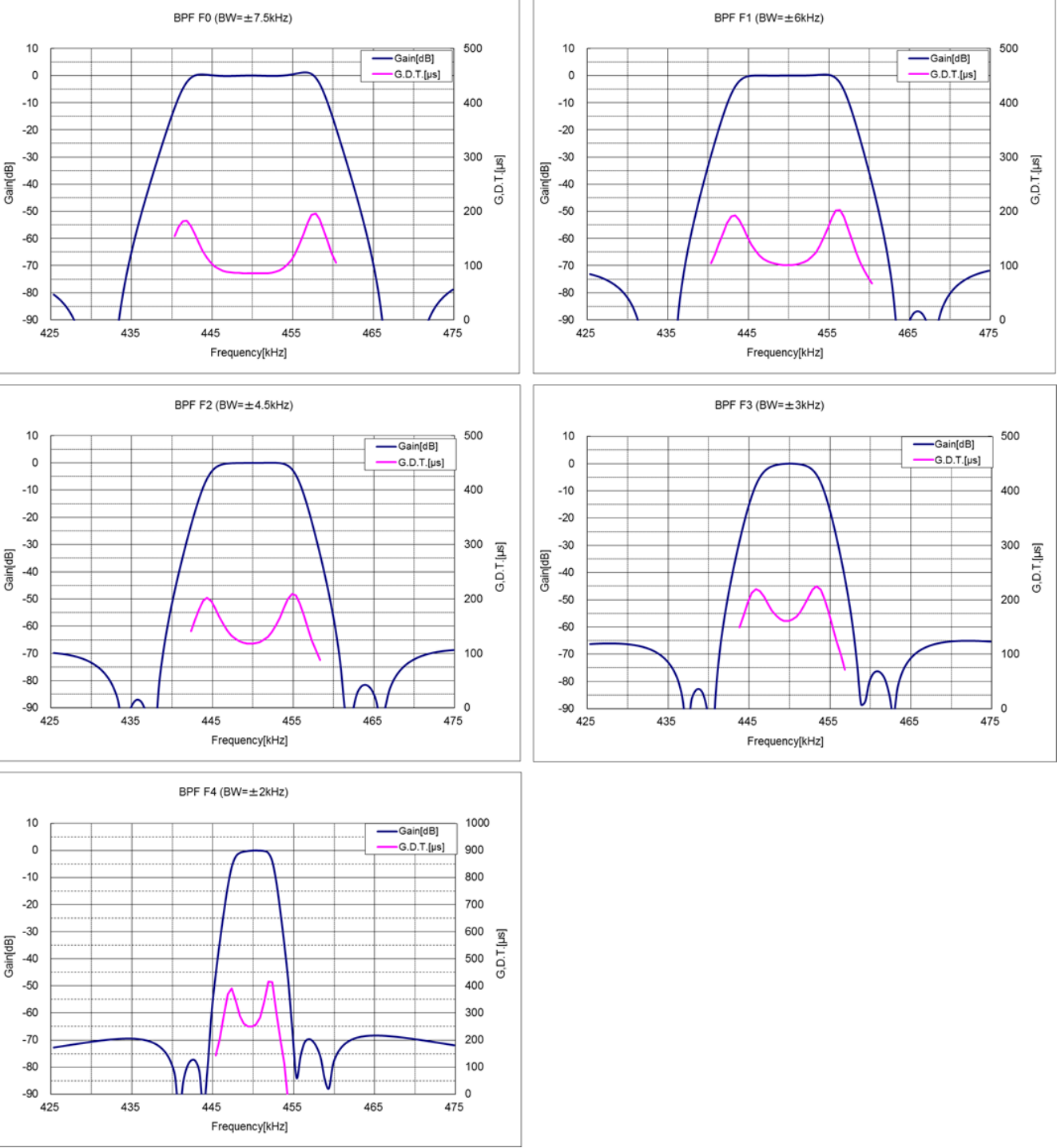
## 6.4) F3 (H type)

| Parameter   | Conditions      | Min. | Typ. | Max. | Unit | Remarks |
|---|-----------------|------|------|------|------|---------|
| Attenuation Characteristics<br>(relative to the gain at 450kHz) | 441kHz          |      |      | -50  | dB   |         |
|   | 447kHz          | -6   |      |      | dB   |         |
|   | 453kHz          | -6   |      |      | dB   |         |
|   | 459kHz          |      |      | -50  | dB   |         |
| Gain ripple   | Within 450±2kHz |      |      | 2    | dB   |         |

## 6.5) F4 (J type)

| Parameter   | Conditions        | Min. | Typ. | Max. | Unit | Remarks |
|---|-------------------|------|------|------|------|---------|
| Attenuation Characteristics<br>(relative to the gain at 450kHz) | 443kHz            |      |      | -50  | dB   |         |
|   | 448kHz            | -8   |      |      | dB   |         |
|   | 452kHz            | -8   |      |      | dB   |         |
|   | 457kHz            |      |      | -50  | dB   |         |
| Gain ripple   | Within 450±1.5kHz |      |      | 3.5  | dB   |         |

# Filter Characteristics



## 7) IFBUF Characteristics

| Parameter     | Conditions  | Min. | Typ. | Max. | Unit | Remarks |
|---------------|---|------|------|------|------|---------|
| Settling time | IFBUF to IFOUT,<br>IFBUF=0.32Vpp/step<br>C <sub>L2</sub> =21pF, {IFOG[2:0]}=001 |      | 100  |      | ns   |         |

Note ) Convergence time within 1% when 0.32Vpp step signal input to IFBUF pin

## 8) Current Consumption

| Parameter           | Symbol | Conditions   | Min. | Typ. | Max. | Unit |
|---------------------|--------|--|------|------|------|------|
| Current Consumption | IDD0   | Mode0<br>Power down                                |      |      | 0.01 | mA   |
|                     | IDD1   | Mode1<br>(Prohibited)                              |      |      | -    | mA   |
|                     | IDD2   | Mode2<br>Standby(Initial value)                    |      | 0.1  | 0.15 | mA   |
|                     | IDD3   | Mode3  |      | 1    | 1.5  | mA   |
|                     | IDD4   | Mode4, Digital Mode 1 with no signal input         |      | 7    | 11   | mA   |
|                     | IDD5   | Mode5 Digital Modo 2 with no signal input. Note 2) |      | 7.5  | 12   | mA   |
|                     | IDD6   | Mode6 Analog Mode with no signal input Note 2)     |      | 7.5  | 12   | mA   |
|                     | IDD7   | Mode7 Full Power On with no signal nput Note 2)    |      | 8.5  | 13   | mA   |

Note 1) Current Consumption is AVDD pin.

Note 2) Tripler circuit : ON

Note 3) Do not use Mode1.

## Analog Characteristics (ADC)

Unless otherwise noted VDD=2.7 to 5.5V, Ta=-40°C to 85°C.

fs=1MHz , ADVDD = 3.0V, AD\_SCLK=20MHz

| Parameter                             | Min. | Typ. | Max.  | Unit |
|---------------------------------------|------|------|-------|------|
| Resolution                            |      | 12   |       | Bits |
| No Missing Codes Note 2)              | 11   |      |       | Bits |
| Integral Nonlinearity (INL) Error     |      | ±2   |       | LSB  |
| Differential Nonlinearity (DNL) Error |      | ±1   |       | LSB  |
| Input Voltage Range                   | 0    |      | ADVDD | V    |
| ADVDD Power Current                   |      | 2    | 3.8   | mA   |

Note 1) The above is the characteristics of only A/D converter block.

Note 2) Design guarantee value

## Register Map and Function Description

| Name    | Address       | D17       | D16          | D15          | D14           | D13          | D12          | D11          | D10          | D9           | D8            | D7            | D6           | D5           | D4           | D3           | D2           | D1           | D0           |
|---------|---------------|-----------|--------------|--------------|---------------|--------------|--------------|--------------|--------------|--------------|---------------|---------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| NUM     | 0x01          | NUM [17]  | NUM [16]     | NUM [15]     | NUM [14]      | NUM [13]     | NUM [12]     | NUM [11]     | NUM [10]     | NUM [9]      | NUM [8]       | NUM [7]       | NUM [6]      | NUM [5]      | NUM [4]      | NUM [3]      | NUM [2]      | NUM [1]      | NUM [0]      |
|         | Initial Value | 0         | 0            | 0            | 0             | 0            | 0            | 0            | 0            | 0            | 0             | 0             | 0            | 0            | 0            | 0            | 0            | 0            | 0            |
| INT     | 0x02          | CP1 [2]   | CP1 [1]      | CP1 [0]      | INT [14]      | INT [13]     | INT [12]     | INT [11]     | INT [10]     | INT [9]      | INT [8]       | INT [7]       | INT [6]      | INT [5]      | INT [4]      | INT [3]      | INT [2]      | INT [1]      | INT [0]      |
|         | Initial value | 0         | 0            | 0            | 0             | 0            | 0            | 0            | 0            | 0            | 0             | 0             | 0            | 0            | 0            | 0            | 0            | 0            | 0            |
| DIV     | 0x03          | 0         | INTE         | CP HiZ       | DITH          | LDCKSEL [1]  | LDCKSEL [0]  | LD           | CP POLA      | PRE [1]      | PRE [0]       | R1 [7]        | R1 [6]       | R1 [5]       | R1 [4]       | R1 [3]       | R1 [2]       | R1 [1]       | R1 [0]       |
|         | Initial value | 0         | 0            | 0            | 0             | 0            | 0            | 0            | 0            | 0            | 0             | 1             | 0            | 0            | 0            | 0            | 0            | 0            | 0            |
| CP_FAST | 0x04          | 0         | FAST EN      | CP2 [2]      | CP2 [1]       | CP2 [0]      | FAST [12]    | FAST [11]    | FAST [10]    | FAST [9]     | FAST [8]      | FAST [7]      | FAST [6]     | FAST [5]     | FAST [4]     | FAST [3]     | FAST [2]     | FAST [1]     | FAST [0]     |
|         | Initial value | 0         | 0            | 0            | 0             | 0            | 1            | 0            | 0            | 0            | 0             | 0             | 0            | 0            | 0            | 0            | 0            | 0            | 0            |
| NSQ     | 0x05          | VTSEL [1] | VTSEL [0]    | 0            | 0             | 0            | 0            | 0            | 0            | 0            | 0             | 0             | 0            | 0            | 0            | 0            | 0            | 0            | 0            |
|         | Initial value | 0         | 0            | 0            | 0             | 0            | 0            | 0            | 0            | 0            | 0             | 0             | 0            | 0            | 0            | 0            | 0            | 0            | 0            |
| OFFSET  | 0x06          | OFST [17] | OFST [16]    | OFST [15]    | OFST [14]     | OFST [13]    | OFST [12]    | OFST [11]    | OFST [10]    | OFST [9]     | OFST [8]      | OFST [7]      | OFST [6]     | OFST [5]     | OFST [4]     | OFST [3]     | OFST [2]     | OFST [1]     | OFST [0]     |
|         | Initial value | 0         | 0            | 0            | 0             | 0            | 0            | 0            | 0            | 0            | 0             | 0             | 0            | 0            | 0            | 0            | 0            | 0            | 0            |
| IFBPF   | 0x07          | AGC_KEE P | AGCLVL_H [2] | AGCLVL_H [1] | AGCLVL_H [0]  | AGCLVL_L [2] | AGCLVL_L [1] | AGCLVL_L [0] | CAL          | AGC_FAS T    | AGC_ TIME [1] | AGC_ TIME [0] | AGC1_ STEP   | AGC_ OFF     | BPF_BW [2]   | BPF_BW [1]   | BPF_BW [0]   | LOFREQ [1]   | LOFREQ [0]   |
|         | Initial value | 0         | 1            | 0            | 1             | 1            | 0            | 0            | 0            | 1            | 0             | 0             | 1            | 0            | 0            | 0            | 0            | 0            | 1            |
| PGA     | 0x08          | PGA0_L G  | PGA2_G [4]   | PGA2_G [3]   | PGA2_G [2]    | PGA2_G [1]   | PGA2_G [0]   | PGA1_G [5]   | PGA1_G [4]   | PGA1_G [3]   | PGA1_G [2]    | PGA1_G [1]    | PGA1_G [0]   | PGA0_ [2]    | PGA0_ [1]    | PGA0_ [0]    | IFOG [2]     | IFOG [1]     | IFOG [0]     |
|         | Initial value | 0         | 0            | 0            | 0             | 0            | 0            | 0            | 0            | 0            | 0             | 0             | 1            | 0            | 1            | 1            | 0            | 0            | 1            |
| SRST    | 0x09          | 0         | 0            | 0            | 0             | 0            | 0            | 0            | 0            | 0            | 0             | SRST [7]      | SRST [6]     | SRST [5]     | SRST [4]     | SRST [3]     | SRST [2]     | SRST [1]     | SRST [0]     |
|         | Initial value | -         | -            | -            | -             | -            | -            | -            | -            | -            | -             | -             | -            | -            | -            | -            | -            | -            | -            |
| PD      | 0x0A          | 0         | RSSIMD       | 0            | AGC_KEE P_SEL | SDATAOU T_OE | FMIX_IP3     | DISLPF_G [2] | DISLPF_G [1] | DISLPF_G [0] | FMIX_HV       | PDTRI_N       | BS[2]        | BS[1]        | BS[0]        | PDSYNTH_N    | PDADC_N      | PDFSTMI X_N  | BSSEL_F MIX  |
|         | Initial value | 0         | 0            | 0            | 0             | 0            | 0            | 0            | 0            | 0            | 0             | 0             | 0            | 1            | 0            | 0            | 0            | 0            | 0            |
| PD_AGCG | 0x0B          |           |              |              |               |              |              |              | R_AGC1_G [5] | R_AGC1_G [4] | R_AGC1_G [3]  | R_AGC1_G [2]  | R_AGC1_G [1] | R_AGC1_G [0] | R_AGC2_G [4] | R_AGC2_G [3] | R_AGC2_G [2] | R_AGC2_G [1] | R_AGC2_G [0] |
|         | Initial value |           |              |              |               |              |              |              | -            | -            | -             | -             | -            | -            | -            | -            | -            | -            | -            |

Note1) Writing into address 0x01 is enabled when writing into address 0x02 is performed. Be sure to write into address 0x01 first and then address 0x02.

