

## 1. Overview

The AK1221 is high linearity mixer. RF and Lo frequency range coverage is from 700 to 3500MHz and IF coverage is from 20 to 1000MHz. The RF input provides single-ended 50Ω interface. Lo ports are 50Ω matched and complementary input should be decoupled to the ground. IF output ports are differential open drain outputs. The linearity and power consumption performances can be optimized by the resistance connected to the BIAS Pin.

## 2. Features

- ☐ Operating Frequency: 700MHz to 3500MHz
- ☐ Linearity vs. Power selectable architecture  
Power Consumption: 45mA, IIP3: +25dBm, Gain: -0.5dB, NF: 14dB
- ☐ Lo input level: 0dBm ±5dB
- ☐ Operating Supply Voltage: 4.75 to 5.25 V
- ☐ Package: 16pin UQFN (0.5mm pitch, 3mm × 3mm × 0.60mm)
- ☐ Operating Temperature Range: -40 to 85°C

## 3. Applications

- ☐ Cellular BTS / Repeater
- ☐ Two-way Radios (PMR/LMR)

|                          |
|--------------------------|
| <b>4. Table contents</b> |
|--------------------------|

|     |                                    |    |
|-----|------------------------------------|----|
| 1.  | Overview                           | 1  |
| 2.  | Features                           | 1  |
| 3.  | Applications                       | 1  |
| 4.  | Table contents                     | 2  |
| 5.  | Block Diagram                      | 3  |
| 6.  | System Diagram                     | 4  |
| 7.  | Pin Functional Description         | 5  |
| 8.  | Absolute Maximum Ratings           | 7  |
| 9.  | Recommended Operating Range        | 7  |
| 10. | Electrical Characteristics         | 8  |
| 11. | Typical Performance                | 9  |
| 12. | Typical Evaluation Board Schematic | 16 |
| 13. | LSI Interface Schematic            | 18 |
| 14. | Application Information            | 19 |
| 15. | Outer Dimensions                   | 24 |
| 16. | Marking                            | 25 |

## 5. Block Diagram

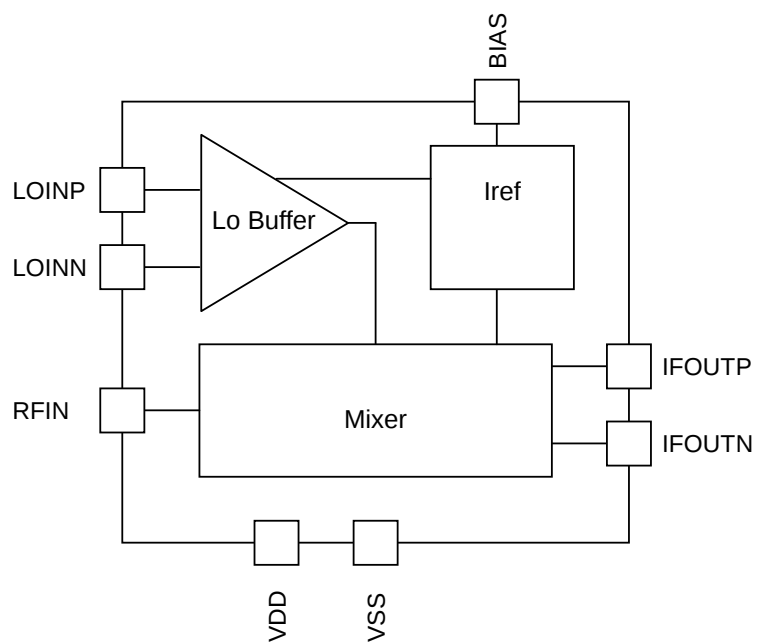


Figure 1. Block Diagram

6. System Diagram

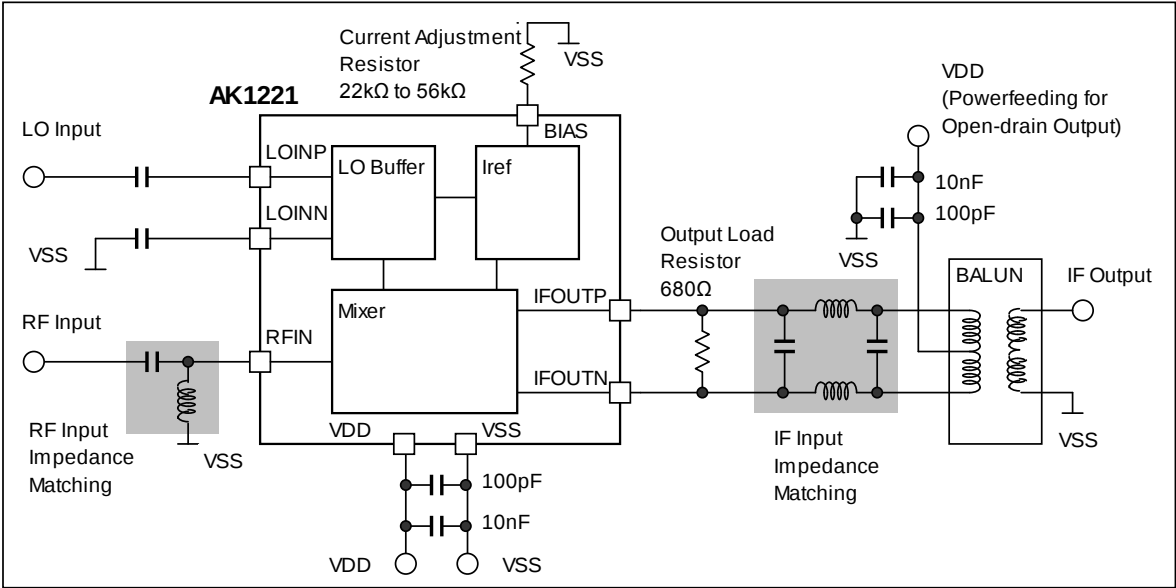


Figure 2. System Diagram

## 7. Pin Functional Description

**Table 1 Pin Function**

| No. | Name   | I/O | Pin Functions                         | Remarks                                                                   |
|-----|--------|-----|---------------------------------------|---------------------------------------------------------------------------|
| 1   | RFIN   | AI  | RF Input                              | Connecting an inductor between this pin and ground.                       |
| 2   | VSS    | G   | Ground pin                            |                                                                           |
| 3   | VSS    | G   | Ground pin                            |                                                                           |
| 4   | LOINN  | AI  | Lo Input Negative                     |                                                                           |
| 5   | LOINP  | AI  | Lo Input Positive                     |                                                                           |
| 6   | VDD    | P   | Power Supply                          |                                                                           |
| 7   | VDD    | P   | Power Supply                          |                                                                           |
| 8   | VDD    | P   | Power Supply                          |                                                                           |
| 9   | VDD    | P   | Power Supply                          |                                                                           |
| 10  | BIAS   | AIO | Resistance pin for current adjustment | Connecting a resistor between this pin and ground.                        |
| 11  | IFOUTN | AO  | IF Output Negative                    | This pin is open drain output.<br>It needs power feeding via an inductor. |
| 12  | IFOUTP | AO  | IF Output Positive                    | This pin is open drain output.<br>It needs power feeding via an inductor. |
| 13  | VSS    | G   | Ground pin                            |                                                                           |
| 14  | VSS    | G   | Ground pin                            |                                                                           |
| 15  | VSS    | G   | Ground pin                            |                                                                           |
| 16  | VSS    | G   | Ground pin                            |                                                                           |

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

|                       |                        |                      |
|-----------------------|------------------------|----------------------|
| AI : Analog input pin | AO : Analog output pin | AIO : Analog I/O pin |
| P : Power supply pin  | G : Ground pin         |                      |

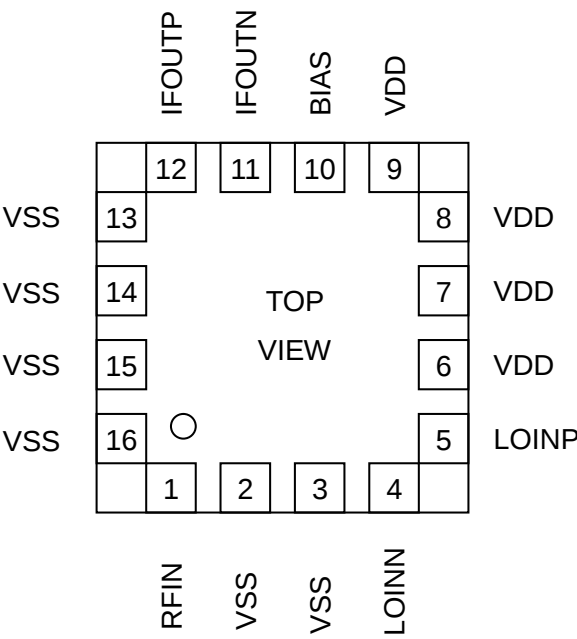


Figure 3. Package Pin Layout

## 8. Absolute Maximum Ratings

Table 2 Absolute Maximum Ratings

| Parameter           | Symbol | Min. | Max. | Unit | Remarks |
|---------------------|--------|------|------|------|---------|
| Supply Voltage      | VDD    | -0.3 | 5.5  | V    |         |
| RF Input Power      | RFPOW  |      | 12   | dBm  |         |
| LO Input Power      | LOPOW  |      | 12   | dBm  |         |
| Storage Temperature | Tstg   | -55  | 125  | °C   |         |

Exceeding these maximum ratings may result in damage to the AK1221. Normal operation is not guaranteed at these extremes.

