Application Report

SCBA029–July 2010

LF HDX System Parameter Calculation for TMS37157 (PaLFI)

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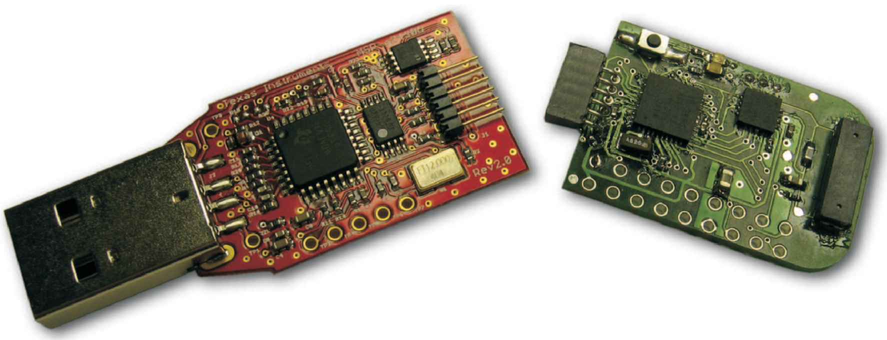
ABSTRACT

The Texas Instruments low frequency half-duplex (HDX) transponder technology allows the possibility to improve the communication distance between the transponder and reader. This application report provides information for the calculation of the basic system parameters.

The TMS37157 TI transponder IC is based on the TI HDX RFID concept. Using the given formulas, the performance and component parameters can be simulated and adjusted according to the application requirements.



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1 TMS37157 Dual Interface RFID IC

The TMS37157 TI RFID transponder IC passive low-frequency interface (PaLFI) is designed to work in the low-frequency band (134.2 kHz) and uses the HDX RFID communication protocol.

The IC provides a dual communication interface: one interface is used for the communication over the RF interface and one for the communication over the SPI interface.

The IC fully operates as a passive RFID transponder without any need for external power supply. For additional functionality, the IC can be directly connected to a MSP430 microcontroller via the SPI interface.

Depending on the system parameters and antennas used on both reader and tag side, the PaLFI can supply current derived from the magnetic field from the reader to the connected microcontroller over various distances.

This application report shows how to design the parameters to meet the system performance requirements (see Figure 1).

