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APPLICATION NOTE 4852

Designing an AM/FM Active Antenna LNA Solution with the MAX2180 LNA

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Abstract: This article is a reference design (RD) for an automobile AM/FM active antenna. The RD presents the flexibility of the MAX2180 active antenna low-noise amplifier (LNA) and shows how to set the AM and FM gain and the automatic gain control attack point. Single and dual antenna schematics are detailed, including the input and output matching circuits. Using this design together with the data sheet and device's evaluation (EV) kit, a prototype antenna can easily be developed for a wide range of active antenna requirements.

Introduction

This application note presents a reference design (RD) for an AM/FM car antenna. The design features the MAX2180, a highly integrated AM/FM low-noise amplifier (LNA) intended for active antenna modules. The LNA integrates Maxim's automatic gain control technology in both the AM and FM signal paths with user-settable attack points. The maximum gain for the AM and FM signal-paths is also variable to accommodate a wide range of customer requirements. The RD will detail the flexibility and performance of this integrated automotive solution.

Click here for an overview of the wireless components used in a typical radio transceiver.

Overview

Automotive antenna requirements continue to push for smaller, more integrated solutions while maintaining the high performance expected from modern AM/FM radios. Some solutions require automatic gain control (AGC) while others use fixed-gain LNAs for the lowest cost. Some solutions provide a regulated supply voltage to the active antenna, but most still operate off of the battery. The resulting challenge to antenna solution suppliers is how to meet the wide range of industry requirements without constantly redesigning discrete solutions or using costly ICs which still require external PIN diodes and regulators. With limited resources and space, the ideal solution for antenna providers would be a high-performance, low-cost, yet flexible IC which easily meets a range of requirements without redesign, BOM changes, and board spins.

A few vendors currently offer integrated AM/FM solutions for active antennas. Unfortunately they require external PIN diodes to provide the AGC. Those solutions also require either a regulated supply or an external pass transistor if operating off the battery. These external components add cost and expand the solution footprint. If AGC is not required, then solution providers typically use discrete devices for the lowest cost. The problem with discrete designs is that any change in the required gain, supply voltage, or footprint requires a redesign. This complicates quoting opportunities and requires additional design resources which are always in short supply.

Optimal Antenna Solution and the MAX2180

Maxim Integrated Products developed an AM/FM antenna solution that integrates all active components and meets today's demanding automotive antenna requirements. The antenna features a MAX2180 LNA. The MAX2180 uses an internal high-voltage CMOS process that integrates both the AM and FM AGC as well as a high-voltage regulator in a small 4mm x 4mm TQFP package. This design eliminates all PIN diodes and the external regulator or pass transistor while operating off the battery or a regulated supply. The MAX2180 allows the maximum AM and FM gain as well as the AGC attack points to be varied. It also includes antenna monitoring with a 15mA current draw during a fault condition.

The LNA's on-chip regulator operates from 7V to 24V. To protect against thermal damage, an integrated temperature sensor limits the maximum junction temperature by folding back the current. This keeps the amplifier active regardless of the ambient conditions.

The AM input is high impedance with a low output impedance, while the FM amplifier provides a 50Ω input and output impedance. The maximum AM gain can be programmed from 0dB to 6dB by varying an external resistor. The maximum FM gain can be varied from 5.8dB to 8.5dB for R1 = 0Ω. For an improved noise figure, R1 should be 390Ω, thus increasing the gain range up to 10.0dB to 10.8dB. Both signal paths have 30dB of gain control range using Maxim's patented AGC circuitry. Additionally, the AGC attack points can be varied to provide the desired maximum output level to the head unit.

Designing with the MAX2180 is simplified by using the data sheet's tables to select the required signal-path gains and AGC attack points. This customization/range of values allows one design to meet multiple requirements without respinning the board. As shown in **Figure 1**, the MAX2180 provides higher integration than competing solutions while retaining the flexibility to meet a range of requirements. **Figure 2** shows an application schematic for a single-antenna solution.

