Application Report

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TMS3705 Passive Antenna Solution

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ABSTRACT

The Texas Instruments low-frequency transponder technology provides the possibility to use a simple passive antenna in combination with various antenna cable lengths. This solution significantly reduces system costs because the active part of the transceiver can be added to the already existing host system, e.g., the body control module (BCM) of a vehicle.

In comparison to a standard system, no additional components are necessary, i.e., voltage regular and blocking capacitors. Due to the possibility of varying the cable length, it is possible to develop a universal control module that can be used in many different architectures.

Contents

List of Figures

1 Introduction

This application report provides supplementary information about the Texas Instruments 134.2 kHz RFID Base Station IC TMS3705x. In particular, the document shows the possibility of using a remote passive antenna using a simple two-wire antenna cable with a length up to 4 meters.

In principle, the TMS3705x serves as an interface between the transponder and a Microcontroller using a bi-directional serial interface. The transponder is supplied with energy and data by on-off keying of the carrier. According to the TRP specification, the bit encoding must be handled by the Microcontroller. At the end of the telegram sent to the transponder, the transmitter is completely switched off and the transponder sends the data back by frequency modulation (FM) using two frequencies.

The TMS3705x is a highly integrated device for communication with all of the Texas Instruments low-frequency transponders; the amount of necessary external components is minimized.

2 Main Features

- Only a few external components
- Reference designs available
- Increased passenger safety as no module on steering column is required
- Increased flexibility in housing and system design
- High degree of flexibility for the antenna placement
- Easy design to support: Left-/Right- steering vehicles
- Reduced shock/reliability stress as only the antenna is at the steering column

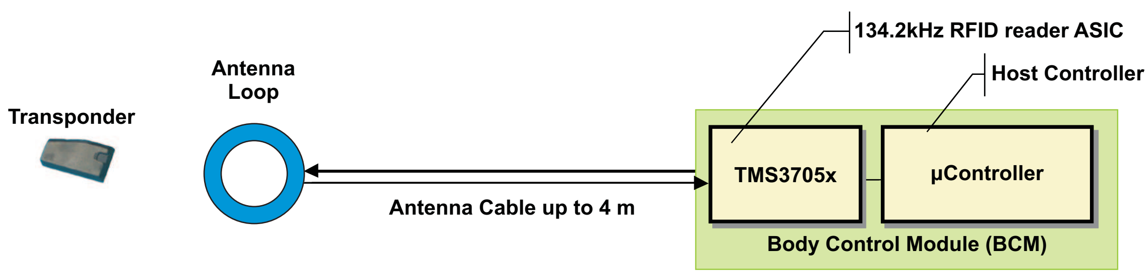

Figure 1. HDX RFID System Block Diagram

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3 System overview

A typical passive transponder system consists of a transponder and a reader (exciter). The air interface between the transponder and the reader behaves like a magnetic transformer with a large air gap. The resulting coupling factor between the transponder and reader is significantly lower compared to traditional magnetic transformers.

There are two LF RFID communication technologies on the market: full duplex (FDX) and half duplex (HDX). The HDX technology is Texas Instruments proprietary RFID technology. The fundamental difference to FDX, which uses load modulation for the communication between the transponder and the reader, is that the HDX transponder generates an active, frequency shift keying (FSK) modulated signal after the reader charges up the charge capacitor inside the transponder.

Therefore, the TI system is specified by the field strength level required to activate the transponder, *Charge & Downlink*, as well as the field strength that is generated by the transponder during the *Uplink* response phase.

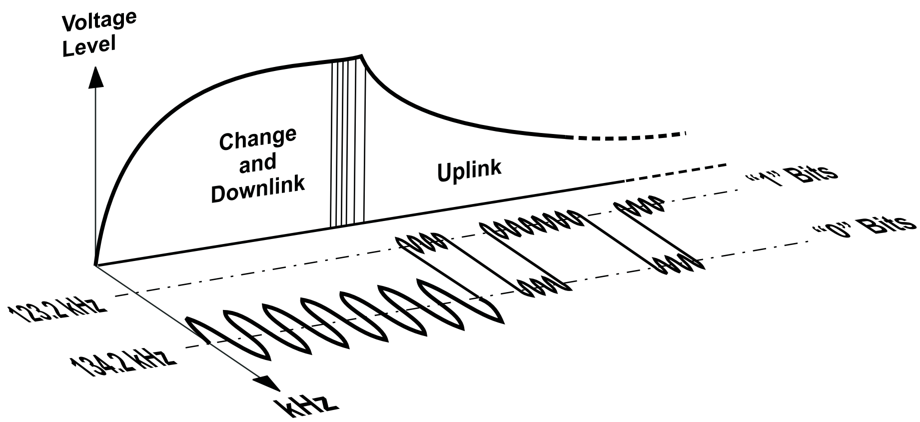

Figure 2. Communication Overview

By splitting the overall communication into *Charge & Downlink* (Reader to TRP) and *Uplink* (TRP to reader), both communication phases can be optimized for a very high reading distance. The signal separation uses an operation with a high-resonance Q-factor and a receiver with high sensitivity (below 1 mV_{PP}) to receive very small transponder signals. There is no distortion by any reader signal since the transmitter is switched off during *Uplink*. In addition, the frequency modulation FSK is much more immune to interference and distortion since the information is not in the amplitude. Due to the greater read range, the Texas Instruments RFID system gives you much more freedom for the mechanical design.