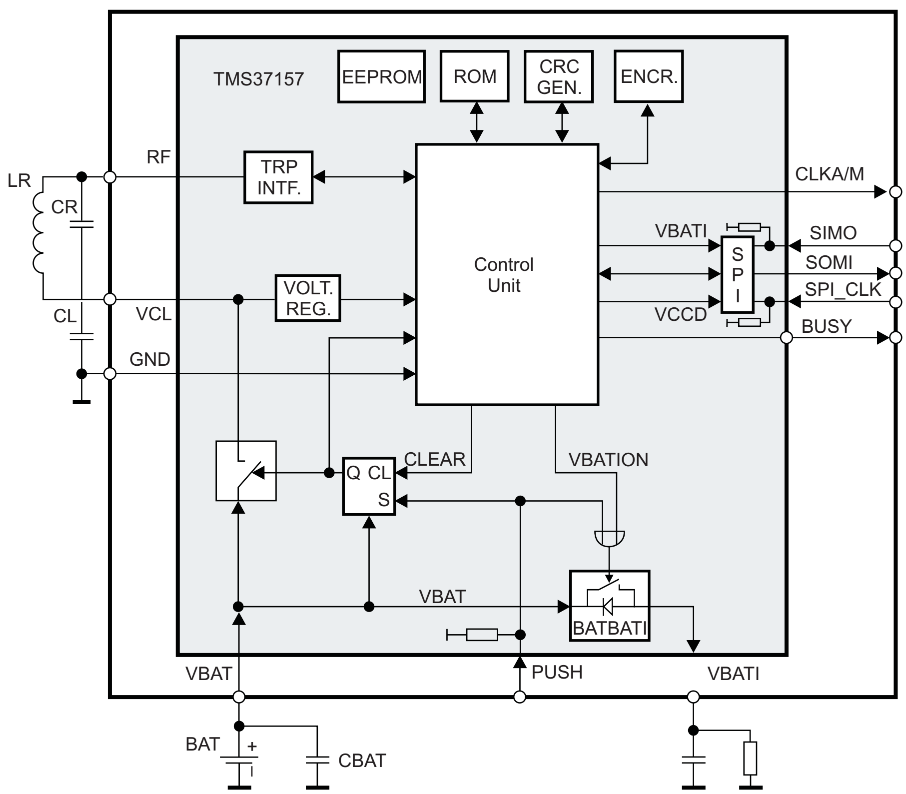

Figure 1. TMS37157 PaLFI Block Diagram

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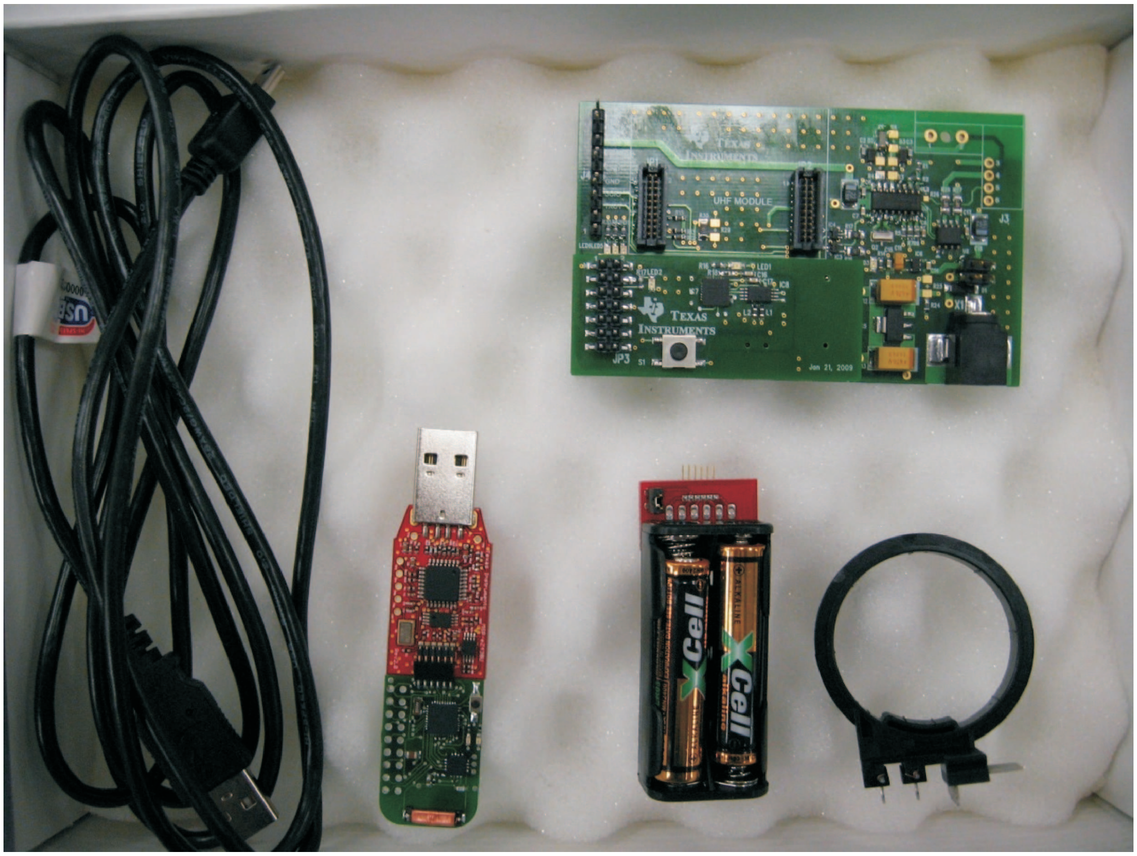

Figure 2. TMS37157 PaLFI EVM

Table 1. Abbreviations

Abbreviation	Description
Atrp	Transponder antenna area
CL	Charge capacitor
d	Distance from the reader antenna
dw	Transponder antenna wire diameter
fres	Transponder resonance frequency
ftx	Operating frequency (134.2 kHz)
H(d)	Reader field strength over distance
H	Reader field strength
ICL	Medium DC standby current of the IC during charge
Itx	Reader antenna current
k	Coupling factor between reader and transponder antenna
Ltrp	Transponder antenna Inductance
Ltx	Reader antenna inductance
Ntrp	Transponder antenna number of turns
Ntx	Reader antenna number of turns
Qant	Reader antenna quality factor
Qant'	Reader antenna total Q (including Rdms)
QRX	Antenna circuit quality factor during receive
Qtrp	Transponder antenna quality factor
QTX	Antenna circuit quality factor during transmit

