AN650

Designing a Transponder Coil for the HCS410

Authors: Mike Sonnabend, Jan van Niekerk
Microchip Technology Inc.

OVERVIEW

This application note explains the design of transponder coils. An Excel spreadsheet is used to automate the update of values, depending on the specified parameters. The spreadsheet file name is `transpnd.xls`. A zip file containing this spreadsheet and a copy of this application note can be downloaded from Microchip's web site at *www.microchip.com*.

The basic approach is to choose the transponder coil external dimensions, since volume will usually be the primary constraint for a coil as it will need to fit into a keyfob, credit card or other small volume. Secondly, properties of the core, coil windings as well as the equivalent load placed across the coil are entered. This fixes the Initial Coil Specification.

Once the initial coil is built, measurements are made on this coil to determine the coil quality factor. These measurements are used to calculate the Optimum Coil Specification for a second coil.

The authors welcome feedback, comments, questions and errata via e-mail.
mike.sonnabend.@microchip.com
jan.van.niekerk@microchip.com

SPREADSHEET FEATURES

The spreadsheet is split into three worksheets. The first worksheet concerns the initial coil specification. The inputs to this worksheet are the:

- coil external dimensions
- core effective relative permeability
- wire resistivity
- coil-packing factor
- transponder resonant frequency
- equivalent load that the HCS410 presents to the resonant circuit.

The worksheet output gives the minimum number of turns that the coil is required to have. The number of turns together with coil dimensions fix the coil inductance, wire resistance, resonating capacitor and wire diameter.

The second worksheet enables the user to change the number of turns from what is suggested in the initial coil specification in order to use a standard value resonating capacitor.

The third worksheet requires a quality (Q) factor measurement to be made on the initial coil when it is optimally resonated. The two measured voltage values are the only inputs required to determine the number of turns for the optimal coil. Once again, the optimal number of turns together with the same coil dimensions fix the coil inductance, wire resistance, resonating capacitor and wire diameter. The second worksheet can also be used to change the number of turns from what is suggested in the Optimum Coil Specification in order to use a standard value resonating capacitor.

INTRODUCTION

Overview of Inductive Communication

Communication between a KEELOQ® transponder and a base station occurs via magnetic coupling between the transponder coil and base station coil. The base station coil forms part of a series Resistance Inductor Capacitor (RLC) circuit. The base station communicates to the transponder by switching the 125kHz signal to the series RLC circuit on and off. Thus, the base station magnetic field is switched on and off.

The transponder coil is connected in parallel with a resonating capacitor (125kHz) and a KEELOQ HCS410 transponder integrated circuit. When the transponder is brought into the base station magnetic field, it magnetically couples with this field and draws energy from it. This loading effect can be observed as a decrease in voltage across the base station resonating capacitor.

The KEELOQ transponder communicates to the base station by “shorting out” its parallel LC circuit. This detunes the transponder and removes the load, which is observed as an increase in voltage across the base station resonating capacitor. The base station capacitor voltage is the input to the base station AM-demodulator circuit. The demodulator extracts the transponder data for further processing by the base station software.

Using the Spread Sheet

Color Coding

The spreadsheet is color coded as shown in the table below.

Color	Meaning
Green	User input. The default values correspond to the HCS410 EV kit transponder coil.
Red	Output.
Gray	System defined.

Units

The units in the spreadsheet have been made SI units. Below is a table with some of the most common conversions that the user may come across.

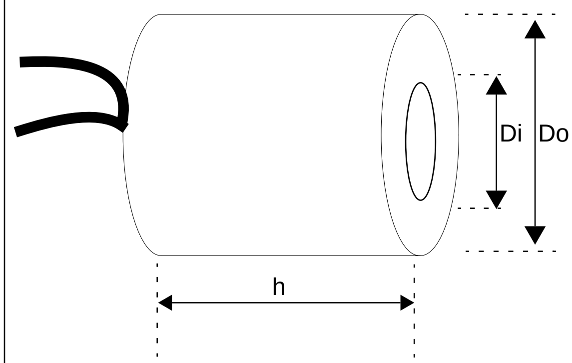
Conversion from:	Operation
Inches (in) to meters (m)	* .0254
Inches (in) to centimeters (cm)	* 2.54
Inches (in) to millimeters (m)	* 25.4
Centimeters (cm) to meters (m)	* 0.01
Millimeters (mm) to meters (m)	* 0.001
Farads (F) to pico farads (nF)	* 1e-9
Henry (H) to micro henry (μH)	* 1e-6

WORKSHEET 1: INITIAL COIL SPECIFICATION

Data Required

The first step is to decide on the dimensions that the coil should have. The dimensions required by the spreadsheet are shown in Figure 1 below.