4 System Options

4.1 Conventional System – Short Antenna Cable

The circuitry in Figure 3 shows the standard TMS3705x schematic if *no* antenna cable is used. For more information, see the *TMS3705 Transponder Base Station IC Datasheet* (SCBS881).

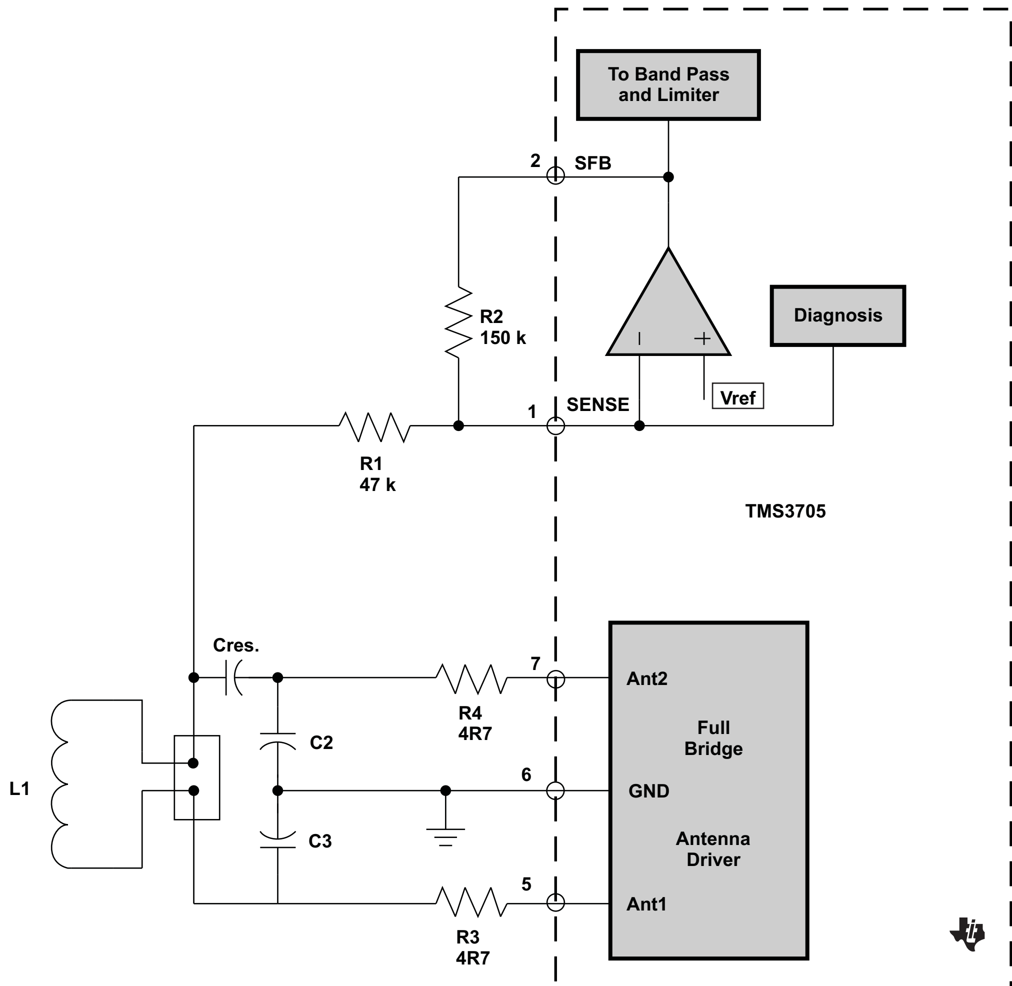

Figure 3. HDX RFID Reader Configuration With ***Short*** **Antenna Cable**

4.2 Remote Antenna System – Long Antenna Cable

The generic circuitry for the *long* cable application shows the additional recommended components that are needed (see Figure 4).