Table 1. Abbreviations (continued)

Abbreviation	Description
Rant	Reader antenna resistance
Rant'	Reader antenna total resistance (including Rdms)
Rdmp	Parallel resistor to the antenna (damping)
Rdms	Serial resistor to the antenna (damping)
Ron	Driver on resistance
rtx	Medium radius of reader antenna ((A+B)/2)/2
rtrp	Medium radius of transponder antenna
Usup	Driver supply voltage
Utx	Reader antenna peak to peak voltage
VCL	Charge voltage
VCL_50	Charge voltage after 50 ms charge time

2 TMS37157 System Description

A typical RFID system consists basically of two main components:

- Reader
- Transponder

The right definition and design of the transponder and reader system parameters will provide the best possible system performance.

The TMS37157 operates as a typical RFID system, but offers additional functionality that can be executed using the MSP430 microcontroller connected directly to the PaLFI via the SPI interface.

A typical application can be seen in Figure 3.

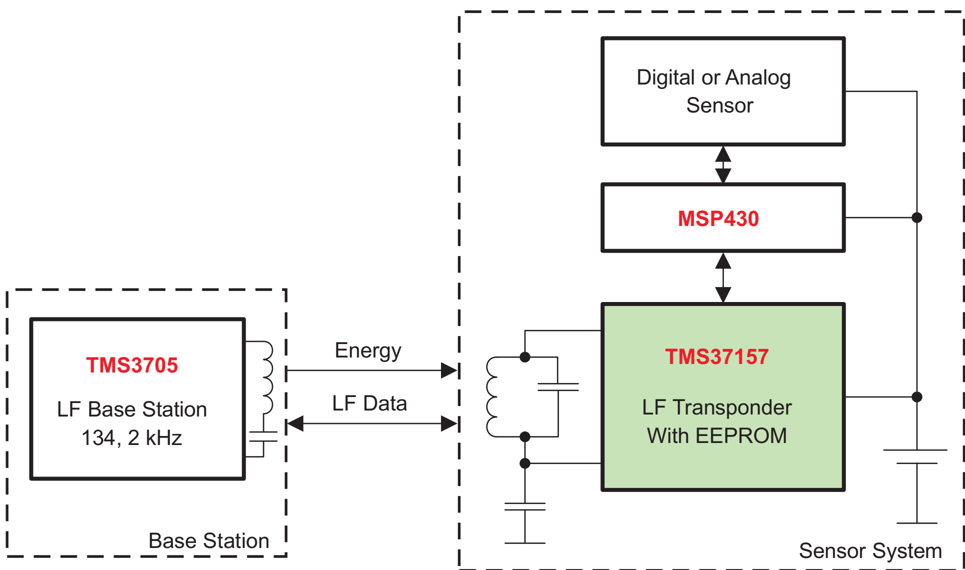

Figure 3. TMS37157 PaLFI Application Example

2.1 RFID Reader

2.1.1 Reader Field Strength

The typically reader (demo reader) using the ASIC TMS3705A [2] uses a circular air coil antenna with the following typical parameter (see Table 2 and Figure 4):

Table 2. Parameter of Demo Reader Antenna

Parameter	Symbol	Value (typ)	Unit
Inner diameter of transmit antenna	A	36	mm
Outer diameter of transmit antenna	B	39	mm
Medium radius of transmit antenna ((A+B)/2)/2	rtx	0.01875	m
Inductance	Ltx	442	µH
Turns	Ntx	72	
Antenna quality factor	Qant	25	