FIGURE 1: COIL DIMENSIONS



Coil Dimensions			
Input	Units	Typ. Value	Description
h	mm	9	Height of coil along its axis.
Do	mm	2.3	Outside diameter of coil.
Di	mm	1.5	Inside diameter of coil. Also core outside diameter if core is used.

Ferrite Core Usage

The next step is to decide if a ferrite core (also called a ferrite slug) is going to be used or not. If an air core is used, then the relative permeability is 1.

There are advantages and disadvantages to using a ferrite core. The advantage is that the coil can have a larger inductance for a given volume. The disadvantage is that the effective permeability can be very sensitive to the core mechanical dimensions.

One method used to get the exact inductance for a coil wound onto a ferrite core is to have sets of samples built up, each with a different numbers of turns wound onto the cores. Measurements for these coils and interpolation will yield the correct number of turns for the ferrite core. Alternatively, some manufacturers will wind the coil onto the ferrite core to a specified inductance.

Ferrite core manufacturers usually publish curves of slug effective permeability vs. slug length divided by slug diameter. There is a large difference between the ferrite material permeability (typically 2300) and the effective permeability of a slug (typically 23). The effective permeability must be used in the spreadsheet.

Core Permeability			
Input	Units	Typ. Value	Description
μr		23.5	Effective relative permeability. This is the ratio of magnetic field strength inside the coil with the core in place, to the magnetic field strength if an air core replaces the core.

Wire Resistivity

The default values in the spreadsheet assume annealed copper wire. The wire resistivity need not be changed unless a different wire material is used. The packing factor can be left at 0.5 if the coil is tightly wound with wire that has a circular cross section.

Wire Resistivity			
Input	Units	Typ. Value	Description
ρ	ohm-m	1.72E-08	Coil wire resistivity at 20°C. Resistivity for annealed copper wire is used. If the coil uses another type of wire, then the corresponding resistivity would have to be used.
K		0.5	Packing factor. This compensates for copper area lost due to wire shape that is round and not square as well as wire insulation. If the coil is wound by hand, then the space factor of less than 0.5 may have to be chosen to compensate for wasted space.

Magnetic Field Operating Frequency

The magnetic field is generated by the base-station and the frequency is set at the base-station. The transponder coil operates at the same frequency and should match the base station magnetic field operating frequency i.e. 125kHz.

Field Operating Frequency			
Input	Units	Typ. Value	Description
F	kHz	125	Coil operating frequency (resonance).

HCS410 Load

The equivalent average load that the HCS410 presents to the transponder resonant circuit can change with the HCS410 configuration i.e. this value will be higher if auto damping is not selected. The average load is in the order of mega ohms when the HCS410 is battery powered.

The HCS410 pool capacitor will average out the resistance of the coil except during transponder to base communication and during auto damping when the HCS410 “shorts” out the coil.

One method to measure the average load is to use a DM303003 HCS410 Evaluation Kit with a transponder that is perfectly resonated. The base-station and transponder are to be programmed in the same way as for the final application. The transponder is placed in the field. The voltage is measured across the coil using a high impedance oscilloscope probe. The coil voltage and exact position of the coil is noted where the transponder just stops working.

The HCS410 is then replaced with a variable resistor. Keeping the coil in exactly the same position noted above, the variable resistor is adjusted until the voltage is exactly the same. This resistor value is the value to be used as equivalent HCS410 load. The value will be in the order of 100k ohm if no battery is used.

HCS410 Load			
Input	Units	Typ. Value	Description
R_P	Ω	60000	This is an equivalent average load that the HCS410 presents to the transponder coil.

Intermediate Calculations

The variables used to calculate the initial coil are given in the table below.

