Car Infotainment

Radio

Car Antenna Amplifier Concepts

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With the antenna driver IC ATR4251, Atmel provides a very successful solution for AM and FM antenna amplifiers. The device is mainly used in the cars radio's reception path facing challenging antenna types and reception positions within the car body. The ATR4251's advantages comprise high reliability and high functional density resulting in small design, maximum AC/ DC parameter repeatability during production and long-time stability. The IC's high flexibility enables to meet the individual customer needs – especially in terms of cost and performance ratio.

As car design requirements more and more dominate technical aspects, however, the technical requirements for car antenna design also change. Since the amount of antennas in a medium- or luxury-class car easily reaches a number of 20 to 30, current antennas need to be almost invisible, or have at least a decent appearance. Consequently, antennas – especially those for radio and TV reception – tend to be integrated into the cars' windows. This is critical due to the limited window area, and also due to the fact that different antenna compete for the best window area position.

It is no surprise that the collected field strength results in a very low antenna voltage, which is even worse if loaded with the high capacitance of a long antenna cable. To avoid this, it is recommended to provide, for example in AM band, not only an LNA with an adjustable gain but also a buffer to drive long 50- or 75-Ohm cables.

Advantages of IC over Discrete Solutions

There are various advantages of antenna solutions using integrated circuits over discrete solutions, amongst others, stable operating point against temperature variation, component tolerances and aging, as well as a smaller design form factor which allows adding features that improve the technical performance but are too cost-expensive when realized as a discrete solution. Even if the amount of passive and active components within the integrated circuit exceeds those of a discrete solution, the stability and reliability of an IC-based solution is far beyond the discrete solution. This is due to the fact that each additional soldering connection is a potential failure root cause – especially in a car with its inherent long-lasting temperature, humidity and vibration test cycles.

However, only combined integrated technologies – e.g., BiCMOS as used in Atmel's integrated antenna amplifiers – can fully play its advantages over both discrete and simple integrated CMOS solutions. An AM antenna has a very high impedance and a fairly low capacitance, resulting in low antenna voltage. For such an antenna, an FET transistor with a low input capacitance is the preferred choice as first stage amplifier to match the antenna. It also needs to be taken into account that the high impedance and the far better noise/ linearity behaviour (compared to a bipolar transistor within the AM frequency band) allow to fully use the small signal from the antenna, and to handle large-signal reception conditions that might occur during driving.

The receiver probably needs a long coaxial cable that may cause a substantial loss due to its high inherent capacitance. The best way to overcome such a challenge is to attach a driver or buffer amplifier right before the cable. A smart biasing technique plus a push-pull circuit, comprising complementary bipolar NPN and PNP transistors, perfectly matches the requirements and will maintain the high linearity performance of the entire amplifier chain.

To achieve best FM amplifier low-noise quality and easy input-output matching, a bipolar transistor is the best choice as GaAs or comparable solutions are too expensive in most cases.

A combination of different transistor types is useful for all other antenna amplifier features such as automatic gain control (AGC), voltage stabilization, plug detection, over-voltage and ESD protection.

For maximum linearity performance and best large-signal behaviour it is advantageous to use the entire battery voltage range, provided that a well-stabilized regulation is in place.

Most advanced CMOS technologies restrict the voltage swing more than necessary due to their inherent low breakthrough voltages. By using bipolar transistors, however, a maximum output voltage swing of up to 12 V_{pp} can be achieved at the output of the FM stage, resulting in excellent OIP3 (145 dBuV) and OIP2 (170 dBuV) values.