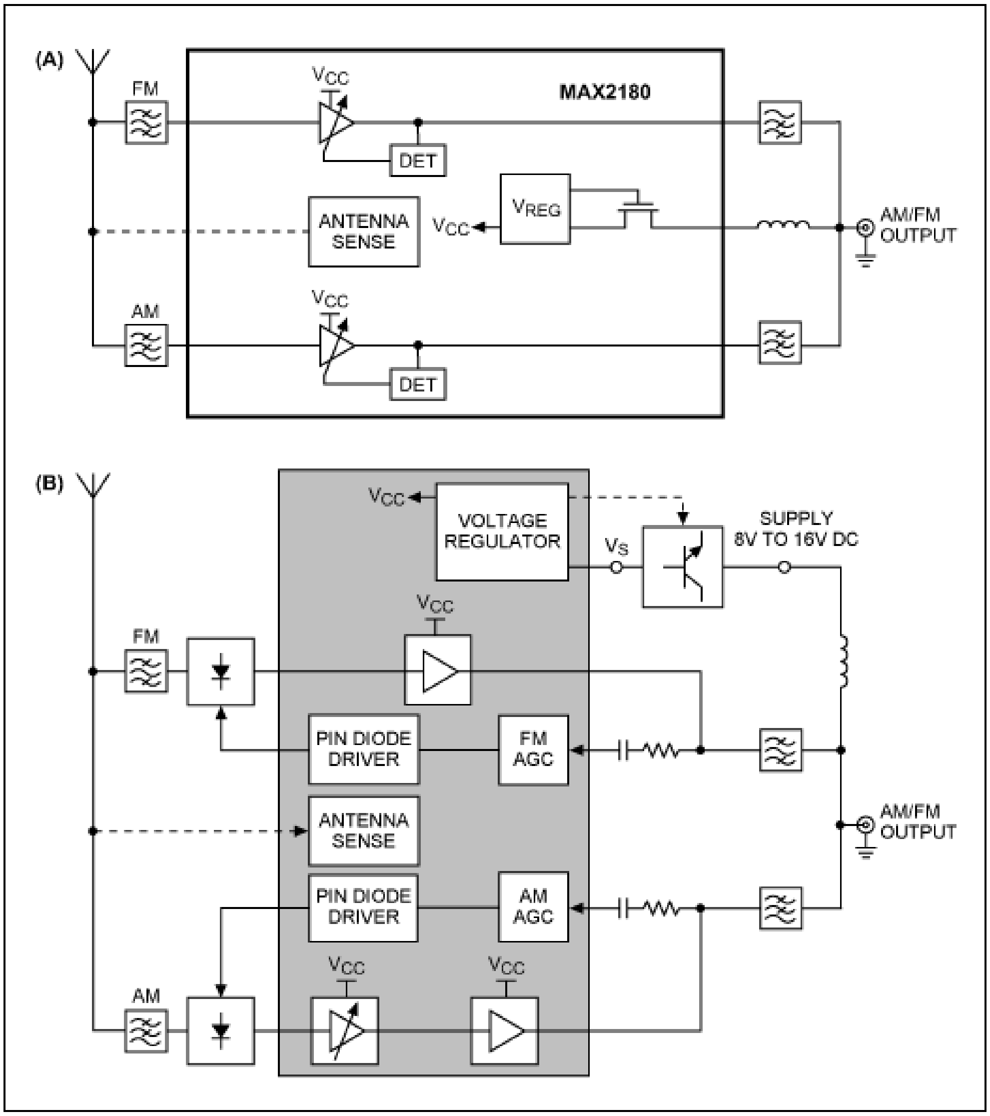

Figure 1. The MAX2180 highly integrated solution (A) vs. competing AM/FM active antenna solutions (B).