Initial Coil Specifications - Variables			
Input	**Units**	**Typical Value**	**Description**
ωr	rad/sec	785398.1634	Transmission frequency in radians per second.
A	sq. mm	36	Area for packing wire into.
R_{ONE}	ohms	5.70374E-5	Coil resistance of one turn which occupies the total volume.
L_{ONE}	Henry	7.36485E-9	Coil inductance of one turn which occupies the total volume.

Output Data

The output data for the initial coil matches the HCS410 equivalent load to the wire resistance and results in minimum number of turns.

Initial Coil Specifications - Output Data			
Input	**Units**	**Typical Value**	**Description**
N_{MIN}	Turns	319.8168897	This is the minimum number of turns that the coil should have to match the HCS410 local resistance.
L_{MIN}	µH	753.2980565	The minimum coil inductance, since inductance increases with number of turns.
R_{MIN}	Ω	5.833943331	Minimum wire resistance, since resistance increases with number of turns.
C_{MAX}	pF	2152.055119	This is the maximum capacitance for the resonating capacitor. The product of L_{MIN} and C_{MAX} is a constant determined from resonant frequency.
D_{MAX}	mm	0.084652661	This is the maximum wire diameter, as fitting more turns into a constant volume requires thinner wire to be used.

WORKSHEET 2: USER ENTERS NUMBER OF TURNS

Data Required

The number of turns as suggested for N_{MIN} or N_{OPT} can be entered as the number of turns. This number can be changed slightly until the output results are as desired i.e. to use a standard value resonating capacitor. Note that too large a change in N will result in a non-optimal coil.

User Enters Number of Turns			
Input	Units	Typ. Value	Description
N	Turns	350	The user is free to select a number of turns that the coil should have. This is useful in order to match the inductance to a standard value capacitor

Output Data

The worksheet output includes the resonating capacitor value which should be a standard value component.

User Enters Number of Turns			
Input	Units	Typical Value	Description
L	uH	902.194437	Coil inductance for number of turns entered by user.
R_{WIRE}	Ω	6.987076595	Wire resistance for number of turns entered by user.
C_{RES}	pF	1796.88421	Resonating capacitor to resonate coil with number of turns entered by user.
D_{WIRE}	mm	0.080920264	Wire diameter; choose closest available wire diameter.

WORKSHEET 3: QUALITY FACTOR MEASUREMENT

The coil shape factor M is obtained from measurements made on the initial coil design. This can only be done after the initial coil has been designed and built. This factor is calculated as follows:

1. Place the coil into the base-station magnetic field.
2. Resonate the coil with a capacitor placed in parallel with the coil, which is the same type (dissipation factor) as the capacitor which will be used with the optimally designed coil.
3. Measures the voltage (V_{CAP}) across the coil using a high impedance oscilloscope probe.
4. Disconnect the capacitor while keeping the resonant circuit in EXACTLY the same place with respect to the magnetic field.
5. Now measure the voltage (V_{NO_CAP}) across the coil using the high impedance oscilloscope probe.

Data Required

The two voltage measurements from the quality factor measurement are the only data required.

Q Factor Measurement			
Input	Units	Typ. Value	Description
V_{CAP}	V	46.25	Voltage across the initial coil plus capacitor when the coil is resonant.
V_{NO_CAP}	V	20.94	Voltage across initial coil with capacitor disconnected and coil kept in exactly the same place.

Intermediate Calculations

The coil shape factor M is found from Q factor measurements on the first coil design. It can subsequently be used for optimization of further coil designs while keeping coil dimensions constant.

Field			
Input	**Units**	**Typical Value**	**Description**
Q		22.086915	Quality factor calculated from V_{CAP}/V_{NO_CAP}
M		3.591551527	This is a proportionality factor between the internal resistance of the coil observed in Q factor measurements and the DC resistance of the coil wire as measured with a multimeter. This factor is dependent on the coil's physical geometry and thus called the "shape factor" M in this application note.
R_{INT}	Ω	0.000204853	Internal resistance for one turn.

Output Data

The Optimum Resonant Circuit Specification is derived for the case where the shape factor has been calculated from Q-factor measurements made on the initial coil design. The number of turns will always be greater than for the initial coil

Optimum Coil Specification			
Input	**Units**	**Typical Value**	**Description**
N_{OPT}	Turns	6.85.3006229	Optimum number of turns that the coil should have once shape factor M is known.
L_{OPT}	uH	3458.806841	Coil inductance for optimum number of turns.
R_{OPT}	Ohm	26.78685141	Wire resistance for optimum number of turns.
C_{OPT}	pF	468.6988932	Resonating capacitor to resonate coil with optimum number of turns.
D_{OPT}	mm	0.057829675	Optimum wire diameter; choose closest available wire diameter.