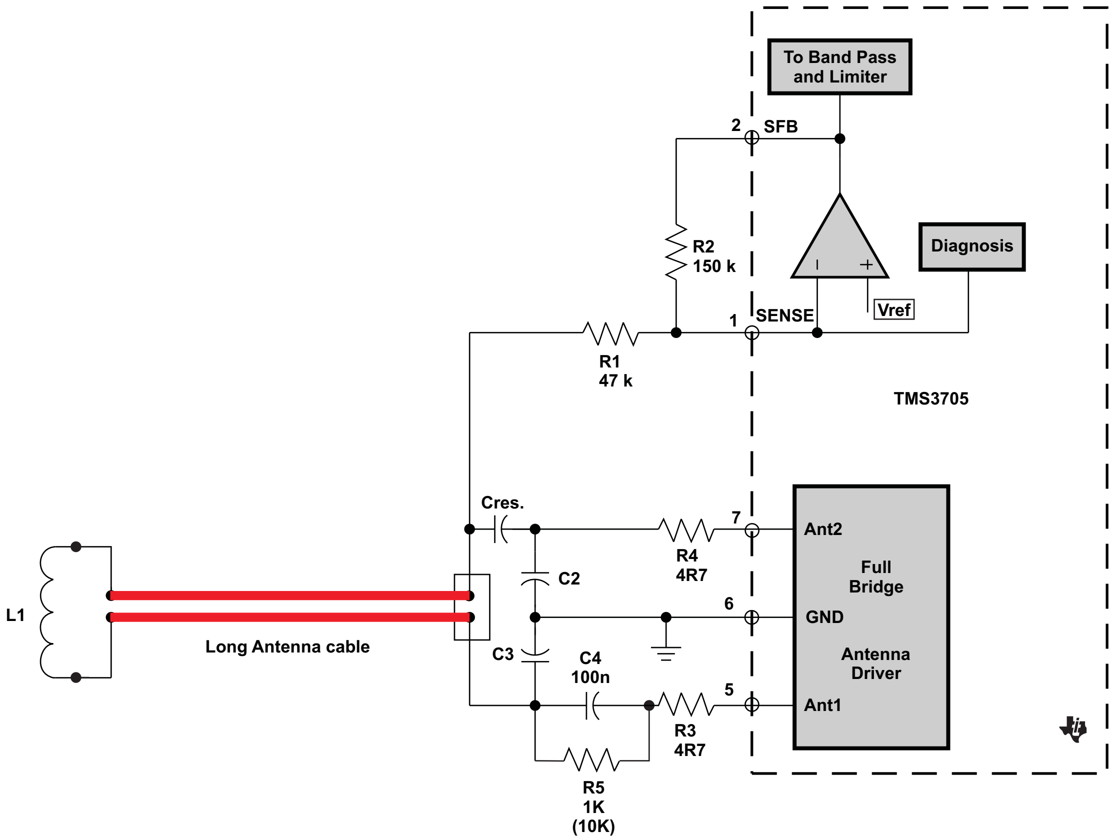

Figure 4. HDX RFID Reader Configuration With *Long* Antenna Cable

4.3 Reader Antenna

A typical immobilizer system is working with an air-coil antenna mounted around the mechanical lock cylinder. The final installation environment must always be considered in the antenna design to avoid any change of the resonance frequency.

The lock cylinder normally lowers the inductance as well as the Q-factor of the antenna coil.

For certain applications, a pre-detuning using a metal plate can avoid future massive de-tuning of the system in a moving environment.

4.4 Resonance Frequency and Component Calculation

The recommended inductance is in a range of 300 µH to 700 µH. The typical inductance used for an immobilizer system is 440 µH, which results in combination with a 3.3 nF capacitor in a resonance frequency of 132 kHz.

$$fres = \frac{1}{2\Pi\sqrt{L * C_{res}}}$$

Frequency	
L[mH]	0.44
Cres.[pf]	3300
Ccable[pf]	0
Cfix[pf]	3300
f[kHz]	132.08

For a remote antenna system with a variable cable length, an inductance in the range of 300 µH is recommended to minimize the resonance shift caused by varying the cable length.

4.5 Resonance Frequency and Q-Factor Consideration

The antenna resonance frequency is mainly determined by the antenna inductance and the fixed resonance capacitor. The antenna Q-factor is mainly determined by the frequency and all resistive loses of the antenna, typically, the DC resistance of the coil.

The inductive reactance is calculated with:

$$X_L = 2\Pi * f * L$$

Example using a typical inductance of 440 µH:

$$X_L = 2\Pi * 134.2\ kHz * 440\ \mu H$$
$$X_L = 371\,\Omega$$

The antenna quality factor is given with:

$$Q_L = \frac{X_L}{R_{DC}}$$

The resistor RDC should be measured at the resonance frequency in case magnetic or electric conductive material is located in the vicinity of the coil. RDC is the sum of resistive, eddy current, and hysteresis losses; the resistive losses are the sum of the copper resistance of the antenna. For high-Q antennas, litz-wire should be used to reduce the impact of the skin effect.