## 9. Recommended Operating Range

Table 3 Recommended Operating Range

| Parameter             | Symbol | Min. | Typ. | Max. | Unit | Remarks |
|-----------------------|--------|------|------|------|------|---------|
| Operating Temperature | Ta     | -40  |      | 85   | °C   |         |
| Supply Voltage        | VDD    | 4.75 | 5    | 5.25 | V    |         |

The specifications are applicable within the recommended operating range (supply voltage/operating temperature).

## 10. Electrical Characteristics

### 1. Analog Circuit Characteristics

Unless otherwise noted IF output=150MHz, Lo Input Level=-5dBm to +5dBm,

Output Load Resistor (R<sub>Load</sub>)=680Ω, VDD=4.75 to 5.25V, Ta=-40°C to 85°C

| Parameter                                       |           | Min. | Typ. | Max. | Unit | Remarks                                                  |
|-------------------------------------------------|-----------|------|------|------|------|----------------------------------------------------------|
| RF Input Frequency                              |           | 700  |      | 3500 | MHz  |                                                          |
| Lo Input Frequency                              |           | 700  |      | 3500 | MHz  |                                                          |
| IF output Frequency                             |           | 20   |      | 1000 | MHz  |                                                          |
| Lo Input Power                                  |           | -5   | 0    | +5   | dBm  |                                                          |
| Current Adjustment Resistor(BIAS)               |           | 22   |      | 56   | kΩ   |                                                          |
| IDD                                             | BIAS=22kΩ |      | 64   | 87   | mA   | The total current of VDD pin, IFOUTP pin and IFOUTN pin. |
|                                                 | BIAS=33kΩ |      | 45   | 64   | mA   |                                                          |
|                                                 | BIAS=56kΩ |      | 30   | 44   | mA   |                                                          |
| RFIN=2500MHz, Current Adjustment Resistor =33kΩ |           |      |      |      |      |                                                          |
| Conversion Gain                                 |           | -2.5 | -0.5 | 1.5  | dB   |                                                          |
| SSB Noise Figure                                |           |      | 14   | 16.5 | dB   | Design guarantee value                                   |
| IP1dB                                           |           | 7    | 10   |      | dBm  |                                                          |
| IIP3                                            |           | 21   | 25   |      | dBm  | Design guarantee value                                   |

## 11. Typical Performance

Unless otherwise noted, RF input =2500MHz, Lo input =2350MHz, IF output =150MHz,  
Output Load Resistor (R<sub>Load</sub>)=680Ω

### 1. Current Adjustment Resistor vs. IIP, NF, P1dB, Gain, IDD

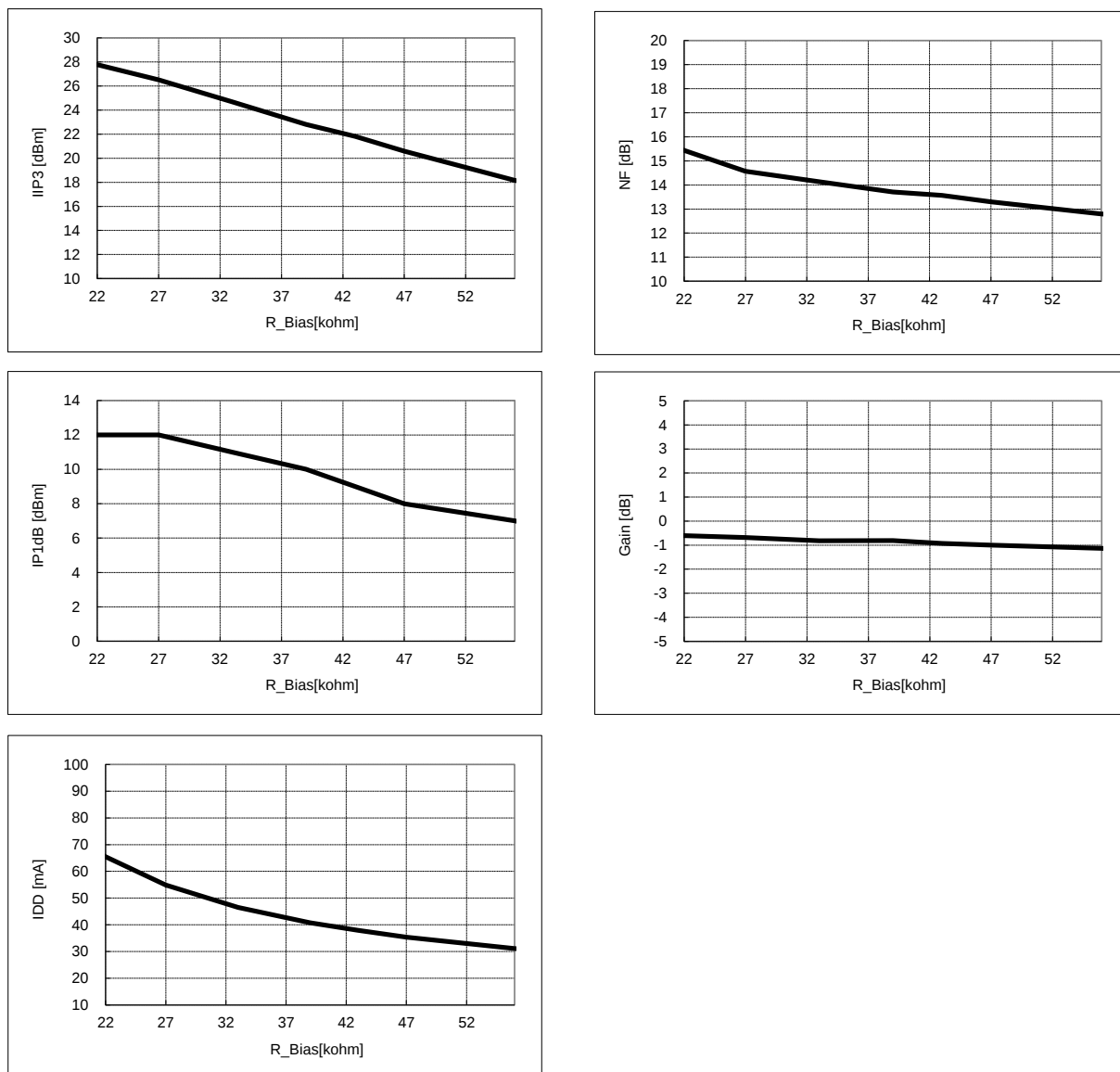


Figure 4. Current Adjustment Resistor vs. IIP3, NF, P1dB, Gain, IDD

Note ) A resistor with 5% tolerance are used.