Note2) The initial register values are not defined. Therefore, even after [PDN] is set to "High", each bit initial value remains undefined. In order to set all register values, it is required to write the data in all addresses of the register.

Note3) Do not access the data except specified address 0x0c to 0x1f.

**Address 0x01**

Note) Writing into address 0x01 is enabled when writing into address 0x02 is performed.

**NUM[17:0] : Set the numerator in 2's complementary representation.**

**Address 0x02**

**CP1[2:0]: Sets the current value for the charge pump in normal operation (Charge Pump 1).**

Charge Pump 1 current is determined by the following formula:

$CP1\_min = 0.57 / \text{Resistance connected to the [BIAS] pin}$

Charge Pump 1 current =  $CP1\_min \times (CP1 \text{ setting} + 1)$

|          | Charge Pump 1 current [uA] |       |       |
|----------|----------------------------|-------|-------|
| CP1[2:0] | 22kΩ                       | 27 kΩ | 33 kΩ |
| 000      | 25.9                       | 21.1  | 17.3  |
| 001      | 51.8                       | 42.2  | 34.5  |
| 010      | 77.7                       | 63.3  | 51.8  |
| 011      | 103.6                      | 84.4  | 69.1  |
| 100      | 129.5                      | 100.6 | 86.4  |
| 101      | 155.5                      | 126.7 | 103.6 |
| 110      | 181.4                      | 147.8 | 120.9 |
| 111      | 207.3                      | 168.9 | 138.2 |

**INT[14:0] : Sets the integer.**

When {PRE[1:0]} = "00", P = 4 is selected and then an integer from 48 to 8191 can be set.

When {PRE[1:0]} = "01", P = 8 is selected and then an integer from 116 to 16383 can be set.

When {PRE[1:0]} = "10" or "11", P = 16 is selected and then an integer from 348 to 32767 can be set.

**Address 0x03**

**INTE : INTEGER mode**

0 : Disable

1 : Enable (The delta-sigma circuit is integer mode operation.  
Don't use DFM operation.)

**CPHIZ : Selects normal or TRI-STATE for the CP1/CP2 output.**

0 : Charge pumps are activated. (Use this setting for normal operation.)

1 : TRI-STATE (The charge pump output is put in the high-impedance (Hi-Z) state.)

**DITH : Selects dithering ON or OFF for a delta-sigma circuit.**

0 : DITH OFF (Low Noise mode)

1 : DITH ON (Low Spurious mode)

When OFFSET register is used, set DITH=0(OFF).

**LDCKSEL[1:0] : Sets phase error values for lock detect.**

When DITH="1" :

$VCO \text{ frequency} > [\text{REFIN}] \text{ pin input frequency} / [\text{LDCKSEL}[1:0] \text{ setting} + 1] \times 7$

When DITH="0" :

$VCO \text{ frequency} > [\text{REFIN}] \text{ pin input frequency} / [\text{LDCKSEL}[1:0] \text{ setting} + 1] \times 4$

"00" : 1 cycle of the REFIN clock (This cannot be used for the reference dividing ratio  $\leq 3$ .)

"01" : 2 cycle of the REFIN clock (This cannot be used for the reference dividing ratio  $\leq 5$ .)

"10" : 3 cycle of the REFIN clock (This cannot be used for the reference dividing ratio  $\leq 6$ .)

"11" : 1 cycle of the REFIN clock (This must be used for the reference dividing ratio = 3)

**LD** : Selects analog or digital for the lock detect.

0 : Digital Lock Detect

1 : Analog Lock Detect

**CPPOLA** : Selects positive or negative output polarity for Charge Pump1 and Charge Pump2.

0 : Positive

1 : Negative

**PRE[1:0]** : Selects a dividing ratio for the prescaler.

"00" : P=4

"01" : P=8

"10" : P=16

"11" : P=16

**R1[7:0]** : Sets a dividing ratio for the reference clock.

This can be set in the range from 3 (3 divisions) to 255 (255 divisions). 0 to 2 cannot be set.

#### Address 0x04

**FASTEN** : Enables or disables the Fast Lockup mode. **FAST**

0 : The switchover settings specified in CP2[2:0] and FAST[12:0] are disabled.

1 : The switchover settings specified in CP2[2:0] and FAST[12:0] are enabled.

**CP2[2:0]** : Sets the current value for the charge pump for the Fast Lockup mode

(Charge Pump 2).

Charge Pump 2 current is determined by the following formula:

$CP2\_min = 0.57 / \text{Resistance connected to the [BIAS] pin}$

Charge Pump 2 current =  $CP2\_min \times (CP2 \text{ setting} + 4)$  [mA]

| CP2[2:0] | Charge Pump 2 current [mA] |       |       |
|----------|----------------------------|-------|-------|
|          | 33kΩ                       | 27 kΩ | 22 kΩ |
| 000      | 0.69                       | 0.84  | 1.04  |
| 001      | 0.86                       | 1.06  | 1.30  |
| 010      | 1.04                       | 1.27  | 1.55  |
| 011      | 1.21                       | 1.48  | 1.81  |
| 100      | 1.38                       | 1.69  | 2.07  |
| 101      | 1.55                       | 1.90  | 2.33  |
| 110      | 1.73                       | 2.11  | 2.59  |
| 111      | 1.90                       | 2.32  | 2.85  |

**FAST[12:0]** : Sets the FAST counter value.

A decimal number from 1 to 8191 can be set. This counter value is used to set the time period during which the charge pump for the Fast Lockup mode is ON.

The charge pump for the Fast Lockup mode is turned OFF after the time period calculated by [this count value x phase detector frequency cycle]. 0 cannot be set.

#### Address 0x05

**VTSEL[1:0]** : Sets the noise detection level of noise squelch circuit.

00 : 0.4V/0.5V (default)      01 : 0.8V/0.9V

10 : 1.1V/1.2V                      11 : 1.4V/1.5V

**Address 0x06****OFST[17:0] : Set the adjustable frequency offset in 2's complementary representation.**

OFFSET register must be written at the speed calculated by " $1/3.5 \times \text{RF Frequency} / (\text{INT} + 7)$ ". If the writing speed is faster than this, the setting isn't valid.

This register is offset from carrier frequency.

After this register is accessed, NUM[17:0] and INT[14:0] are recalculated and their recalculated data are used in delta-sigma and N-divider. When this register is not used, this register must be written 00000 (hexadecimal).

When OFFSET register is used, set DITH=0(OFF).

**Address 0x07****AGC\_KEEP : The function of AGC1/2 gain keeping**

When the AGC function is active, the gain setting of AGC1/2 is kept during {AGC\_KEEP}=1.

On the other hand, the gain setting of AGC1/2 is changed by IFIP signal during {AGC\_KEEP}=0.

0 : the gain setting of AGC1/2 is changed by IFIP signal. (default)

1 : the gain setting of AGC1/2 is kept.

**AGCLVL\_H[2:0]: Setting the upper limit of AGC threshold level.**

| AGCLVL_H<br>[2] | AGCLVL_H<br>[1] | AGCLVL_H<br>[0] | upper limit   |
|-----------------|-----------------|-----------------|---------------|
| 0               | 0               | 0               | -5dB          |
| 0               | 0               | 1               | -4dB          |
| 0               | 1               | 0               | -3dB          |
| 0               | 1               | 1               | -2dB          |
| 1               | 0               | 0               | -1dB          |
| 1               | 0               | 1               | 0dB (default) |
| 1               | 1               | 0               | 1dB           |
| 1               | 1               | 1               | 2dB           |

**AGCLVL\_L[2:0]: Setting the lower limit of AGC threshold level.**

| AGCLVL_L<br>[2] | AGCLVL_L<br>[1] | AGCLVL_L<br>[0] | lower limit   |
|-----------------|-----------------|-----------------|---------------|
| 0               | 0               | 0               | -8dB          |
| 0               | 0               | 1               | -6dB          |
| 0               | 1               | 0               | -4dB          |
| 0               | 1               | 1               | -2dB          |
| 1               | 0               | 0               | 0dB (default) |
| 1               | 0               | 1               | 1dB           |
| 1               | 1               | 0               | 2dB           |
| 1               | 1               | 1               | 3dB           |

Note 1) When the AGC1/2 output level is bigger than the upper limit value, AGC1/2 gain is decreased. When the AGC1/2 output level is smaller than the lower limit value, AGC1/2 gain is increased. The upper/lower limit level is tunable based on default setting limit value.

Note 2) When AGC function is active ({AGC\_OFF}=0), AGC1/2 works as Note1..

**CAL : Discriminator circuit calibration start trigger Discriminator**

0 : Invalid

1 : Start

Note ) : Calibration is performed synchronized with the rising edge of {CAL}.

After calibration completed, this register is set to "0" automatically. It takes 1.3ms before calibration is completed. Refer to "calibration procedure" for further information.



**AGC\_FAST : AGC control switching**

0 : AGC control is operated with AGC response time described in AGC\_TIME[1:0].

1 : The time constant of response time is changed by conditions that AGC1/AGC2 output level converges between the upper limit and lower limit(convergence) or not(attack/release).

attack/release : AGC response time is the same as AGC\_TIME="00".

convergence : AGC response time is set with AGC\_TIME[1:0].

This setting provides the fast response time that can be followed the burst signal. (default)

**AGC\_TIME[1:0] : AGC response time setting**

This register set response time for AGC1 gain and AGC2 gain to change by 1step.

| AGC_TIME<br>[1] | AGC_TIME<br>[0] | AGC response time [ms] |         |         |                     |         |         |
|-----------------|-----------------|------------------------|---------|---------|---------------------|---------|---------|
|                 |                 | AGC1_STEP=0 setting    |         |         | AGC1_STEP=1 setting |         |         |
|                 |                 | State A                | State B | State C | State A             | State B | State C |
| 0               | 0               | (0.6)                  | (8.5)   | (8.5)   | (0.4)               | (4.4)   | (4.4)   |
| 0               | 1               | (67)                   | (95)    | (95)    | (34)                | (58)    | (58)    |
| 1               | 0               | (134)                  | (182)   | (182)   | (67)                | (111)   | (111)   |
| 1               | 1               | (267)                  | (355)   | (355)   | (134)               | (218)   | (218)   |

Note ) : Values above indicate response time during AGC gain changes from maximum to minimum or from minimum to maximum.

State A: AGC1 output level is beyond the upper limit.

State B: AGC1 output level is within the upper limit and AGC2 output level is beyond the upper limit.

State C: AGC2 output level is under the lower limit.

