The MC13135/MC13136 are the second generation of single chip, dual conversion FM communications receivers developed by Motorola. Major improvements in signal handling, RSSI and first oscillator operation have been made. In addition, recovered audio distortion and audio drive have improved. Using Motorola’s MOSAIIC™ 1.5 process, these receivers offer low noise, high gain and stability over a wide operating voltage range.

Both the MC13135 and MC13136 include a Colpitts oscillator, VCO tuning diode, low noise first and second mixer and LO, high gain limiting IF, and RSSI. The MC13135 is designed for use with an LC quadrature detector and has an uncommitted op amp that can be used either for an RSSI buffer or as a data comparator. The MC13136 can be used with either a ceramic discriminator or an LC quad coil and the op amp is internally connected for a voltage buffered RSSI output.

These devices can be used as stand-alone VHF receivers or as the lower IF of a triple conversion system. Applications include cordless telephones, short range data links, walkie-talkies, low cost land mobile, amateur radio receivers, baby monitors and scanners.

- Complete Dual Conversion FM Receiver – Antenna to Audio Output
- Input Frequency Range – 200 MHz
- Voltage Buffered RSSI with 70 dB of Usable Range
- Low Voltage Operation – 2.0 to 6.0 Vdc (2 Cell NiCad Supply)
- Low Current Drain – 3.5 mA Typ
- Low Impedance Audio Output < 25 Ω
- VHF Colpitts First LO for Crystal or VCO Operation
- Isolated Tuning Diode
- Buffered First LO Output to Drive CMOS PLL Synthesizer

Each device contains 142 active transistors.
## MAXIMUM RATINGS

<table>
<thead>
<tr>
<th>Rating</th>
<th>Pin</th>
<th>Symbol</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Supply Voltage</td>
<td>4, 19</td>
<td>VCC (max)</td>
<td>6.5</td>
<td>Vdc</td>
</tr>
<tr>
<td>RF Input Voltage</td>
<td>22</td>
<td>RFin</td>
<td>1.0</td>
<td>Vrms</td>
</tr>
<tr>
<td>Junction Temperature</td>
<td></td>
<td>TJ</td>
<td>+150</td>
<td>°C</td>
</tr>
<tr>
<td>Storage Temperature Range</td>
<td></td>
<td>Tstg</td>
<td>– 65 to +150</td>
<td>°C</td>
</tr>
</tbody>
</table>

## RECOMMENDED OPERATING CONDITIONS

<table>
<thead>
<tr>
<th>Rating</th>
<th>Pin</th>
<th>Symbol</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Supply Voltage</td>
<td>4, 19</td>
<td>VCC</td>
<td>2.0 to 6.0</td>
<td>Vdc</td>
</tr>
<tr>
<td>Maximum 1st IF</td>
<td></td>
<td>fIF1</td>
<td>21</td>
<td>MHz</td>
</tr>
<tr>
<td>Maximum 2nd IF</td>
<td></td>
<td>fIF2</td>
<td>3.0</td>
<td>MHz</td>
</tr>
<tr>
<td>Ambient Temperature Range</td>
<td></td>
<td>TA</td>
<td>– 40 to +85</td>
<td>°C</td>
</tr>
</tbody>
</table>