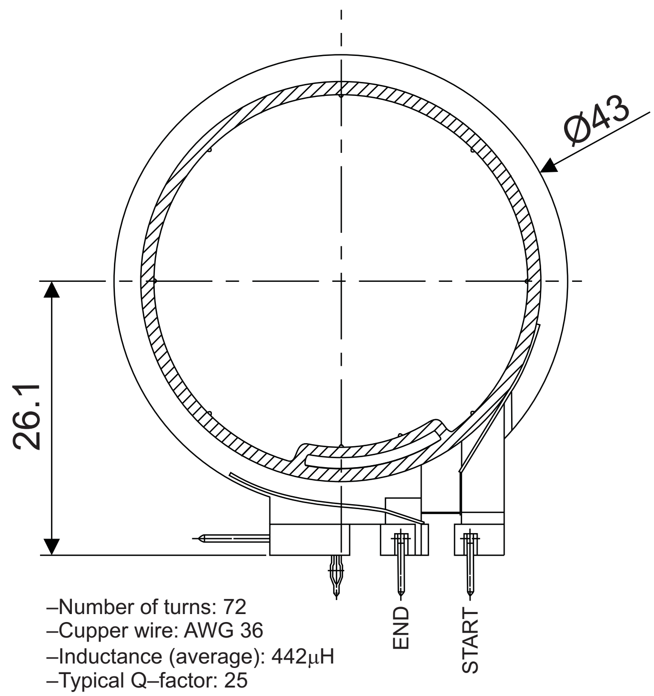

Figure 4. Demo Reader Antenna

2.1.2 Antenna Current and Voltage Calculation

The antenna current (Itx) needed for field strength calculation can be measured with either a current probe or be calculated after a measurement of antenna peak-to-peak voltage (Utx) and antenna quality factor (Qant):

$$Itx = \frac{1}{2 \cdot \pi \cdot ftx \cdot Ltx \cdot \left(\frac{1}{Qant} + 1\right)} \cdot \frac{Utx}{2 \cdot \sqrt{2}} = \frac{1}{(Rant + 2 \cdot \pi \cdot ftx \cdot Ltx)} \cdot \frac{Utx}{2 \cdot \sqrt{2}} \quad (1)$$

$$Rant = \frac{2 \cdot \pi \cdot ftx \cdot Lant}{Qant} \quad (2)$$

The maximum peak-to-peak antenna voltage Utx is:

$$Utx[Vpp] = Itx \cdot 2 \cdot \sqrt{2} \cdot \left(Rant + \left(2 \cdot \pi \cdot ftx \cdot Lant\right)\right) \quad (3)$$

2.1.3 Reader Field Strength Calculation

The field strength H generated by the reader in the distance d in case of a certain antenna current Itx, is calculated with the following formula:

$$H[d] = \frac{Ntx \cdot rtx^2 \cdot Itx}{2 \cdot \left(d^2 + rtx^2\right)^{1.5}} \quad (4)$$

$$H[dB\mu V/m] = 20 \cdot \log\left(H[A/m] \cdot 10^6\right) + 51.5 \quad (5)$$

Figure 5 shows a typical calculated and measured field strength over distance.