**AGC1\_STEP : AGC1 gain switching range setting**

0 :  $\pm 1$ dB

1 :  $\pm 2$ dB (default)

**AGC\_OFF : AGC ON/OFF setting**

0 : ON (default)

1 : Off

**BPF\_BW[2:0] : BPF band width setting**

| BPF_BW<br>[2] | BPF_BW<br>[1] | BPF_BW<br>[0] | Name | 6dB attenuation | Attenuation<br>band width       | Remarks                                |
|---------------|---------------|---------------|------|-----------------|---------------------------------|--|
| 1             | 0/1           | 0/1           | F0   | $\pm 7.5$ kHz   | $\pm 15$ kHz<br>(within 50dB)   |  |
| 0             | 0             | 0             | F1   | $\pm 6$ kHz     | $\pm 12.5$ kHz<br>(within 50dB) |  |
| 0             | 0             | 1             | F2   | $\pm 4.5$ kHz   | $\pm 11$ kHz<br>(within 50dB)   |  |
| 0             | 1             | 0             | F3   | $\pm 3$ kHz     | $\pm 9$ kHz<br>(within 50dB)    |  |
| 0             | 1             | 1             | F4   | $\pm 2$ kHz     | $\pm 7$ kHz<br>(within 50dB)    | 8dB attenuation<br>at F4 : $\pm 2$ kHz |

**LOFREQ[1:0] : Local frequency setting**

| LOFREQ<br>[1] | LOFREQ<br>[0] | Local Frequency |
|---------------|---------------|-----------------|
| 0             | 0             | 45.9MHz         |
| 0             | 1             | 50.4MHz         |
| 1             | 0             | 57.6MHz         |
| 1             | 1             | 28.8MHz         |

**Address 0x08****PGA0[2:0]: Gain setting of PGA0+2nd MIX**

| PGA0[2] | PGA0[1] | PGA0[0] | PGA0+2nd MIX gain [dB] |
|---------|---------|---------|------------------------|
| 0       | 0       | 0       | (42)                   |
| 0       | 0       | 1       | (44)                   |
| 0       | 1       | 0       | (46)                   |
| 0       | 1       | 1       | (48) (default)         |
| 1       | 0       | 0       | (50)                   |
| 1       | 0       | 1       | (52)                   |
| 1       | 1       | 0       | (54)                   |
| 1       | 1       | 1       | (56)                   |

Note ) Test circuit is shown Figure 8 on page 15.

**PGA0\_LG: When {PGA0\_LG}=1, PGA0+2nd MIX gain is fixed 28dB regardless of {PGA0[2:0]}.**

0 : PGA0+2nd MIX gain is controlled by setting of {PGA0[2:0]} (default)

1 : PGA0+2nd MIX gain is 28dB fixed regardless of setting of {PGA0[2:0]}.

**PGA2\_G[4:0] : When AGC\_OFF="1", AGC2 gain setting is available.**

| PGA2_G[4] | PGA 2_G[3] | PGA 2_G[2] | PGA 2_G[1] | PGA 2_G[0] | Gain[dB] |
|-----------|------------|------------|------------|------------|----------|
| 0         | 1          | 1          | 0          | 0          | 12       |
| 0         | 1          | 0          | 1          | 1          | 11       |
| 0         | 1          | 0          | 1          | 0          | 10       |
| 0         | 1          | 0          | 0          | 1          | 9        |
| 0         | 1          | 0          | 0          | 0          | 8        |
| 0         | 0          | 1          | 1          | 1          | 7        |
| 0         | 0          | 1          | 1          | 0          | 6        |
| 0         | 0          | 1          | 0          | 1          | 5        |
| 0         | 0          | 1          | 0          | 0          | 4        |
| 0         | 0          | 0          | 1          | 1          | 3        |
| 0         | 0          | 0          | 1          | 0          | 2        |
| 0         | 0          | 0          | 0          | 1          | 1        |
| 0         | 0          | 0          | 0          | 0          | 0        |

Note: Do not set the combination of the code which is not defined in the table given above.

**PGA1\_G[5:0] : When AGC\_OFF="1", AGC1 gain setting is available.**

| PGA1_G[5] | PGA1_G[4] | PGA1_G[3] | PGA1_G[2] | PGA1_G[1] | PGA1_G[0] | Gain[dB] |
|-----------|-----------|-----------|-----------|-----------|-----------|----------|
| 0         | 1         | 0         | 1         | 0         | 1         | 21       |
| 0         | 1         | 0         | 1         | 0         | 0         | 20       |
| 0         | 1         | 0         | 0         | 1         | 1         | 19       |
| 0         | 1         | 0         | 0         | 1         | 0         | 18       |
| 0         | 1         | 0         | 0         | 0         | 1         | 17       |
| 0         | 1         | 0         | 0         | 0         | 0         | 16       |
| 0         | 0         | 1         | 1         | 1         | 1         | 15       |
| 0         | 0         | 1         | 1         | 1         | 0         | 14       |
| 0         | 0         | 1         | 1         | 0         | 1         | 13       |
| 0         | 0         | 1         | 1         | 0         | 0         | 12       |
| 0         | 0         | 1         | 0         | 1         | 1         | 11       |
| 0         | 0         | 1         | 0         | 1         | 0         | 10       |
| 0         | 0         | 1         | 0         | 0         | 1         | 9        |
| 0         | 0         | 1         | 0         | 0         | 0         | 8        |
| 0         | 0         | 0         | 1         | 1         | 1         | 7        |
| 0         | 0         | 0         | 1         | 1         | 0         | 6        |
| 0         | 0         | 0         | 1         | 0         | 1         | 5        |
| 0         | 0         | 0         | 1         | 0         | 0         | 4        |
| 0         | 0         | 0         | 0         | 1         | 1         | 3        |
| 0         | 0         | 0         | 0         | 1         | 0         | 2        |
| 0         | 0         | 0         | 0         | 0         | 1         | 1        |
| 0         | 0         | 0         | 0         | 0         | 0         | 0        |
| 1         | 1         | 1         | 1         | 1         | 1         | -1       |
| 1         | 1         | 1         | 1         | 1         | 0         | -2       |
| 1         | 1         | 1         | 1         | 0         | 1         | -3       |
| 1         | 1         | 1         | 1         | 0         | 0         | -4       |
| 1         | 1         | 1         | 0         | 1         | 1         | -5       |
| 1         | 1         | 1         | 0         | 1         | 0         | -6       |
| 1         | 1         | 1         | 0         | 0         | 1         | -7       |
| 1         | 1         | 1         | 0         | 0         | 0         | -8       |
| 1         | 1         | 0         | 1         | 1         | 1         | -9       |
| 1         | 1         | 0         | 1         | 1         | 0         | -10      |
| 1         | 1         | 0         | 1         | 0         | 1         | -11      |
| 1         | 1         | 0         | 1         | 0         | 0         | -12      |
| 1         | 1         | 0         | 0         | 1         | 1         | -13      |
| 1         | 1         | 0         | 0         | 1         | 0         | -14      |
| 1         | 1         | 0         | 0         | 0         | 1         | -15      |
| 1         | 1         | 0         | 0         | 0         | 0         | -16      |
| 1         | 0         | 1         | 1         | 1         | 1         | -17      |
| 1         | 0         | 1         | 1         | 1         | 0         | -18      |
| 1         | 0         | 1         | 1         | 0         | 1         | -19      |

Note: Do not set the combination of the code which is not defined in the table given above.

**IFOG[2:0] : IFBUF Gain setting.**

| IFOG [2] | IFOG [1] | IFOG [0] | IFBUF Gain[dB] |
|----------|----------|----------|----------------|
| 0        | 0        | 0        | 0              |
| 0        | 0        | 1        | 3 (default)    |
| 0        | 1        | 0        | 6              |
| 0        | 1        | 1        | 9              |
| 1        | 0        | 0        | 12             |
| 1        | 0        | 1        | 15             |

**Address 0x09****Software-reset**

When data 0x09:10101010 is written to the SRST[7:0] register, software reset is performed.

**Address 0x0A****PDN,BS[2:0] : 2nd IF Block Operation mode setting**

| PDN | BS [2] | BS [1] | BS [0] | Mode name             | LDO D | LDOA, AGNDIN | LOBUF, VIREF | 2nd MIX ~SMF, DIV, AGCCNT | IFBU F | LIMITE R, RSSI | DISCRI, Noise Squelch |
|-----|--------|--------|--------|-----------------------|-------|--------------|--------------|---------------------------|--------|----------------|-----------------------|
| 0   | -      | -      | -      | Mode0 (Power Down0)   | OFF   | OFF          | OFF          | OFF                       | OFF    | OFF            | OFF                   |
| 1   | 0      | 0      | 1      | Mode1 (Note 1)        | ON    | OFF          | OFF          | OFF                       | OFF    | OFF            | OFF                   |
| 1   | 0      | 1      | 0      | Mode2 (Initial value) | ON    | ON           | OFF          | OFF                       | OFF    | OFF            | OFF                   |
| 1   | 0      | 1      | 1      | Mode3                 | ON    | ON           | ON           | OFF                       | OFF    | OFF            | OFF                   |
| 1   | 1      | 0      | 0      | Mode4                 | ON    | ON           | ON           | ON                        | ON     | OFF            | OFF                   |
| 1   | 1      | 0      | 1      | Mode5                 | ON    | ON           | ON           | ON                        | ON     | ON             | OFF                   |
| 1   | 1      | 1      | 0      | Mode6                 | ON    | ON           | ON           | ON                        | OFF    | ON             | ON                    |
| 1   | 1      | 1      | 1      | Mode7                 | ON    | ON           | ON           | ON                        | ON     | ON             | ON                    |

Note 1) : Do not use Mode1.

Note 2) : Do not set the combination of the code which is not defined in the table given above.

**DISLPF\_G[2:0]: Setting of the demodulation output level**

| DISLPF_G[2] | DISLPF_G [1] | DISLPF_G [0] | Demodulation output level when $\pm 1.5\text{kHz}$ dev. signal input |
|-------------|--------------|--------------|--|
| 0           | 0            | 1            | 100mVrms   |
| 0           | 1            | 0            | 200mVrms   |
| 0           | 1            | 1            | 300mVrms   |
| 1           | 0            | 1            | 50mVrms  |
| 1           | 1            | 0            | 100mVrms   |
| 1           | 1            | 1            | 150mVrms   |

Note ) The demodulation output level ( $\pm 1.5\text{kHz}$  dev. signal input, AUDIOOUT pin output) can be set to 50mVrms typ. to 300mVrms typ. by setting of {DISLPF\_G[2:0]}.

Note ) Do not set the combination of the code which is not defined in the table given above.

**AGC\_KEEP\_SEL: Select AGC function of gain keeping**

This register set the control way of the function of gain keeping.

- 0 : Control by the register {AGC\_KEEP} setting (default)
- 1 : Control by the pin of AGC\_KEEP

**SDATAOUT\_OE: Select output signal of DETO/SDATAOUT pin**

The signal of DETO or SDATAOUT can be output from DETO/SDATAOUT pin.

- 0 : DETO signal output (default)
- 1 : SDATAOUT signal output

**FMIX\_IP3: NF/IIP3 priority select of 1st Mixer**

IIP3 performance of 1st Mixer is improved by setting {FMIX\_IP3}=1 without more supply current. Then Current Adjustment Resistor (BIAS1/2) must be used < 47kΩ. If NF performance is more important than IIP3, setting {FMIX\_IP3}=0.

- 0 : NF performance is preference (default)
- 1 : IIP3 performance improvement

**FMIX\_HV: High IIP3 mode of 1st Mixer**

IIP3 performance of 1st Mixer is improved by adjustment of BIAS1/2 resistance and setting {FMIX\_HV}="1". When FMIX\_HV="1" setting, MIXVDD must be set more than 4.5V.

- 0 : BIAS1/2 ≥ 39kΩ (default)
- 1 : 18kΩ ≤ BIAS1/2 < 39kΩ

**PDTRI\_N: Tripler circuit On/Off**

REFIN signal can be input from LO2NDIN pin by setting tripler circuit off. Then REFIN input is one third of the 2nd LO input frequency.

- 0 : Off (default)
- 1 : On

**PDSYNTH\_N: SYNTH On/Off**

- 0 : Off (default)
- 1 : On

**PDADC\_N: ADC On/Off**

- 0 : Off (default)
- 1 : On

**PDFSTMIX\_N: 1st MIXER On/Off**

- 0 : Off (default)
- 1 : On

**BSSEL\_FMIX: Bias resistance select**

- 0 : BIAS2 pin is enable (default)
- 1 : BIAS1 pin is enable

**Address 0x0B**

**R\_AGC1\_G[5:0]:** Read the gain setting of AGC1 when {AGC\_OFF}=0

**R\_AGC2\_G[4:0]:** Read the gain setting of AGC2 when {AGC\_OFF}=0

## Block Diagram (PLL SYNTH)

The AK2400 is a Delta-Sigma Fractional-N PLL (Phase Locked Loop) frequency synthesizer with a frequency switching function, covering a wide range of frequencies from 10 to 1000MHz. This product consists of an 18-bit Delta-Sigma modulator, a low-noise phase frequency comparator, a highly accurate charge pump, a reference divider, dual-module prescaler (P/P+1) and frequency offset adjustable circuits. An excellent PLL can be achieved by combining this synthesizer with the external loop filter and VCO (Voltage Controlled Oscillator). The operating supply voltage is from 2.7 to 5.5V; and the charge pump and serial interface can be driven by individual supply voltages.