## ELECTRICAL CHARACTERISTICS

**MC13135**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Condition</th>
<th>Symbol</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Drain Current</td>
<td>No Input Signal</td>
<td>ICC</td>
<td>–</td>
<td>4.0</td>
<td>6.0</td>
<td>mAdc</td>
</tr>
<tr>
<td>Sensitivity (Input for 12 dB SINAD)</td>
<td>Matched Input</td>
<td>Vsin</td>
<td>–</td>
<td>1.0</td>
<td>–</td>
<td>µVrms</td>
</tr>
<tr>
<td>Recovered Audio</td>
<td>VRF = 1.0 mV</td>
<td>AFO</td>
<td>170</td>
<td>215</td>
<td>220</td>
<td>300</td>
</tr>
<tr>
<td>Limiter Output Level (Pin 14, MC13136)</td>
<td></td>
<td>Vlim</td>
<td>–</td>
<td>130</td>
<td>–</td>
<td>mVrms</td>
</tr>
<tr>
<td>1st Mixer Conversion Gain</td>
<td>VRF = – 40 dBm</td>
<td>MXgain1</td>
<td>–</td>
<td>12</td>
<td>–</td>
<td>dB</td>
</tr>
<tr>
<td>2nd Mixer Conversion Gain</td>
<td>VRF = – 40 dBm</td>
<td>MXgain2</td>
<td>–</td>
<td>13</td>
<td>–</td>
<td>dB</td>
</tr>
<tr>
<td>First LO Buffered Output</td>
<td>VLO</td>
<td>–</td>
<td>100</td>
<td>–</td>
<td>mVrms</td>
<td></td>
</tr>
<tr>
<td>Total Harmonic Distortion</td>
<td>VRF = – 30 dBm</td>
<td>THD</td>
<td>–</td>
<td>1.2</td>
<td>3.0</td>
<td>%</td>
</tr>
<tr>
<td>Demodulator Bandwidth</td>
<td>BW</td>
<td>–</td>
<td>50</td>
<td>–</td>
<td>kHz</td>
<td></td>
</tr>
<tr>
<td>RSSI Dynamic Range</td>
<td>–</td>
<td>RSSI</td>
<td>–</td>
<td>70</td>
<td>–</td>
<td>dB</td>
</tr>
<tr>
<td>First Mixer 3rd Order Intercept (Input)</td>
<td>Matched Unmatched</td>
<td>TOImix1</td>
<td>–</td>
<td>–17</td>
<td>–</td>
<td>dBm</td>
</tr>
<tr>
<td>Second Mixer 3rd Order Intercept (RF Input)</td>
<td>Matched Input</td>
<td>TOImix2</td>
<td>–</td>
<td>–27</td>
<td>–</td>
<td>dBm</td>
</tr>
<tr>
<td>First LO Buffer Output Resistance</td>
<td>–</td>
<td>RLO</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>Ω</td>
</tr>
<tr>
<td>First Mixer Parallel Input Resistance</td>
<td>–</td>
<td>R</td>
<td>–</td>
<td>722</td>
<td>–</td>
<td>Ω</td>
</tr>
<tr>
<td>First Mixer Parallel Input Capacitance</td>
<td>–</td>
<td>C</td>
<td>–</td>
<td>3.3</td>
<td>–</td>
<td>pF</td>
</tr>
<tr>
<td>First Mixer Output Impedance</td>
<td>–</td>
<td>ZO</td>
<td>–</td>
<td>330</td>
<td>–</td>
<td>Ω</td>
</tr>
<tr>
<td>Second Mixer Input Impedance</td>
<td>–</td>
<td>Zo</td>
<td>–</td>
<td>4.0</td>
<td>–</td>
<td>kΩ</td>
</tr>
<tr>
<td>Second Mixer Output Impedance</td>
<td>–</td>
<td>ZO</td>
<td>–</td>
<td>1.8</td>
<td>–</td>
<td>kΩ</td>
</tr>
<tr>
<td>Detector Output Impedance</td>
<td>–</td>
<td>ZO</td>
<td>–</td>
<td>25</td>
<td>–</td>
<td>Ω</td>
</tr>
</tbody>
</table>
Although the MC13136 can be operated with a ceramic discriminator, the recovered audio measurements for both the MC13135 and MC13136 are made with an LC quadrature detector. The typical recovered audio will depend on the external circuit; either the Q of the quad coil, or the RC matching network for the ceramic discriminator. On the MC13136, an external capacitor between Pins 13 and 14 can be used with a quad coil for slightly higher recovered audio. See Figures 10 through 13 for additional information.

Since adding a matching circuit to the RF input increases the signal level to the mixer, the third order intercept (TOI) point is better with an unmatched input (50 Ω from Pin 21 to Pin 22). Typical values for both have been included in the Electrical Characterization Table. TOI measurements were taken at the pins with a high impedance probe/spectrum analyzer system. The first mixer input impedance was measured at the pin with a network analyzer.
Figure 2. Supply Current versus Supply Voltage

Figure 3. RSSI Output versus RF Input

Figure 4. Varactor Capacitance, Resistance versus Bias Voltage

Figure 5. Oscillator Frequency versus Varactor Bias

Figure 6. Signal Levels versus RF Input

Figure 7. Signal + Noise, Noise, and AM Rejection versus Input Power
Figure 8. Op Amp Gain and Phase versus Frequency

Figure 9. First Mixer Third Order Intermodulation (Unmatched Input)

Figure 10. Recovered Audio versus Deviation for MC13135

Figure 11. Distortion versus Deviation for MC13135

Figure 12. Recovered Audio versus Deviation for MC13136

Figure 13. Distortion versus Deviation for MC13136
The MC13135/13136 are complete dual conversion receivers. They include two local oscillators, two mixers, a limiting IF amplifier and detector, and an op amp. Both provide a voltage buffered RSSI with 70 dB of usable range, isolated tuning diode and buffered LO output for PLL operation, and a separate VCC pin for the first mixer and LO. Improvements have been made in the temperature performance of both the recovered audio and the RSSI.

VCC
Two separate VCC lines enable the first LO and mixer to continue running while the rest of the circuit is powered down. They also isolate the RF from the rest of the internal circuit.

Local Oscillators
The local oscillators are grounded collector Colpitts, which can be easily crystal–controlled or VCO controlled with the on–board varactor and external PLL. The first LO transistor is internally biased, but the emitter is pinned–out and IQ can be increased for high frequency or VCO operation. The collector is not pinned out, so for crystal operation, the LO is generally limited to 3rd overtone crystal frequencies; typically around 60 MHz. For higher frequency operation, the LO can be provided externally as shown in Figure 16.