APPENDIX A: FORMULAS USED IN THE SPREADSHEET

This appendix gives the formulas used in the spreadsheet. All values use metric units.

For a frequency f in Hertz, the radians per second frequency is given by:

$$\omega_r = 2\pi f$$

Area A for packing wire is determined from coil outside diameter Do, coil inside diameter Di and coil axial length h as:

$$A = \frac{(Do - Di)}{2} \times h$$

R_{ONE} is the wire resistance of one turn of wire that has resistivity ρ and occupies total available volume adjusted by packing factor K:

$$R_{ONE} = \rho\pi\frac{(Do + Di)}{2AK}$$

L_{ONE} the inductance for one turn of wire that occupies the total available volume, wound onto a core of relative permeability μr is given by:

$$L_{ONE} = \frac{\mu_r (Do + Di)^2}{127000(26Do + 36h - 14Di)}$$

Minimum number of turns N_{MIN}, for a load with equivalent resistance R_P connected in parallel across the parallel resonant circuit is given by:

$$N_{MIN} = \frac{\sqrt{R_P\ R_{ONE}}}{\omega_r\ L_{ONE}}$$

The coil inductance for N turns is given by:

$$L = L_{ONE}\ N^2$$

The reason for the factor N squared comes from the empirical formula given in reference [1].

Similarly the resistance of the coil wire R_{WIRE} is given by:

$$R_{WIRE} = R_{ONE}\ N^2$$

The reason for the factor N squared and not just N is that for a constant coil volume, increasing N from 1 turn to N turns increases the resistance as follows:

- Resistance increases by a factor of N due to coil length increasing N times
- Resistance also increases by a further factor of N due to the wire cross sectional area being reduced by a factor of N due to the constant area for the conductors to fit into.

The resonant capacitor C is given by the formula:

$$C = \frac{1}{\omega_r^2\ L}$$

The wire diameter D_{WIRE} is given by the formula:

$$D_{WIRE} = 2\sqrt{\frac{AK}{\pi N}}$$

The closest available wire diameter is chosen to wind the coil with.

With coil quality factor measurement giving the voltage V_{CAP} across the coil when it is perfectly resonated with a resonating capacitor, and V_{NO_CAP} when the capacitor is disconnected, the coil quality factor Q is calculated as:

$$Q = \frac{V_{CAP}}{V_{NO\_CAP}}$$

The transponder resonant circuit consists of a coil connected in parallel with a capacitor. The quality factor of this resonant circuit Q is defined as:

$$Q = \frac{\omega L}{R_{TOTAL}}$$

Appendix B; Nature of the internal resistance "R_{INT}" shows that the internal flux resistance for one turn of wire R_{INT} it is related to the wire resistance for one turn of wire R_{ONE} by the measured magnetic shape factor M:

$$R_{INT} = R_{ONE} M$$

and that the total coil resistance can be written as:

$$R_{TOTAL} = (R_{ONE} + R_{INT})N^2$$

Using the three equations above and coil inductance for N turns, the coil shape factor can be written as:

$$M = \frac{\omega\ L_{ONE}}{Q\ R_{ONE}} - 1$$

From Appendix E, the optimum number of turns N, for a load with equivalent resistance R_P connected in parallel across the parallel resonant circuit is given by:

$$N = \frac{\sqrt{R_P\ (R_{ONE} + R_{INT})}}{\omega_r\ L_{ONE}}$$

APPENDIX B: NATURE OF THE INTERNAL RESISTANCE RINT

Induced Electromotive Force

Faraday's law states that the induced electro motive force (EMF) E in a circuit is numerically equal to the rate of change of the flux Φ through it. Expanding this statement for a coil of N turns in which the flux Φ varies at the same rate through each turn gives the induced EMF as:

$$E = -N\frac{d\Phi}{dt}$$

If the coil has a core other than vacuum, then the magnetic flux is increased by a factor equal to the relative permeability μr:

$$E = -\mu_r N\frac{d\Phi}{dt}$$

Letting the magnetic flux be:

$$\Phi = \hat{\Phi}cos(\omega t)$$

gives:

$$E = \mu_r N\omega \hat{\Phi}sin(\omega t)$$

This voltage is the voltage across the coil when no resonating capacitor is used. Since no current flows through the coil, any resistances associated with the coil do not affect E.