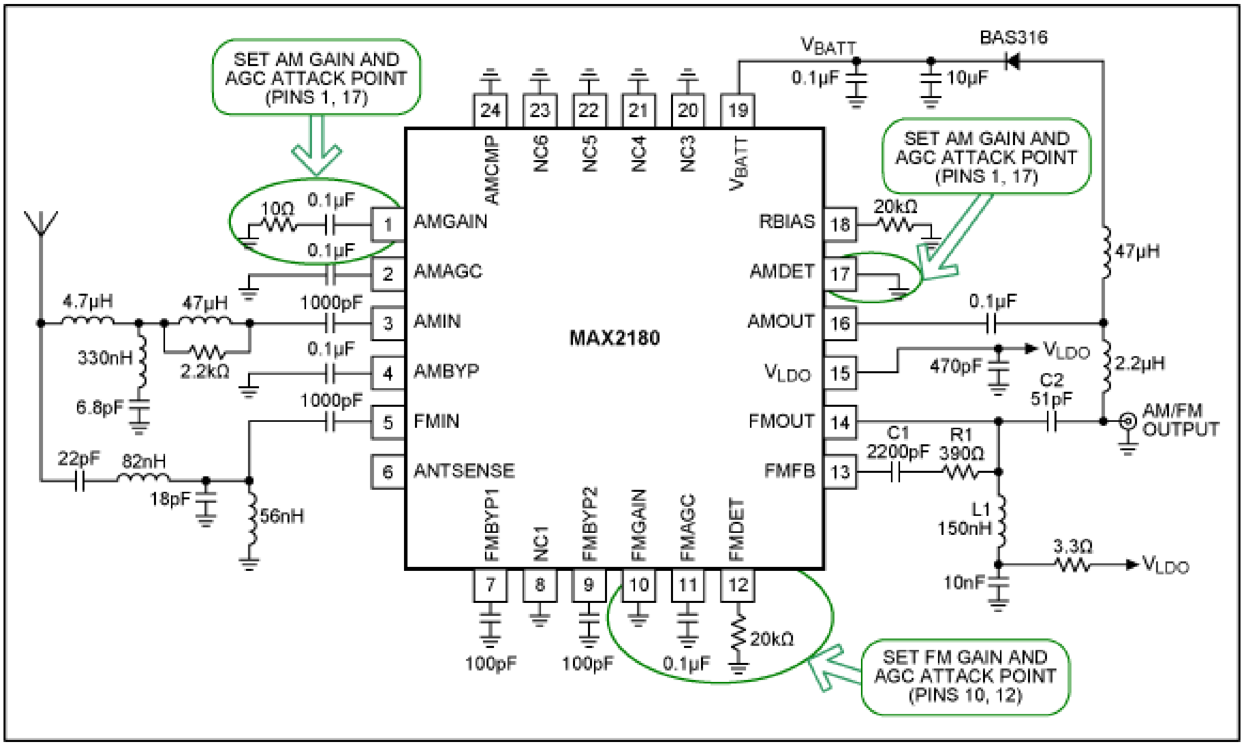

Figure 2. Application schematic for a single-antenna solution features the MAX2180.

Design Example

Our test example is a low-gain antenna for a small automobile. This application needs more gain , but a short cable in a small car reduces loss from the antenna to the head unit, which has a targeted maximum input level of +80dBµV for AM and +95dBµV for FM.

AM: pin 1 resistor = 0Ω for a gain of 6.5dB (**Table 1**) and pin 17 is shorted to ground for an AM output AGC attack point of +79dBµV (**Table 2**).

FM: pin 10 is shorted to ground for an FM gain of 8.5dB (**Table 3**) and pin 12 resistor = 39kΩ to ground for an FM output AGC attack point of +94dBµV (**Table 4**).