5 Recommended Antenna Parameter for *Long Cable* Systems

5.1 Antenna Inductance

To reduce the impact of the parasitic antenna cable capacitance of a *long* antenna cable system, it is recommended to lower the antenna inductance to about 300 µH.

Using a lower antenna inductance, a larger fixed capacitance value is required to keep the resonance frequency of the system almost constant. As a result of using a larger fixed capacitor value, the influence of the parasitic antenna cable capacitance is reduced.

The resonance frequency is calculated with:

$$fres = \frac{1}{2\Pi\sqrt{L * C_{res}}}$$

The total resonance capacitance is calculated with:

$$C_{res} = C_{fix} + C_{able};$$

Frequency;		
L[mH]	0.44	4.40E-04
Cres.[pF]	3300	3.3E-09
Ccable[pF]	0	
Cfix[pF]	3300	
f[kHz]	**132.08**	

Frequency;		
L[mH]	0.44	4.40E-04
Cres.[pF]	3540	3.54E-09
Ccable[pF]	240	
Cfix[pF]	3300	
f[kHz]	**127.52**	

Lant = 440 µH

Frequency;		
L[mH]	0.3	3.00E-04
Cres.[pF]	4850	4.85E-09
Ccable[pF]	0	
Cfix[pF]	4850	
f[kHz]	**131.94**	

Frequency;		
L[mH]	0.3	3.00E-04
Cres.[pF]	5090	5.09E-09
Ccable[pF]	240	
Cfix[pF]	4850	
f[kHz]	**128.80**	

Lant = 300 µH

5.2 Antenna Cable Options

Figure 5 shows the following cable types that have been tested.

The capacitance of the cable is determined by the mechanical construction of the cable and its dielectric. Depending of the cable type and length, the antenna inductances may need to be recalculated; it is recommended to use a twisted pair in order to minimize unwanted radiations. see Section 5.1.

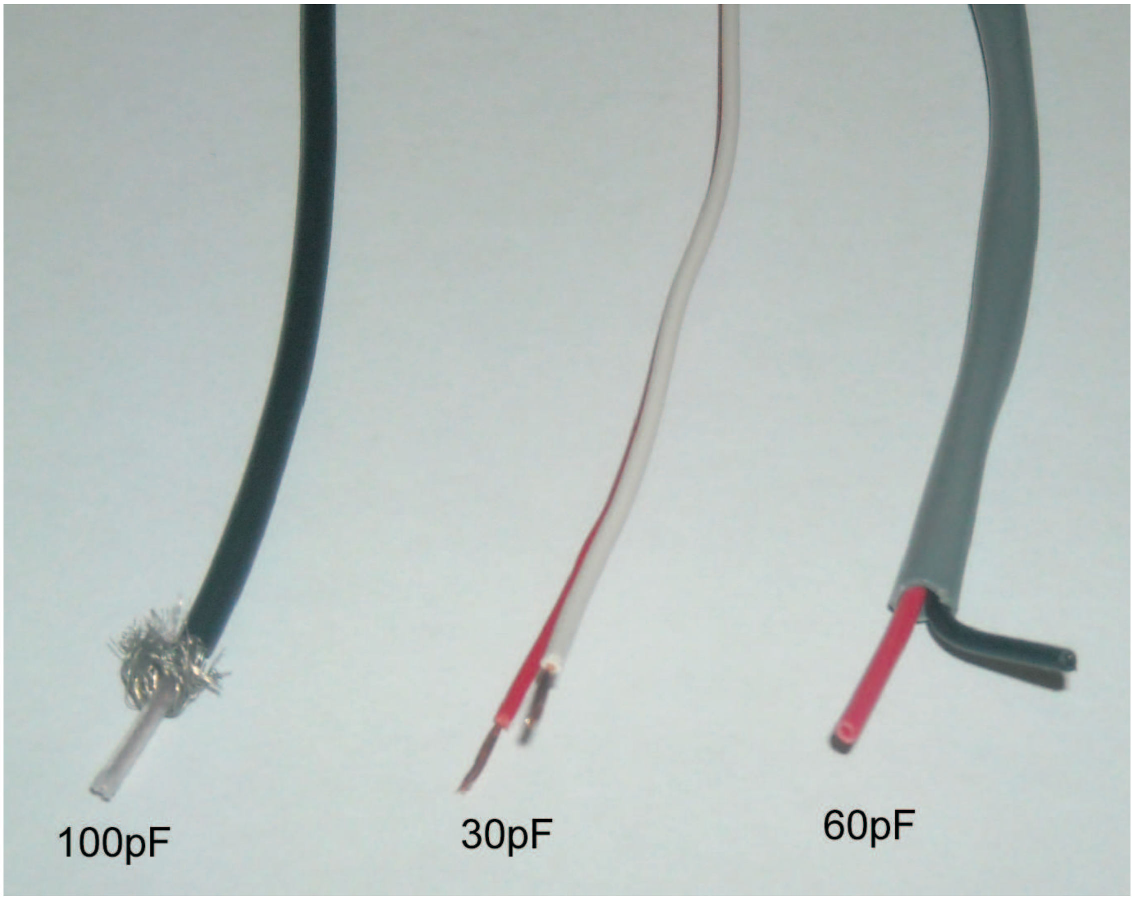

Figure 5. Antenna Cable Types

$$C = \Sigma_r \Sigma_0 \,.\, \frac{A}{d}$$

5.3 Simulation

A simulation with a cable capacitance of 60 pF/meter is shown in Figure 6.