Induced Current

If the coil is shorted out with a capacitor that resonates with the coil inductance at the magnetic field frequency, then induced current flows through the coil. The current in turn generates a magnetic field that opposes the magnetic field that creates it.

Using the Biot Savart law it can be shown that the magnetic flux produced by a coil is given by:

$$\Phi = k\ \mu_0\ \mu_r\ NI$$

where:

μ_0 is the permeability of vacuum.

μ_r is the relative permeability of the core.

N is the number of turns on the coil.

I is the RMS current flowing in the coil due to the base station magnetic field.

k is a factor based on the coil dimensions.

Φ is the flux through the coil due to the current I.

The flux is produced by the current is opposite in phase to base-station flux but proportional in magnitude.

The transponder circuit current is thus:

$$I = \frac{\Phi}{k\ \mu_0\ \mu_r\ N}$$

Transponder Resistance

The transponder coil internal resistance RFLUX due to magnetic flux considerations is thus:

$$R_{FLUX} \propto \frac{E}{I}$$

Substituting for E and I gives:

$$R_{FLUX} \propto k\ \mu_0\ \mu_r^2\ \omega\ N^2$$

It can be seen that RFLUX is independent of the magnetic flux Φ but it is proportional to the coil physical dimensions that determine k:

Using a proportionality factor P:

$$R_{FLUX} = P\ k\ \mu_0\ \mu_r^2\ \omega N^2$$

letting:

$$R_{INT} = P\ k\ \mu_0\ \mu_r^2\ \omega$$

then:

$$R_{FLUX} = R_{INT}\ N^2$$

The transponder coil wire resistance for a constant coil volume, is equal to:

$$R_{WIRE} = R_{ONE}\ N^2$$

where:

$$R_{ONE} = \rho\pi\frac{(Do+Di)}{2AK}$$

and:

ρ is the resistivity of coil wire material i.e. copper.

Do is the coil outside diameter.

Di is the coil inside diameter.

A is the total area for packing the wire into.

K is the packing factor i.e. fraction of coil cross section occupied by copper.

The nature of RFLUX is that it is proportional to N squared as is RWIRE. Thus RINT can be set proportional to RONE by using a factor of proportionality M. This will remain true regardless of the number of turns N and the magnetic flux Φ.

$$R_{INT} = MR_{ONE}$$

Thus the total resistance for the transponder can be written as:

$$R_{TOTAL} = R_{WIRE} + R_{FLUX}$$

Substituting for RWIRE and RFLUX:

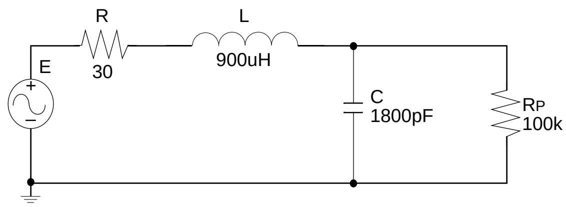
$$R_{TOTAL} = R_{ONE}\ N^2 + R_{INT}\ N^2$$

Substituting for RINT:

$$R_{TOTAL} = R_{ONE}\ N^2 + MR_{ONE}\ N^2$$

APPENDIX C: RESONANT FREQUENCY FOR TRANSPONDER

The equivalent circuit for a transponder is shown below.



E is a voltage source that represents the voltage induced in the coil due to the magnetic field.

R represents the total internal resistance of the coil.

L is the coil inductance.

C is the resonating capacitor capacitance.

Rp is the resistive load presented to the resonant circuit by the HCS410.

The resonant frequency for the above circuit will now be derived.