Table 1. AM Signal-Path Gain

Pin 1 (Ω)	AM gain (dB, typ)
0	6.5
22	5
68	2.5
180	0.5
330	-1

Table 2. AM Signal-Path Attack Point

Pin 2	AM output attack point (dBµV, typ)
Ground	79
Open	83
V_{LDO}	86

Table 3. FM Signal Path Gain

Pin 10	FM Gain(dB, typ; no external resistor)	FM Gain (dB, typ; external resistor = 390Ω)
V_{LDO}	8.5	10.8
Open	7.1	10.3
Ground	5.8	10

Table 4. FM Signal-Path Attack Point

Pin 12 (kΩ)	FM output attack point (dBμV, typ)
0	104
10	100
18	96
27	95
39	94
47	93
56	92
68	90

Input Circuits

For a single antenna, the diplexer must minimize the effective input capacitance to not load the high-impedance AM input. In the AM frequency band the antenna generally is high impedance, so any added shunt capacitance will attenuate the AM signal. The circuit must also provide a good match for the FM input for optimal noise figure and frequency response while also rejecting the other band of signals.

At the AM input an FM "trap" is used to minimize the FM signal level into the AM input. To avoid loading the FM band, the trap has depth of 60dBc and a 4.7μH inductor is placed between the antenna and the trap. To prevent FM-to-AM distortion, a series inductor at the AM input improves the feedback in the FM band. The FM section of the diplexer matches a 50Ω antenna to the FM input while also attenuating the AM band by over 90dB. The number of inductors should be minimized, as every added component degrades the noise figure due to limited Q.

Dual-antenna solutions (**Figure 3**) allow for simplified filtering and slightly better FM matching with fewer components.

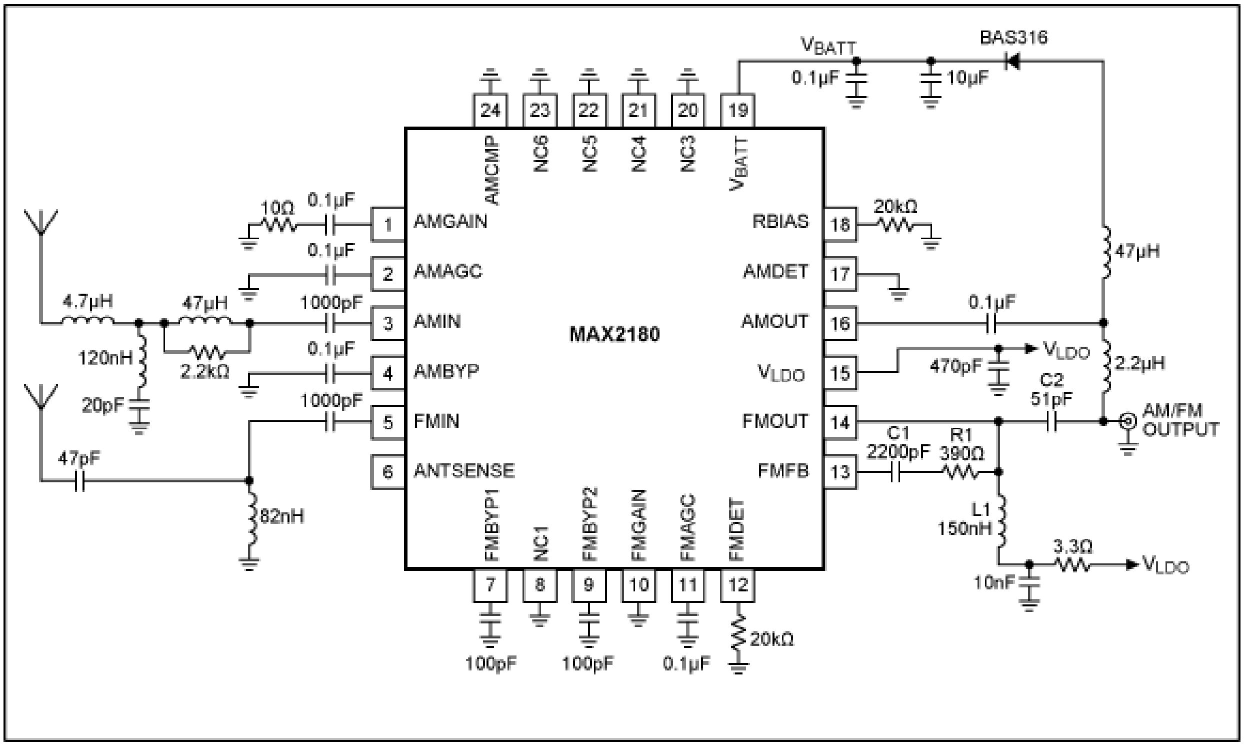

Figure 3. Application schematic for a dual-antenna solution features the MAX2180.