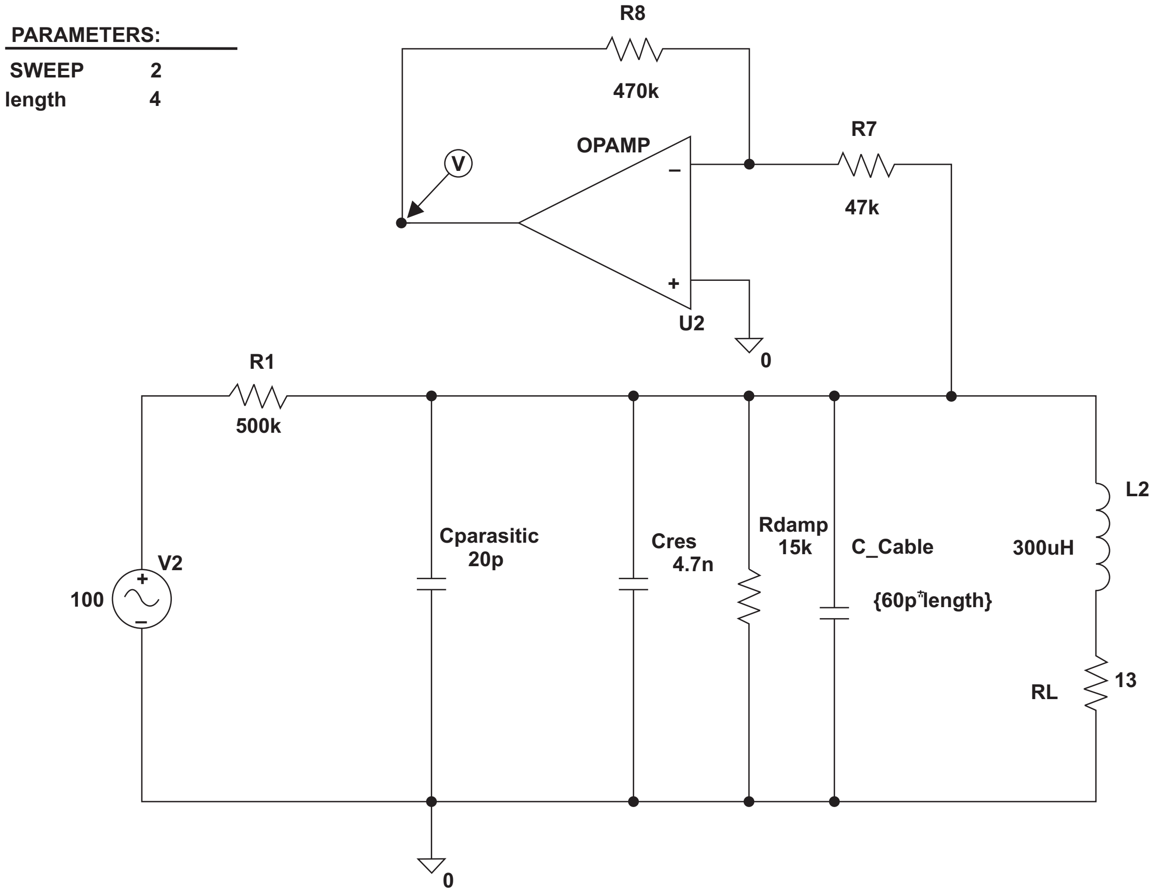

Figure 6. Schematic Used for *Long Cable* Simulation

The reader antenna forms a resonance circuit with the tuning capacitors. It is important to notice that the reader operates in series resonance during transmit (*Charge&DownLink*). In receive mode (*Uplink*), the reader forms a parallel resonance circuitry with the tuning capacitor and the antenna. In receive mode (*parallel resonance*) the Q-factor of the antenna resonance circuit is slightly higher.

Therefore, the simulation was done using a parallel resonance circuitry model.

Figure 7 shows that there is no significant shift of the resonance frequency.

