CEL California Eastern Laboratories

AN1018

APPLICATION NOTE

Designing An AM Receiver For Low Power Wireless Systems Using The NEC UPC2768GR IC

INTRODUCTION

A wide variety of low power wireless communication systems have surfaced in recent years. Automotive keyless entry, home security, bar code readers, and child monitors are just a few of the many applications for this technology. Most low power wireless systems transmit less than 1mW of power and operate in the FCC PART 15 band (260-470 MHz) where licensing is not required at such low power levels. Operating range varies from just a few feet (bar code readers) to a few hundred feet (garage door openers) depending on the application. Naturally, many of these systems must be lightweight and battery driven to meet portability requirements. Most importantly, however, cost must be highly competitive to survive in demanding commercial markets.

When designing low power radio receivers for systems such as those described above, management of performance, size, and cost trade-offs can be complicated. The NEC UPC2768GR downconverter IC was developed to simplify system design. The chip combines solid performance with high functionality in a very small 20-pin SSOP package. By integrating the UPC2768GR IC into a receiver design, total parts count is reduced and manual tuning of reactive elements is eliminated. In the next sections, a brief description of the UPC2768GR circuit will be presented followed by an example of the UPC2768GR in an automotive keyless entry receiver application.

CIRCUIT DESCRIPTION

The UPC2768GR is a frequency converter IC manufactured in the NESAT-III 20 GHz Si bipolar process developed by NEC. The IC contains a downconverter and a limiting amplifier (Figure 1).

The downconverter consists of an RF input amplifier, Gilbert cell mixer, local oscillator, and IF amplifier. The RF input stage is a differential amplifier which has 15dB of gain when driven single-ended. The input stage also features good noise performance for improved sensitivity and excellent reverse isolation to minimize LO re-radiation. The Gilbert cell mixer generates 8 dB of conversion gain. Due to the double-balanced nature of the Gilbert cell, excellent suppression of LO and RF is achieved at the output. The local oscillator uses an external tank circuit to set the oscillation frequency and can be operated beyond 500 MHz. In applications where an external oscillator is used, the local oscillator stage can serve as a 10 dB gain buffer. The differential IF amplifier with 15 dB of gain completes the downconverter. In all, 38dB of conversion gain is available. From a 3 V supply, the downconverter typically draws 5.6 mA.

The 5 stage IF limiting amplifier provides an additional 44 dB of gain from dc-25 MHz. Global feedback is employed to maintain dc stability. The limiting amplifier draws only 1.4 mA from a 3 V supply.

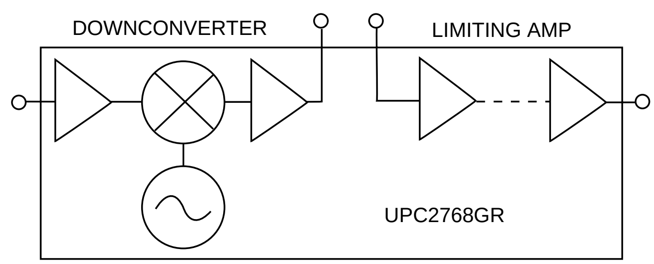

Figure 1: UPC2768GR functional block diagram

The UPC2768GR is also equipped with a power save circuit. By grounding the power save pin, the chip can be put in an OFF state where it draws less than 100 μA of current.

SYSTEM DESCRIPTION: KEYLESS ENTRY RECEIVER

Remote entry receivers for automobiles are one of the largest and fastest growing applications for low power wireless technology. Receivers for this application generally fall into two broad categories: superregenerative and superheterodyne.

Although earlier receiver designs were predominantly superregenerative, the current trend is toward superheterodyne to meet more demanding system requirements. A typical superheterodyne receiver block diagram is shown in Figure 2.

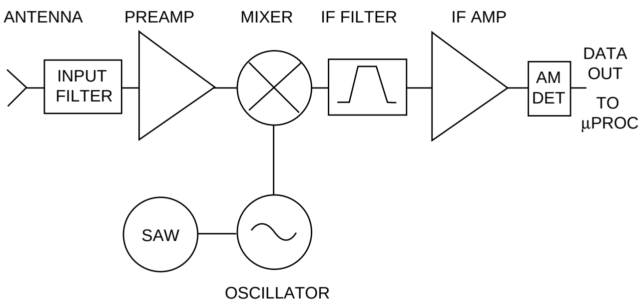

Figure 2. Superheterodyne receiver block diagram.