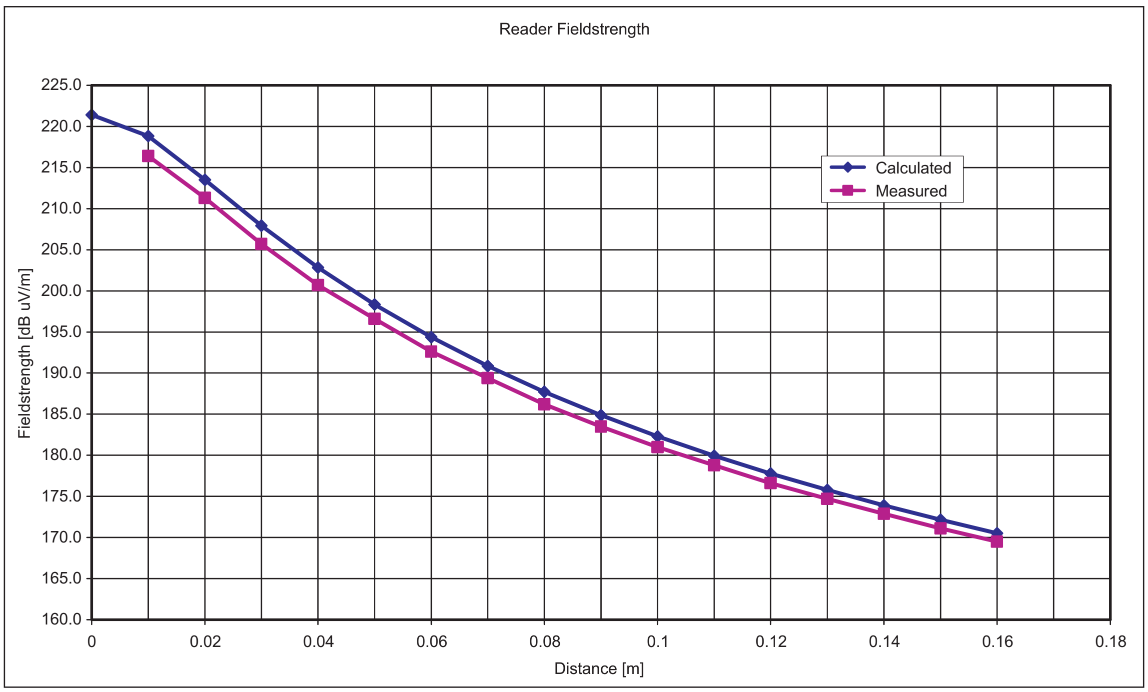

Figure 5. Calculated Reader Field Strength Over Distance

2.2 Transponder Parameter

2.2.1 Typical LF Transponder Antenna

A typical LF transponder antenna has the following typical parameter (see Table 3):

Table 3. Typical Parameter of a LF Transponder Antenna

Parameter	Symbol	Value (typ)	Unit
Magnetic field constant	µ0	$1.25664*10^{-6}$	Vs/Am
Height of transponder antenna	htrp	0.04	m
Width of transponder antenna	wtrp	0.07	m
Equivalent radius	rtrp	0.03	m
Area of loop	Atrp	2.827e-3	m^2
Inductance	Ltrp	2.66	mH
Typical transponder quality factor	Qtrp	35	
Turns	Ntrp	146	
Diameter of wire	dw	0.2	mm

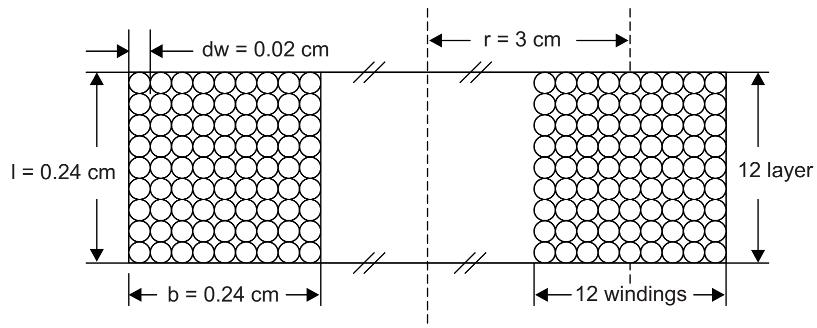

Figure 6. Transponder Antenna Dimension

Calculation of the resulting inductance of the antenna:

$$Ltrp[\mu H] = \frac{0.8 \cdot (rtrp \cdot Ntrp)^2}{(6 \cdot rtrp + 9 \cdot l + 10 \cdot b) \cdot 2.56} \quad (6)$$

Calculation of the number of windings if the antenna inductance is known:

$$Ntrp = \sqrt{\frac{Ltrp \cdot (6 \cdot rtrp + 9 \cdot l + 10 \cdot b) \cdot 2.56}{0.8 \cdot rtrp^2}} \quad (7)$$

2.3 Coupling Between Reader and Transponder

The coupling factor (k) over distance (d) between the reader and the transponder antenna is calculated by the following formula:

$$k = \frac{\mu 0 \cdot Ntx \cdot Ntrp \cdot rtx^2 \cdot Atrp}{2 \cdot \left(d^2 + rtx^2\right)^{1.5} \cdot \sqrt{Ltx \cdot Ltrp}} \quad (8)$$