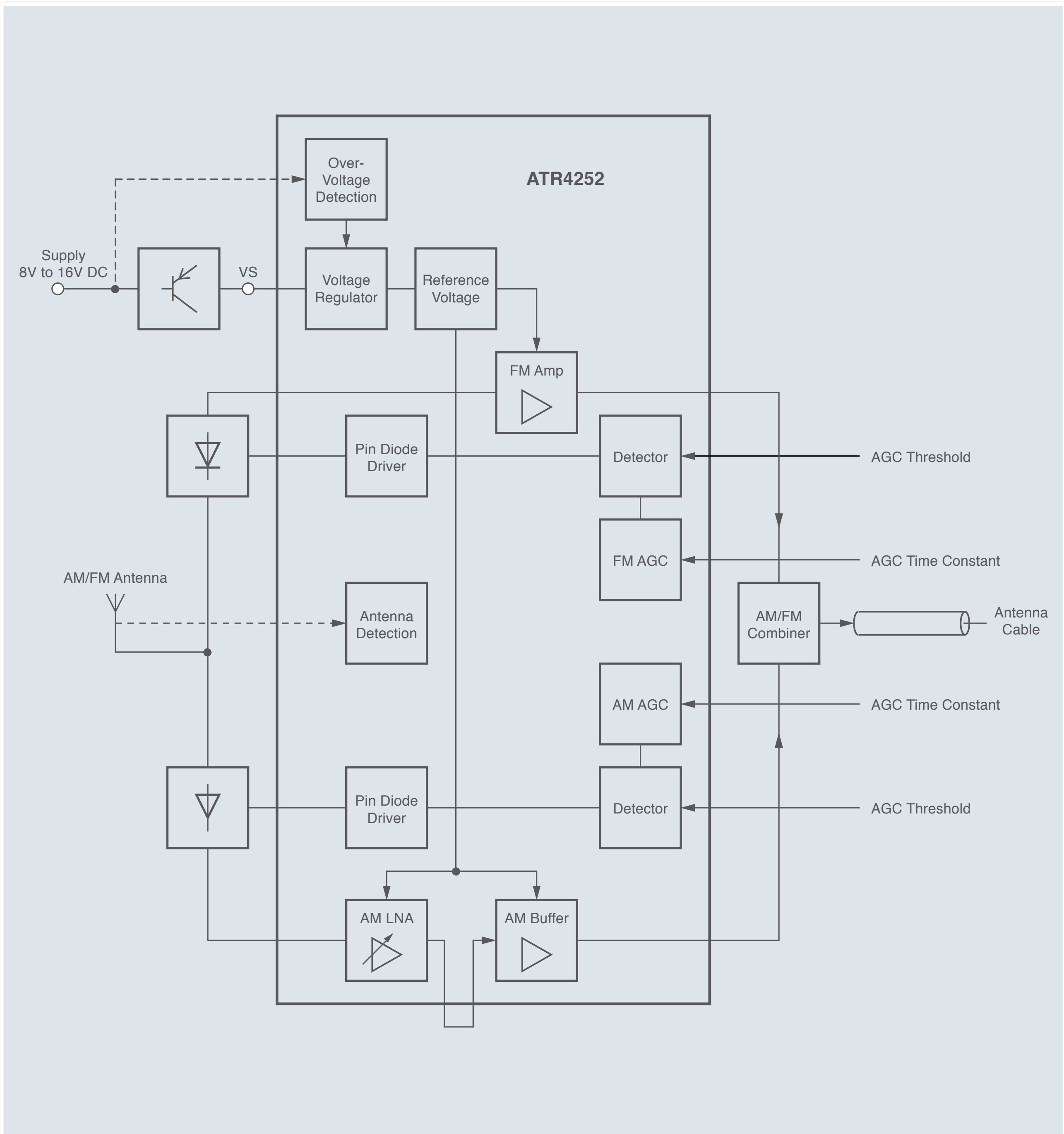

Figure 1. ATR4252 Block Diagram

For the functional block "AGC" it is also advantageous to use mixed circuitry, e.g., bipolar transistors as current sources for the PIN diode attenuators because bipolar transistors require less space than comparable MOS transistors for the same function.

Antenna Amplifier ATR4252

The ATR4252 is a further enhancement: it integrates even more external components, functional blocks and features, and the technical characteristics of the already existing blocks have been improved.

Performance Improvements

The ATR4252 provides outstanding noise level and linearity performance in both separate as well as combined AM and FM band amplifiers. The goal for the FM amplifier was to reduce the noise figure (NF) while maintaining the best possible intermodulation performance.

To perform this task, extensive simulations of the circuit, bond wires, package and external components were carried out. The achieved results for the common base configuration are shown in figure 2, which illustrates the noise figure comparison of final simulation run and measurement within the 80- to 170-MHz FM frequency band.