2. Over temperature vs. IIP3, NF, P1dB, Gain, IDD

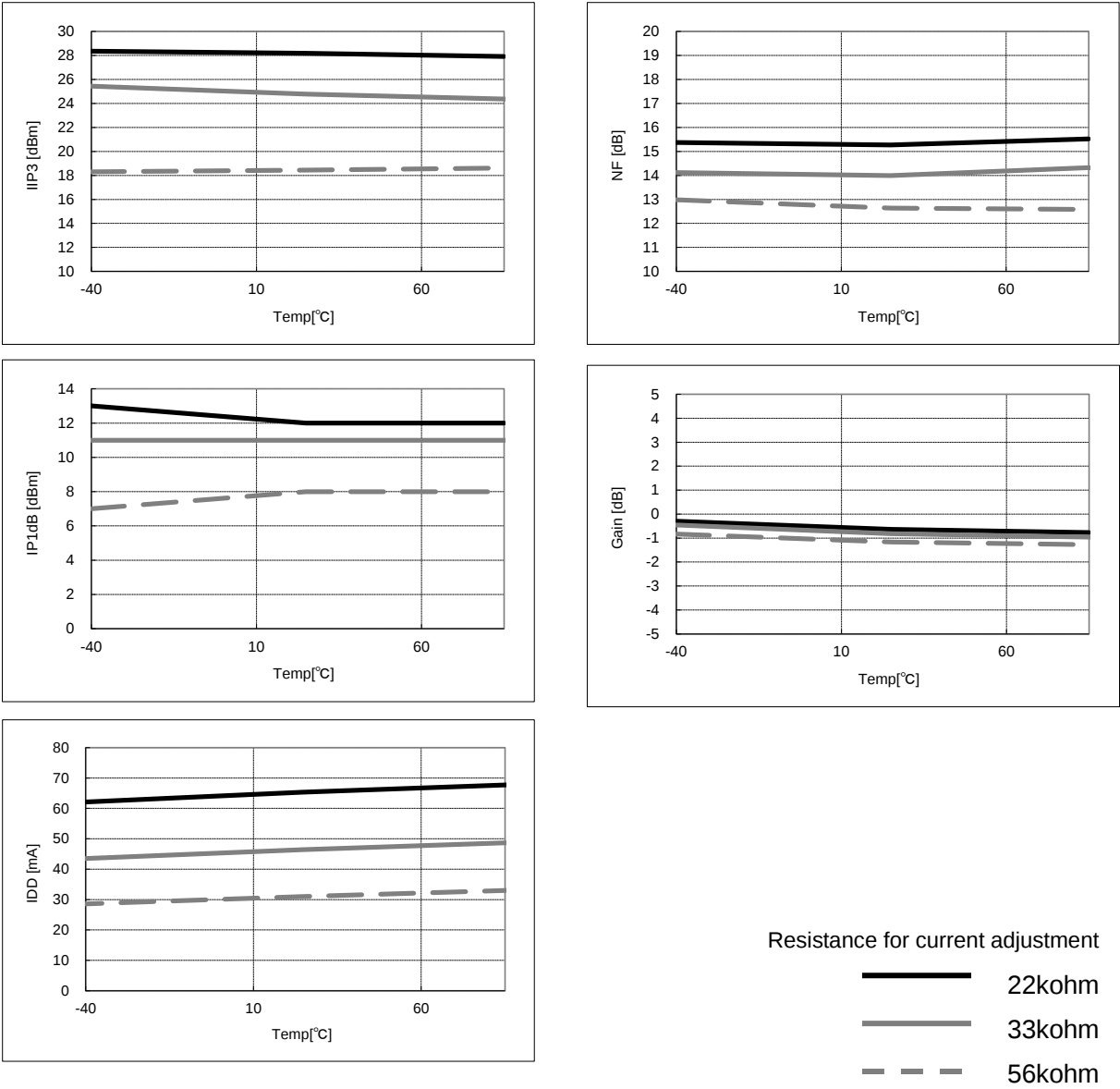


Figure 5. Over temperature vs. IIP3, NF, IP1dB, Gain, IDD

3. Supply voltage vs. IIP3, NF, P1dB, Gain, IDD

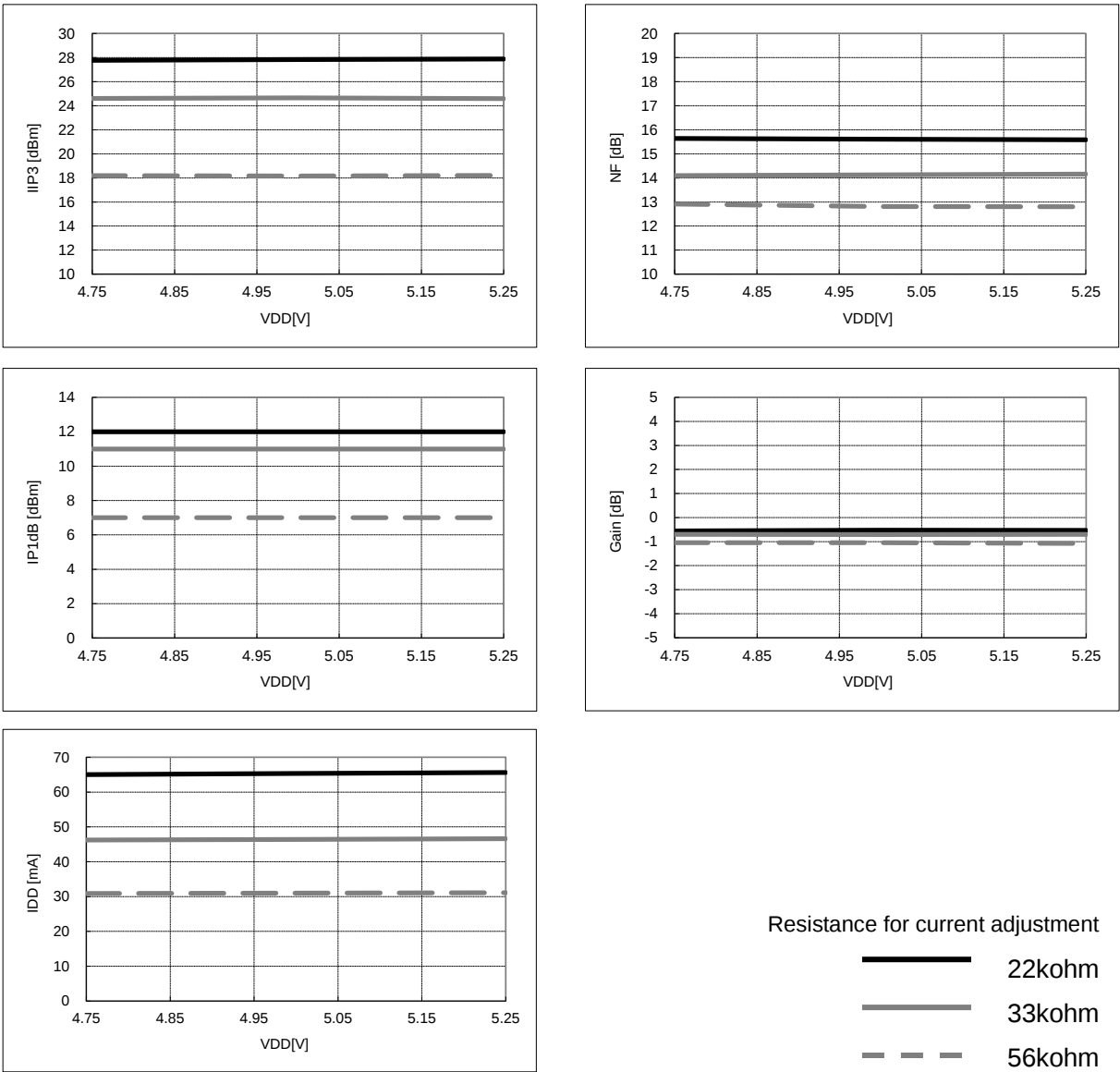


Figure 6. Supply voltage vs. IIP3, NF, IP1dB, Gain, IDD

4. RF input frequency vs. IIP3, NF, Gain

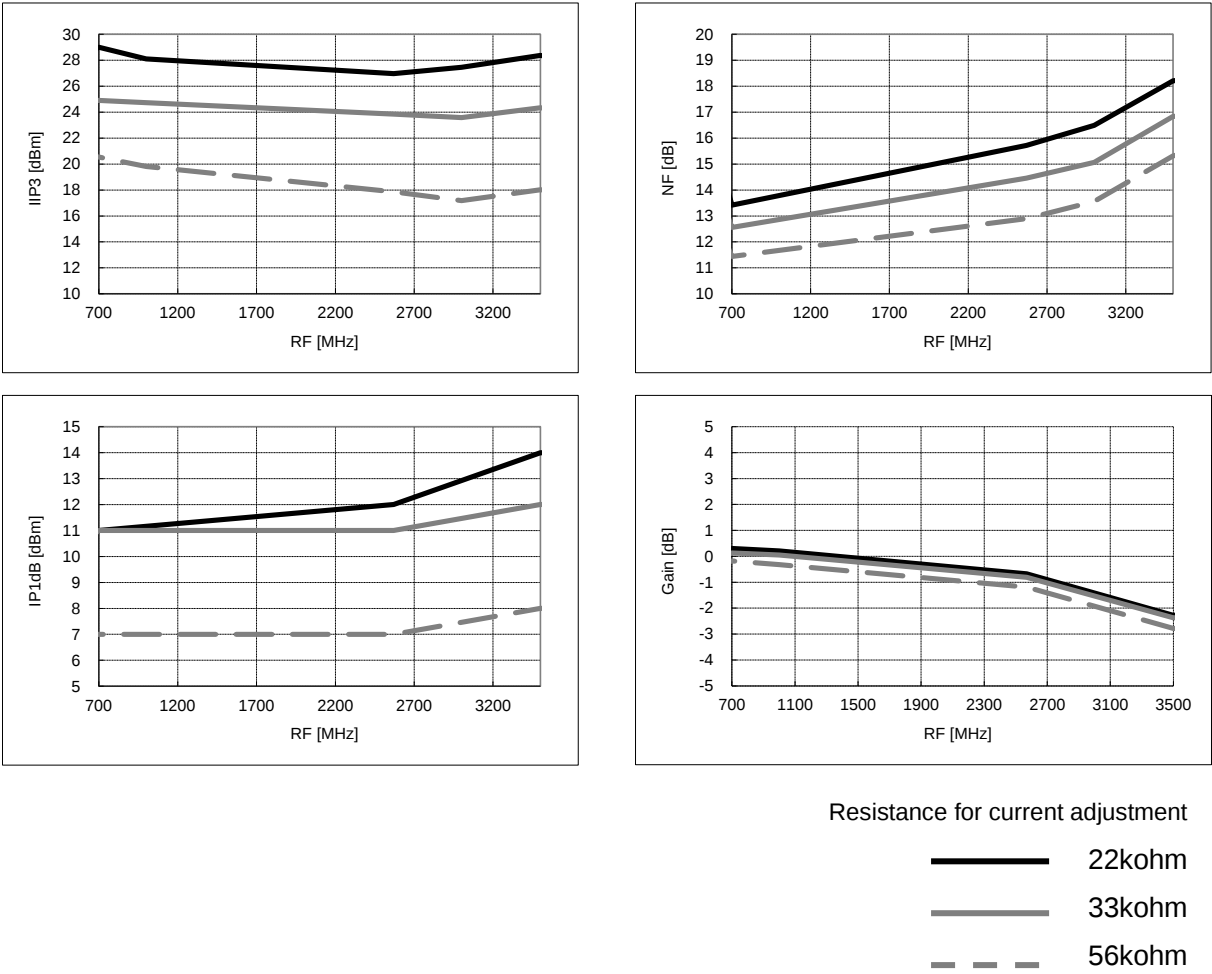


Figure 7. RF input frequency vs. IIP3, NF, Gain

5. IF input frequency vs. IIP3, NF, Gain

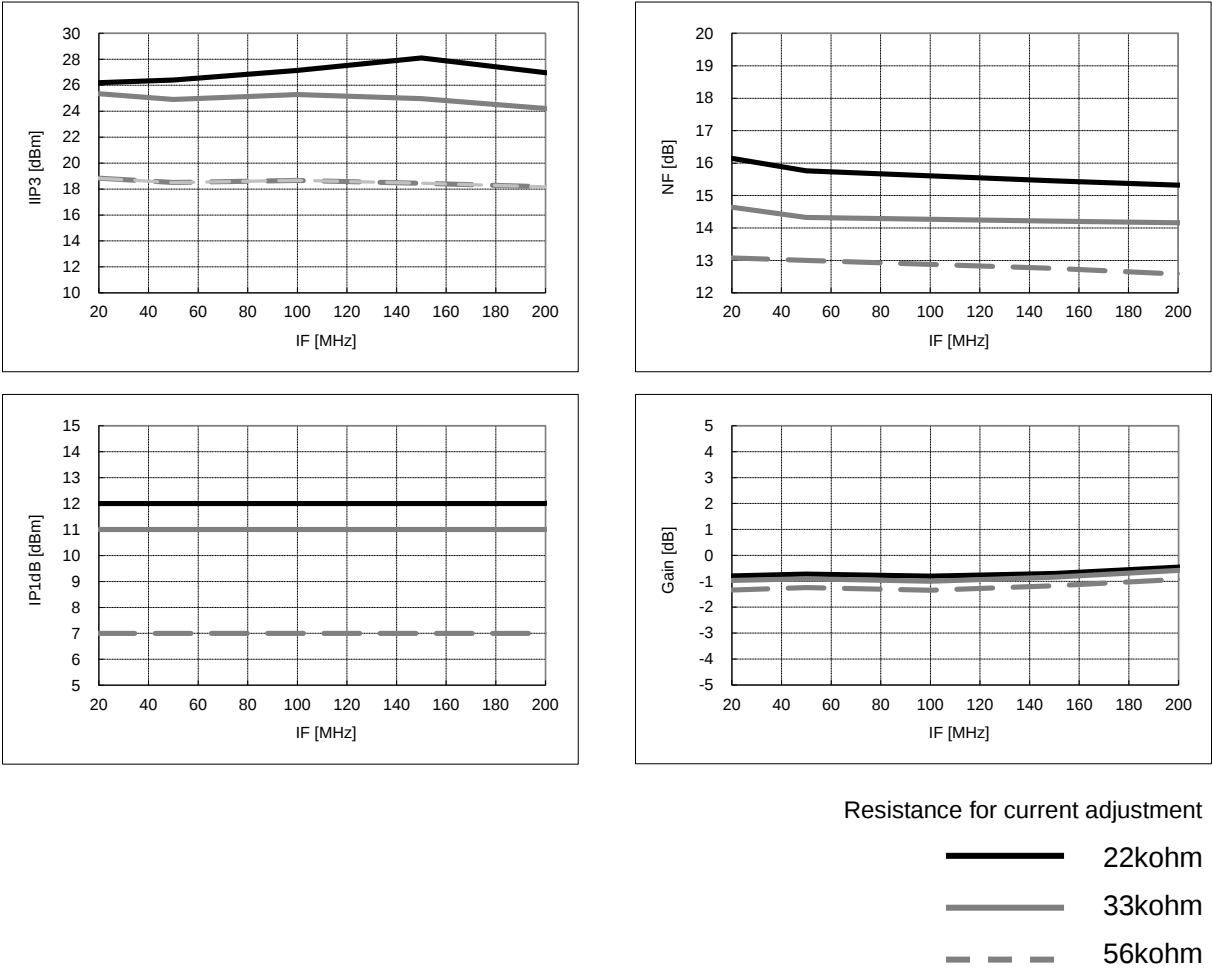


