CALMOS™

# CA412

## FM RECEIVER FOR CELLULAR RADIO

- **Chip plus external components form high sensitivity FM radio receiver**
- **Sensitivity less than 2 μV (12 dB SINAD)**
- **Second IF frequency either 455 KHz or 10.7 MHz**
- **Received Signal Strength Indicator output gives DC voltage out logarithmically proportional to input power**
- **Fade output differentiates between momentary signal fades and truly low input power**

The CA412 cellular radio chip forms the basis of a double conversion superheterodyne FM radio receiver, with added features for cellular radio.

The CA412 with external components provides the second IF strip including mixer, IF amplifier and limiter, detector, and audio amplifier. Thus an absolute minimum number of external components required around the CA412.

The device also contains circuits to give DC voltage out logarithmically proportional to input power, and to distinguish between truly low input power and momentary fades.

The system sensitivity is less than 2 μV (12 dB SINAD). The input frequency range to the mixer is 35 - 110 MHz. The maximum IF frequency is 10.7 MHz, with IF = 455 KHz operation readily available.

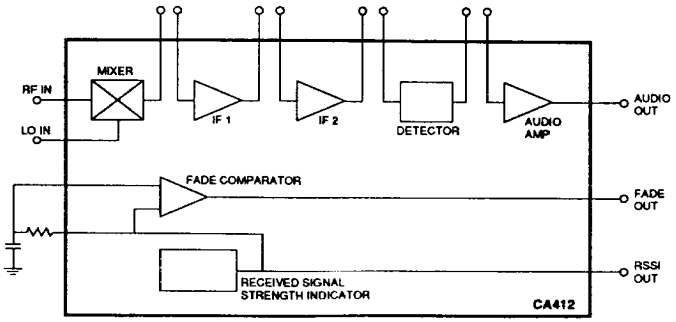


**Figure 1 : CA412 FUNCTIONAL BLOCK DIAGRAM**

| | | | |
|---|---|---|---|
| 1 | IF FILTER BIAS | 17 | RSSI BYPASS |
| 2 | IF 1 OUT | 18 | RSSI |
| 3 | IF 1 VCC/2 | 19 | COMP IN |
| 4 | IF 1 DECOUPLE | 20 | FADE |
| 5 | IF 1 IN | 21 | AUDIO IN – |
| 6 | IF 1 BANDGAP | 22 | AUDIO IN + |
| 7 | IF 1 GND | 23 | AUDIO OUT |
| 8 | GND - SUBSTRATE | 24 | VCC |
| 9 | MIXER BIAS - E | 25 | VCC/2 |
| 10 | MIXER BIAS - BG | 26 | GND - SUBSTRATE |
| 11 | RF IN 2 | 27 | QUAD DET GND |
| 12 | RF IN 1 | 28 | DEMOD AUDIO |
| 13 | LO IN 2 | 29 | QUAD DET IN |
| 14 | LO IN 1 | 30 | IF 2 OUT |
| 15 | MIXER OUT 1 | 31 | IF 2 DECOUPLE |
| 16 | MIXER OUT 2 | 32 | IF 2 IN |

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| | | | |
|---|---|---|---|
| 1 | GND | 15 | VCC/2 |
| 2 | MIXER BIAS - BG | 16 | GND - SUBSTRATE |
| 3 | RF IN 2 | 17 | DEMOD AUDIO |
| 4 | RF IN 1 | 18 | QUAD DET IN |
| 5 | LO IN 2 | 19 | IF 2 OUT |
| 6 | LO IN 1 | 20 | IF 2 DECOUPLE |
| 7 | MIXER OUT 1 | 21 | IF 2 IN |
| 8 | MIXER OUT 2 | 22 | IF FILTER BIAS |
| 9 | RSSI BYPASS | 23 | IF 1 OUT |
| 10 | RSSI | 24 | IF 1 VCC/2 |
| 11 | AUDIO IN – | 25 | IF 1 DECOUPLE |
| 12 | AUDIO IN + | 26 | IF 1 IN |
| 13 | AUDIO OUT | 27 | IF 1 BANDGAP |
| 14 | VCC | 28 | MIXER BIAS - E |