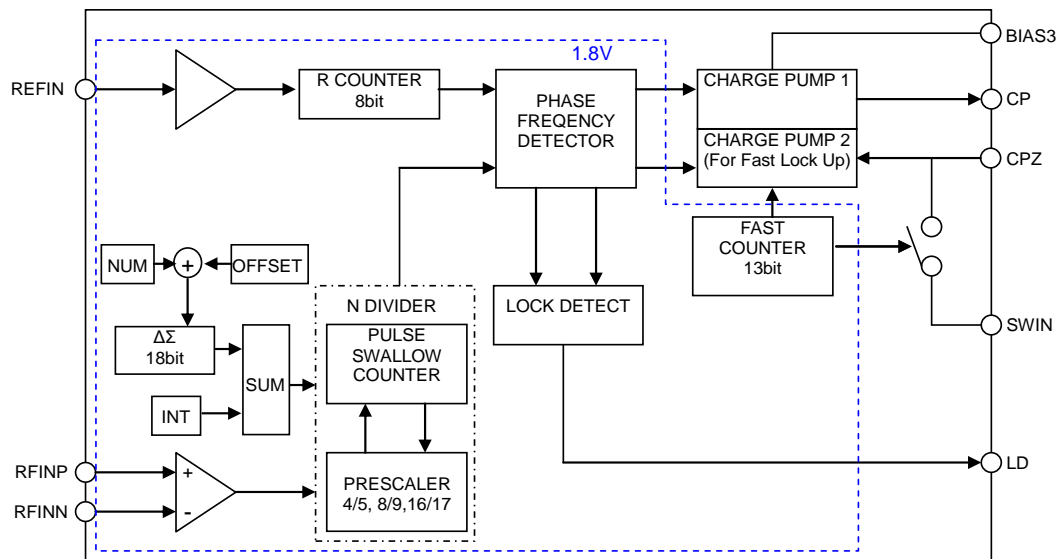


Figure 9 Block Diagram (PLL SYNTH)

## Lock Detect function (PLL SYNTH)

In AK2400, "lock detect" output can be selected by  $D[11] = \{LD\}$  in <Address3>. When  $\{LD\}$  is set to "1", the phase frequency detector output provides a phase detection status as an analog level (comparison result). This is called "Analog Lock Detect". When  $\{LD\}$  is set to "0", the lock detect signal outputs according to the on-chip logic. This is called "Digital Lock Detect".

### Analog Lock Detect

In analog lock detect, the phase frequency detector output comes from the [LD] pin.

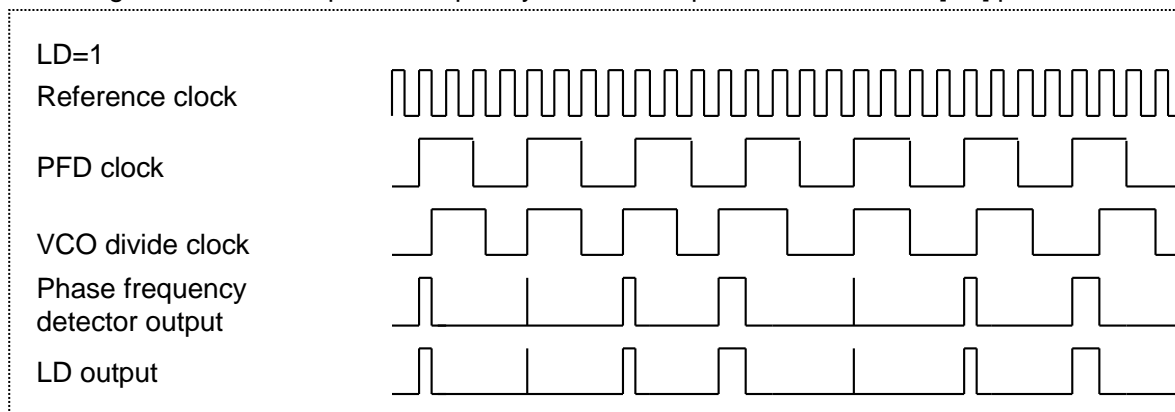


Figure 10 Analog Lock Detect

### Digital Lock Detect

In the digital lock detect, the LD pin outputs "Low" every time when the frequency is set. And the LD pin outputs is "High" (which means the locked state) when a phase error smaller than  $T$  is detected for 63 times consecutively. If the phase error is larger than  $T$  is detected for 63 times consecutively when the LD pin outputs "High", the LD pin outputs "Low" (which means the unlocked state).

The accuracy of the phase detect is set by LDCKSEL[1:0].

- "00" : 1 cycle of the REFIN clock (This cannot be used for the reference dividing ratio  $\leq 3$ .)
- "01" : 2 cycle of the REFIN clock (This cannot be used for the reference dividing ratio  $\leq 5$ .)
- "10" : 3 cycle of the REFIN clock (This cannot be used for the reference dividing ratio  $\leq 6$ .)

Since the AK2400 is a Delta-Sigma Fractional-N type, a phase error up to 7 times larger than the VCO period frequency may occur in the phase frequency detector. Therefore the LDCKSEL[1:0] setting should be large enough to cover the amplitude of the Delta-Sigma Fractional frequency. However, if the VCO frequency does not satisfy either of the following formula, the digital lock detect cannot be used. In such case, the analog lock detect should be used.

When  $\{DITH\} = D[14]$  in <Address3> is set to "1" (DITH ON):

$$\text{VCO frequency} > [\text{REFIN}] \text{ pin input frequency} / [\text{LDCKSEL}[1:0] \text{ setting} + 1] \times 7$$

When  $\{DITH\} = D[14]$  in <Address3> is set to "0" (DITH OFF):

$$\text{VCO frequency} > [\text{REFIN}] \text{ pin input frequency} / [\text{LDCKSEL}[1:0] \text{ setting} + 1] \times 4$$

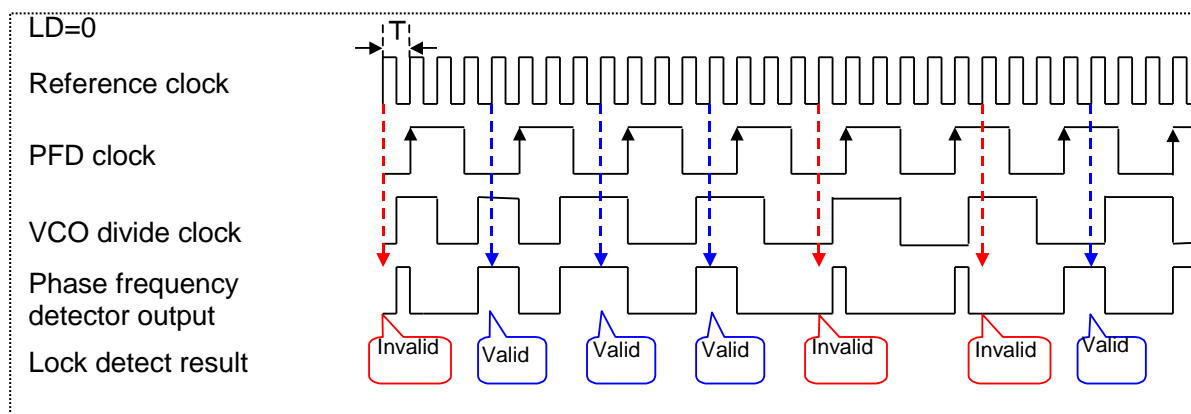


Figure 11 Digital Lock Detect

Transition Flow Chart: Unlock State to Lock State

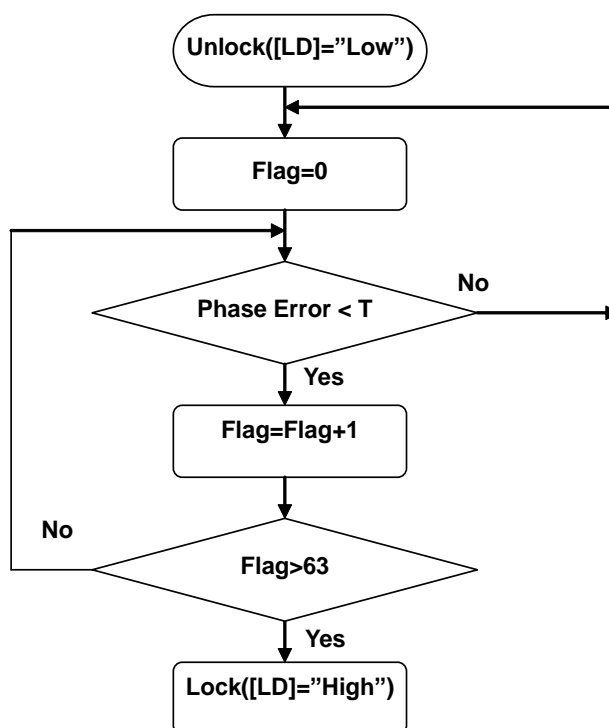


Figure 12-1 Unlock State to Lock State



## Transition Flow Chart: Lock State to Unlock State

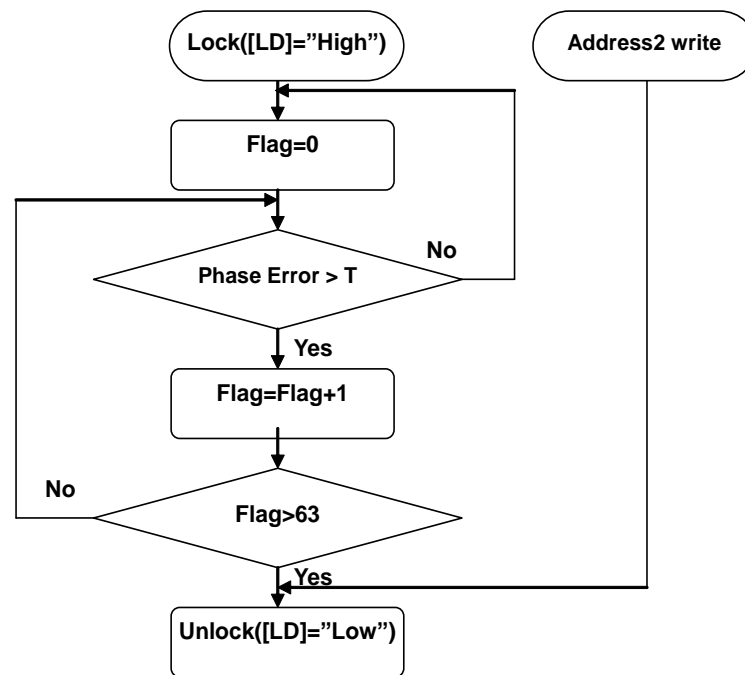


Figure 12-2 Digital Lock Detect

## Frequency Setting (PLL SYNTH)

### Frequency Setup

AK2400 is a Fractional-N type synthesizer that takes  $2^{18}$  as the denominator, which calculates the integer and numerator to be set using the following formulas:

$$\begin{aligned} \text{Frequency setting} &= F_{\text{PFD}} \times (\text{Integer} + \text{Numerator} / 2^{18}) \\ \text{Integer} &= \text{ROUND} (\text{Target Frequency} / F_{\text{PFD}}) \\ \text{Numerator} &= \text{ROUND} \{ (\text{Target Frequency} - \text{Integer} \times F_{\text{PFD}}) / (F_{\text{PFD}} / 2^{18}) \} \end{aligned}$$

Note)

ROUND: Rounded off to the nearest integer

$F_{\text{PFD}}$  : Phase Frequency Detector comparative Frequency ([REFIN] pin input frequency / R divider ratio)

### Calculation examples

Example 1) The numerator is positive when the target frequency is 950.0375MHz and the Phase Frequency Detector comparative Frequency is 1MHz.

$$\text{Integer} = 950.0375\text{MHz} / 1\text{MHz} = 950.0375$$

It is rounded off to 950 (decimal) = 3B6 (hexadecimal) = 0011 1011 0110 (binary)

$$\text{Numerator} = (950.0375\text{MHz} - 950 \times 1\text{MHz}) / (1\text{MHz} / 2^{18}) = 9830.4$$

It is rounded off to 9830 (decimal) = 2666 (hexadecimal) = 10 0110 0110 0110 (binary)

$$\text{Frequency setting} = 1\text{MHz} \times (950 + 9830 / 2^{18}) = 950.0374985\text{MHz}$$

(In this case the error between the calculated frequency and the target frequency is 1.5Hz.)

Example 2) The numerator is negative when the target frequency is 950.550MHz and the Phase Frequency Detector comparative Frequency is 1MHz.

$$\text{Integer} = 950.550\text{MHz} / 1\text{MHz} = 950.550$$

It is rounded off to 951 (decimal) = 3B7 (hexadecimal) = 0011 1011 0111 (binary)

$$\text{Numerator} = (950.550\text{MHz} - 951 \times 1\text{MHz}) / (1\text{MHz} / 2^{18}) = -117964.8$$

It is rounded off to -117965 (decimal), which is deduced from  $2^{18}$  to be converted into binary for 2's complementary expression.

$$2^{18} - 117965 \text{ (decimal)} = 144179 \text{ (decimal)} = 23333 \text{ (hexadecimal)} = 10 0011 0011 0011 0011 \text{ (binary)}$$

$$\text{Frequency setting} = 1\text{MHz} \times (951 + (-117965/2^{18})) = 950.5499992\text{MHz}$$

(In this case the error between the calculated frequency and the target frequency is 0.8Hz.)