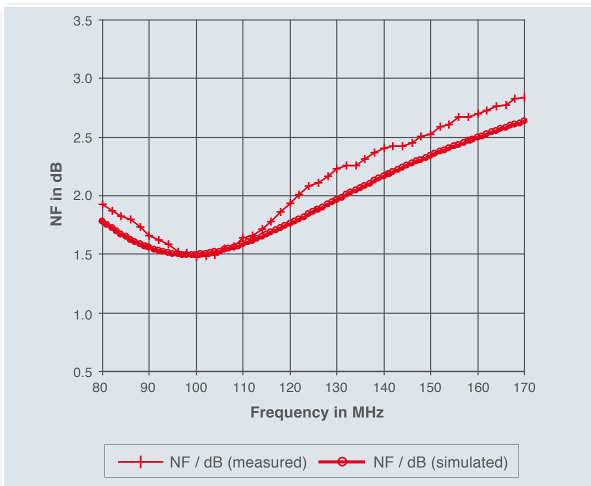

Figure 2. FM Amplifier Noise Figure

Thanks to proper current density, dedicated biasing techniques and further means, the achieved NF of 1.5 dB in FM is even better than results with dedicated discrete RF transistors, and matches well with the pre-running simulations.
When combining the AM and FM parts, however, it is inevitable to raise the FM noise figure at the combining point, depending on the required bandwidth of the AM amplifier part. If a maximum bandwidth of 30 MHz (especially for DRM reception) has to pass the low-pass filter of the combination point network, the noise figure will be about 1.9 dB. For the most common AM bandwidth of 450 kHz to 1.7 MHz, however, the increase is only 0.1 dB. This results in a final noise figure of about 1.6 dB, which is still a very good value.

If the designer wants to focus mainly on maximum linearity (more than 145 dBuV for OIP3) and less on the NF performance, this can easily be accomplished by adapting one external resistor placed at the emitter of the FM transistor.

A further reduction in BOM cost leads to the common emitter circuit that can also be realized using the ATR4252. The benefit of cost and board space reduction is accompanied with a slight reduction in noise and intermodulation performance.

AM Amplifier

One of the AM amplifier design goals was to provide a voltage gain of about 9 dB in addition to the insertion gain of the transimpedance amplifier used in ATR4251, while keeping the noise and intermodulation level on the same level as with ATR4251.
This has been achieved by using a monolithic combination of MOS and bipolar technology. The DC biasing of the relevant RF transistors, for example, has been optimized for best noise and intermodulation performance. Since the ATR4252 offers maximum modularity, it is possible to insert an external filter between LNA output and buffer input. Moreover, the voltage supply range has been extended to lower values (8V) without noticeable performance reduction.

In all other cases where this lower value is not needed, the ATR4252 provides a well stabilized and filtered supply voltage of 10V due to the integrated voltage stabilization circuit and one external PNP power transistor. This stabilization loop is able to suppress ripple and noise by more than 40 dB.

Overvoltage Protection and Antenna Detection

The antenna detection functionality is used to detect errors that may occur due to the following three main failure root causes:

1. A antenna plug that has not been fit properly during car production
2. A broken cable or a damaged reception structure of a printed glass antenna
3. A temporarily bad cable connection to antenna that is caused by vibrations/ movements of the car

The ATR4252 enables to set-up diagnostic system, which can be realized as an additional plug contact in the antenna-cable-amplifier chain or placed into the DC path of a window heating field in case the antenna is part of this structure.

This is possible because the integrated diagnostic system can both drive a current as well as detect a current that flows into the circuit. To realize one of the two possible placements in the heating structure (just below the 12V level or just above the GND level) it can detect a voltage window in the range of 0V to 3V, and 6V to 16V. The failure signalization to the car's diagnostic system is performed by a predefined DC current reduction of the complete antenna amplifier down to 20 mA.

Finally the overvoltage protection unit is able to reduce the overall current consumption of the complete IC to an innocuous value of 12 mA in case the applied DC voltage exceeds 16V.

Summary

Thanks to the device's outstanding technical features, the new integrated antenna amplifier ATR4252 enables to meet the car industry's highest performance and quality requirements. Its inbuilt flexibility allows creating one standard platform for the different car markets and antenna types, thus resulting in cost-efficient and durable products.