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| | | | |
|---|---|---|---|
| 1 | IF FILTER BIAS | 16 | RSSI BYPASS |
| 2 | IF 1 OUT | 17 | RSSI |
| 3 | IF 1 VCC/2 | 18 | COMP IN |
| 4 | IF 1 DECOUPLE | 19 | FADE |
| 5 | IF 1 IN | 20 | AUDIO IN – |
| 6 | IF 1 BANDGAP | 21 | AUDIO IN + |
| 7 | IF 1 GND | 22 | AUDIO OUT |
| 8 | MIXER BIAS - E | 23 | VCC |
| 9 | MIXER BIAS - BG | 24 | VCC/2 |
| 10 | RF IN 2 | 25 | GND - SUBSTRATE |
| 11 | RF IN 1 | 26 | DEMOD AUDIO |
| 12 | LO IN 2 | 27 | QUAD DET IN |
| 13 | LO IN 1 | 28 | IF 2 OUT |
| 14 | MIXER OUT 1 | 29 | IF 2 DECOUPLE |
| 15 | MIXER OUT 2 | 30 | IF 2 IN |

**30 - LEAD QUILL PACKAGE**

Quill package is available for samples only

**Figure 2 : CA412 PIN CONFIGURATIONS**

**Table 1 : ELECTRICAL CHARACTERISTICS ($T_A$ = –40° to +85°C, V+ = 7.5V)[1]**

| Parameter | Condition | Min | Typ | Max | Units |
|---|---|---|---|---|---|
| **General** | | | | | |
| Supply Voltage | | 4 | | 8 | V |
| Supply Current | | | 7.5 | 9 | mA |
| Bandgap voltage reference | | 1.15 | 1.20 | 1.25 | V |
| Sensitivity | 12 dB SINAD, C-Message weighted with 6 dB/octave de-emphasis, LO @ 25 MHz | | | 1.7 | µV |
| AM rejection | RF level -50 dBm | 26 | | | dB |
| Capture ratio | | | 3 | 6 | dB |
| RF frequency | | | | 110 | MHz |
| LO frequency | | | | 110 | MHz |
| IF frequency | | | | 12 | MHz |
| **Mixer (LO input level 160 mVrms)** | | | | | |
| Voltage conversion gain | 3K load | 20 | | | dB |
| Linearity, IF rejection at 10.7 MHz | | 25 | | | dB |
| Linearity, intermodulation rejection | | 60 | | | dB |
| Isolation, LO input to RF input at LO frequency | | 25 | | | dB |
| Isolation, LO input to mixer output at LO frequency | | 20 | | | dB |
| **IF Amplifier** | | | | | |
| 3 dB BW, IF1 and IF2 | | 12 | | | MHz |
| Voltage gain total at: 10.7 MHz, IF1 and IF2 | | 98 | | | dB |
| **Quadrature Detector** | | | | | |
| Output Impedance | | | 30 | | KΩ |
| Recovered Audio | | | 300 | | mV/kHz |
| Audio Amplifier | | | | | |
| Audio Output | | | | 5 | Vpk-pk |
| **RSSI** | | | | | |
| Offset Voltage | 12 dB SINAD | | | 0.4 | V |
| Slope | | 37 | | 62 | mV/dB |
| Dynamic Range | | 80 | | | dB |
| Output Current | | | ±25 | | µA |
| Output Impedance @ 1 KHz | | | | 1 | KΩ |
| **Fade Comparator** | | | | | |
| Offset Voltage | VI+ - VI– | 310 | 326 | 342 | mV |
| Hysteresis | | | 25 | | mV |

Note: 1. Circuit of Figure 6, unless otherwise noted.

