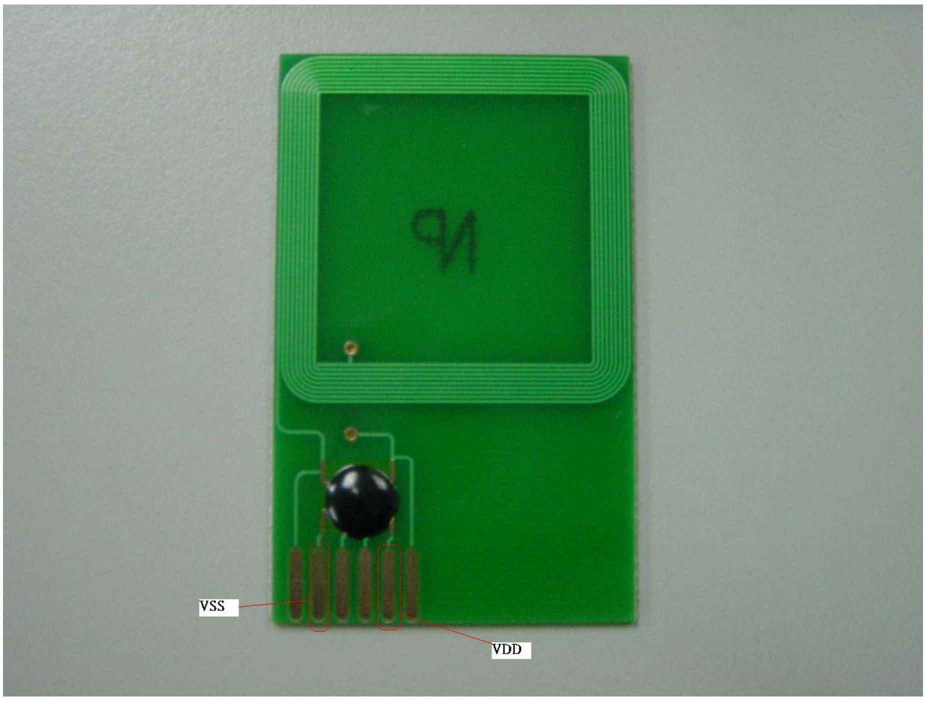
Introduction How to Use RFID

D/N: HA0090E

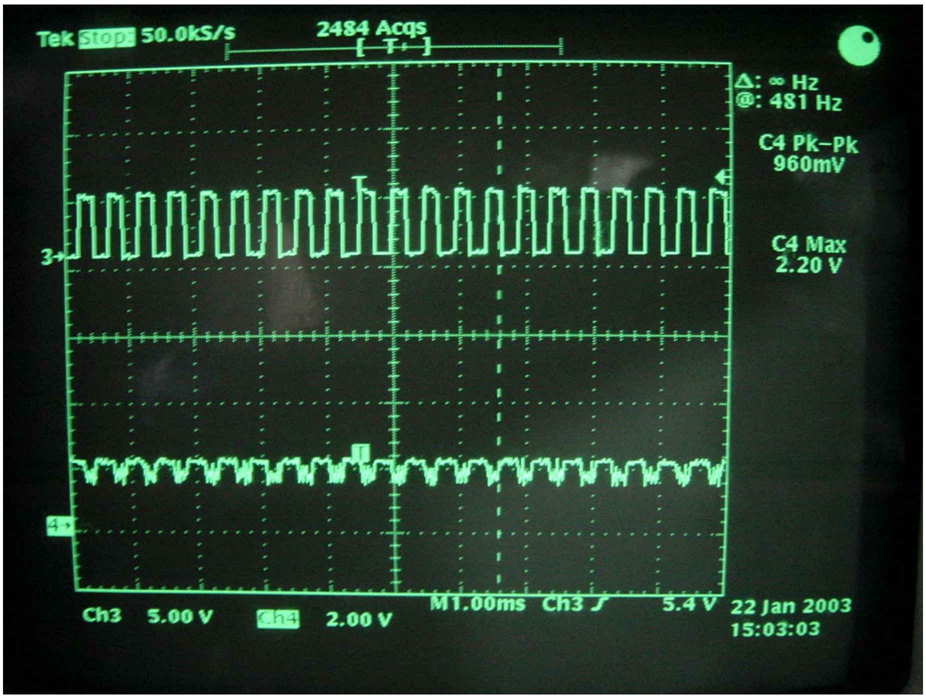
HT672A Working Voltage Recommendations and V_{DD} Measurement Method

The HT672A operating voltage, V_{DD} , must be greater than 2.2V, and can be measured using the following method:

- Step 1
  Extend out the HT672A V_{DD} and V_{SS} pins as shown in the diagram:



- Step 2
  Connect VDD to a suitable oscilloscope and VSS to ground. Then move a tag slowly downwards closer to the reader's antenna, to see the VDD start to charge up to 2.2V and to see the reader output data signal as shown in the following diagram. In this way the VDD voltage can be measured.

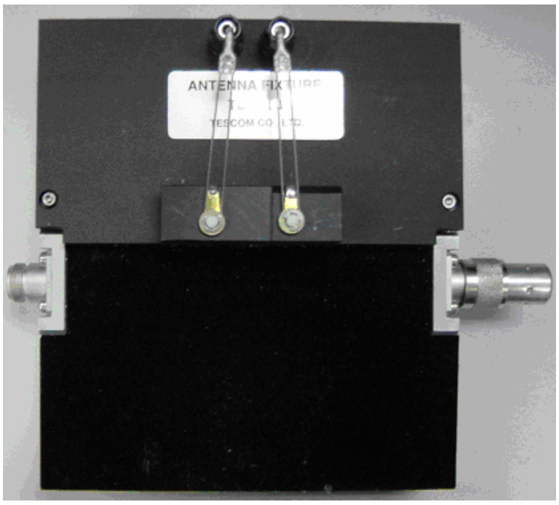


V_{DD} Measurement Method

Measuring the Reader Output Power and Recommended Power Output Value

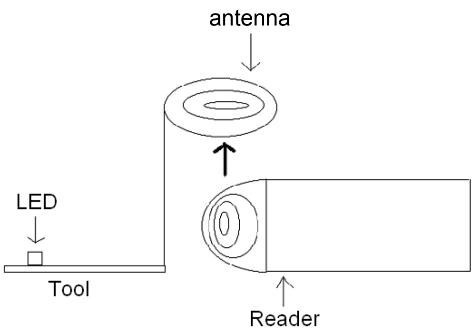
Two methods to measure the Reader Output Power

- Using a spectrum anaylser
  Connect the test platform (TC-5003B) to the spectrum analyzer and then place the reader on the centre of the test platform. Adjust variable capacitor on the terminal of the reader antenna to obtain the best effect.