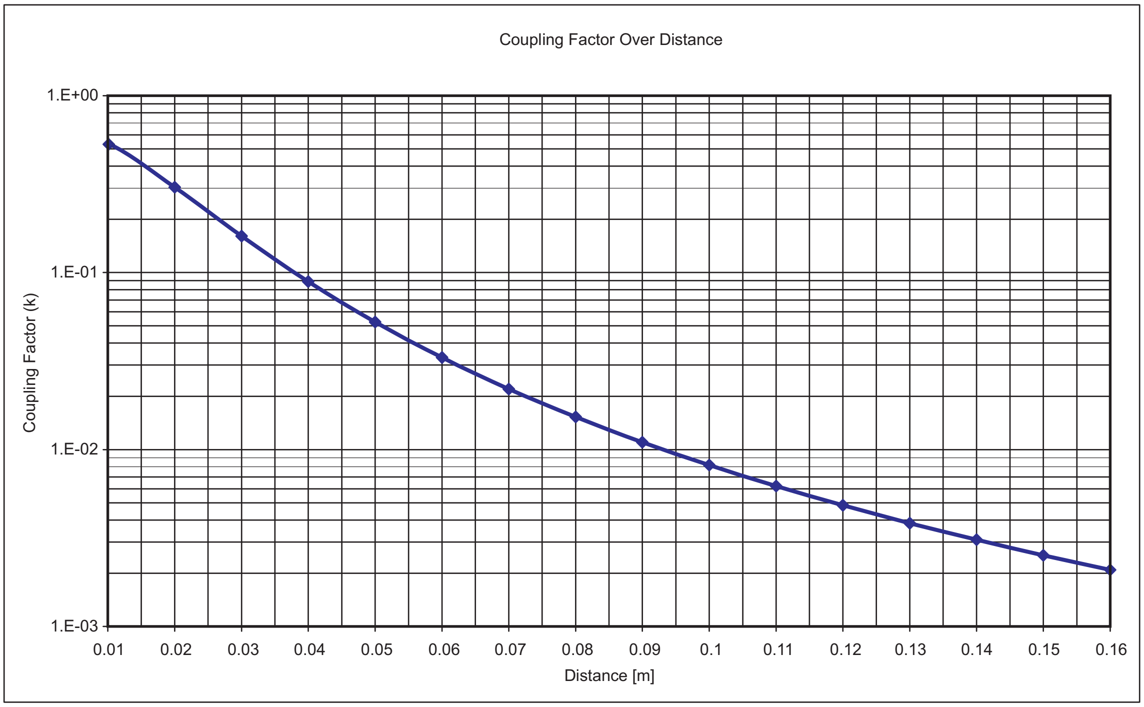

Figure 7. Coupling Factor Over Distance

2.4 Calculation and Simulation of Charge Voltage for HDX Systems

Figure 8 shows the simulation model for determination of charge voltage VCL.

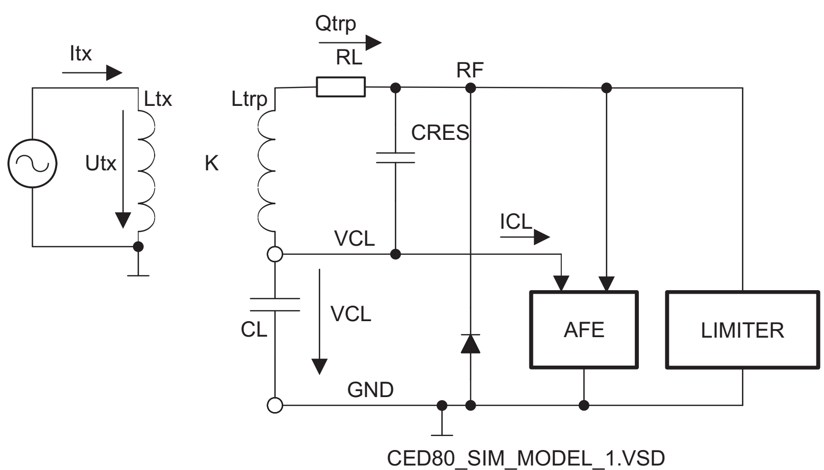

Figure 8. Simulation Model for Charge Voltage

The final charge voltage VCL can be calculated with the following formula:

$$VCL = \left(Itx \cdot k \cdot \sqrt{Ltx \cdot Ltrp} - ICL \cdot \sqrt{2} \cdot Ltrp\right) \cdot 2 \cdot \pi \cdot fres \cdot Qtrp \cdot \sqrt{2} + \frac{ICL}{Itx \cdot k \cdot \sqrt{2}} \cdot \sqrt{\frac{Ltrp}{Ltx}} - 0.5$$

$$\left(\text{Assuming}\ldots fres = ftx = 134.2\ kHz\right)$$

(9)