**Table 2 : ABSOLUTE MAXIMUM RATINGS**

| | |
|---|---|
| Storage Temperature Range | –65° to +150°C |

**Stresses beyond those listed above may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.**

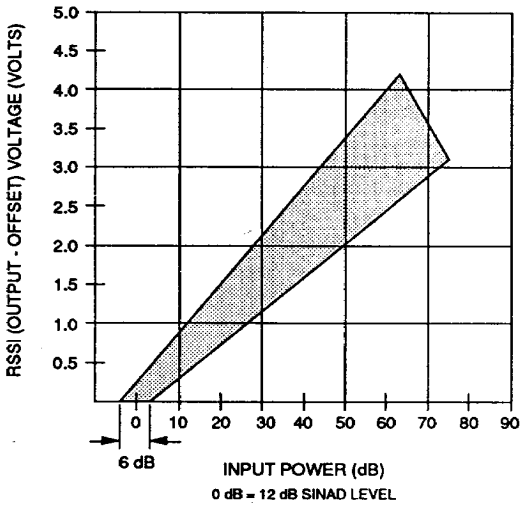



**Figure 3 : RECEIVED SIGNAL STRENGTH INDICATOR OUTPUT VOLTAGE ENVELOPE ($T_A$ = –40° to +85°C)**

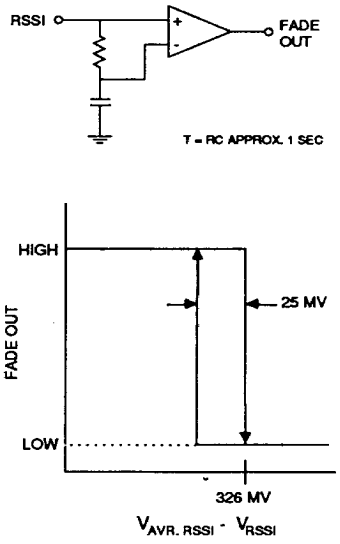



**Figure 4 : FADE COMPARATOR (TYPICAL)**

## FUNCTIONAL DESCRIPTION

### Mixer

The double balanced mixer is configured for flexibility of external circuitry and bias stability with an input frequency range up to 110 MHz. The mixer is biased from the on-chip bandgap voltage reference, an external voltage divider and an external current-setting resistor. The mixer load is external to track with bias current, resulting in relatively constant transconductance and mixer conversion gain over temperature.

### IF1 Amplifier Block

This limiting IF amplifier is made up of five temperature compensated differential stages. Limited voltage swing is 200 mV, and total *signal in-to-signal out* voltage gain is 46 dB at 10.7 MHz. The first $I_{IF}$ is operated between dedicated VCC/2 and GND pins that can be decoupled locally to reduce the possibility of unwanted noise or signal injection.

### IF2 Amplifier Block

The second IF amplifier is made up of 6 differential stages. Voltage gain is 60 dB at 10.7 MHz, and voltage swing is limited at 200 mVp-p. As with the first IF, each differential amplifier stage is temperature compensated to maintain constant gain over temperature. DC biasing of the second IF amplifier includes a feedback loop that sets up a voltage of VCC/2 at the 2nd IF Decouple pin. The input pin to the second IF (IF IN 2) is referenced to VCC/2 (not IF1 VCC/2). The buffered output of IF2 OUT is connected to some form of quadrature circuit (tuned LC or ceramic discriminator) which is then connected directly to the input pin of the quadrature detector.

### Quadrature Detector

The quadrature detector circuit is a fully balanced demodulator. The output voltage is available at the Demod Audio pin, which has a capacitor connected to ground in order to reduce the higher frequency noise component of the FM demodulated signal. The DC level of the de-mod audio output is at VCC/2 when no FM signal is present. The sense of the demodulated audio is that an increase in IF frequency produces a decrease in detector output voltage.

### Audio Amplifier

The audio amplifier has a nominal open loop 3 dB breakpoint of about 1.8 MHz. The amplifier closed loop amplitude frequency response is flat from 200 Hz to 20 kHz to within ±0.25 dB in order to pass audio and data simultaneously. Both inverting and non-inverting inputs are available externally. Closed loop gain is set by external components.

### RSSI - Received Signal Strength Indicator

The function of the RSSI circuitry is to accurately monitor the RF input level. The emitter follower output voltage at the RSSI output pin is proportional to Log (RF power in). The RSSI dynamic range is 80-90 dB from an RF input level required to achieve 12 dB SINAD at the audio output with de-emphasis and C-message weighted filtering.

With no RF signal the RSSI output is at the offset voltage for that device, in the range 0 - 0.4 volts. At high RF levels, RSSI out levels off at about 4 volts.

### Fade Comparator

The Fade Comparator is used to detect sudden decreases in RF level and will change output state if the drop in RF level exceeds a certain threshold.

It is used to differentiate between momentary fades and true decreases in signal level. It can be used to increase the reliability of cell handover. It also facilitates switching between two antennaes.

### Bandgap Voltage Reference

The bandgap reference voltage is set at 1.22 volts nominal and is used to stabilize bias currents throughout the IC.

### VCC/2 Supply

The VCC/2 supply provides a stable voltage at half the supply voltage. It is used to bias the bandgap reference voltage circuitry and to stabilize bias conditions throughout the device.