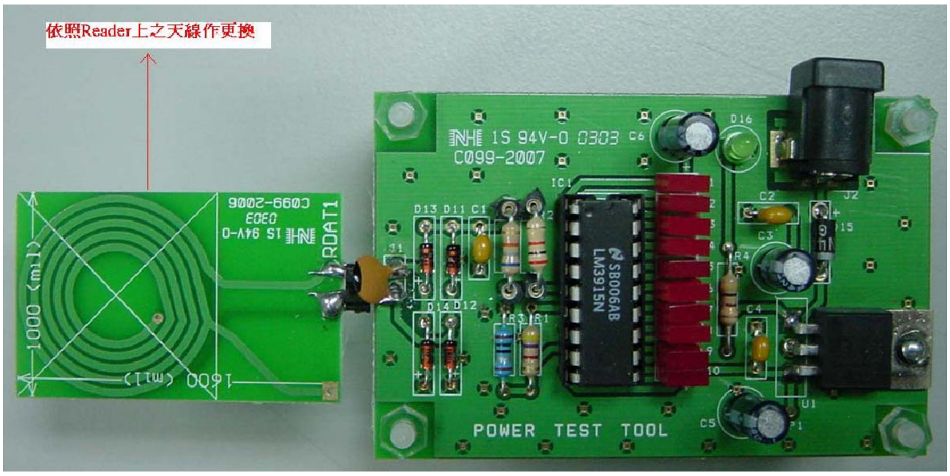


RF Test Platform – Connect to a Spectrum Analyser

- After bridge rectification
  This power test tool obtains a DC value of the reader generated magnetic field strength. The signal is then used as an input to a LM3915 Dot/Bar Display Driver to drive an LED display to give a visual indication of the field strength.



RFID Power Test Tool Measurement Diagram



RFID Power Test Tool

- Using the RFID power test tool:
  - Input voltage DC 9V
  - When all the LEDs are illuminated then the power level will be greater than −12 dBm
  - When one LED is extinguished then the power level is between −12 and −14 dBm
  - When two LEDs are extinguished then the power level is between −14 ~ −16 dBm
  - When three LEDs are extinguished then the power level is between −16 ~ −18 dBm
  - When three LEDs are extinguished then the power level is between −18 ~ −20 dBm
  - When five LEDs are extinguished then the power level is between −20 ~ −22 dBm

Recommended Power Output Value

- When the Reader is using a large antenna (2 inch) the power should reach −8 dBm
- When the Reader is using a small antenna (1 inch) the power should reach −13 dBm

How to Comply with the FCC Harmonic Specification

The FCC harmonic test specification is shown below:

- Radiation standards

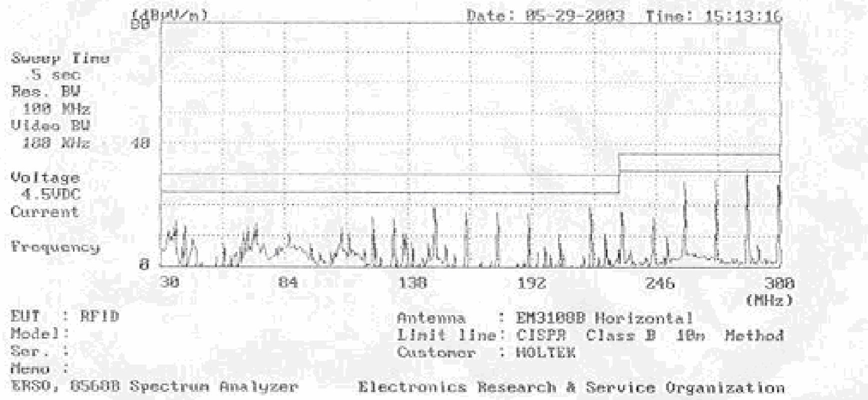
Frequency (MHz)	Class B (Home Use)	Class A (Industry Use)
30~88	40 dBμ	39 dBμ
88~216	43.5 dBμ	43.5 dBμ
216~960	46 dBμ	46.4 dBμ
960 以上	54 dBμ	49.5 dBμ

- Transmit standards:

Frequency (MHz)	Class B (Home use)	Class A (Industry use)
0.45~1.75	48 dBμ	60 dBμ
1.75~30	48 dBμ	69.5 dBμ

Note Radiation strength within 1 metre cannot exceed 109 dBμ

The present company's RFID Reader FCC test is shown below, all conformed within spec.



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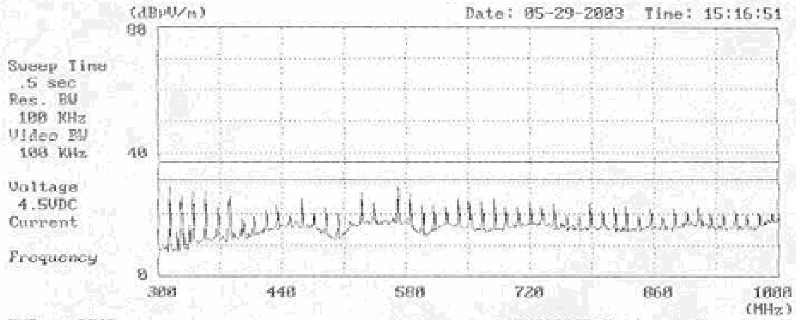
ERSO EM3108B Horizontal CISPR Class B 10m Method

	Freq	Measu	Over	Limit	Read	CabL	AntF
	MHz	dB	dB	dB	dB	dB	dB
	148.919	19.4	-10.6	30.0	16.0	1.1	2.3
	217.027	19.0	-11.0	30.0	19.5	1.4	-1.8
	258.108	27.7	-9.3	37.0	23.2	1.5	3.0
	271.622	28.2	-8.8	37.0	24.9	1.6	1.7
!	285.135	31.8	-5.2	37.0	29.4	1.6	0.8
	298.649	26.6	-10.4	37.0	23.7	1.7	1.3



EUT : RFID
Model:
Ser. :
Memo :
Antenna : EM96005B Horizontal
Limit line: CISPR Class B 10m Method
Customer : HOLTEK
ERSO, 8568B Spectrum Analyzer Electronics Research & Service Organization

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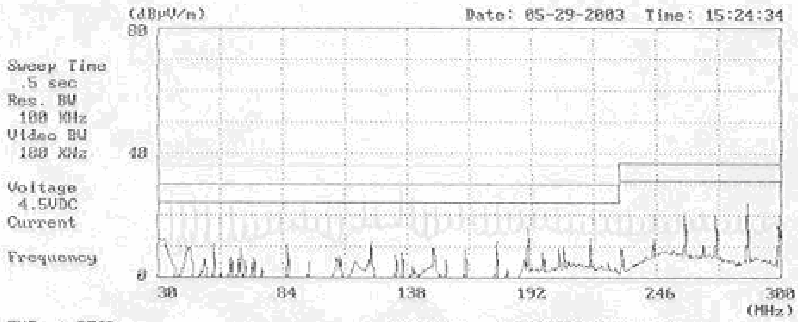
ERSO EM96005B Horizontal CISPR Class B 10m Method