Notice that with the exception of the filters, SAW resonator, and detector, the UPC2768GR can replace the entire receive block. The following sections will describe how the remaining elements can be implemented around the UPC2768GR to form a complete receiver.

INPUT FILTERING

Due to strong interference from signals in the FM radio band (87 MHz-107 MHz), filtering is required at the input. Received signals in the FM band can be as high as +10 dBm in areas where a transmitter is nearby. The most problematic interferers in this band are those which are subharmonics of the desired RF input frequency. For example, in U.S. automotive keyless entry applications where the input signal is at 315 MHz, an interferer at 105 MHz ($f_{RF}/3$) can severely degrade the receiver sensitivity if adequate filtering is not present at the input. In extreme cases, the receiver can actually be jammed by such signals.

Narrowband interference problems such as this can be effectively eliminated with notch filters. Notch filters possess excellent rejection characteristics and are easy to implement in the FM band. In Figure 3, the UPC2768GR is shown with a series LC notch filter at the RF input.

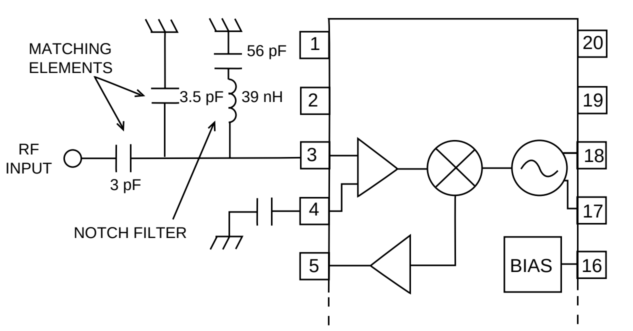

Figure 3. Input notch filter.

The notch frequency is determined by the following expression:

$$f_{notch} = 1/(2\pi\sqrt{LC})$$

Note that the values of L and C were chosen to produce a notch at 105 MHz.

INPUT MATCHING

Impedance mismatch at the input can significantly degrade overall system sensitivity. In order to minimize the effects of mismatch loss a matching network can be added. In most receiver systems, the UPC2768GR is preceded by an antenna or perhaps a SAW filter. Typically, these elements have impedances in the 50-75Ω range. The input impedance (pin 3) of the UPC2768GR, on the other hand, is quite high and capacitive in nature as shown by the S11 plot in Figure 4.

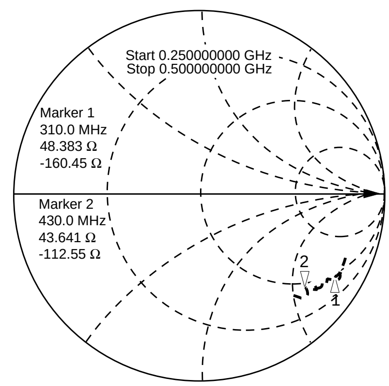

Figure 4: UPC2768GR input S_{11}.

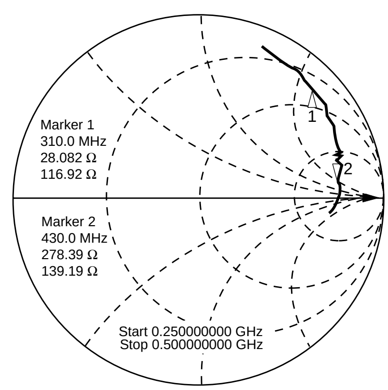

Figure 5. Input S_{11} of UPC2768 + notch filter.

Inclusion of the notch filter rotates the impedance to the inductive half of the Smith chart as shown in Figure 5.

Now the impedance shown in Figure 5 must be matched to 50Ω at the system frequency. This can be accomplished by first inserting a shunt capacitor to rotate S11 clockwise toward the unit circle. Then, a series blocking capacitor can be inserted to bring the impedance back to 50Ω. This is all shown graphically in Figure 6.

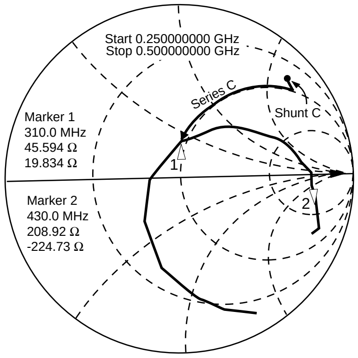

Figure 6: Matching procedure.