## Frequency switching adjustment (PLL SYNTH)

AK2400 has an offset adjustable register which can tune the carrier frequency set by {NUM[17:0]} in <Address1> and {INT[14:0]} in <Address2>. When the offset register: {OFST[17:0]} in <Address6> is accessed, {NUM[17:0]} and {INT[14:0]} are recalculated automatically and their recalculated data are used in delta-sigma and N-divider. This operation is suitable for AFC and DFM applications. When frequency offset is not used, the offset register must be written 00000 (hexadecimal). When OFFSET register is used, set DITH=0(OFF).

### Setting examples

Example 1) The frequency offset is positive when the frequency offset is 100Hz and the Phase Frequency Detector comparative frequency is 1MHz.

$$\text{Frequency offset} = 100\text{Hz} / (1\text{MHz}/2^{18}) = 26.2$$

It is round off to 26 (decimal) = 1A (hexadecimal) = 11010 (binary)

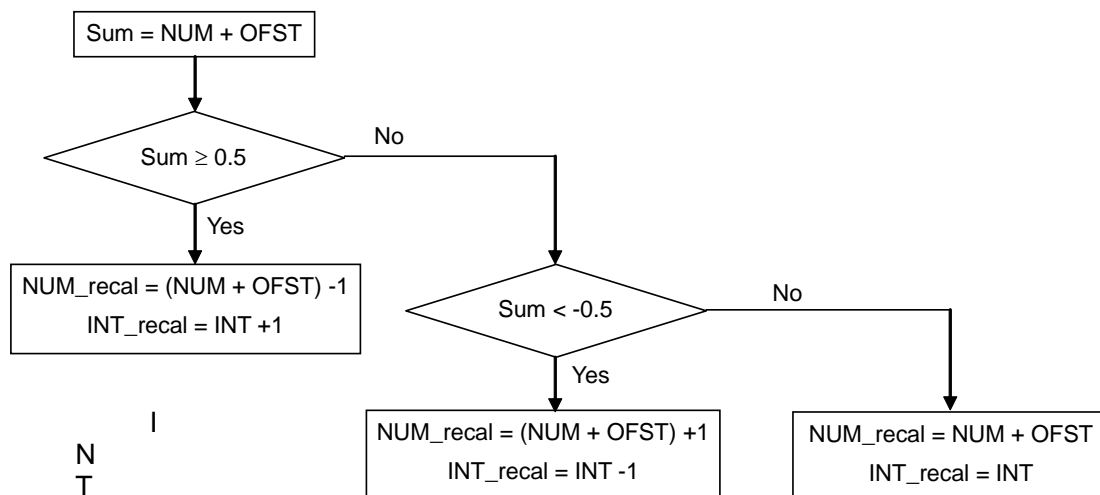
Example 2) The frequency offset is negative when the frequency offset is -100Hz and the Phase Frequency Detector comparative frequency is 1MHz.

$$\text{Frequency offset} = -100\text{Hz} / (1\text{MHz}/2^{18}) = -26.2$$

It is round off to -26 (decimal), which is deduced from  $2^{18}$  to be converted into binary for 2's complementary expression.

$$2^{18} - 26 = 262118 \text{ (decimal)} = 3FFE6 \text{ (hexadecimal)} = 11\ 1111\ 1111\ 1110\ 0110 \text{ (binary)}$$

### Algorithm of recalculation



written data in integer register {INT[14:0]}

NUM written data in numerator register {NUM[17:0]}

OFST written data in offset register {OFST[17:0]}

INT\_recal recalculated integer data

NUM\_recal recalculated numerator data

Figure 13 Frequency switching adjustment

## Charge Pump and Loop Filter (PLL SYNTH)

AK2400 has two charge pumps; Charge Pump 1 for normal operation and Charge Pump 2 for Fast Lockup mode. The internal timer is used to switch these two charge pumps to achieve a Fast Lock PLL.

The loop filter is external and connected to [CP], [SWIN] and [CPZ] pins. [CPZ] pin should be connected to R2 and C2, which are intermediate nodes, even if the Fast Lockup is not used. Therefore, R2 must be connected to [CP] pin, while C2 must be connected to the ground.

R2 and R2' are connected in parallel with internal switch in Fast Lockup. These R2 and R2' parallel resistance value is required for calculating loop bandwidth and phase margin in Fast Lockup operation.

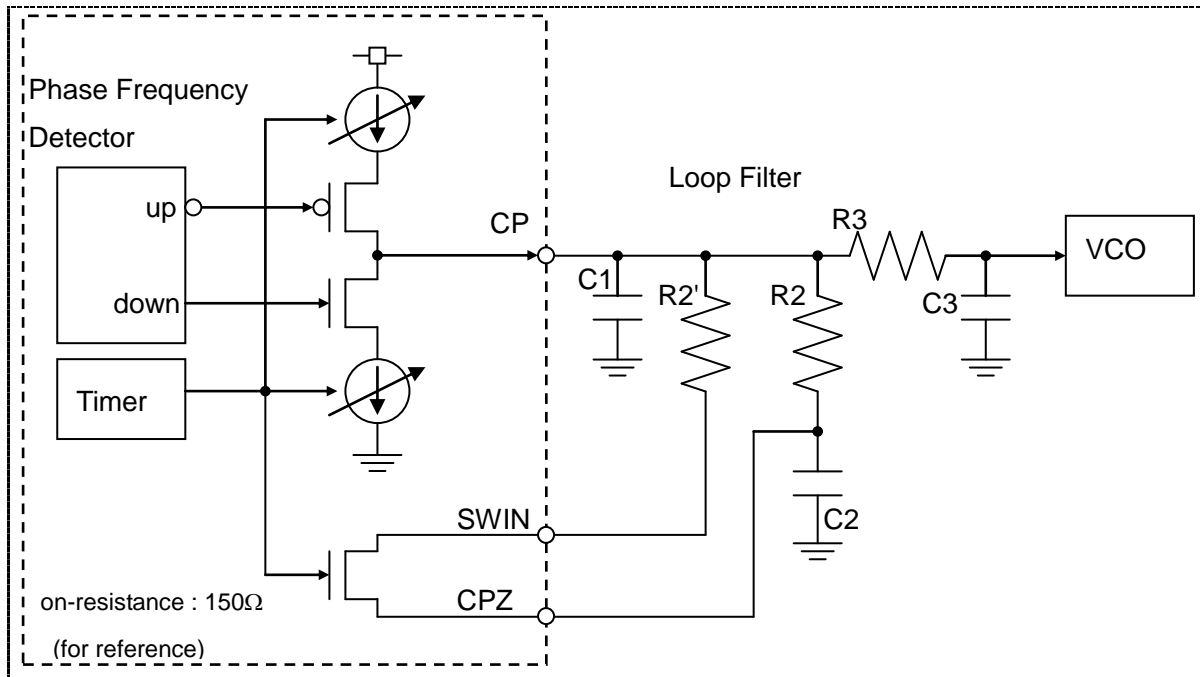


Figure 14 Charge pump and Loop Filter

## Fast lock-up mode (PLL SYNTH)

Setting D[16] = {FASTEN} in <Address4> to "1" enables the Fast Lock Up mode for the AK2400. Changing a frequency setting (The frequency is changed at the rising edge of [CSN], when <Address1> and <Address2> are accessed.) or [PDSYNTH\_N] pin is set from "Low" to "High" with {FASTEN}=1 enables the Fast Lockup mode. The loop filter switch turns ON during the timer period specified by the counter value in D[12:0] = {FAST[12:0]} in <Address4>, and the charge pump for the Fast Lockup mode (Charge Pump 2) is enabled. After the timer period elapsed, the loop filter switch turns OFF. The charge pump for normal operation (Charge Pump 1) is enabled. D[12:0] = {FAST[12:0]} in <Address4> is used to set the timer period for this mode.

The following formula is used to calculate the time period:

Phase detector frequency cycle x counter value set in {FAST[12:0]}

The charge pump current can be changed with the register setting in 8 steps in normal operation (Charge Pump 1) and 8 steps in the Fast Lockup operation (Charge Pump 2).

The charge pump current for normal operation (Charge Pump 1) is determined by the setting in {CP1[2:0]}, which is a 3-bit address of D[17:15] in <Address2>, and a value of the resistance connected to the BIAS3 pin. The following formulas show the relationship between the resistance value, the register setting and the electric current value.

Charge Pump 1 minimum current (CP1\_min) = 0.57 / Resistance connected to the BIAS3 pin

Charge Pump 1 current = CP1\_min x ({CP1[2:0]} + 1)

The charge pump current for the Fast Lockup mode operation (Charge Pump 2 current) is determined by the setting in {CP2[2:0]}, which is a 3-bit address of D[15:13] in <Address4>, and a value of the resistance connected to the BIAS3 pin. The following formula show the relationship between the resistance value, the register setting and the electric current value.

Charge Pump 2 minimum current (CP2\_min) = 5.7 / Resistance connected to the BIAS3 pin

Charge Pump 2 minimum current (CP2\_min) = CP2\_min x ({CP2[2:0]} + 4)

The allowed range value for the resistance (connected to the BIAS3 pin (19)) is from 22 to 33 [kΩ] for both normal and Fast Lockup mode operations.

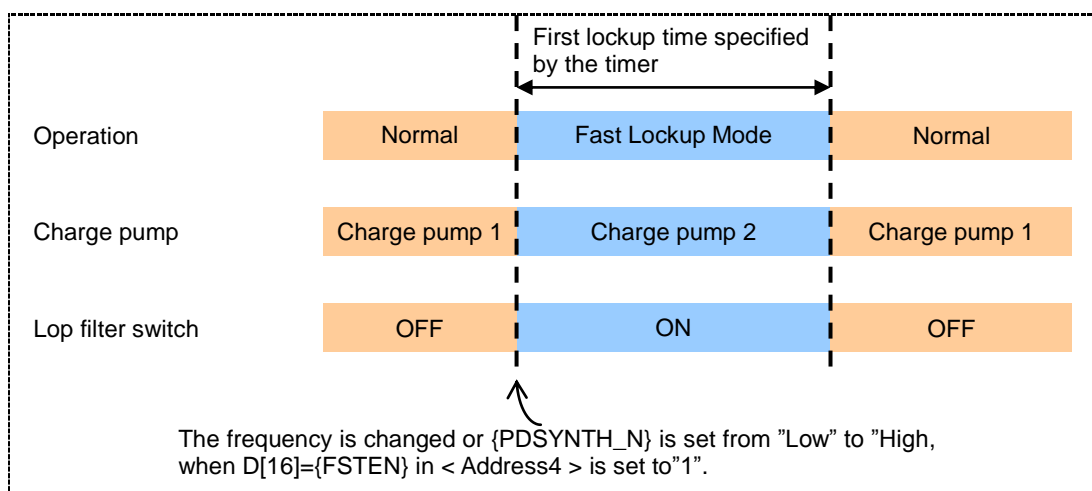


Figure 15 Timing Chart for Fast Lockup Mode

## Calibration Procedure (Discriminator)

AK2400 employs a function to calibrate free-running frequency of VCO in Discriminator and demodulated signal level. Before starting RX Operation, calibration is required in order to acquire proper VCO operation range and demodulated signal level.

Following procedure is required before calibration.

- <1> Start up the external TCXO and continuously supply LO signal to AK2400.
- <2> Set "110" to 0x0A {BS[2:0]} and start up all circuits. After this operation, the circuits necessary for calibration (LOBUF, VIREF, Discriminator) will be powered on and calibration can be possible in 500us.
- <3> Calibration is begun by setting "1" to address 0x07 {CAL}. When the calibration is executed once, the calibration operation cannot be stopped excluding master reset. Even if "0" is written in {CAL}, the calibration is completely executed.
- <4> Calibration data is maintained excluding the time when the master reset is executed or DVDD power supply is down.
- <5> It takes 1.5ms for Discriminator to become steady after the calibration is completed.