Freq	Measu	Over	Limit	Read	CabL	AntF
MHz	dB	dB	dB	dB	dB	dB
311.211	29.0	-8.0	37.0	19.6	1.7	7.7
325.225	25.7	-11.3	37.0	16.5	1.7	7.4
337.838	27.2	-9.8	37.0	16.2	1.8	9.2
351.852	27.1	-9.9	37.0	14.4	1.8	10.9
379.880	25.4	-11.6	37.0	12.6	1.9	10.9
528.428	27.0	-10.0	37.0	10.0	2.4	14.6
569.069	28.7	-8.3	37.0	11.3	2.5	14.9
583.083	26.2	-10.8	37.0	10.2	2.5	13.5
637.738	25.3	-11.7	37.0	9.3	2.6	13.3



EUT : RFID
Model:
Ser. :
Memo :
Antenna : EM3108B Vertical
Limit line: CISPR Class B 10m Method
Customer : HOLTEK
ERSO, 8568B Spectrum Analyzer Electronics Research & Service Organization

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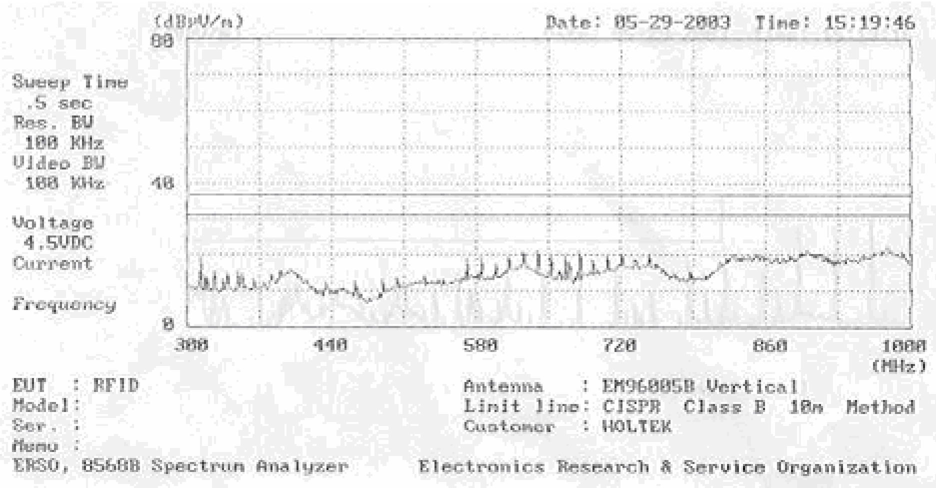
ERSO EM3108B Vertical CISPR Class B 10m Method

Freq	Measu	Over	Limit	Read	CabL	AntF
MHz	dB	dB	dB	dB	dB	dB
190.000	16.5	-13.5	30.0	13.6	1.3	1.6
258.108	20.6	-16.4	37.0	12.6	1.5	6.5
271.622	20.0	-17.0	37.0	12.1	1.6	6.3
285.135	24.2	-12.8	37.0	18.0	1.6	4.6



Designing the Tag Antenna

Antenna Design

In RFID systems the antenna can be seen as a pair of coupled inductors. In order to achieve high inductor coupling efficiency, the two inductors must both have similar resonant frequencies of close to 13.56MHz. Therefore it is imperative to know the antenna inductance value for correct matching with its resonant capacitor and according to the different application's requirements to know the antenna calculated Q value and the inductor's resistance.

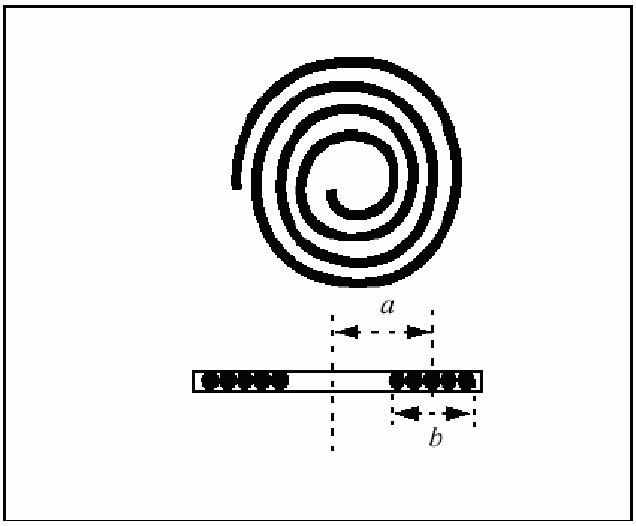
- Antenna Inductor Value

  The value and means of calculating the antenna inductance will vary with the shape and size of the antenna. Using an equation to calculate the value and actual measurements can result in differences of 20%. This is especially true for inductors with a limited number of turns, perhaps only even a single turn, or for inductors with a many turns, which because of stray capacitance effects, will also result in large variations. If it is required to find a precise value of inductor, or inductor model, via calculation, then it is necessary to input the inductor shape and size information into the simulation computer and then use 3D or 2D magnetic field simulation software, to obtain the required precision. Therefore in practical applications, it is normal to first use a formula to obtain an estimate for inductor size and number of turns. After construction the actual measured value can be compared with the calculated value and then fine adjustments carried out. Otherwise the estimated shape and size of the antenna can be entered into a computer and magnetic field simulation software used, the results of which can be used to make fine adjustments before the final antenna is constructed. The following introduces several inductor design formulas:

– Equation for calculating the Inductance of a Spiral Wound Coil with a Single Layer for the Transponder and Reader:

$$L = \frac{(aN)^2}{8a + 11b} \qquad (\mu H)$$

where
a: average radius of the coil in cm
N: number of turns
b: winding depth in cm

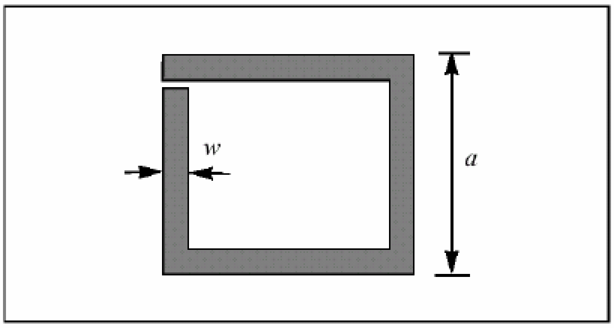


Spiral Wound Coil with Single Layer

– Equation to calculate the Inductance of a Flat Square coil for the Transponder and Reader:

$$L = 0.0467aN^2\left\{\log_{10}\left(2\frac{a^2}{t+w}\right) - \log_{10}(2.414a)\right\} + 0.02032aN^2\left\{0.914 + \left[\frac{0.2235}{a}(t+w)\right]\right\}$$

where
L: in μH
N: number of turns
a: side length in inches
t: thickness in inches
w: width in inches