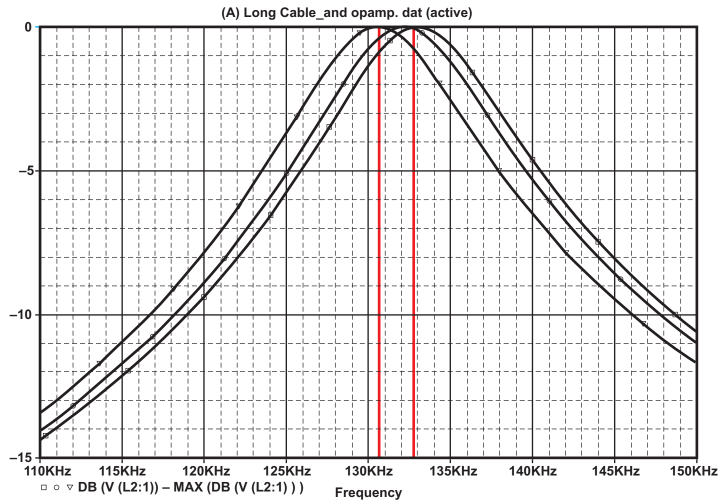

Figure 7. Simulation Result - Frequency Shift Due to *Long* Antenna Cable

6 Schematic for a *Long* Cable Reader System

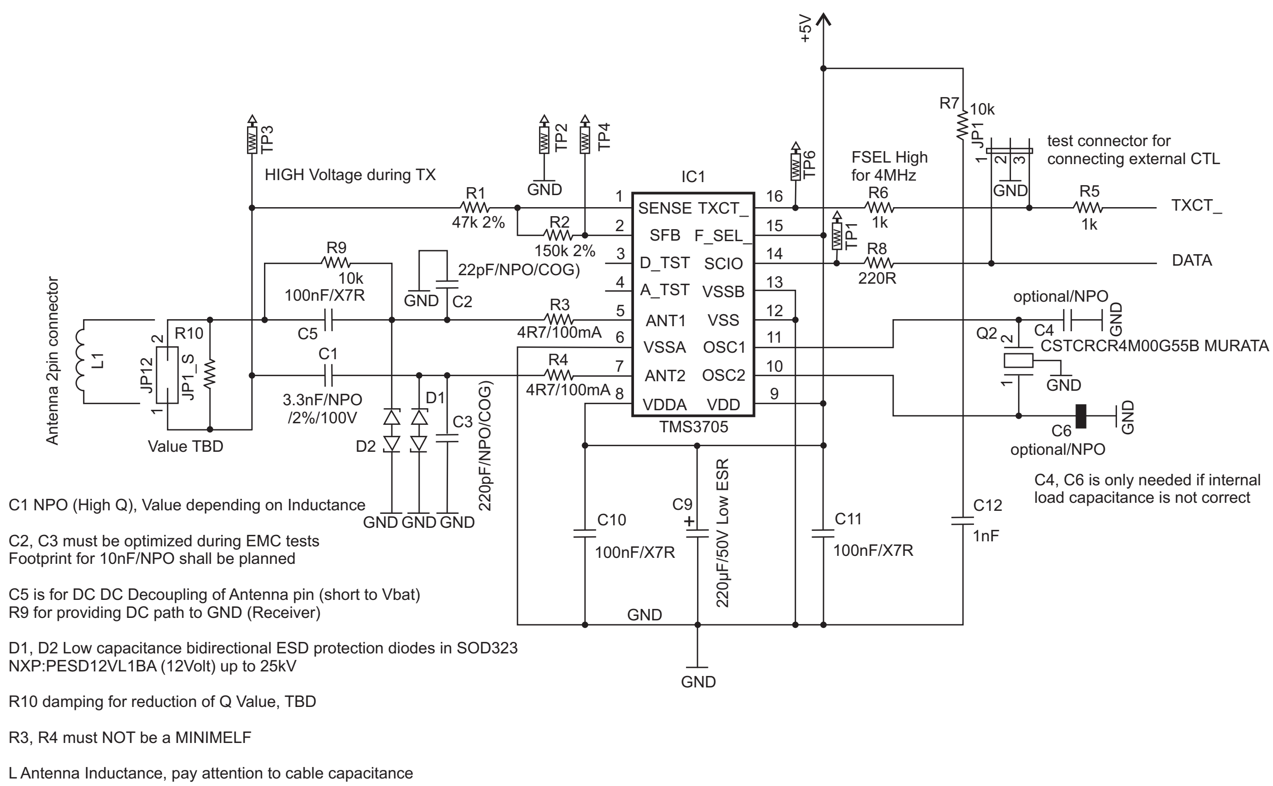

Figure 8. HDX RFID Reader Schematic

6.1 Low-Pass Filter

The two 4.7Ω resistors (R3, R4) in series to antenna output (Ant1, Ant2) in combination with the two capacitors (C2, C3) to GND are forming a low-pass filter to suppress unwanted harmonics at higher frequencies.