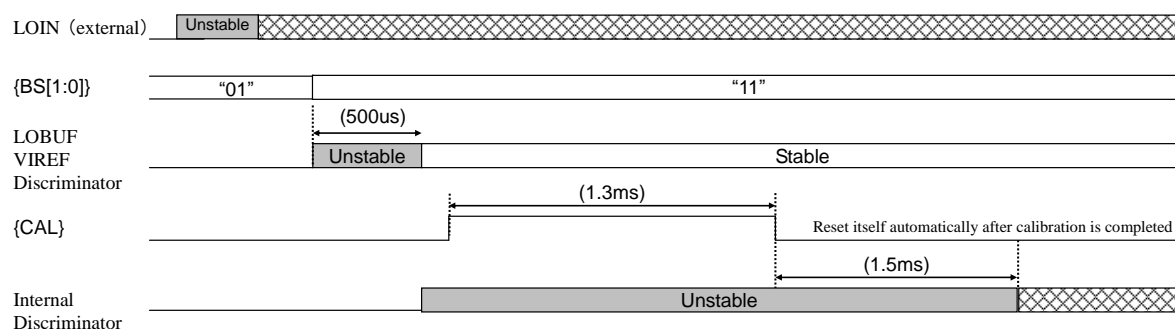


Figure 16 Power-up sequence recommendation

## Typical Evaluation Board Schematic (PLL SYNTH)

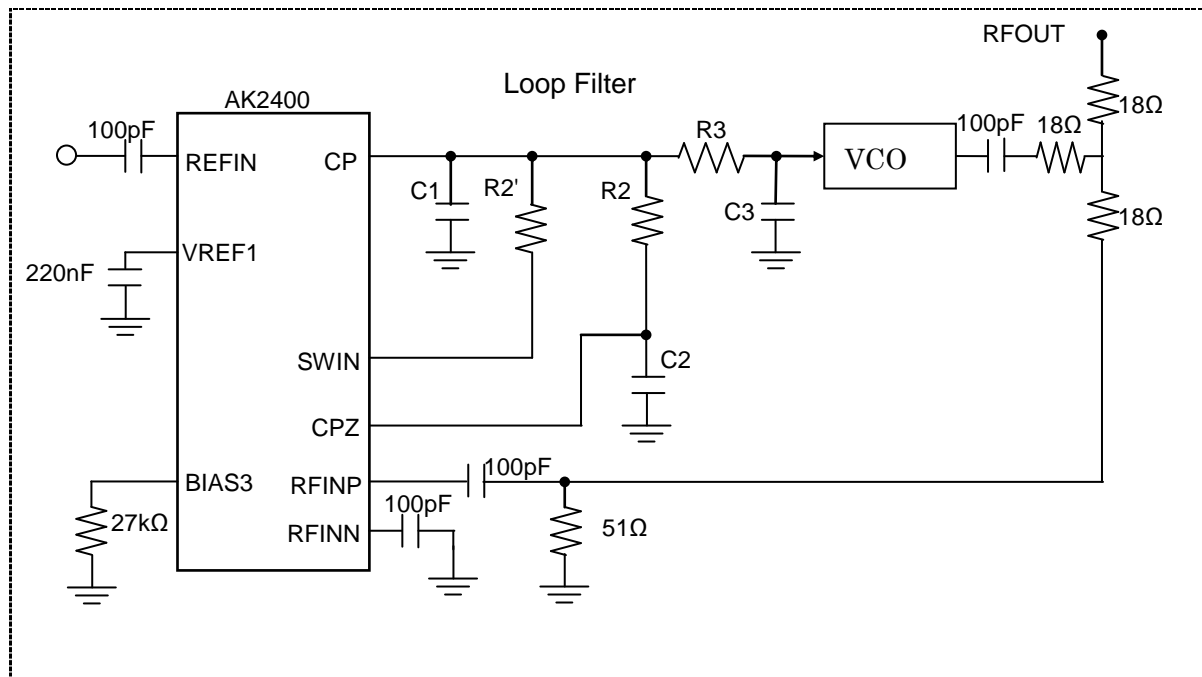


Figure 17 Typical Evaluation Board Schematic (PLL SYNTH)

[CPZ] pin should be connected to R2 and C2, which are intermediate nodes, even if the Fast Lockup feature is not used. For the output destination from [CPZ] pin, see “Charge Pump and Loop Filter” on page 36.

R2 and R2' are connected in parallel with internal switch in Fast Lockup. These R2 and R2' parallel resistance value is required for calculating loop bandwidth and phase margin in Fast Lockup. The on-resistance value of the internal switch is 150Ω for reference.

### 1. PVDD, CPVDD

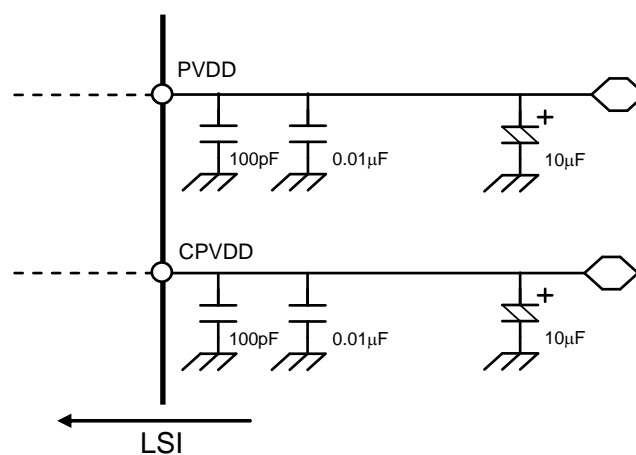


Figure 18 PVDD, CPVDD

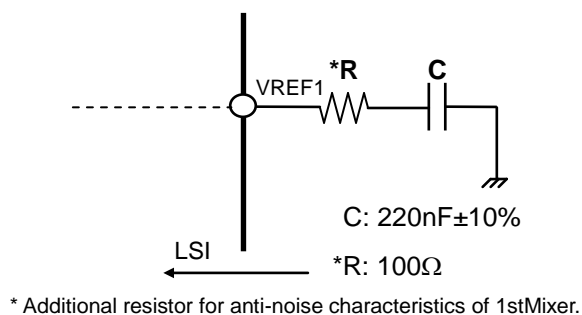
**2. VREF1**

Figure 19 PVDD, CPVDD

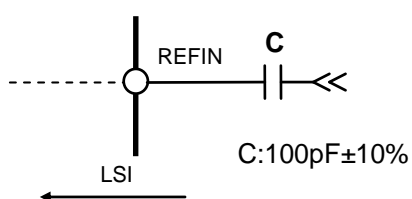
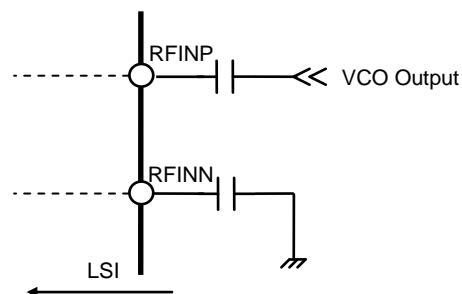
**3. REFIN**

Figure 20 REFIN

**4. RFINP, RFINN**

Refer to typical Evaluation Board Schematic.

Figure 21 RFINP, RFINN

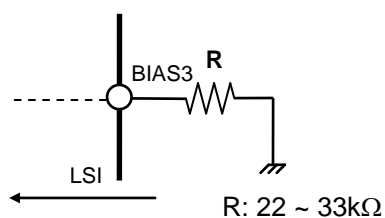
**5. BIAS3**

Figure 22 BIAS3



## Typical Evaluation Board Schematic (1st MIXER)

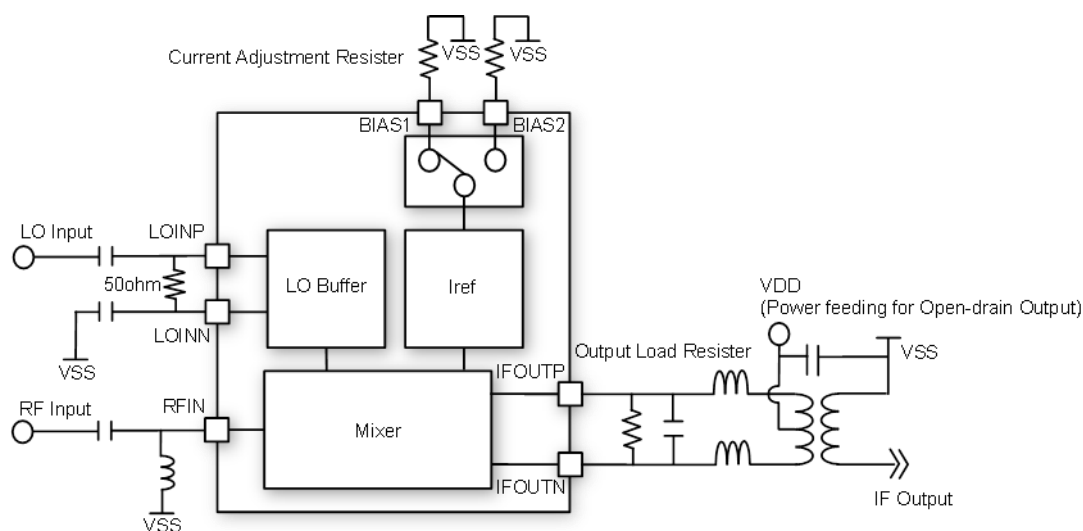


Figure 23 Typical Evaluation Board Schematic (1st MIXER)

- Note 1) The exposed pad at the center of the backside should be connected to ground.  
 Note 2) The open drain output needs power feeding via an inductor. (IFOUTP pin and IFOUTN pin)  
 Note 3) It is necessary to adjust impedance matching as to its setting frequency. (RF input and IF output)  
 Note 4) If 1st Mixer is not used, each pin are terminated as below.  
 Register {BSSEL\_FMIX}, {PDFSTIX\_N}, {FMIX\_HV} and {FMIX\_IP3} on Address 0x0A must be set to 0

| No. | Name   | Terminating condition |
|-----|--------|-----------------------|
| 1   | RFIN   | OPEN                  |
| 2   | AVSS1  | VSS                   |
| 3   | IFOUTP | OPEN                  |
| 4   | IFOUTN | OPEN                  |
| 5   | MIXVDD | VSS                   |
| 53  | BIAS2  | VSS                   |
| 54  | BIAS1  | VSS                   |
| 55  | LOINP  | OPEN                  |
| 56  | LOINN  | OPEN                  |

### ·Impedance matching network for RF Input pin

RF Input port with impedance matching network (highpass filter) is shown as below. Typical evaluation board component values in 50Ω interface are shown as below.

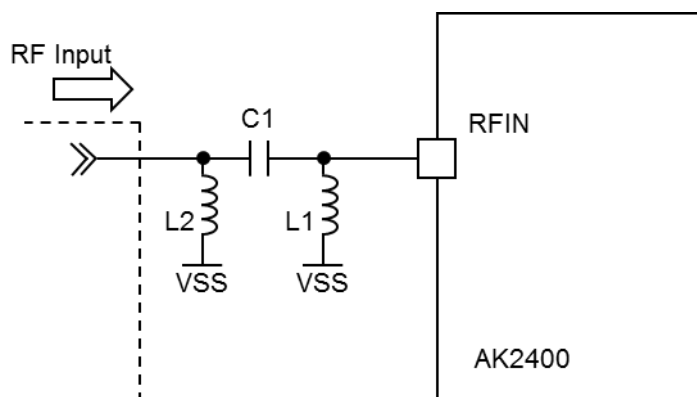


Figure 24 RF Input port with impedance matching network

| RF Input Frequency [MHz] | C1 [pF] | L1 [nH] | L2 [nH] |
|--------------------------|---------|---------|---------|
| 70                       | 82      | 200     | -       |
| 160                      | 39      | 100     | -       |
| 300                      | 18      | 33      | -       |
| 600                      | 18      | 33      | -       |
| 900                      | 18      | 33      | -       |

### ·Impedance matching network for LO Input pin

LOIN port can be matched with resistive impedance matching network in 10MHz < LO Input < 2000MHz. Typical evaluation board component values in 50Ω interface is shown as below.

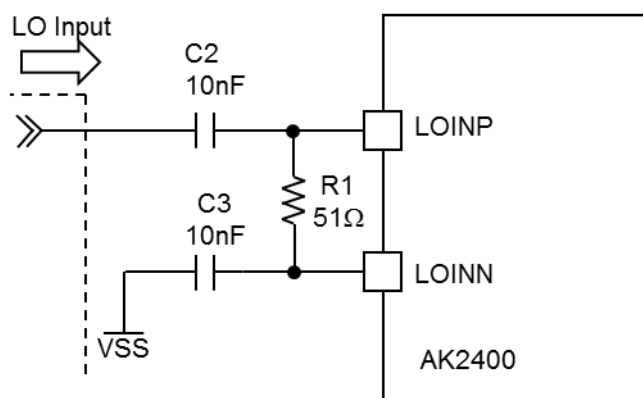


Figure 25 LO Input port with impedance matching network

### ·Impedance matching network for IF Output pin

IF output port with impedance matching network (lowpass filter and balun) is shown as below. IFOUTP and IFOUTN pins need power feeding via center tap of balun. Typical evaluation board component values in 50Ω interface are shown as below.