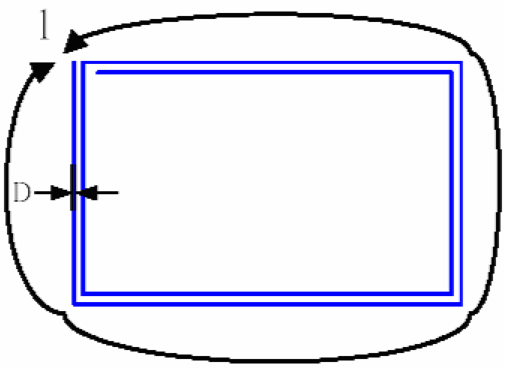
Inductance of a Flat Square Coil

– Equation to calculate the Inductance of a Rectangular Coil for the Transponder:

$$L = 2 \times l \times \left(\ln \frac{l}{D} - 1.04 \right) \times N^{p} \quad \text{(nH)}$$

where
l: length of one coil
N: number of turns
D: diameter of wire or conductor width
P: power depends on coil technology

P	Coil Construction
1.8	Wired coil
1.7	Etched coil
1.5~1.7	Printed coil



Inductance of a Rectangular Coil

- Inductor Resistance Value

  For resonators with a Q value less than 100, most of their losses are due to external loads and inductor resistance. As external loads are already known, therefore for this calculated inductor A.C. resistor, it is possible to calculate the unloaded Q value.

  As high frequency currents are found to only flow in the surface of conductors, a phenomenon which is known as the skin effect, this results in a conductor resistance will vary with frequency.

$$\delta = \frac{1}{\pi f \mu \sigma}$$

where:
f : frequency
μ : permeability of the material
σ : conductivity

At frequencies of 13.56MHz or less, for copper conductors, the skin depth can be calculated by:

$$\delta = \frac{1}{\sqrt{\pi f (4\pi \times 10^{-7})(5.8 \times 10^{-7})}} = \frac{0.0179}{\sqrt{f}} = 0.187(\mathrm{mm})$$

A circular metallic conductor wire A.C. resistance value is given by:

$$R_{(AC)} \approx \frac{1}{2\sigma \pi \delta}$$

where δ is the skin depth,

Taking a circular metallic conductor as an example, the A.C. resistance and D.C. resistance have the following relationship:

$$R_{(AC)} \approx R_{(DC)} \frac{a}{2\delta}$$

where a is the coil radius

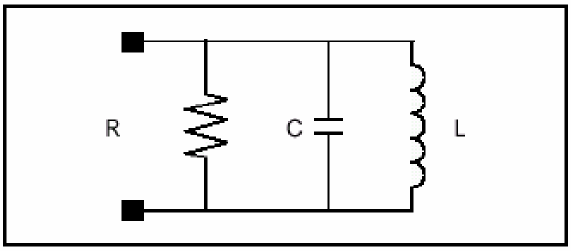
Circular copper conductors at a frequency of 13.56MHz, if the conductor radius is less than 0.187mm, then the A.C. resistance value is approximately equal to the D.C. resistance value.

If a printed circuit is used to manufacture the inductor, the copper tracks have a thickness of about 0.035mm. The value is actually determined by the type of board used, which can give a range of 15-70μm, however the most common type is 35μm. At a frequency of 13.56MHz, as the copper track thickness is less than the skin depth, it is not necessary to take skin effects into account. As a result the resistance value of the inductor can be simply measured with a multimeter. With this series resistance and inductance, and if a series capacitor is added, then it will form a series resonator, from which the Q value can be directly estimated.

- Resonator Q value

  In RFID systems, in order to increase the coupling efficiency and reduce losses, the Reader and Transponder terminal antennae are resonator forms. The resonator Q value will directly influence parameters such as operation range, the magnetic field strength, bandwidth, acceptable external component tolerance etc. The following introduces how to form resonator circuits using inductors, resistors and capacitors.

  – Parallel Resonant Circuit



Parallel Resonant Circuit

In a parallel resonant circuit, the inductor L, capacitor C and resistor R, determine the resonant frequency, the resonator Q and bandwidth.

$$B = \frac{1}{2\pi RC}$$

$$Q = \frac{\text{Energy Stored in the System per One Cycle}}{\text{Energy Dissipated in the System per One Cycle}}$$

$$= \frac{resistance}{reactance} = \frac{R}{\varpi L} = \omega CR = \frac{f_0}{B} = R\sqrt{\frac{C}{L}}$$

$\omega = 2\pi f$ = angular frequency

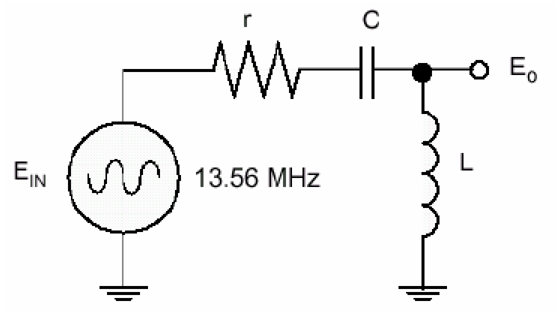
f_0 = resonant frequency

B = bandwidth

r = ohmic losses

– Series Resonant Circuit

In a parallel resonant circuit, the inductor L, capacitor C and resistor R, determine the resonant frequency, the resonator Q and bandwidth.



Series Resonant Circuit

$$B = \frac{r}{2\pi L}$$

$$Q = \frac{\text{Energy Stored in the System per One Cycle}}{\text{Energy Dissipated in the System per One Cycle}}$$

$$= \frac{reactance}{resistance} = \frac{\varpi L}{r} = \frac{1}{\omega Cr} = \frac{f_0}{B} = \frac{1}{r}\sqrt{\frac{L}{C}}$$

ω = $2\pi f$ = angular frequency

f_0 = resonant frequency

B = bandwidth

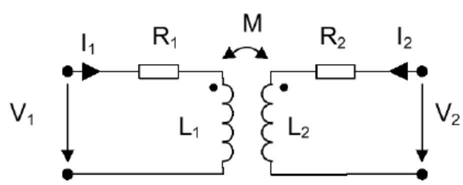
r = ohmic losses

When determining which Q value to use, it is important to note that higher Q values will result in higher coupling efficiencies and the smallest power losses and generate the strongest magnetic fields. However the disadvantages are that they will be more susceptible to environmental influences, will have a narrower bandwidth and during manufacture may require fine tuning. In the case of situations over longer distances (>70cm), even after the security system has been installed it may require adjustment again, in order to reduce the effects of nearby metallic objects on the resonator frequency. As for low Q systems, coupling efficiency is lower, however they offer broader bandwidth and can tolerate higher data transmission rates. In addition they are less susceptible to environmental influences and have lower costs and wider applications for shorter distance systems.