IF FILTERING

An IF frequency of 10.7 MHz is widely used because ceramic filters are commonly available (e.g. Murata SFE10.7MA). Ceramic filters are typically very narrowband (<500 kHz) and possess excellent rejection characteristics. In high gain receiver systems such as automotive keyless entry, sharp filtering is essential in minimizing overall noise power.

When using the UPC2768GR, IF filtering is recommended between the mixer and IF amplifier (pins 5&7) to prevent undesired spurs generated by the mixer from saturating the IF amplifier. A shunt LC filter is effective here because of its low insertion loss and zero group delay characteristics (Figure 7). Ceramic filters should not be used here because poor group delay introduces instabilities in the system.

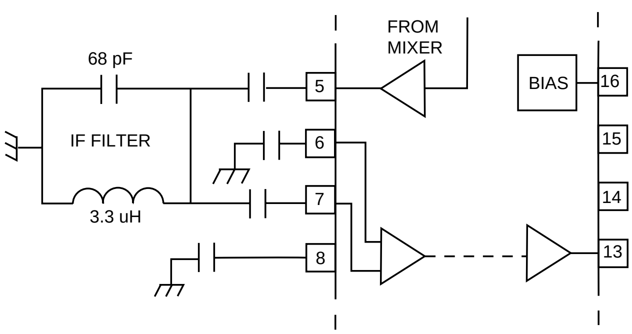

Figure 7: Shunt LC filter (IF = 10.7 MHz).

IF filtering is also required at the output of the IF amplifier (pin 13). At this point, a ceramic filter should be applied in order to effectively eliminate higher order harmonics generated by the limiter and also to minimize noise bandwidth (Figure 8).

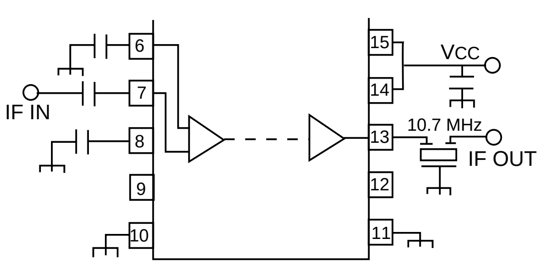

Figure 8: Ceramic IF Filter (IF=10.7MHz).

LOCAL OSCILLATOR AND SAW

In most modern, low power, wireless systems, superheterodyne receivers employing SAW resonators are used.

In addition to having excellent frequency stability, SAW resonators eliminate the need for manual tuning. The UPC2768GR contains an oscillator which can be easily configured with a SAW resonator (Figure 9).

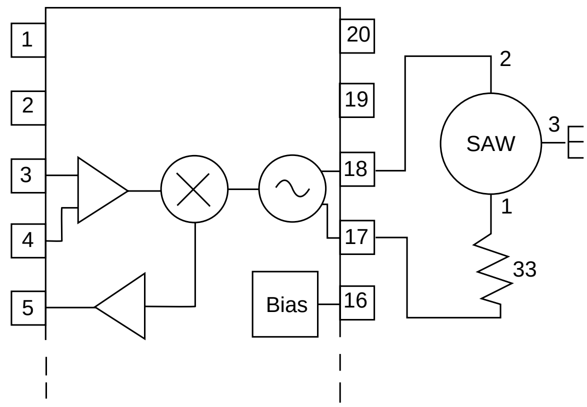

Figure 9: UPC2768GR SAW oscillator.

The SAW resonator is used in a two-port configuration. Notice that R_{osc} is the only additional element required to complete the oscillator circuit. R_{osc} is placed in series with the SAW resonator to provide an appropriate matching impedance.

DETECTOR CIRCUIT

In AM systems, data recovery can be accomplished by the addition of a diode-based detector circuit. A typical detector circuit is shown in Figure 10. The diode bias is established at approximately 30 uA by the 20kΩ and 82kΩ resistors. A 1500pF shunt capacitor to ground (C1) is used at the output of the diode detector to filter out the IF carrier leaving just the detected data. The detected data is then amplified through two op amp stages (MM33172 dual op amp IC or equivalent) to yield the final data output.

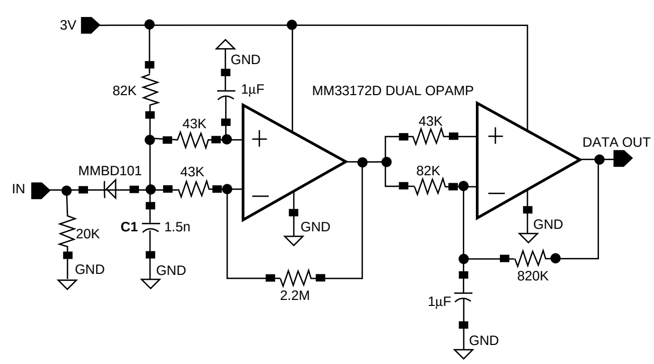

Figure 10: Diode detector circuit.