The impedance seen by E is

$$Z = R + i\times w\times L + \frac{R_P \dfrac{1}{i\times w\times C}}{R_P + \dfrac{1}{i\times w\times C}}$$

Manipulating this gives:

$$Z = \frac{(R\times R_P{}^2\times w^2\times C^2 + R + i\times w^3\times L\times R_P{}^2\times C^2 + i\times w\times L - i\times R_P{}^2\times w\times C + R_P)}{(R_p{}^2\times w^2\times C^2 + 1)}$$

At resonance, the impedance is purely resistive, which means that's the imaginary portion of the equation is zero. This gives frequency as:

$$\omega = \sqrt{\frac{1}{LC} + \frac{1}{R_P{}^2 C^2}}$$

It can be seen that the load affects the resonant frequency. If the load is taken off, then the resonant frequency is:

$$\omega = \frac{1}{\sqrt{LC}}$$

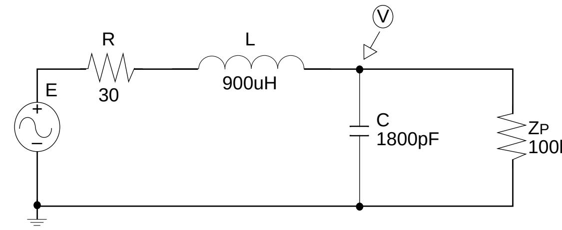
If the load resistance is decreased, the point at which the number inside the square root becomes negative causes the frequency to be imaginary and oscillation stops.

To calculate at which point the load lowers the resonant frequency by x%, using the equations above:

$$R_P = \frac{100}{\sqrt{x}\sqrt{200-x}}\sqrt{\frac{L}{C}}$$

APPENDIX D: MAXIMUM POWER TRANSFER

It is desirable to match resonant circuit to the load Zp for maximum power transfer.



The voltage across the load ZP is:

$$V = E\times\frac{\dfrac{Z_P\times\dfrac{1}{i\times w\times C}}{Z_P + \dfrac{1}{i\times w\times C}}}{R + i\times w\times L + \dfrac{Z_P\dfrac{1}{i\times w\times C}}{Z_P + \dfrac{1}{i\times w\times C}}}$$

This can be simplified to:

$$V = \frac{i\times Z_p\times E}{(R\times Z_P\times w\times C - i\times R + i\times w^2\times L\times Z_p\times C + w\times L - i\times Z_p)}$$

The power in the load ZP is given by:

$$P = \frac{V^2}{Z_P}$$

Substituting for V gives:

$$P = -Z_p\times\frac{E^2}{(R\times Z_P\times w\times C - i\times R + i\times w^2\times L\times Z_p\times C + w\times L - i\times Z_p)^2}$$

To find the maximum power transfer to the load ZP, the expression for power is differentiated with respect to ZP and set to zero. The roots of this equation will give value of ZP for maximum power transfer.

$$\frac{d}{dZ_P}P = 0$$

Solving for ZP gives:

$$Z_P = \frac{-(i\times R - w\times L)}{(R\times w\times C + i\times w^2\times L\times C - i))}$$

At resonance, assuming that ZP has a negligent effect on frequency:

$$\omega = \frac{1}{\sqrt{LC}}$$

which can be written as:

$$C = \frac{1}{L\omega^2}$$

Substituting for C into the optimum ZP equation gives:

$$Z_P = \frac{(-i\times R + w\times L)}{R}\times w\times L$$

The quality factor Q is defined as:

$$Q = \frac{\omega L}{R}$$

which can be re-written as:

$$R = \frac{\omega L}{Q}$$

Substituting this R into the equation for ZP gives:

$$Z_P = \omega L(Q - i)$$

This shows that for maximum power transfer, the load must have a capacitive reactance equal to (L and a resistance component equal to (LQ. Since the Q for a transponder is always going to be above 10, and since the HCS410 is modeled as a resistive load, maximum power transfer occurs when:

$$Z_P = \omega LQ$$

APPENDIX E: OPTIMUM NUMBER OF TURNS

Have already shown in “APPENDIX D: Maximum Power Transfer” that maximum power transfer occurs when:

$$Z_P = \omega LQ$$

Q is defined as:

$$Q = \frac{\omega L}{R}$$

Substituting for Q in ZP gives:

$$Z_P = \frac{\omega^2 L^2}{R}$$

“Appendix A: Formulas used in the spreadsheet” gives inductance as:

$$L = L_{ONE} N^2$$

“Appendix B: Nature of the Internal Resistance RINT” gives the total resistance in the transponder resonant circuit as:

$$R_{TOTAL} = R_{ONE} N^2 + R_{INT} N^2$$

Substituting the above two equations for L and R in ZP gives:

$$Z_P = \frac{\omega^2 L_{ONE}{}^2 N^4}{R_{ONE} N^2 + R_{INT} N^2}$$

Simplifying:

$$Z_P = \frac{\omega^2 L_{ONE}{}^2 N^2}{R_{ONE} + R_{INT}}$$

Solving for optimum number of turns N gives:

$$N = \frac{\sqrt{Z_P(R_{ONE} + R_{INT})}}{\omega L_{ONE}}$$

Note that RINT was defined as:

$$R_{INT} = MR_{ONE}$$

where M is the coil shape factor.

APPENDIX F: REFERENCES

1. Babani, B.B., ed. 1974. *Coil Design and Construction Manual.* London: Bernards (publishers) Limited.
2. Nelkon, M., & Parker, P. ed. 1970. *Advanced Level Physics.* London: Heinemann Educational Books Ltd.

NOTES:

Note the following details of the code protection feature on PICmicro® MCUs.

- The PICmicro family meets the specifications contained in the Microchip Data Sheet.
- Microchip believes that its family of PICmicro microcontrollers is one of the most secure products of its kind on the market today, when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods used to breach the code protection feature. All of these methods, to our knowledge, require using the PICmicro microcontroller in a manner outside the operating specifications contained in the data sheet. The person doing so may be engaged in theft of intellectual property.
- Microchip is willing to work with the customer who is concerned about the integrity of their code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of their code. Code protection does not mean that we are guaranteeing the product as “unbreakable”.
- Code protection is constantly evolving. We at Microchip are committed to continuously improving the code protection features of our product.

If you have any further questions about this matter, please contact the local sales office nearest to you.

DNV Certification, Inc. USA
DNV MSC The Netherlands Accredited by the RvA
ISO 9001 / QS-9000 REGISTERED FIRM

Microchip received QS-9000 quality system certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona in July 1999. The Company’s quality system processes and procedures are QS-9000 compliant for its PICmicro® 8-bit MCUs, KEELOQ® code hopping devices, Serial EEPROMs and microperipheral products. In addition, Microchip’s quality system for the design and manufacture of development systems is ISO 9001 certified.

MICROCHIP

WORLDWIDE SALES AND SERVICE

AMERICAS

Corporate Office
2355 West Chandler Blvd.
Chandler, AZ 85224-6199
Tel: 480-792-7200 Fax: 480-792-7277
Technical Support: 480-792-7627
Web Address: http://www.microchip.com

Rocky Mountain
2355 West Chandler Blvd.
Chandler, AZ 85224-6199
Tel: 480-792-7966 Fax: 480-792-7456

Atlanta
500 Sugar Mill Road, Suite 200B
Atlanta, GA 30350
Tel: 770-640-0034 Fax: 770-640-0307

Boston
2 Lan Drive, Suite 120
Westford, MA 01886
Tel: 978-692-3848 Fax: 978-692-3821

Chicago
333 Pierce Road, Suite 180
Itasca, IL 60143
Tel: 630-285-0071 Fax: 630-285-0075

Dallas
4570 Westgrove Drive, Suite 160
Addison, TX 75001
Tel: 972-818-7423 Fax: 972-818-2924

Detroit
Tri-Atria Office Building
32255 Northwestern Highway, Suite 190
Farmington Hills, MI 48334
Tel: 248-538-2250 Fax: 248-538-2260

Kokomo
2767 S. Albright Road
Kokomo, Indiana 46902
Tel: 765-864-8360 Fax: 765-864-8387

Los Angeles
18201 Von Karman, Suite 1090
Irvine, CA 92612
Tel: 949-263-1888 Fax: 949-263-1338

New York
150 Motor Parkway, Suite 202
Hauppauge, NY 11788
Tel: 631-273-5305 Fax: 631-273-5335

San Jose
Microchip Technology Inc.
2107 North First Street, Suite 590
San Jose, CA 95131
Tel: 408-436-7950 Fax: 408-436-7955

Toronto
6285 Northam Drive, Suite 108
Mississauga, Ontario L4V 1X5, Canada
Tel: 905-673-0699 Fax: 905-673-6509