Figure 8. IF input frequency vs. IIP3, NF, Gain

6. Lo input power vs. IIP3, NF, Gain

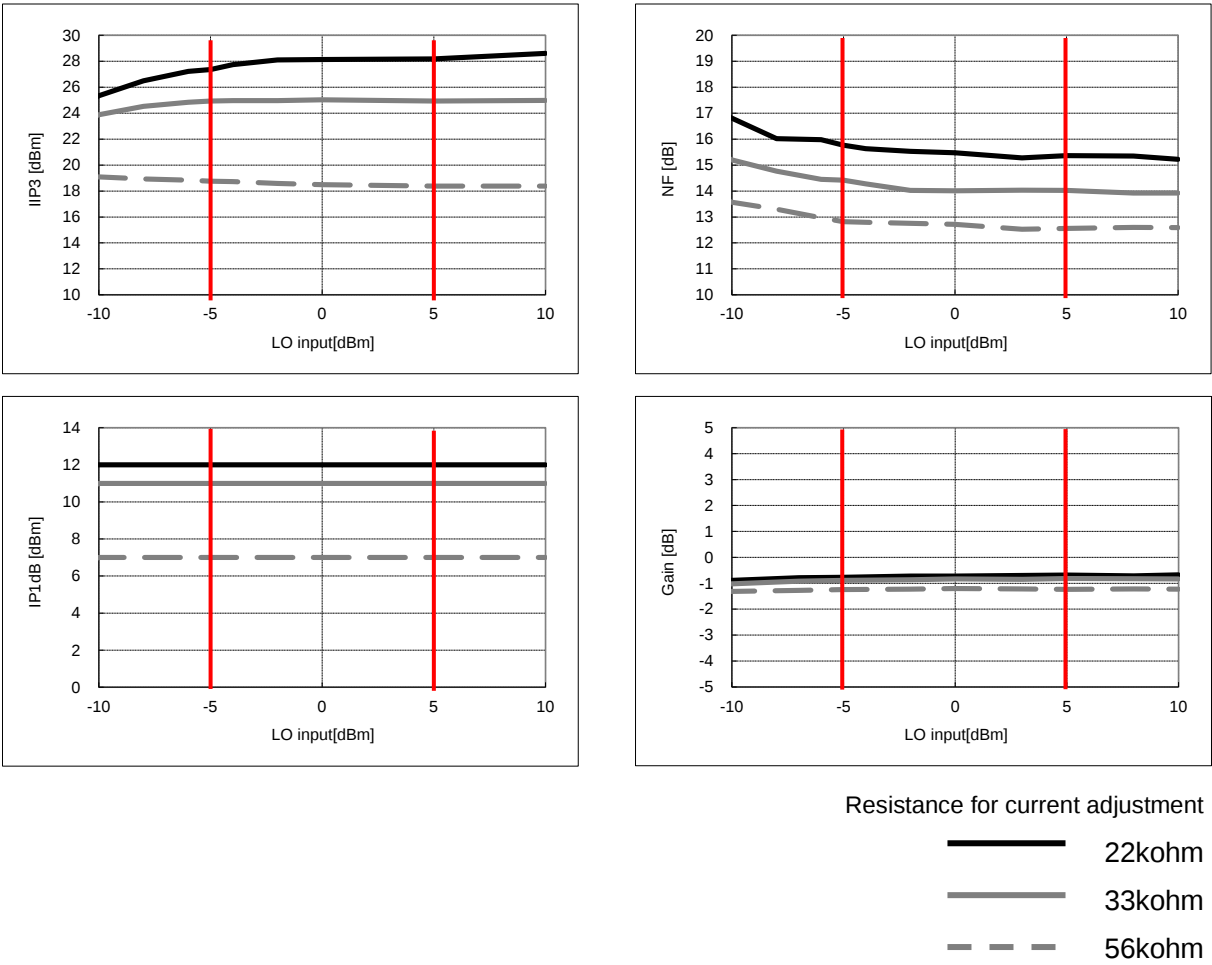


Figure 9. Lo input power vs. IIP3, NF, Gain

7. Output Load Resistor(RLoad) vs. IIP3, NF, Gain

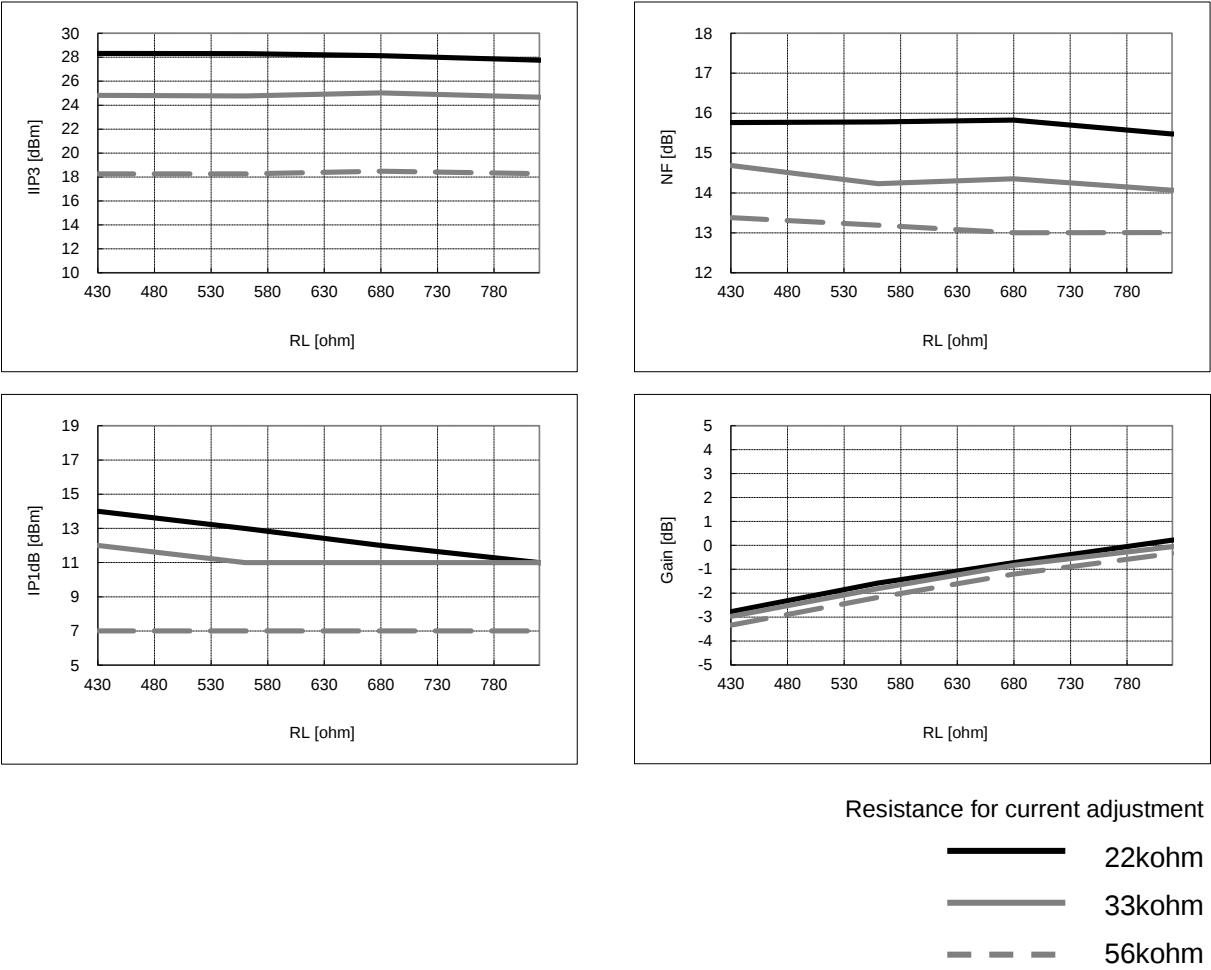


Figure 10. Output Load Resistor(RLoad) vs. IIP3, NF, Gain

8. Leakage

RFIN=2500MHz,-20dBm,LO input=2350MHz,0dBm,RLoad=680Ω,Ta=25℃ VDD=5V

| Parameter       | BIAS | Typ. | Unit |
|-----------------|------|------|------|