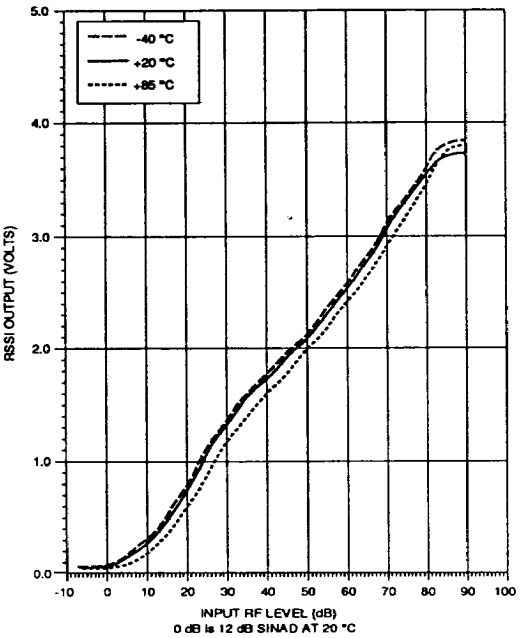


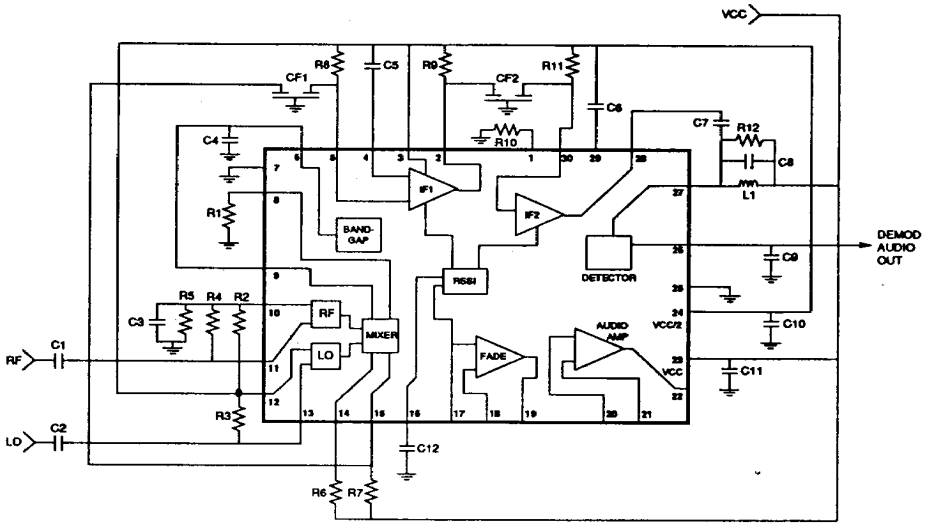

**Figure 5 : RSSI OUTPUT (TYPICAL) at -40, +20, +85 °C**

## APPLICATION DESCRIPTION

R1 sets the bias current in the Mixer. The bandgap reference voltage is decoupled and applied to the Mixer. The LO inputs to the Mixer are biased at VCC/2. The RF inputs to the Mixer are biased at a voltage between VCC/2 and bandgap, set up by voltage divider R2/R5. R3 and R4 set the input impedances at the LO and RF inputs to the Mixer. R6 and R7 are Mixer load (and gain setting) resistors. Filter CF1 determines the selectivity of the circuit. CF2 is the mid-IF noise bandwidth setting filter. The values of R9, R10 and R11 are important in that they influence both IF gain and the RSSI characteristic. The RSSI can be most effectively trimmed by R10. C7/R12/C8/L1 is the quadrature network giving a 90 degree phase shift at the IF frequency. C9 is a filter capacitor to remove IF ripple. C12 is the RSSI output filter capacitor. The RSSI response time is set by C12 and an on-chip 13K resistor.

The sensitivity of this circuit (455 KHz, ceramic filters) is 1.7 µV max.

An application schematic diagram is available for using the CA412 at a second IF frequency of 10.7 MHz, with ceramic filters. An application schematic diagram is also available for a 10.7 MHz crystal filter circuit, the sensitivity of which is 1.7 µV max.




| | | | | | |
|---|---|---|---|---|---|
| R1 | 240 | C1 | 0.1 µF | L1 | 370 µH |
| R2 | 15K | C2 | 0.1 µF | CF1, | Ceramic Filters |
| R3 | 270 | C3 | 0.1 µF | CF2 | Murata CFU455B2 |
| R4 | 270 | C4 | 4.7 µF | | 455 KHz, BW = 30 KHz |
| R5 | 22K | C5 | 0.1 µF | | ZI = 1.5K, ZO = 1.5K |
| R6 | 1.5K | C6 | 0.1 µF | | |
| R7 | 1.5K | C7 | 15 pF | | |
| R8 | 1.5K | C8 | 330 pF | | |
| R9 | 1.5K | C9 | 250 pF | | |
| R10 | 1.6K | C10 | 4.7 µF | | |
| R11 | 1.5K | C11 | 4.7 µF | | |
| R12 | 6.2K | C12 | 0.1 µF | | |

**Figure 6 : CA412 APPLICATIONS SCHEMATIC and PARTS LIST (455 KHz, Ceramic Filters, Pin Numbers for Quill Package)**