ICL is the medium DC standby current of the IC during charge and Qtrp is the total transponder quality factor, represented by RL in the simulation model:

$$Qtrp = \frac{2 \cdot \pi \cdot fRES \cdot Ltrp}{RL}$$

(10)

The charge voltage without limitation after 50 ms can be calculated by:

$$VCL\_50 = VCL \cdot \left(1 - e^{\frac{-0.05}{4 \cdot \pi \cdot fres \cdot Qtrp \cdot Ltrp \cdot CL}}\right)$$

(11)

For the chart shown in Figure 9, the parameters shown in Table 4 are assumed.

Table 4. Parameter for VCL Calculations

Parameter	Symbol	Value (typ)	Unit
Transponder Quality Factor	Qtrp	35	
Standby Current During Charge	ICL	5	µA
Charge Capacitor	CL+CBAT	100	µF

Figure 9 shows the typical charge voltage (limited) over distance for a 50 ms charge burst.

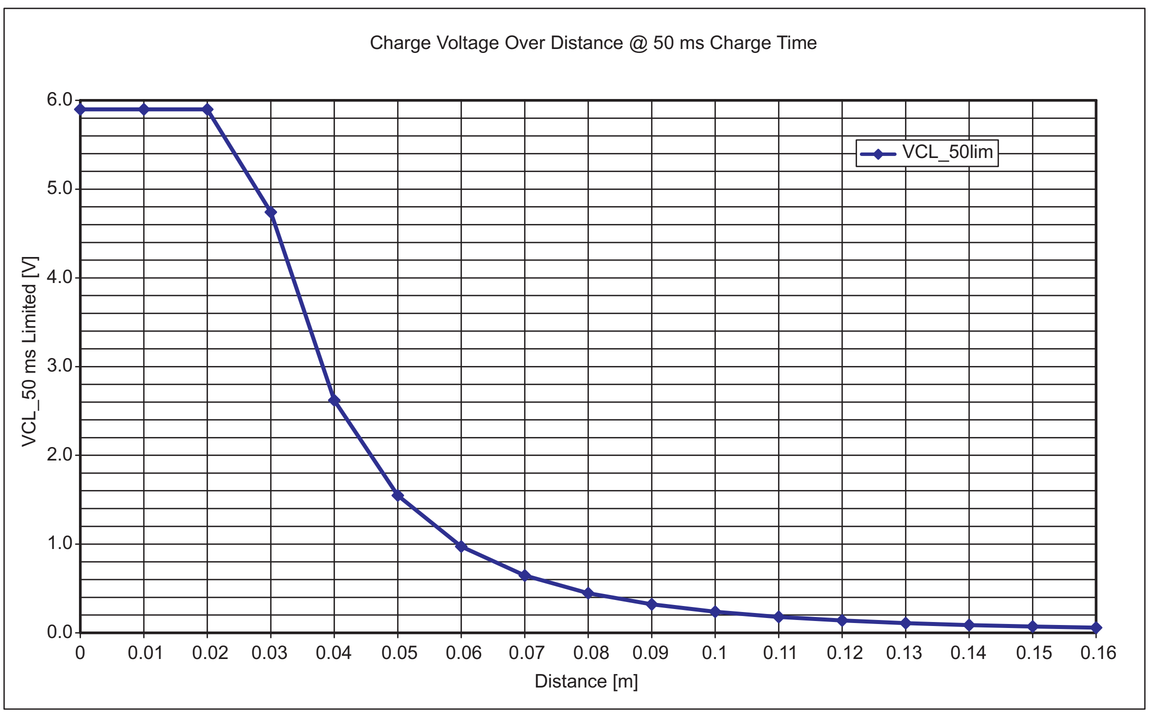

Figure 9. Typical Charge Voltage Over Distance

3 Reference

1. *TMS37157 Passive Low Frequency Interface Device With EEPROM and 134.2 kHz Transponder Interface Data Sheet* (SWRS083)
2. *TMS3705 Transponder Base Station IC Data Sheet* (SCBS881)
3. *UCC27423, UCC27424, UCC27425 Dual 4-A High Speed Low-Side MOSFET Drivers With Enable Data Sheet* (SLUS545)

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