Output Circuits

The output circuit needs to combine both the AM and FM outputs while feeding the phantom supply to the integrated high-voltage regulator. To help attenuate any AM signals reaching the regulator, the phantom supply reaches the integrated regulator through a large inductor connected to the AC-coupled AM output. The AM output connects to the output connector through a second, but smaller, inductor which keeps the FM output from distorting the AM output stage. The FM output is AC-coupled with a small blocking capacitor to prevent any IM2 products (A-B) from distorting the AM output. A feedback path is also present. The suggested solution is a 390Ω resistor (R1) in series with a 2200pF capacitor (C1) for optimal noise-figure performance. A pad following the output-blocking capacitor (C2) can be used to adjust the total gain as needed. A pullup inductor (L1) to the FMOUT is sized for impedance matching and gain. A simple R/C filter (3.3Ω/10nF) between the LDO output (V_{LDO}) improves the FM noise figure. The FMBYP pins require 100pF bypass capacitors to provide an AGC range of 30dB.

Thermal Considerations

The circuit-board design needs to provide a low thermal impedance from the part's exposed paddle to the module chassis. To support this pins 20 to 23 can be grounded, allowing for a solid copper plane from the exposed paddle to the chassis solder point or screw hole passing under these pins (**Figure 4**). The part integrates a temperature sensor which will gradually decrease the current draw once the die reaches a temperature of +135°C. The part remains operational while it protects against thermal damage.

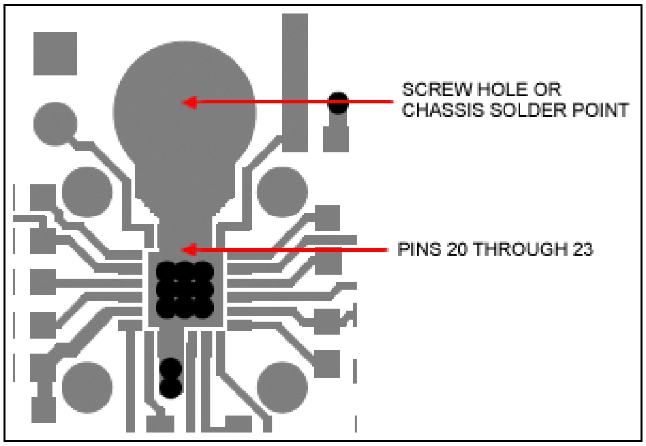

Figure 4. Printed circuit board (PCB) shows a low thermal-resistance solution.

Conclusion

The MAX2180 AM/FM antenna LNA combines all the capabilities and features required to design an automotive antenna module that will meet a range of high-performance requirements. Because of the LNA's flexibility, the antenna can be modified for evolving application requirements without a complete redesign or costly BOM changes. Cost-sensitive solutions can use the highly integrated MAX2180, reduce the number of discrete external components, save board space, and still meet today's low-noise high-linearity requirements.

The FM signal path in this RD provides an OIP3 of +133dBµV and an OIP2 of +180dBµV. Operation from a 7V to 24V supply voltage is supported with guaranteed performance from 8V to 15V. The MAX2180 is available in a 4mm x 4mm TQFP package and has an ESD rating of ±4kV HBM. Samples and EV kits are available.

Related Parts		
MAX2180	AM/FM Car Antenna Low-Noise Amplifier	Free Samples

More Information
For Technical Support: http://www.maximintegrated.com/support
For Samples: http://www.maximintegrated.com/samples
Other Questions and Comments: http://www.maximintegrated.com/contact

Application Note 4852: http://www.maximintegrated.com/an4852
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