BOARD LAYOUT

The layout of a pc board which accommodates the UPC2768GR, all of its associated external components, and an AM detector circuit is shown in Figure 11. The design was fabricated on 28 mil thick epoxy glass material and measures only 1" x 1.5".

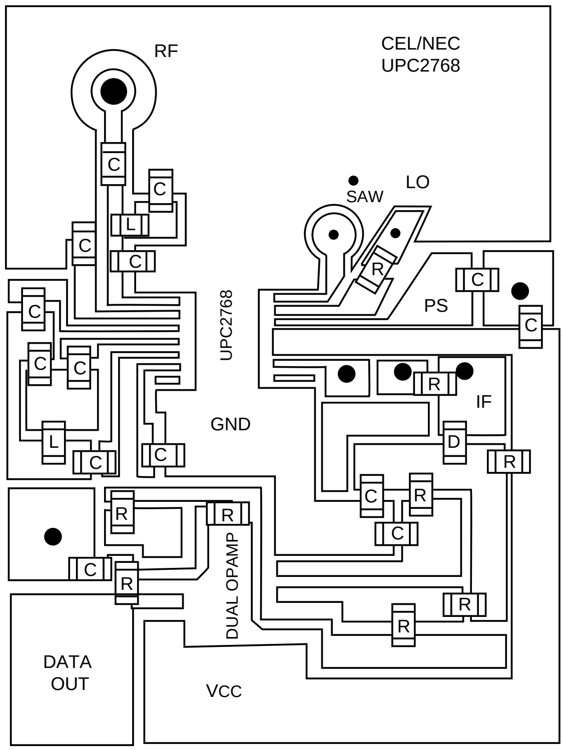

Figure 11: PC Board layout.

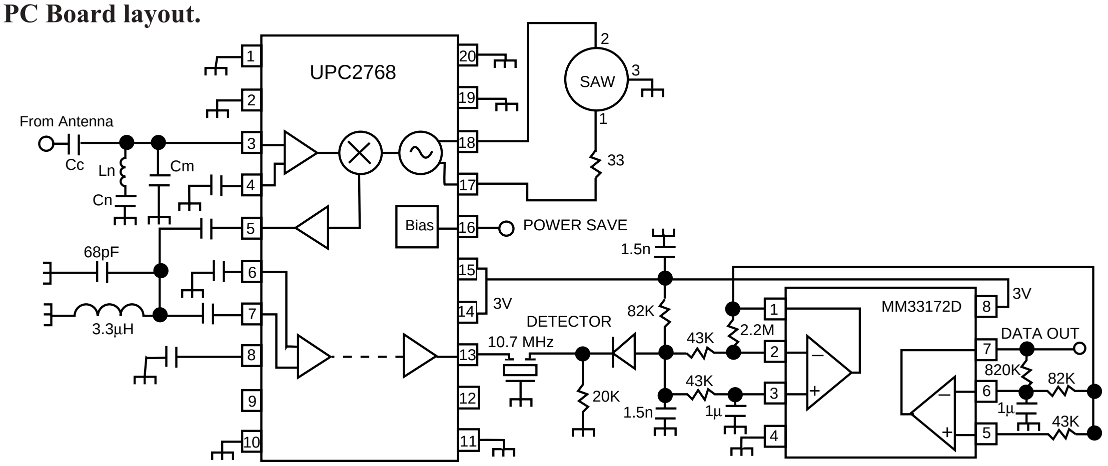

Figure 12: ASK Receiver for Keyless Entry.

FINISHED RECEIVER

A schematic of the completed receiver is shown in Figure 12. Input sensitivity and dynamic range of this receiver were measured. Data was successfully recovered for inputs ranging from -100 dBm to 0 dBm.

CONCLUSION

The receiver described in this article is just one of many possible applications for the NEC UPC2768GR. By integrating the UPC2768GR into a receiver, design is simplified, total parts count is reduced, and costly tuning of reactive elements is eliminated. In short, the UPC2768GR offers solid performance and high functionality in a small, affordable 20-pin SSOP package. It is these characteristics which make it ideally suited for low power wireless systems.

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