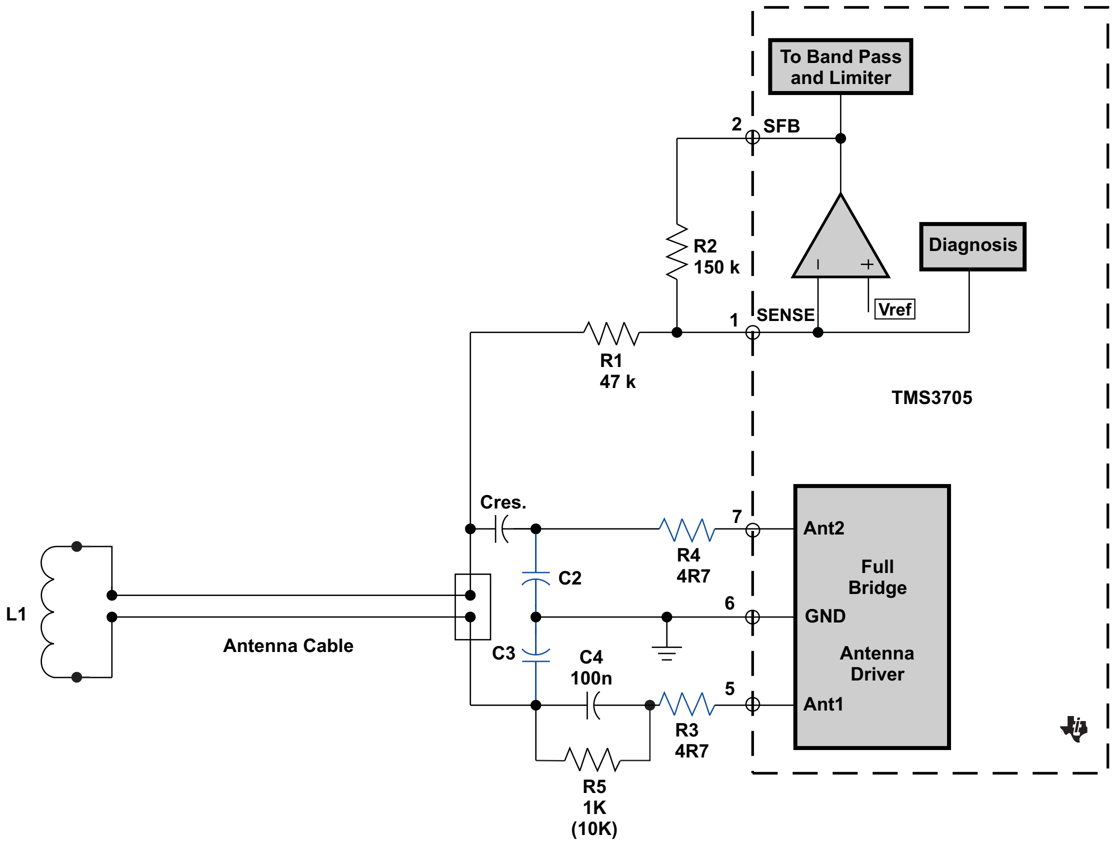

Figure 9. HDX RFID Reader – Schematic Low-Pass Filter

Depending on the cable type, the value of C2 and C3 has to be adapted to minimize unwanted emissions. It is important that C2 and C3 are NPO(COG) capacitor types.

The low pass cut-off frequency (R4/C2 and R3/C3) can be calculated as follows:

$$fc = \frac{1}{2\Pi * R * C}$$

6.2 Fault Protection – Shorts Against Vbat

The TMS3705 is internally protected against shorts to GND but not to Vbat. In a standard system where the antenna is combined with the immobilizer module, a short to Vbat is very unlikely.

If a long antenna cable is used, the probability for a short to Vbat is higher, especially if the antenna cable is fed in a cable harness together with other supply lines.