| RF – LO Leakage | 22kΩ | -36  | dBc  |
|                 | 56kΩ | -36  | dBc  |
| RF – IF Leakage | 22kΩ | -61  | dBc  |
|                 | 56kΩ | -57  | dBc  |
| LO – RF Leakage | 22kΩ | -44  | dBc  |
|                 | 56kΩ | -44  | dBc  |
| LO – IF Leakage | 22kΩ | -58  | dBc  |
|                 | 56kΩ | -66  | dBc  |

12. Typical Evaluation Board Schematic

1. Typical Evaluation Board Schematic

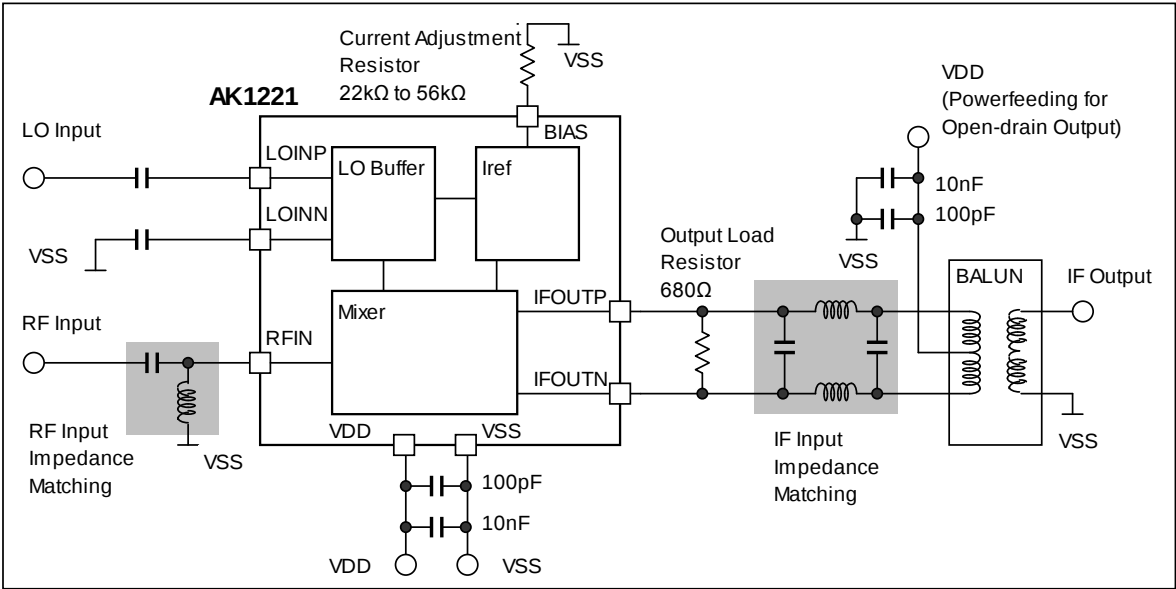
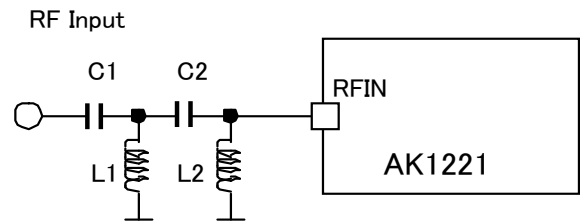