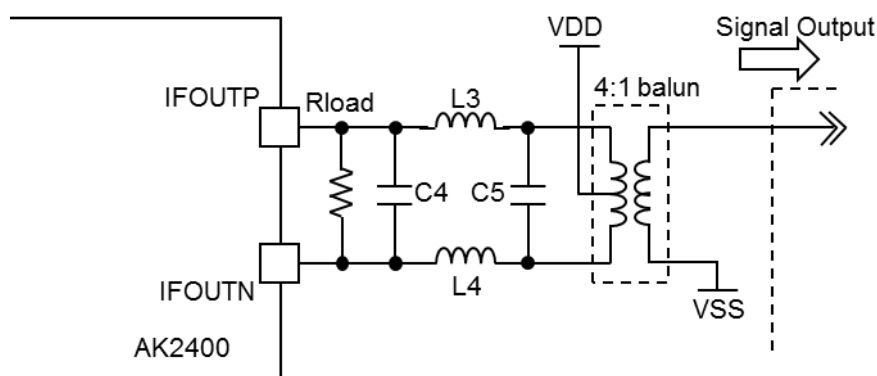


Figure 26 IF output port with impedance matching network

| IF Output Frequency [MHz] | Rload [kΩ] | L3/L4 [nH] | C4 [pF] | C5 [pF] |
|---------------------------|------------|------------|---------|---------|
| 29.25                     | 2.2        | 1800       | 6       | -       |
| 46.35                     | 2.2        | 1000       | 3.3     | -       |
| 50.85                     | 2.2        | 1000       | 2.4     | -       |
| 58.05                     | 2.2        | 1000       | 1.6     | -       |

### ·Impedance matching network with LC

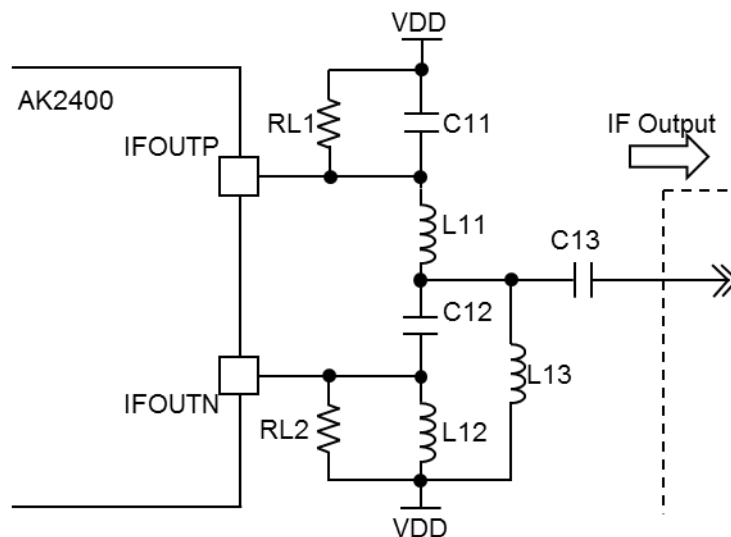


Figure 27 Impedance matching network with LC

Impedance matching network with LC is shown. AK2400 1st Mixer has open drain outputs, so RL1 + RL2 is output load resistance. C11 and L11 compose lowpass filter. C12 and L12 are for highpass filter. C13 is DC blocking capacitor and L13 is RF choke. OUTP and OUTN pins need power feeding via L11, L12 and L13.

The differential voltage from IFOUTP/N can be converted to a single-ended by L11, L12, C11 and C12 properly. The differential impedance (RL1 + RL2) is converted to single-ended output terminating impedance Ro.

L11, C11, L12 and C12 are calculated as below.  $f_{out}$  is IF output frequency.

$$C_{11} = C_{12} = \frac{1}{2\pi * f_{IF} * \sqrt{(R_{L1} + R_{L2}) * R_O}}$$

$$L_{11} = L_{12} = \frac{\sqrt{(R_{L1} + R_{L2}) * R_O}}{2\pi * f_{IF}}$$

For example, in the case of IF Output = 50MHz, Output Load Resistor (Rload) = 2.2k $\Omega$  in 50 $\Omega$  interface, L11, C11, L12 and C12 are calculated as below.

$$C_{11} = C_{12} = \frac{1}{2\pi * (50 * 10^6) * \sqrt{(2.2 * 10^3) * 50}} = 9.6\text{pF}$$

$$L_{11} = L_{12} = \frac{\sqrt{(2.2 * 10^3) * 50}}{2\pi * (50 * 10^6)} = 1056\text{nH}$$

L13 and C13 should be large enough not to affect the impedance at IF output frequency. In some cases the impedance matching can be optimized by L13 and C13.

For example, in the case of IF Output = 50MHz, Output Load Resistor (Rload) = 2.2k $\Omega$  in 50 $\Omega$  interface, it is recommended to choose 2200nH and 1000pF as L13 and C13. If any correction is needed, it can be adjusted by reducing the value of L13 and C13.

These calculated values are approximation. In some cases, some correction is needed due to the effect of parasitic capacitance of external parts or/and PCBs. The impedance matching network components should be decided through enough evaluation on AK2400.

Typical evaluation board component values in 50 $\Omega$  interface are shown as below.

| IF Output Frequency [MHz] | RL1/RL2 [k $\Omega$ ] | L11/L12 [nH] | C11/C12 [pF] | L13 [nH] | C13 [pF] |
|---------------------------|-----------------------|--------------|--------------|----------|----------|
| 29.25                     | 1.1                   | 1800         | 15           | 2200     | 270      |
| 46.35                     | 1.1                   | 1000         | 10           | 2200     | 220      |
| 50.85                     | 1.1                   | 1000         | 9.1          | 2200     | 82       |
| 58.05                     | 1.1                   | 1000         | 8.2          | 2200     | 39       |

The phase and amplitude balance is achieved at IF Output frequency by using impedance matching network with LC. The port-to-port leakage is improved with the phase and amplitude balance is achieved at RF, LO, and IF frequency with wide band balun.

## Typical Evaluation Board Schematic (2nd IF)

### 1) Power supply stabilizing capacitors

Connect capacitors between VDD and VSS pins to eliminate ripple and noise included in power supply. For maximum effect, the capacitors should be placed at a shortest distance between the pins.

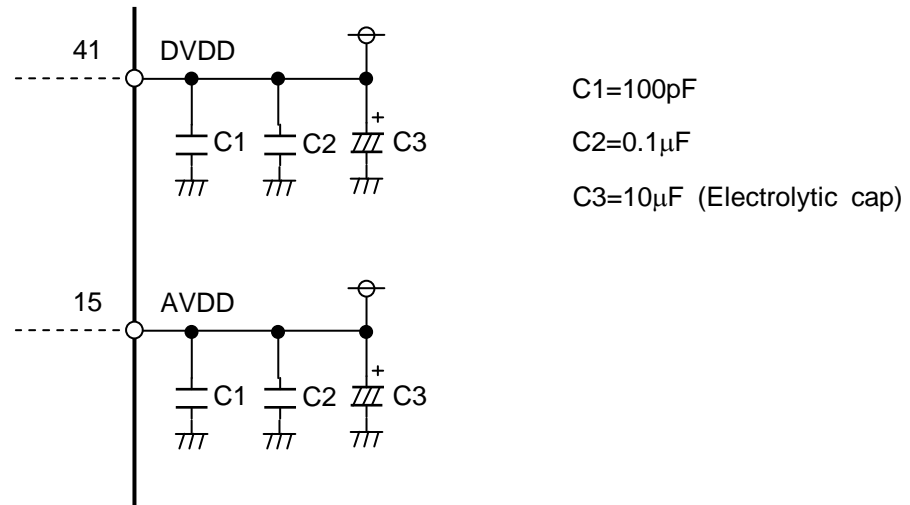


Figure 28 DVDD, AVDD

### 2) AGND stabilizing capacitors

It is recommended that capacitors with 1μF or larger be connected between VSS and the AGND and AGNDIN pins to stabilize the AGND signal. The capacitors must be placed as close to the pins as possible.

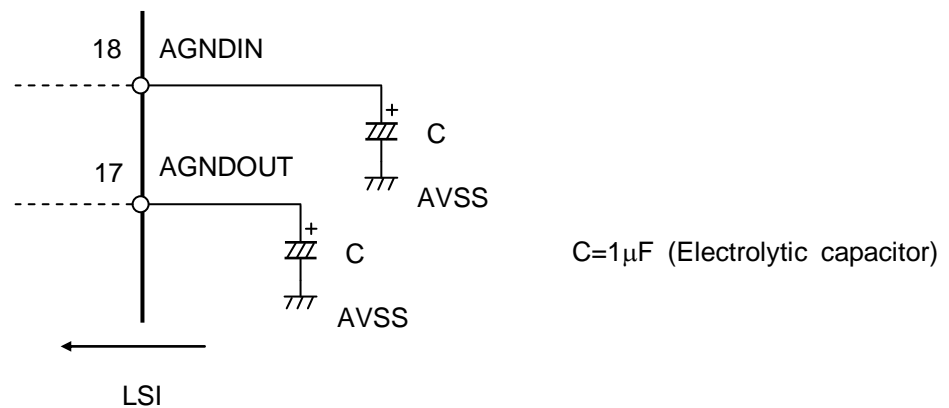


Figure 29 AGNDIN, AGNDOUT

### 3) BIAS4 pin

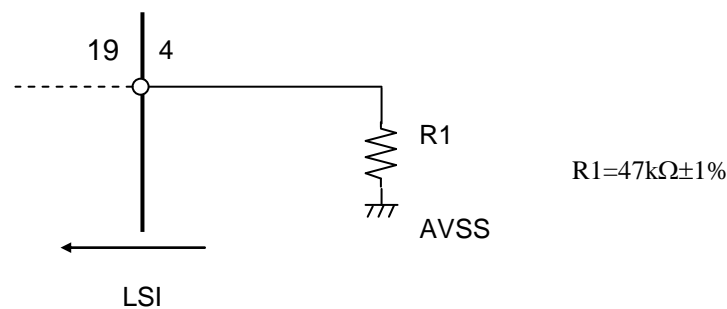
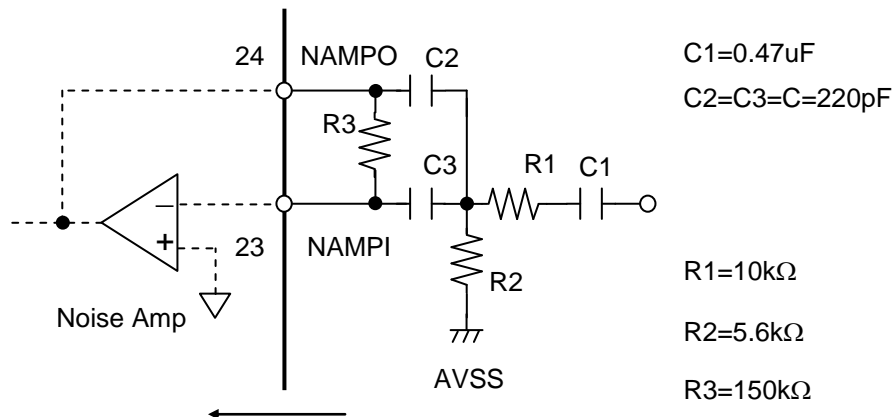


Figure 30 BIAS4

## 4) Noise Amp

The following gives a sample configuration of a BPF when input frequency is 31kHz.  
Some parameters can be calculated using following (1) to (3) equations.



$$(1) f_0 = \frac{1}{2\pi\sqrt{R_3(R_1 // R_2)C^2}}$$

$$(2) G_v = \frac{R_3}{2R_1}$$

$$(3) Q^2 = \frac{R_3}{4(R_1 // R_2)}$$

Figure 31 NAMPO, NAMPI

## 5) NRECTO pin

Rise time of noise detection is proportionate to  $C1=0.1\mu F$  and internal resistance  $75k\Omega$