ASIA/PACIFIC

Australia
Microchip Technology Australia Pty Ltd
Suite 22, 41 Rawson Street
Epping 2121, NSW
Australia
Tel: 61-2-9868-6733 Fax: 61-2-9868-6755

China - Beijing
Microchip Technology Consulting (Shanghai) Co., Ltd., Beijing Liaison Office
Unit 915
Bei Hai Wan Tai Bldg.
No. 6 Chaoyangmen Beidajie
Beijing, 100027, No. China
Tel: 86-10-85282100 Fax: 86-10-85282104

China - Chengdu
Microchip Technology Consulting (Shanghai) Co., Ltd., Chengdu Liaison Office
Rm. 2401, 24th Floor,
Ming Xing Financial Tower
No. 88 TIDU Street
Chengdu 610016, China
Tel: 86-28-6766200 Fax: 86-28-6766599

China - Fuzhou
Microchip Technology Consulting (Shanghai) Co., Ltd., Fuzhou Liaison Office
Unit 28F, World Trade Plaza
No. 71 Wusi Road
Fuzhou 350001, China
Tel: 86-591-7503506 Fax: 86-591-7503521

China - Shanghai
Microchip Technology Consulting (Shanghai) Co., Ltd.
Room 701, Bldg. B
Far East International Plaza
No. 317 Xian Xia Road
Shanghai, 200051
Tel: 86-21-6275-5700 Fax: 86-21-6275-5060

China - Shenzhen
Microchip Technology Consulting (Shanghai) Co., Ltd., Shenzhen Liaison Office
Rm. 1315, 13/F, Shenzhen Kerry Centre,
Renminnan Lu
Shenzhen 518001, China
Tel: 86-755-2350361 Fax: 86-755-2366086

Hong Kong
Microchip Technology Hongkong Ltd.
Unit 901-6, Tower 2, Metroplaza
223 Hing Fong Road
Kwai Fong, N.T., Hong Kong
Tel: 852-2401-1200 Fax: 852-2401-3431

India
Microchip Technology Inc.
India Liaison Office
Divyasree Chambers
1 Floor, Wing A (A3/A4)
No. 11, O'Shaugnessey Road
Bangalore, 560 025, India
Tel: 91-80-2290061 Fax: 91-80-2290062

Japan
Microchip Technology Japan K.K.
Benex S-1 6F
3-18-20, Shinyokohama
Kohoku-Ku, Yokohama-shi
Kanagawa, 222-0033, Japan
Tel: 81-45-471- 6166 Fax: 81-45-471-6122

Korea
Microchip Technology Korea
168-1, Youngbo Bldg. 3 Floor
Samsung-Dong, Kangnam-Ku
Seoul, Korea 135-882
Tel: 82-2-554-7200 Fax: 82-2-558-5934

Singapore
Microchip Technology Singapore Pte Ltd.
200 Middle Road
#07-02 Prime Centre
Singapore, 188980
Tel: 65-334-8870 Fax: 65-334-8850

Taiwan
Microchip Technology Taiwan
11F-3, No. 207
Tung Hua North Road
Taipei, 105, Taiwan
Tel: 886-2-2717-7175 Fax: 886-2-2545-0139

EUROPE

Denmark
Microchip Technology Nordic ApS
Regus Business Centre
Lautrup hoj 1-3
Ballerup DK-2750 Denmark
Tel: 45 4420 9895 Fax: 45 4420 9910

France
Microchip Technology SARL
Parc d'Activite du Moulin de Massy
43 Rue du Saule Trapu
Batiment A - ler Etage
91300 Massy, France
Tel: 33-1-69-53-63-20 Fax: 33-1-69-30-90-79

Germany
Microchip Technology GmbH
Gustav-Heinemann Ring 125
D-81739 Munich, Germany
Tel: 49-89-627-144 0 Fax: 49-89-627-144-44

Italy
Microchip Technology SRL
Centro Direzionale Colleoni
Palazzo Taurus 1 V. Le Colleoni 1
20041 Agrate Brianza
Milan, Italy
Tel: 39-039-65791-1 Fax: 39-039-6899883

United Kingdom
Arizona Microchip Technology Ltd.
505 Eskdale Road
Winnersh Triangle
Wokingham
Berkshire, England RG41 5TU
Tel: 44 118 921 5869 Fax: 44-118 921-5820

01/18/02