Figure 11. Typical Evaluation Board Schematic

- Note 1) The open drain output needs power feeding via a inductor. (IFOUTP pin and IFOUTN pin)
- Note 2) It is necessary to adjust impedance matching as to its setting frequency. (RF input and IF output)

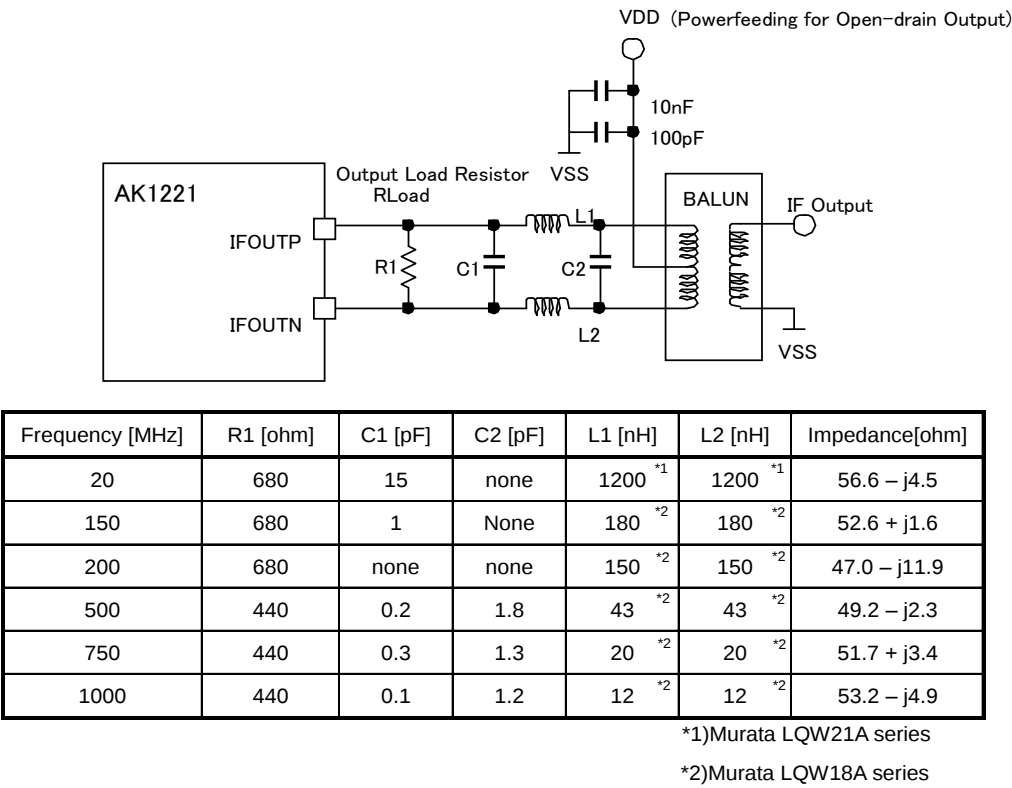
2. Example of impedance matching

2 -1 RFIN

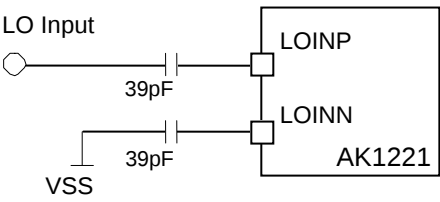


| Frequency[MHz] | C1[pF] | C2[pF] | L1[nH] | L2[nH] | Impedance[ohm] |
|----------------|--------|--------|--------|--------|----------------|
| 700            | none   | 20     | none   | 39     | 42.9 - j5.4    |
| 2500           | 39     | 2.2    | 1.8    | 10     | 61.2 - j12.8   |
| 3500           | 39     | 1.0    | 1.0    | 10     | 40.7 - j5.1    |

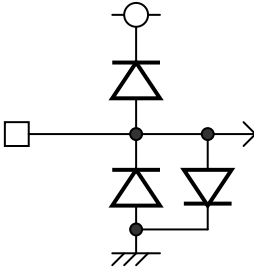
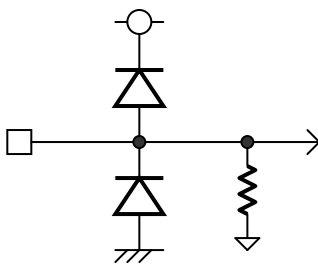
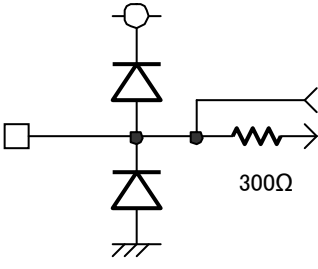
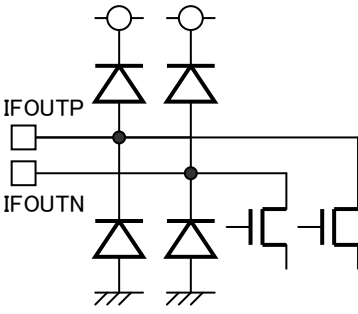
2 - 2 IFOUT



2 – 3 LOINP/LOINN

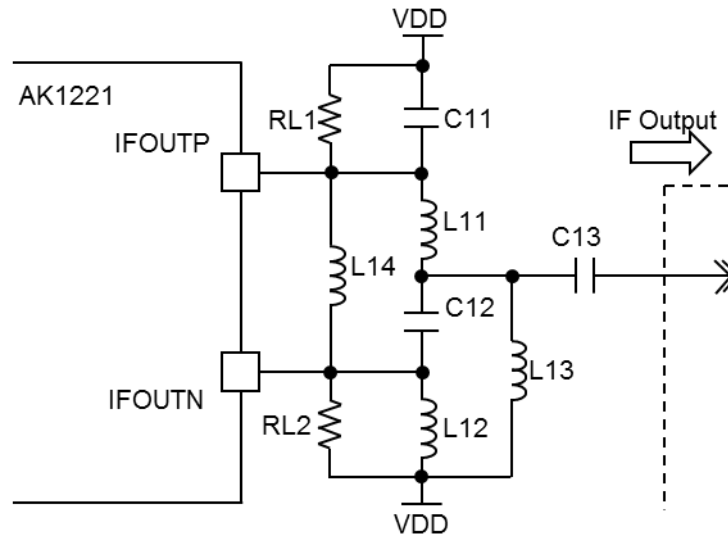


13. LSI Interface Schematic

| No. | Name   | I/O | Function                                                                                               |
|-----|--------|-----|--------------------------------------------------------------------------------------------------------|
| 1   | RFIN   | I   | RF Input pin<br>     |
| 4   | LOINN  | I   | Lo Input pins<br>   |
| 5   | LOINP  |     |                                                                                                        |
| 10  | BIAS   | I/O | Analog I/O pin<br> |
| 11  | IFOUTN | O   | IF Output pins<br> |
| 12  | IFOUTP |     |                                                                                                        |

## 14. Application Information

### •Impedance matching network with LC



**Figure 12. Impedance matching network with LC**

Impedance matching network with LC is shown in Figure 12. AK1221 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. IFOUTP and IFOUTN 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  $R_o$ .

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

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

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

For example, in the case of IF Output = 50MHz, Output Load Resistor ( $R_{load}$ ) = 660Ω in 50Ω interface, L11, C11, L12 and C12 are calculated as below.

$$C_{11} = C_{12} = \frac{1}{2\pi * (150 * 10^6) * \sqrt{660 * 50}} = 5.84\text{pF}$$

$$L_{11} = L_{12} = \frac{\sqrt{660 * 50}}{2\pi * (150 * 10^6)} = 193\text{nH}$$

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 = 150MHz, Output Load Resistor (Rload) = 660Ω in 50Ω 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.