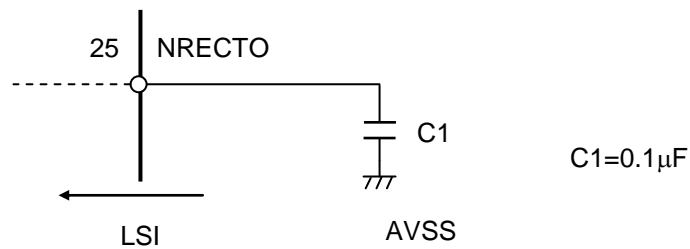


Figure 32 NRECTO

## 6) RSSIOUT pin

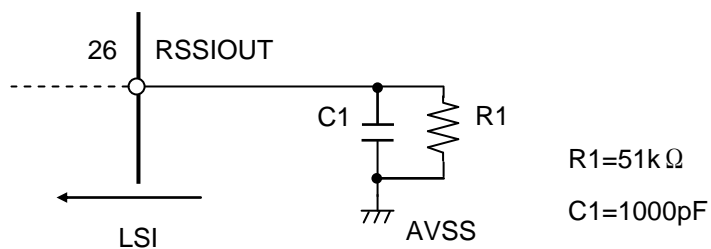


Figure 33 RSSIOUT

## 7) Discriminator

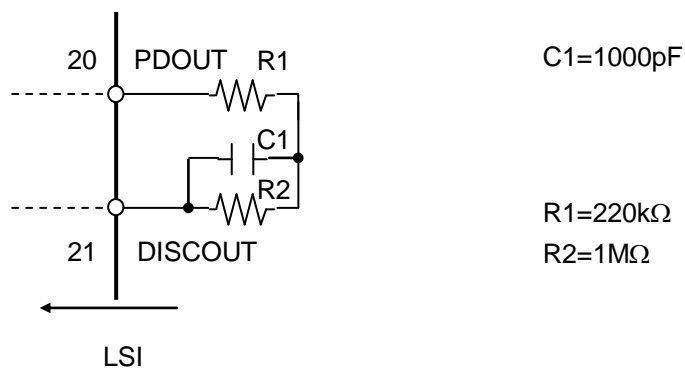


Figure 34 Discriminator

## 8) Tripler circuit

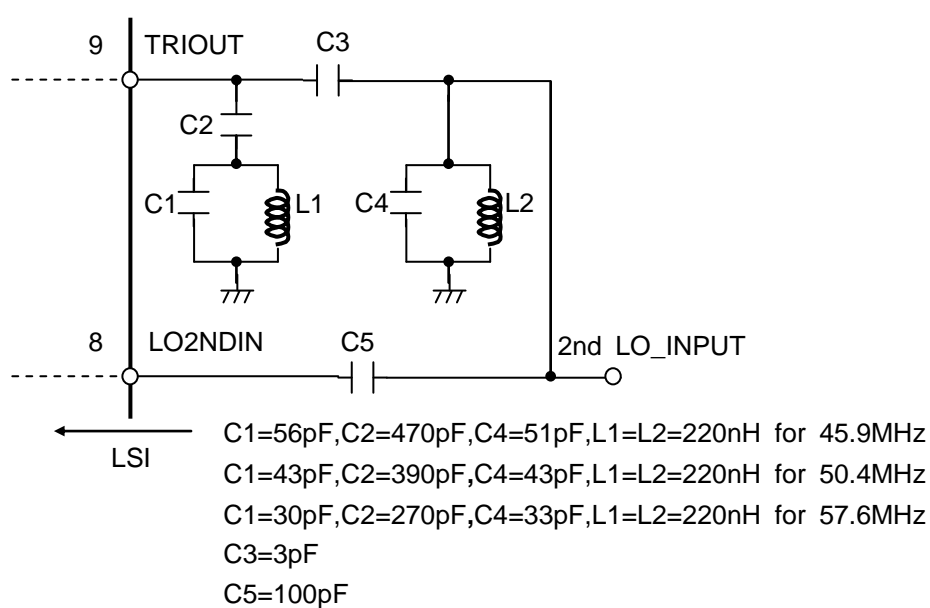


Figure 35 Tripler circuit

## 9) VREFA output

It is recommended that capacitors with 220nF or larger be connected between AVSS and VREFA pin to stabilize the VREFA signal. The capacitors must be placed as close to the pins as possible.

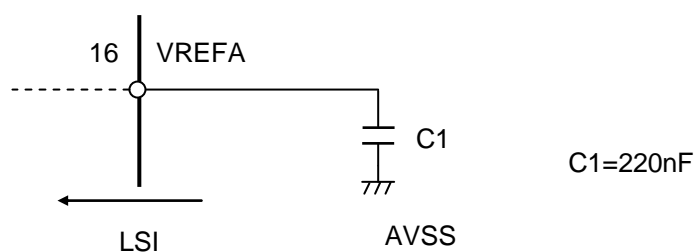


Figure 36 VREFA

## 10) DETO/SDATAOUT output

When {SDATAOUT\_OE} is set "0", DETO signal is output. DETO is open-drain output.

When {SDATAOUT\_OE} is set "1", SDATAOUT signal is output. SDATAOUT is CMOS output and output level is DVDD voltage.

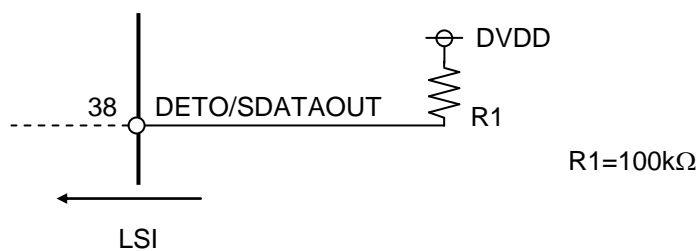
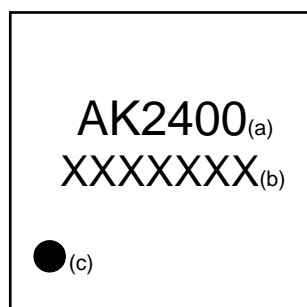


Figure 37 DETO/SDATAOUT



## Package

### Marking



- a: Product number : AK2400  
 b: Date code : XXXXXXX  
 c: 1 pin marking : ●  
 d: Style : QFN  
 e: Number of pins : 56

Figure 38 Marking

### Mechanical Outline

Package: 56pin-QFN (8 x 8 mm、0.5 mm pitch)

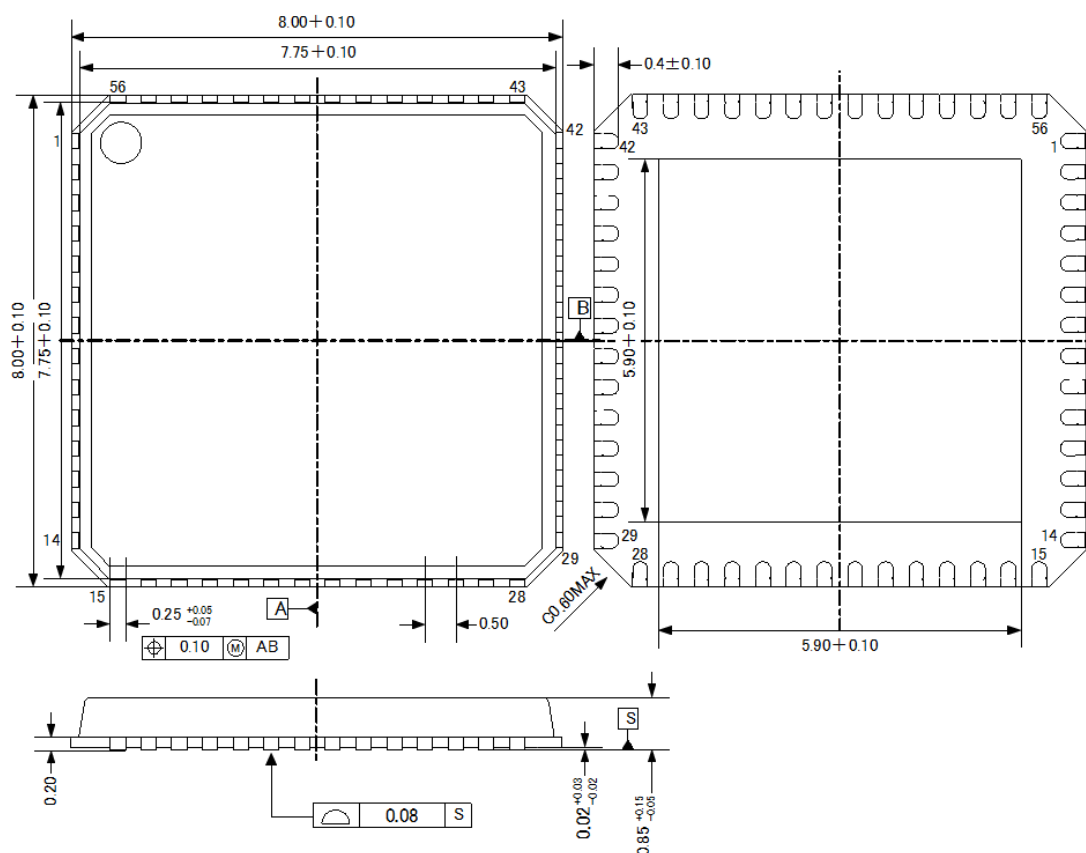


Figure 39 Mechanical Outline

**Revision History**

| Date (Y/M/D) | Revision | Reason              | Page       | Contents  |
|--------------|----------|---------------------|------------|---|
| 14/10/23     | 00       | Initial Version     |            |   |
| 15/04/23     | 01       | Spec change         | 20, 28     | Prohibit Mode1  |
|              |          | Spec addition       | 15         | Expand input frequency range of 2ndMixer to FLO $\pm$ 0.45MHz |
|              |          | Annotation addition | 22, 24, 35 | When OFFSET register is used, set DITH=0(OFF).                |

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**•Related Parts**

| Part#   | Discription   | Comments                              |
|---|---|---------------------------------------|
| <b>Mixer</b>  |   |                                       |
| AK1220  | 100MHz~900MHz High Linearity Down Conversion Mixer                                  | IIP3:+22dBm                           |
| AK1222  | 100MHz~900MHz Low Power Down Conversion Mixer                                       | IDD:2.9mA                             |
| AK1224  | 100MHz~900MHz Low Noise, High Liniarity Down Conversion Mixer                       | NF:8.5dB, IIP3:+18dBm                 |
| AK1228  | 10MHz~2GHz Up/Down Conversion Mixer   | 3V Supply, NF:8.5dB                   |
| AK1221  | 0.7GHz~3.5GHz High Linearity Down Conversion Mixer                                  | IIP3:+25dBm                           |
| AK1223  | 3GHz~8.5GHz High Linearity Down Conversion Mixer                                    | IIP3:+13dB, NF:15dB                   |
| <b>PLL Synthesizer</b>                                |   |                                       |
| AK1541  | 20MHz~600MHz Low Power Fractional-N Synthesizer                                     | IDD:4.6mA                             |
| AK1542A   | 20MHz~600MHz Low Power Integer-N Synthesizer  | IDD:2.2mA                             |
| AK1543  | 400MHz~1.3GHz Low Power Fractional-N Synthesizer                                    | IDD:5.1mA                             |
| AK1544  | 400MHz~1.3GHz Low Power Integer-N Synthesizer                                       | IDD:2.8mA                             |
| AK1590  | 60MHz~1GHz Fractional-N Synthesizer   | IDD:2.5mA                             |
| AK1545  | 0.5GHz~3.5GHz Integer-N Synthesizer   | 16-TSSOP                              |
| AK1546  | 0.5GHz~3GHz Low Phase Noise Integer-N Synthesizer                                   | Normalized C/N:-226dBc/Hz             |
| AK1547  | 0.5GHz~4GHz Integer-N Synthesizer   | 5V Supply                             |
| AK1548  | 1GHz~8GHz Low Phase Noise Integer-N Synthesizer                                     | Normalized C/N:-226dBc/Hz             |
| <b>IFVGA</b>  |   |                                       |
| AK1291  | 100~300MHz Analog Signal Control IF VGA w/ RSSI                                     | Dynamic Range:30dB                    |
| <b>integrated VCO</b>                                 |   |                                       |
| AK1572  | 690MHz~4GHz Down Conversion Mixer with Frac.-N PLL and VCO                          | IIP3:24dBm,<br>-111dBc/Hz@100kHz      |
| AK1575  | 690MHz~4GHz Up Conversion Mixer with Frac.-N PLL and VCO                            | IIP3:24dBm,<br>-111dBc/Hz@100kHz      |
| <b>IF Reciever (2nd Mixer + IF BPF + FM Detector)</b> |   |                                       |
| AK2364  | Built-in programmable AGC+BPF, FM detector IC                                       | IFBPF:±10kHz ~ ±4.5kHz                |
| AK2365A   | Built-in programmable AGC+BPF, IFIC   | IFBPF:±7.5kHz ~ ±2kHz                 |
| <b>Analog BB for PMR/LMR</b>                          |   |                                       |
| AK2345C   | CTCSS Filter, Encoder, Decoder  | 24-VSOP                               |
| AK2360/<br>AK2360A                                    | Inverted frequency(3.376kHz/3.020kHz) scrambler                                     | 8-SON                                 |
| AK2363  | MSK Modem/DTMF Receiver   | 24-QFN                                |
| AK2346B   | 0.3-2.55/3.0kHz Analog audio filter,  | 24-VSOP                               |
| AK2346A   | Emphasis, Compandor, scrambler, MSK Modem   | 24-QFN                                |
| AK2347B   | 0.3-2.55/3.0kHz Analog audio filter<br>Emphasis, Compandor, scrambler, CTCSS filter | 24-VSOP                               |
| <b>Function IC</b>                                    |   |                                       |
| AK2330  | 8-bit 8ch Electronic Volume   | VREF can be selected for each channel |
| AK2331  | 8-bit 4ch Electronic Volume   | VREF can be selected for each channel |

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