Buffer
An amplifier on the 1st LO output converts the single–ended LO output to a differential signal to drive the mixer. Capacitive coupling between the LO and the amplifier minimizes the effects of the change in oscillator current on the mixer. Buffered LO output is pinned–out at Pin 3 for use with a PLL, with a typical output voltage of 320 mVpp at VCC = 4.0 V and with a 5.1 k resistor from Pin 3 to ground. As seen in Figure 14, the buffered LO output varies with the supply voltage and a smaller external resistor may be needed for low voltage operation. The LO buffer operates up to 60 MHz, typically. Above 60 MHz, the output at Pin 3 rolls off at approximately 6.0 dB per octave. Since most PLLs require about 200 mVpp drive, an external amplifier may be required.

Mixers
The first and second mixer are of similar design. Both are double balanced to suppress the LO and input frequencies to give only the sum and difference frequencies out. This configuration typically provides 40 to 60 dB of LO suppression. New design techniques provide improved mixer linearity and third order intercept without increased noise. The gain on the output of the 1st mixer starts to roll off at about 20 MHz, so this receiver could be used with a 21 MHz first IF. It is designed for use with a ceramic filter, with an output impedance of 330 Ω. A series resistor can be used to raise the impedance for use with a crystal filter, which typically has an input impedance of 4.0 kΩ. The second mixer input impedance is approximately 4.0 kΩ; it requires an external 360 Ω parallel resistor for use with a standard ceramic filter.

Limiting IF Amplifier and Detector
The limiter has approximately 110 dB of gain, which starts rolling off at 2.0 MHz. Although not designed for wideband operation, the bandwidth of the audio frequency amplifier has been widened to 50 kHz, which gives less phase shift and enables the receiver to run at higher data rates. However, care should be taken not to exceed the bandwidth allowed by local regulations.

The MC13135 is designed for use with an LC quadrature detector, and does not have sufficient drive to be used with a ceramic discriminator. The MC13136 was designed to use a ceramic discriminator, but can also be run with an LC quad coil, as mentioned in the Test Circuit Information section. The data shown in Figures 12 and 13 was taken using a muRata CDB455C34 ceramic discriminator which has been specially matched to the MC13136. Both the choice of discriminators and the external matching circuit will affect the distortion and recovered audio.

RSSI/Op Amp
The Received Signal Strength Indicator (RSSI) on the MC13135/13136 has about 70 dB of range. The resistor needed to translate the RSSI current to a voltage output has been included on the internal circuit, which gives it a tighter tolerance. A temperature compensated reference current also improves the RSSI accuracy over temperature. On the MC13136, the op amp on board is connected to the output to provide a voltage buffered RSSI. On the MC13135, the op amp is not connected internally and can be used for the RSSI or as a data slicer (see Figure 17c).
Figure 15. PLL Controlled Narrowband FM Receiver at 46/49 MHz

Figure 16. 144 MHz Single Channel Application Circuit

1st LO External Oscillator Circuit

Preamp for MC13135 at 144.455 MHz
MC13135 MC13136

Figure 17a. Single Channel Narrowband FM Receiver at 49.7 MHz

Figure 17b. PC Board Component View

Figure 17c. Optional Data Slicer Circuit
(Using Internal Op Amp)

NOTES:
1. 0.2 \(\mu\)H tunable (unshielded) inductor
2. 39 MHz Series mode resonant
   3rd Overtone Crystal
3. 1.5 \(\mu\)H tunable (shielded) inductor
4. 10.245 MHz Fundamental mode crystal,
   32 pF load
5. 455 kHz ceramic filter, muRata CFU 455B
   or equivalent
6. Quadrature coil, Toko 7MC–8128Z (7mm)
   or Toko RMC–2A6597HM (10mm)
7. 10.7 MHz ceramic filter, muRata SFE10.7MJ–A
   or equivalent
Figure 18. PC Board Solder Side View

Figure 19. PC Board Component View

NOTES:
1. 0.2 \mu \text{H} tunable (unshielded) inductor
2. 39 MHz Series mode resonant
3rd Overtone Crystal
3. 1.5 \mu \text{H} tunable (shielded) inductor
4. 10.245 MHz Fundamental mode crystal, 32 pF load
5. 455 kHz ceramic filter, muRata CFU 455B or equivalent
6. Ceramic discriminator, muRata CDB455C34 or equivalent
7. 10.7 MHz ceramic filter, muRata SFE10.7MJ–A or equivalent
Figure 20a. Single Channel Narrowband FM Receiver at 49.7 MHz

Figure 20b. Optional Audio Amplifier Circuit
Figure 21. MC13135 Internal Schematic

This device contains 142 active transistors.
Figure 22. MC13136 Internal Schematic

This device contains 142 active transistors.