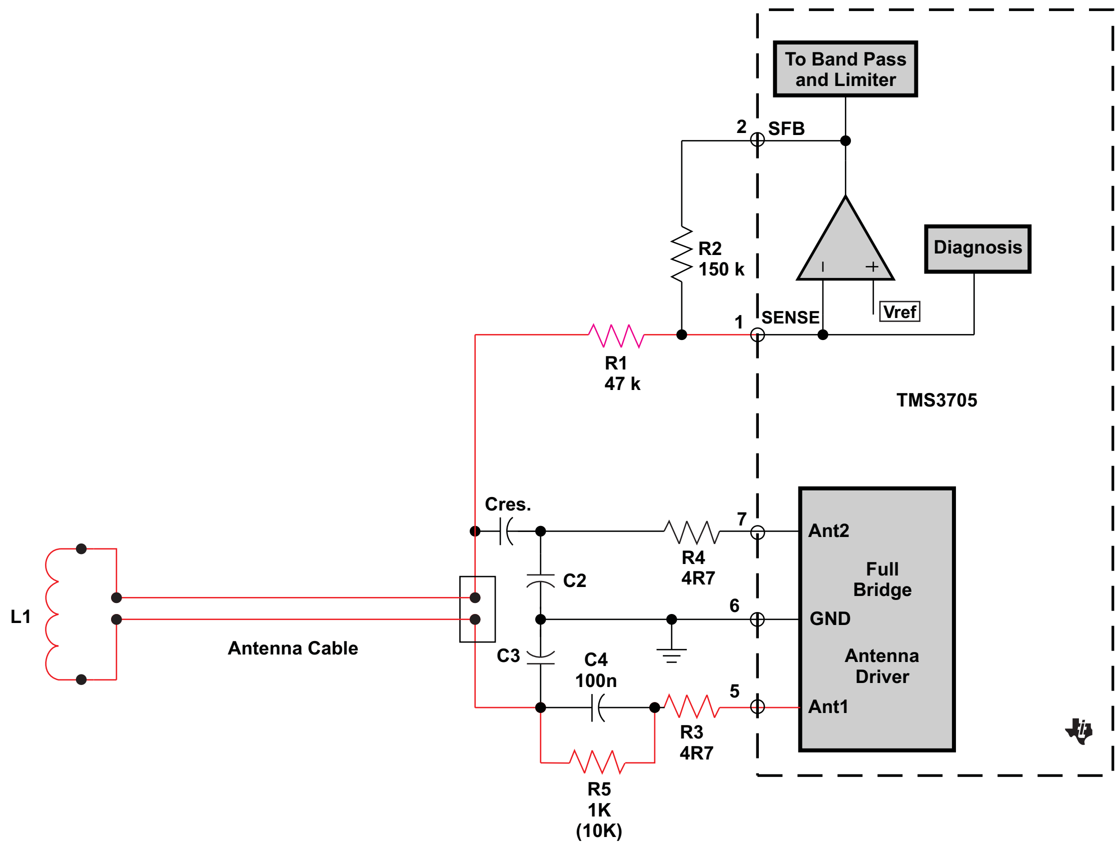

Figure 10. HDX RFID Reader Schematic – DC Path Highlighted

The IC internal FET of ANT1 provides the DC path to GND. To discharge any unwanted load on the antenna cable to GND (see red lines in Figure 10, a DC path to GND needs to be set up. This is done by adding R5 in parallel to C4.

6.3 Electrostatic Discharge (ESD) Protection

The ESD protection of the TMS3705x IC is ±2 kV according to the MIL STD 883. The complete reader circuitry (module) normally needs a higher ESD immunity.

In a passive cable system where the TMS3705x is integrated in a centralized control module, the two antenna connections for the long cable are most critical.

To prevent a potential ESD damage, two bi-directional protection diodes are added. They improve the ESD immunity up to 25 kV.

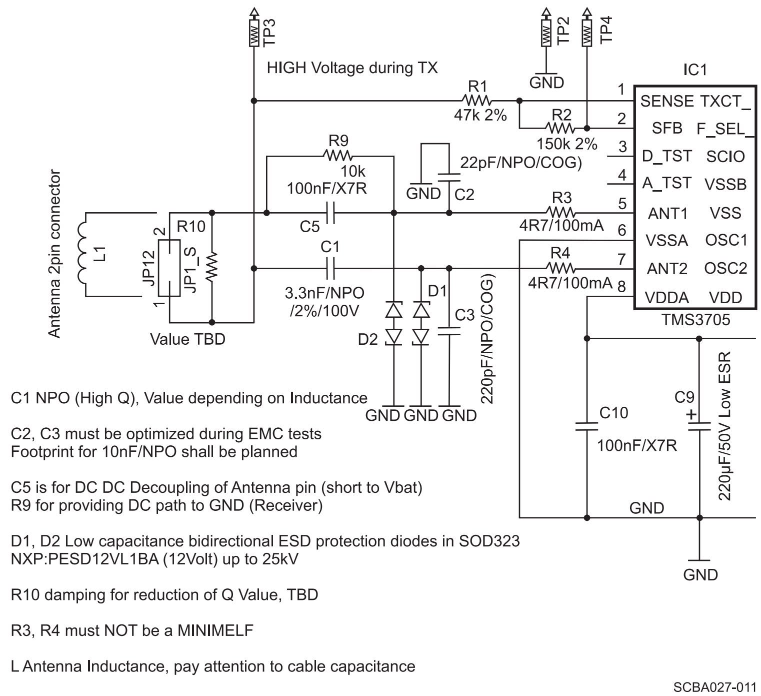

Figure 11. HDX RFID Reader Schematic – ESD Protection Diodes

7 References

- *TMS3705 Transponder Base Station IC Datasheet* (SCBS881)