In some cases L14 can be selected to resonate with IF output capacitance. The typical differential output impedances for several frequencies are below. In the case of IF Output = 150MHz, it is recommended to choose 1000nH as L14.

| IF Output Frequency [MHz] | Differential Output Impedance |         | Matching Element |
|---------------------------|-------------------------------|---------|------------------|
|                           | R[ohm]                        | jX[ohm] | L14 [nH]         |
| 20                        | 2300                          | -J4083  | OPEN             |
| 50                        | 711                           | -J2448  | OPEN             |
| 70                        | 419                           | -J1873  | OPEN             |
| 100                       | 244                           | -J1420  | 2200             |
| 150                       | 109                           | -J932   | 1000             |
| 180                       | 77                            | -J788   | 750              |
| 200                       | 62                            | -J706   | 560              |
| 250                       | 38                            | -J566   | 360              |
| 300                       | 28                            | -J470   | 240              |
| 400                       | 16                            | -J346   | 150              |
| 500                       | 15                            | -J270   | 82               |
| 600                       | 13                            | -J223   | 62               |
| 700                       | 10                            | -J188   | 43               |
| 800                       | 9                             | -J159   | 33               |
| 900                       | 7                             | -J138   | 24               |

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 AK1221.

Typical Performance using impedance matching network with LC is below. RF Input = 2500MHz, IF Output = 150MHz, LO Input = 2350MHz, Output Load Resistor (Rload) = 660Ω, Vdd = 5V, Ta = 25°C, LO Input Level = 0dBm, current adjustment resistor = 33kΩ.

| Ref.     | Value  | Size | Part Number              |
|----------|--------|------|--------------------------|
| RL1, RL2 | 330Ω   | 1005 | KOA RK73B1ETTP331        |
| L11, L12 | 200nH  | 1608 | Murata LQW18ANR20G00     |
| C11, C12 | 6pF    | 1005 | Murata GJM1552C1H6R0DB01 |
| L13      | 2200nH | 2012 | Murata LQW21HN2R2J00     |
| C13      | 1000pF | 1005 | Murata GRM1552C1H102JA01 |
| L14      | 1000nH | 2012 | Murata LQW21HN1R0J00     |

| Parameter             | Min. | Typ. | Max. | Unit |
|-----------------------|------|------|------|------|
| Conversion Gain       |      | -1.1 |      | dB   |
| SSB Noise Figure (NF) |      | 13.8 |      | dB   |
| IP1dB                 |      | 11.6 |      | dBm  |
| IIP3                  |      | 24.8 |      | dBm  |

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.

•Evaluation Board

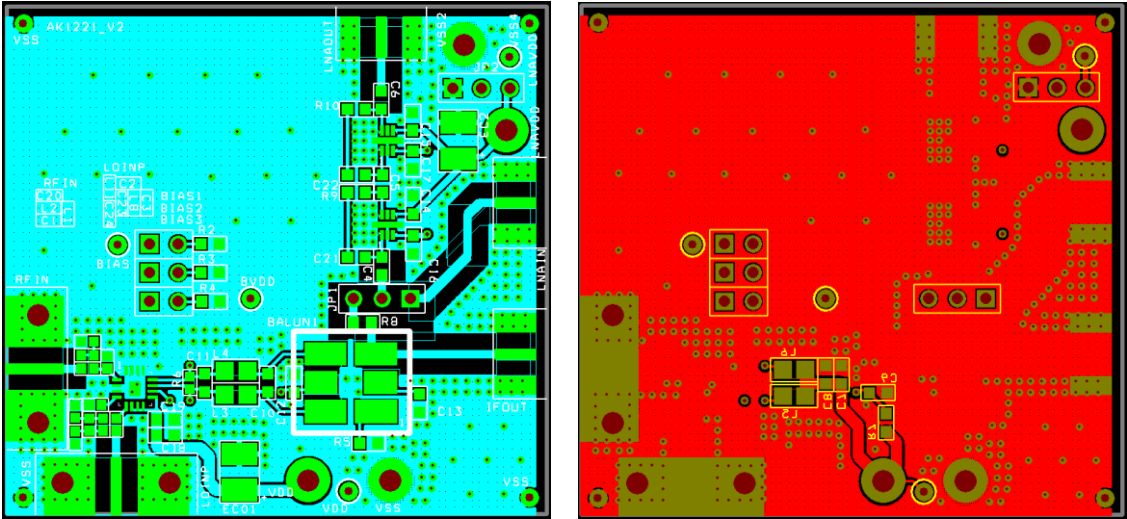


Figure 13. AK1221 Evaluation Board (Balun)

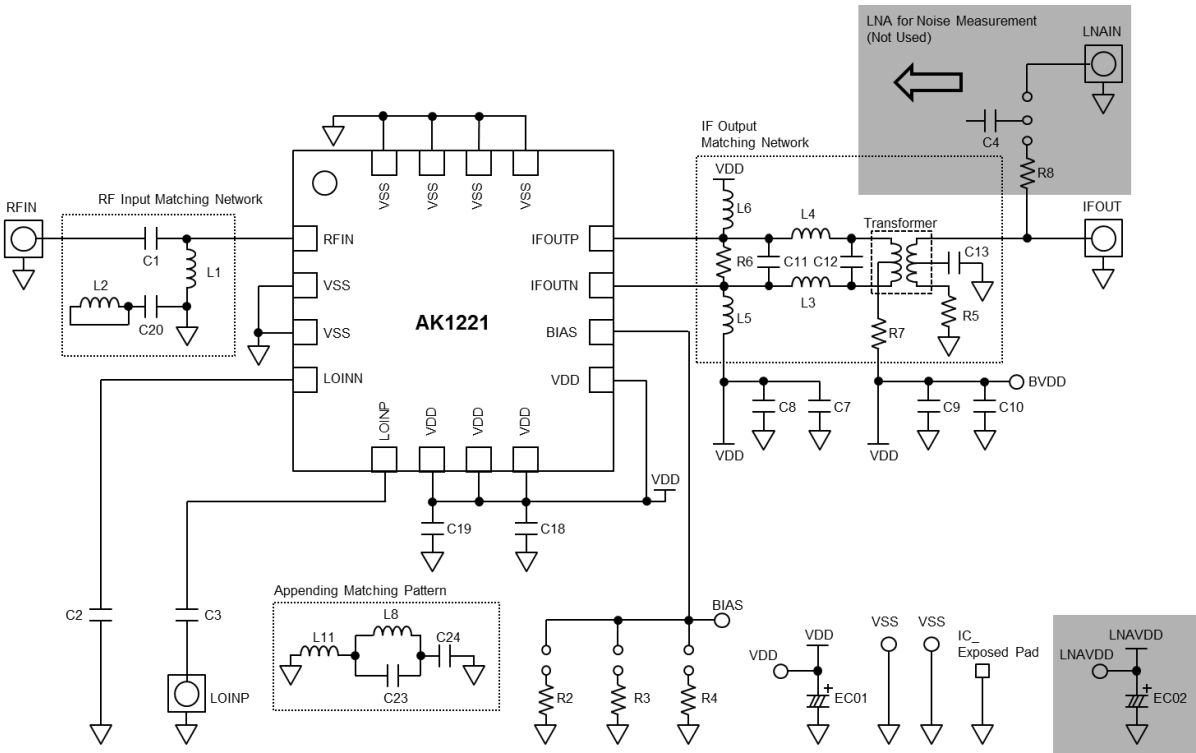


Figure 14. AK1221 Evaluation Board Schematic (Balun)

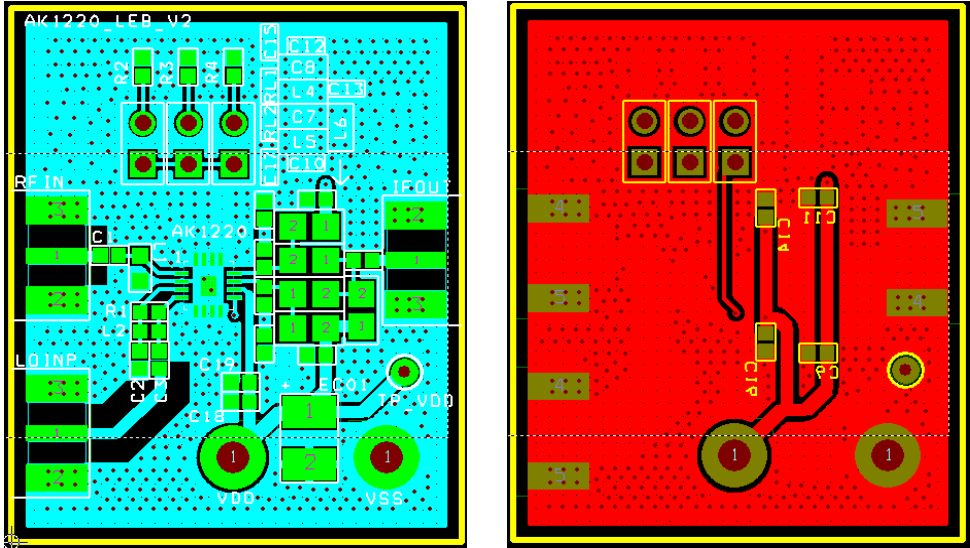


Figure 15. AK1221 Evaluation Board (matching network with LC)