Because the majority of Reader antennae will utilise the circuit board tracks or a wire wounded type of construction, the antenna will be large, making it easier to manufacture high Q values of antenna. Therefore the Reader antenna will have a much higher Q than that of the Transponder. As the Transponder also tends be more concerned with issues such as size and manufacturing cost as well as tolerance to environmental influences, its Q value will be comparatively lower.

- Resonator Mutual Inductance Value

  In RFID systems it is the mutual inductance between two inductors that transmits power as well as the data. The inductor mutual inductance and the inductor size and the distance are related. In order to calculate the RFID coupled energy, it is necessary to calculate the two inductors coupling coefficients.



L1 and L2 Mutual Coupling

The voltage relationship at the two inductor terminals is given by:

$$V_1 = I_1(R_1 + j\omega L_1) + I_2 j\omega M \qquad \text{(V)}$$

$$V_2 = I_2(R_2 + j\omega L_2) + I_1 j\omega M \qquad \text{(V)}$$

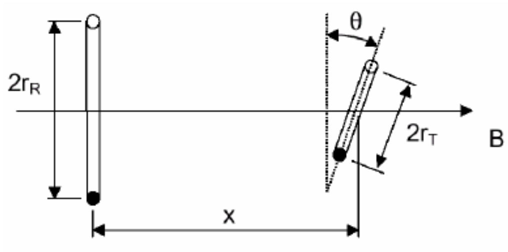
M is the mutual inductance of the two inductors

$$M = k\sqrt{(L_1 \cdot L_2)} \qquad \text{(H)}$$

K is the magnetic coupling coefficient

Taking two circular air-core inductors as an example, their coupling coefficient is determined by:

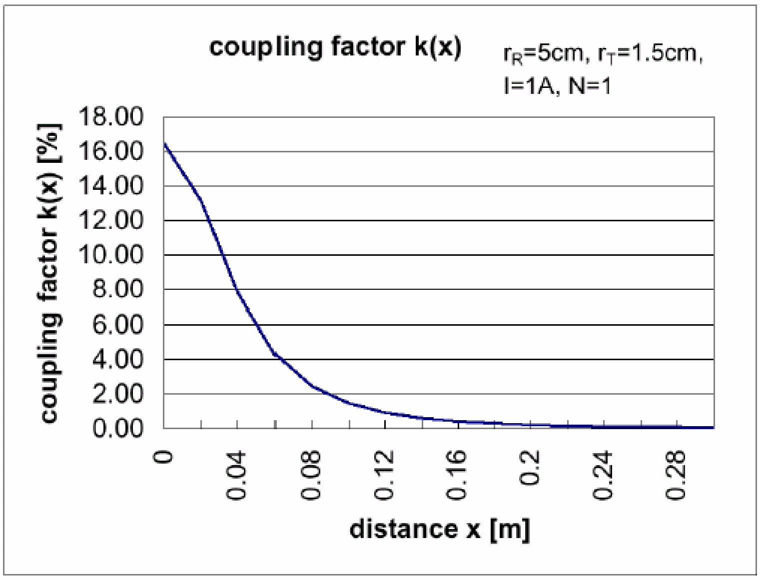
$$k = \frac{r_R^2 \cdot r_T^2 \cdot cos(\theta)}{\sqrt{r_R \cdot r_T} \cdot (r_R^2 + \chi^2)^{3/2}}$$



Two air-core inductors free-space mutual inductance

In applications, in order to obtain the best system characteristics, the best value of K should be designed for a value of 1. Naturally for closer distances, the value of K will be much greater than the designed value. If the value of K is to be increased, the following examples show some methods:

- reduce the value of θ
- using two similar size antennae can increase K greatly
- reduce the distance between the two antennae



Dual Air-core Inductors of Radius 5cm, 1.5cm in Free-space
Mutual Inductance v Distance Relationship

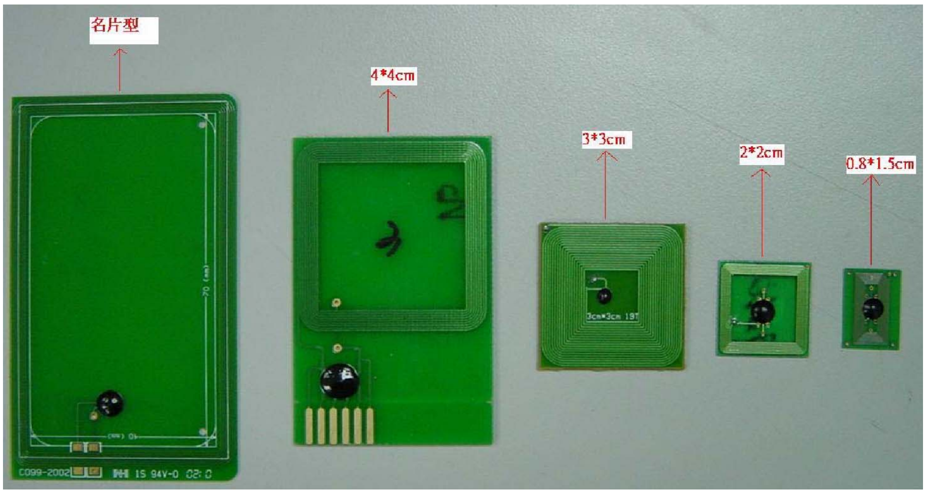
REFERENCES:

- V.G.Welsby, The Theory and Design of Inductance Coils, John Wiley and Sons, Inc., 1960.
- Frederick W. Grover, Inductance Calculations Working Formulas and Tables, Dover Publications, Inc., New York, NY.,1946.
- Keith Henry, Radio Engineering Handbook, McGraw-Hill Book Company, New York, NY.,1963.
- James K.Hardy, High Frequency Circuit Design, Reston Publishing Company, Inc., Reston, Virginia, 1975.

The following Tag antenna sizes are available for supply to customers:

- 8cm×5cm
- 4cm×4cm
- 3cm×3cm
- 2cm×2cm
- 0.8cm×1.5cm

Various kinds of Tag Antenna sizes are shown below:



Various Tag sizes

These can accompany the reader antenna to subdivide into a large antenna (2 inch) and small antenna (1 inch)，as shown in the following diagram:

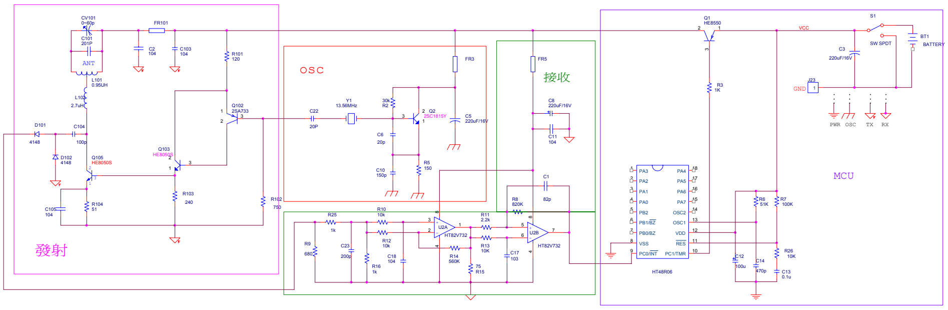
Various Types of Reader Antenna

Different antennas when accompanied by different Tags have an effective distance as shown in the following table:

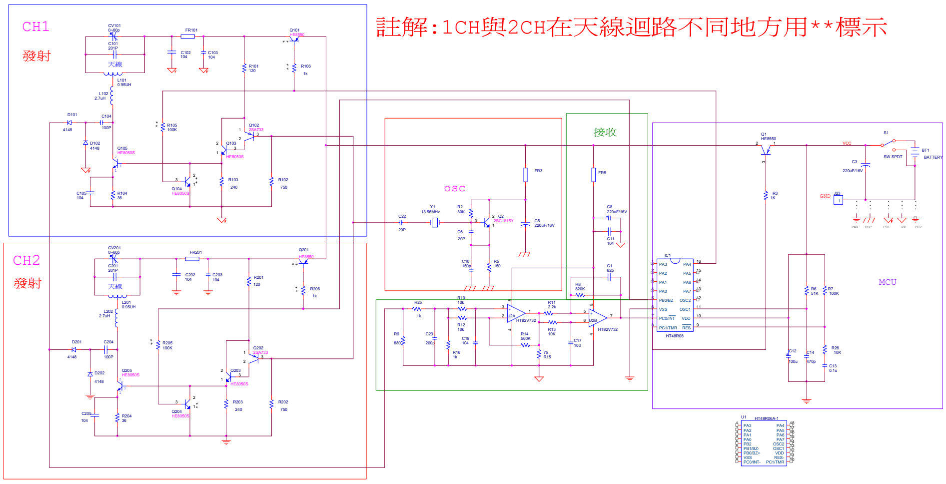
Tag Size - cm	Effective Distance - cm
With Reader using large antenna (2 inch) and voltage at 6V	
8×5	12
4×4	6.5
3×3	7
2×2	5.5
0.8×1.5	3.5
With Reader using large antenna (2 inch) and voltage at 4.5V	
8×5	9
4×4	5
3×3	6
2×2	4.5
0.8×1.5	2.5
With Reader using large antenna (2 inch) and voltage at 3.3V	
8×5	7
4×4	4
3×3	5
2×2	3.5
0.8×1.5	2
With Reader using small antenna (1 inch) and voltage at 6V	
8×5	10
4×4	5
3×3	6
2×2	4
0.8×1.5	3
With Reader using small antenna (1 inch) and voltage at 4.5V	
8×5	6
4×4	4
3×3	5
2×2	2.5
0.8×1.5	2
With Reader using small antenna (1 inch) and voltage at 3.3V	
8×5	4.5
4×4	3.5
3×3	4
2×2	2
0.8×1.5	1.6

Application Circuit and Notes for Accompanying Components.

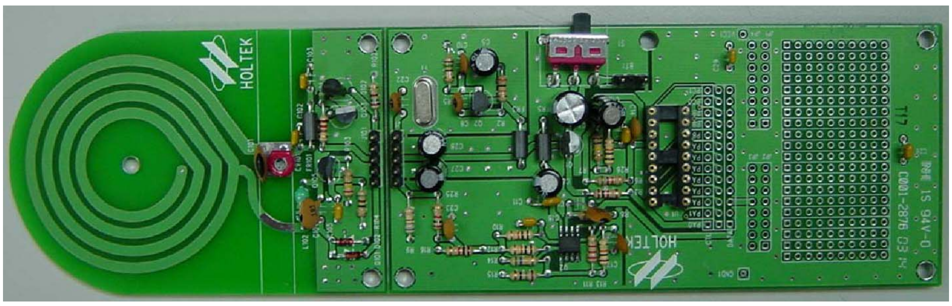
RFID Recommended Circuit Diagram



RFID Recommended Circuit Diagram (Single Antenna)



RFID Recommended Circuit Diagram (Dual Antenna)



RFID Recommended Circuit Board (Single Antenna)

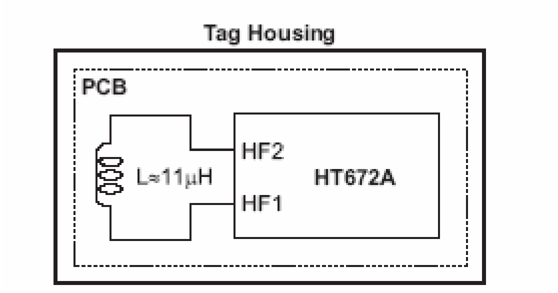
RFID Recommended Circuit Board (2~6 Antennas)

Application Circuit

- Tag section

  The tag contains a circuit board track constructed antenna and an HT672A enclosed within a PCB. Its size can be made according to specific application needs. The internal antenna's inductance value is 11μH, but the optimal value is obtained by fine tuning the internal oscillator capacitor (a nominal value of 10pF can be used).

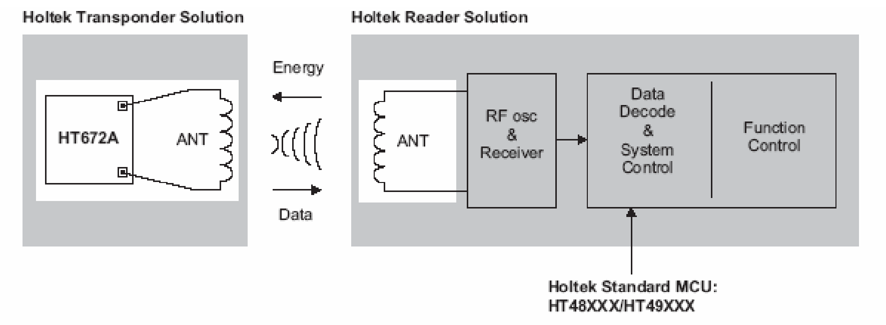
  The Tag outline is shown below:



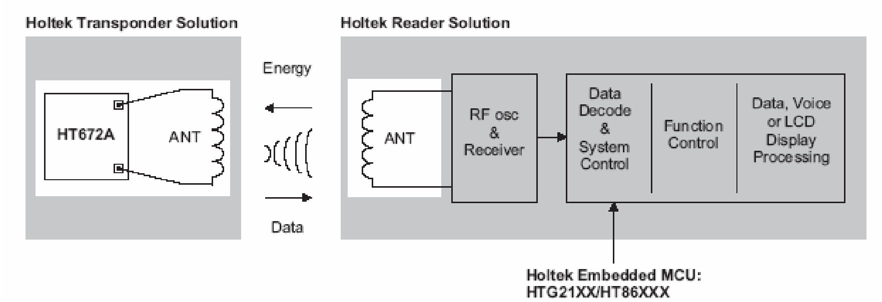
- Application Circuit

  There are single chip or two chip solutions as shown below:

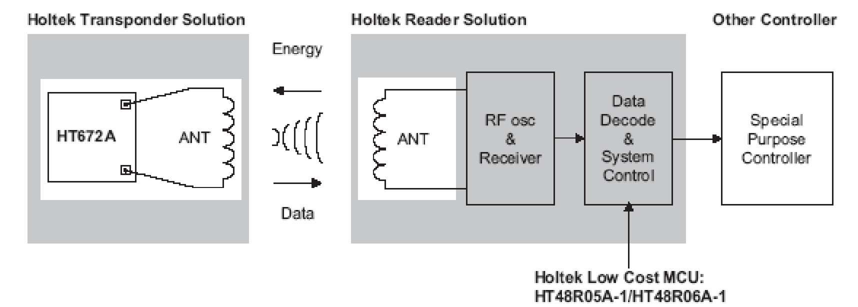
  – Single chip solution (I)



– Single chip solution (II)



– 2-chip solution



Points to note for the connecting lines and accompanying components

- When constructing the reader, the application can be subdivided into four separate areas, transmitter, receiver, oscillator and MCU sections. These four sections should have separate connections to the power ground to minimise noise interference.
- The receiver section should not be located close to the MCU.
- The oscillator sections should be located close to the transmitter.
- On the common circuit board, for the power control, whether single or dual antenna, PC1 is used for control, however this can be changed by the user.
- On the common circuit board, the dual antenna channel uses PA4 and PB0 for control, however this can be changed by the user.
- The transmitter section must be layed out together with the antenna.
- The capacitor must be an NPO type.
- In selecting the 8050S transistor, the important point to note is that the hfe is a rank D or higher device. For more details consult the 8050S specification in the attached he8050s.pdf file.
- For single antenna readers, Q103 and Q105 must use 8050S types, for dual antenna readers, Q103, Q104, Q105, Q203, Q204 and Q205 must use 8050S types, additionally their specification must conform to that mentioned earlier. In this way for

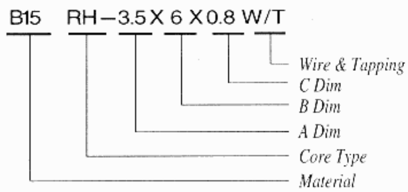
large antennas (2 inch) or small antennas (1 inch), the power can reach up to −8 dBm and −13 dBm.

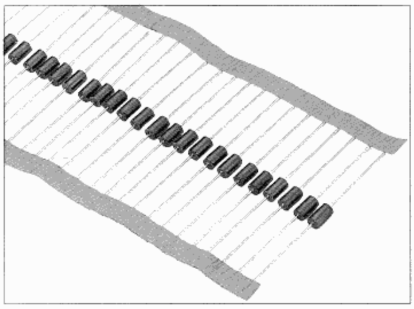
- For the ferrite bead selection, the following specification can be used:
  FR Specification

1. Material:

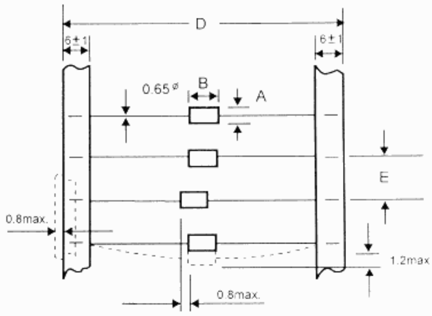
A2G B-7 B-12 B-15

2. Ordering Code:





3. Tapping Dimensions:



4. Applications:

- RHWT TYPE are produced for the automatic insertion into the PC boards.

5. Packaging:

5000 pcs per Reel

6. Dimensions: (m/m)

CORES	A	B	C	D	E	MIN. IMPEDANCE (OHM)	
						25MHz	100MHz
B15RH-3.5X3.5X0.8 W/T	3.5±0.2	3.5±0.2	0.8±0.15	63±3	5.0±0.5	25	45
B15RH-3.5X4.7X0.8 W/T	3.5±0.2	4.7±0.2	0.8±0.15	63±3	5.0±0.5	30	50
B15RH-3.5X5X0.8 W/T	3.5±0.2	5.0±0.3	0.8±0.15	63±3	5.0±0.5	30	50
B15RH-3.5X6X0.8 W/T	3.5±0.2	6.0±0.3	0.8±0.15	63±3	5.0±0.5	35	60
B15RH-3.5X8X0.8 W/T	3.5±0.2	8.0±0.3	0.8±0.15	63±3	5.0±0.5	40	80
B15RH-3.5X9X0.8 W/T	3.5±0.2	9.0±0.3	0.8±0.15	63±3	5.0±0.5	45	100

MCU Support

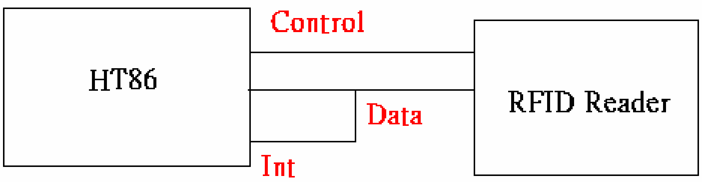
Presently the MCUs that can be used for RFID are listed below:

All HOLTEK Standard/Embedded MCU				
Part	**I/O**	**LCD**	**Voice**	**App.**
HT48	√	—	—	Control
HT49	√	√	—	Display
HT86	√	—	√	Toy

Presently the MCUs that can support RFID are centred on the HT86 series. For this reason for software support the HT86 series are taken as examples for explanation.

MCU and RFID interface connection

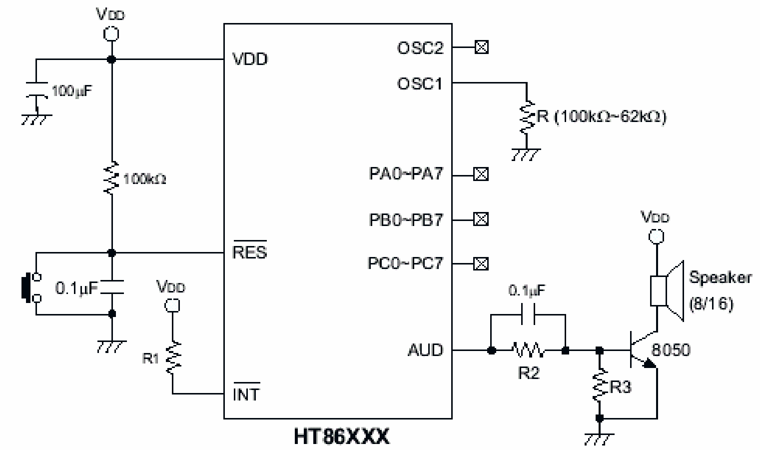
The following diagram shows a simplified drawing of how the HT86 series and the RFID hardware is structured:



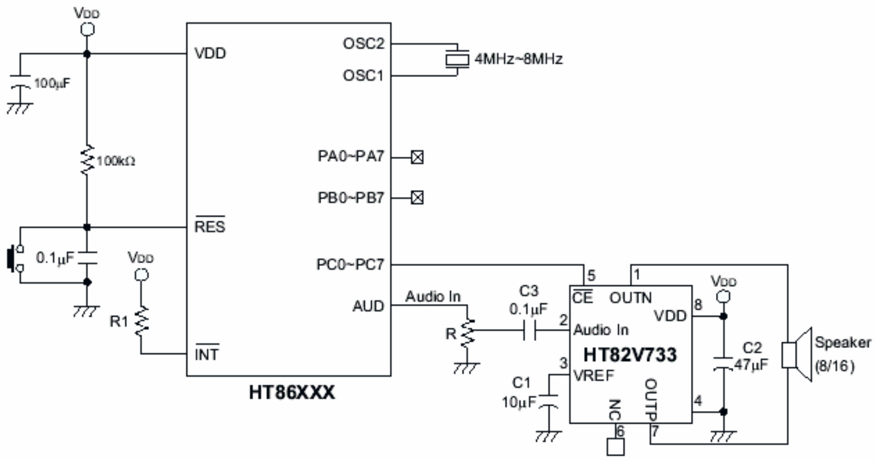
HT86 Series and RFID Structure

The following is an application diagram for the HT86 series of MCUs. It is only required to connect the Reader PC1 control pin to the MCU's PC1 pin, and the PC0 data pin to the MCU PC0 pin. Then the MCU PC0 pin should be connected to the MCU INT pin. As the INT pin is active on either low to high or high to low going edges, this connection will allow the MCU PC0 pin to detect the type of interrupt edge. This will fully accomplish the hardware interface connection. Consult the HT86XXX specification for more details.

Application Circuits



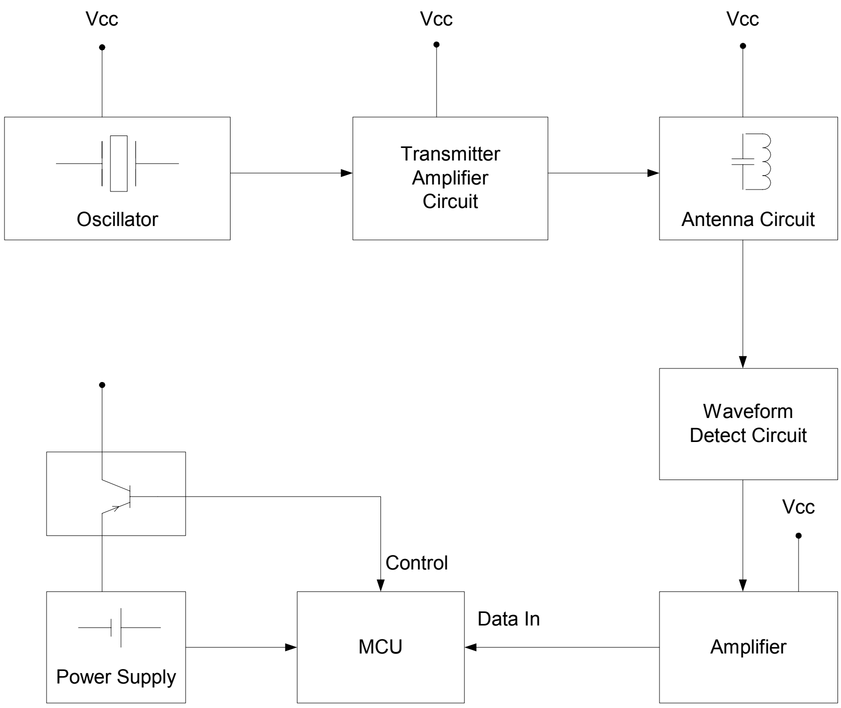
Note: R2>R3



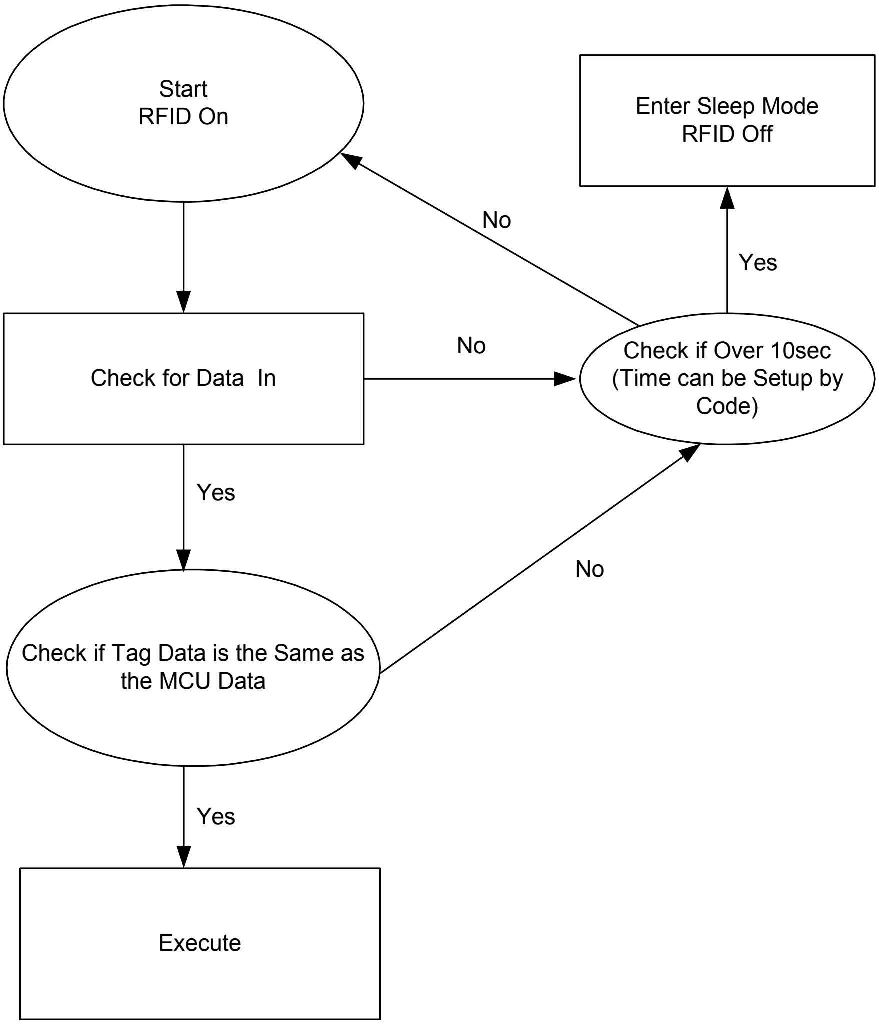
HT86 Series Application Circuit

Overall Design Flowchart

The overall design flowchart can be subdivided into hardware and software flowcharts as shown below:



Hardware Design Flowchart



Software Design Flowchart