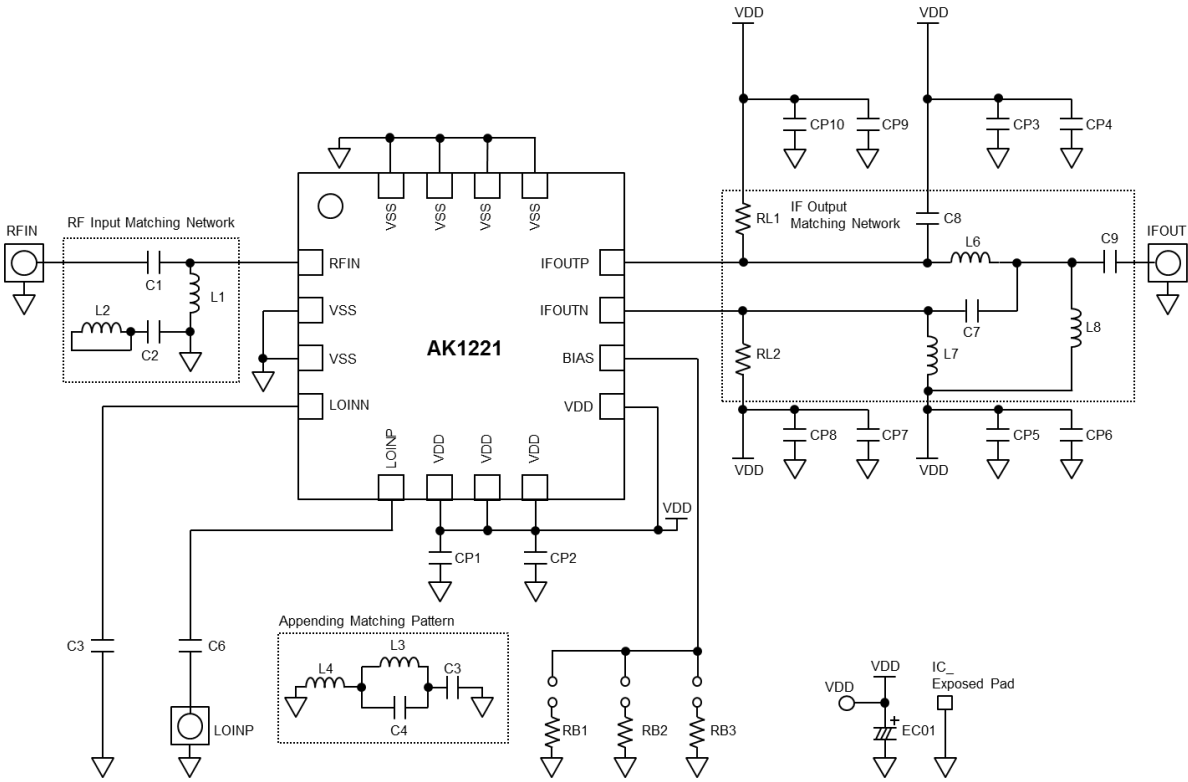


Figure 16. AK1221 Evaluation Board Schematic (matching network with LC)

15. Outer Dimensions

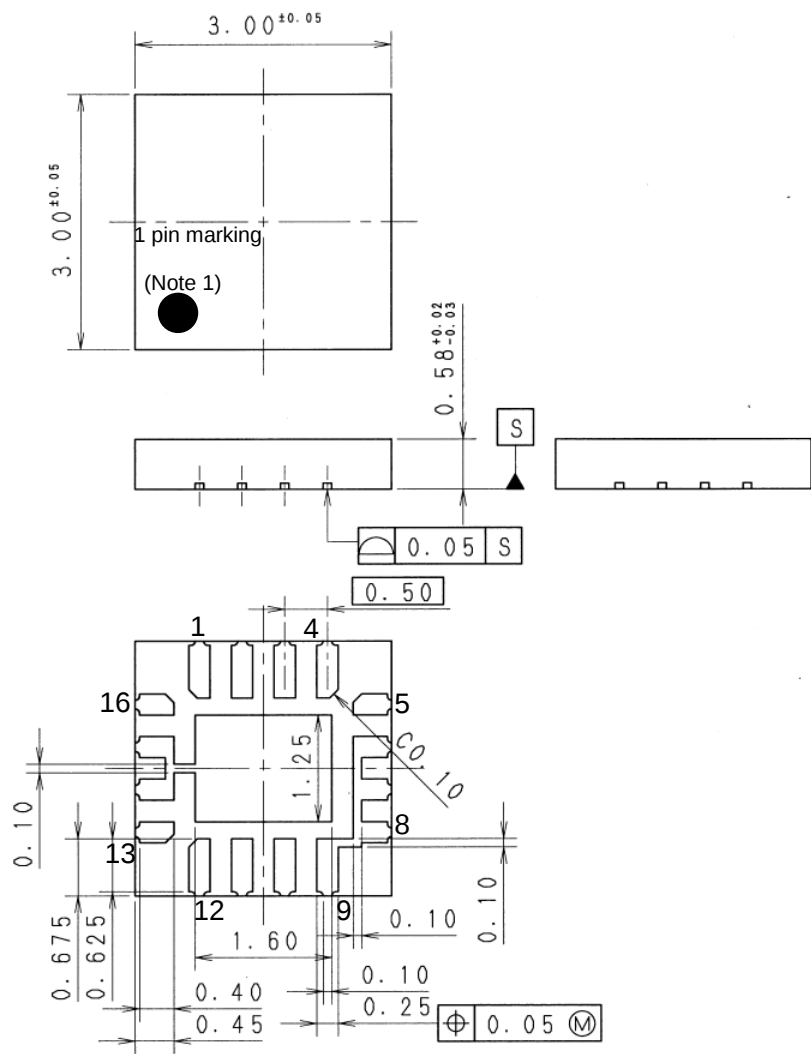
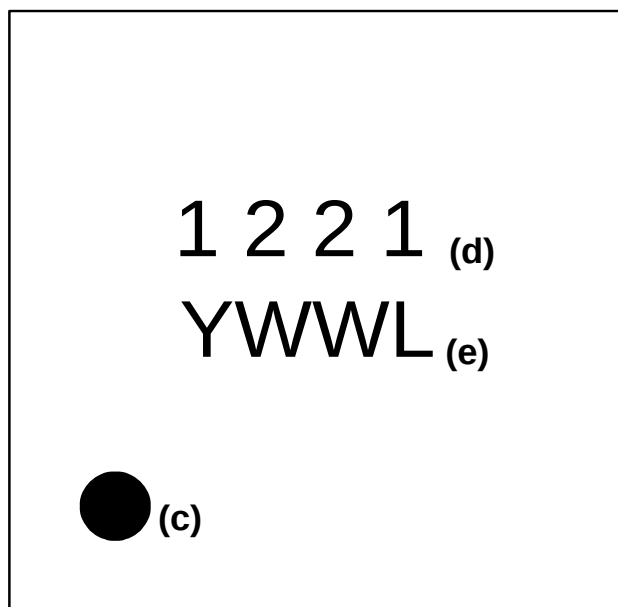


Figure 17. Outer Dimensions

Note 1. 1 pin marking is only a reference for the 1 pin location on the top of package.

**16. Marking**

- (a) Style : UQFN  
(b) Number of pins : 16  
(c) 1 pin marking: : ○  
(d) Product number : 1221  
(e) Date code : YWWL (4 digits)
- Y : Lower 1 digit of calendar year (Year 2012 → 2, 2013 → 3 ...)  
WW : Week  
L : Lot identification, given to each product lot which is made in a week  
→ LOT ID is given in alphabetical order (A, B, C...).

**Figure 18. Marking**

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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, -111dBc/Hz@100kHz         |
| AK1575                                                | 690MHz~4GHz Up Conversion Mixer with Frac.-N PLL and VCO      | IIP3:24dBm, -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                           | 24-VSOP                               |
| AK2347A                                               | Emphasis, Compandor, scrambler, CTCSS filter                  | 24-QFN                                |
| <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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