AN830

RFID Tag and COB Development Guide with Microchip's RFID Devices

Author: *Youbok Lee, Ph.D.*
Microchip Technology Inc.

INTRODUCTION

A passive RFID tag contains an RFID integrated circuit (IC), resonant capacitor (C), and antenna (L), as shown in Figure 1. The antenna and capacitor form a parallel LC resonant circuit. The LC circuit must be tuned to the reader's carrier frequency for maximum performance (read range).

The two most common antenna types for RFID tagging applications are: (a) wire-wound coil and (b) etched (or printed/stamped) spiral inductor on a dielectric substrate. The antenna types are typically determined by carrier frequency, tag's package type, performance, and assembly cost factors. For example, low frequency (< 400 kHz) tags need a few mH of inductance. This inductance is achieved with a few hundreds of turns of wire. This kind of inductance cannot be obtained economically with etched antenna, but with a wire-wound antenna. However, medium frequency (4 - 30 MHz) tags need a few uH of inductance. This inductance can be achieved with a few turns of wire or etched (or printed/stamped) spiral inductor on dielectric substrate.

After the antenna type is chosen, the next step is to attach the silicon device to the antenna. There are two basic methods for the device attachment: (a) using a chip-on-board (COB) or (b) direct die attachment to the antenna. The COB is commonly used for wire-wound antennas and the direct die attachment is for the etched (printed/stamped) antenna types.

The COB is made by packaging a resonant capacitor and an RFID device together in the same package. It has two external terminals for antenna attachment. The inductance of the antenna is determined by the COB's resonant capacitor value and the reader's carrier frequency. The antenna is attached to the COB's two external terminals by welding or soldering. Because most of the COBs are used for ISO cards which need to meet the ISO card standard thickness (0.76 mm) specification, typical thickness of the COB is approximately 0.4 mm. Although the COB package is designed to protect the internal silicon device during the card lamination process which involves mechanical pressure with hot temperature, care is needed to prevent mechanical cracks on the device. The two popular COB package types are IOA2(MOA2) from IST in Taiwan and World II from HEI Inc. in the USA.

Since the direct die attachment reduces a step for making the COB package, it is widely used for low cost and high volume applications such as smart labels. The direct die attachment can be achieved with two different methods: (a) wire bonding or (b) flip-chip with bumped die. For the flip-chip, it needs a special bumping on the die's bond pads. Typically the bump material is made of gold with approximately 25 um of height. The flip-chip assembly process attaches the bumped area to the antenna traces. Several bumping and flip chip assembly methods are available for RFID tags. The wire bonding method needs a relatively simple process for the die attachment. The die is directly wire-bonded to the antenna, and covers the wire bonded area with a black colored epoxy glob top. For small volume production, the wire-bonding method is still less expensive than using the flip-chip process. However, it is less efficient for high volume production. The flip-chip method is preferred for high volume production.

The read range of an RFID tag is greatly affected by the tag's size, tuning, circuit Q, device's power consumption and data modulation depth. The tag's size must be chosen depending on its application and cost constraints. Tags must be tuned precisely to the reader's carrier frequency for long range applications. Since the tag's antenna circuit consists of a combination of L and C components, the tolerance of the component often causes the variation in the read range between tags. Once the inductance is designed, its tolerance is typically within 1 ~ 2%. Therefore, a tag's tuning variation is mostly due to the capacitance tolerance. The capacitance used for the antenna circuit or COB must be chosen carefully. For example, the tolerance must be kept within ~5% and the capacitor's Q factor should be greater than 100 at the operating frequency to maximize the read range performance. The internal resonant capacitors of the MCRF451/452/455 and MCRF360 devices are made with silicon oxide. Their tolerance is approximately less than 5% for the devices in the same wafer and within ~10% from different wafers. Their Q factor is greater than 100 at 13.56 MHz. The capacitance tolerance results in variations in the read range between tags. Therefore, if the read range variation (about 10%) is a concern due to the internal capacitor's tolerance, the MCRF450 and MCRF355 can be used with an external capacitor that has a smaller tolerance (within 2~5%).

The modulation transistor of the 13.56 MHz devices is placed between antenna B and VSS. This transistor creates a junction capacitance between the two pads. This junction capacitance is relatively lossy compared to the on-board capacitors. However, the MCRF450, MCRF451, MCRF455 and MCRF360 are not affected by the junction capacitance. For the MCRF452, this lossy junction capacitance is in parallel with its second 50 pF internal resonant capacitor. The resulting loaded circuit Q of the MCRF452 is about 5~10% lower than that of the other devices.

The capacitance or inductance also can be trimmed within a few percent using proper tuning mechanism. Various tag design assistance and tuning methods that are the subject of pending patent applications are available from Microchip Technology Inc.

The Q factor of a tag's antenna circuit is primarily governed by the antenna's resistance. Therefore, the antenna must be designed to have minimum resistance within a given physical constraint. The antenna resistance becomes smaller with thicker gauge wire or etched metallic traces with a wider trace width. Etched antennas with a four-turn spiral inductor on an ISO card sized dimension can easily be made to be less than 1 ohm with a proper dimensional choice. In this case, the unloaded Q (antenna only) can be greater than 100. The loaded Q (antenna with device) needs to be greater than 50 for long range applications.

Microchip's 13.56 MHz devices consume less than 200 µW of power during reading. This is about 20 times less than other similar devices available from competitors in the industry today. This reduced power consumption means there will be more available power for backscattering (re-radiation), which results in a longer read range.

In conventional RFID tags, data is sent by damping and undamping the antenna voltage. However, for a high Q circuit, it is very difficult to damp the voltage with high speed (high data rate). Therefore, it is difficult to send data with 100% AM modulation with the conventional method. To overcome this problem, Microchip's current 13.56 MHz devices are designed to shift the circuit's tuning frequency instead of damping the coil voltage directly. This can be achieved by shorting and un-shorting one element in the resonant antenna circuit. Microchip's devices have a modulation transistor between antenna B and VSS. The frequency tuning element should be placed in parallel with the modulation transistor (antenna B and VSS). The modulation transistor shorts the frequency switching element when it turns on (sending data "Hi"), and releases when it turns off (sending data "Lo"). When the switching element is released, the circuit tunes to the reader's carrier frequency causing the circuit to develop maximum voltage. When the switching element is shorted, the circuit tunes away from the carrier frequency, therefore, developing less voltage. The reader monitors the changes in the tag's coil voltage, and reconstructs the modulation data. Refer to Microchip's application Note AN707 (DS00707) for more details of this feature.

The device requires three connection points to the external antenna circuit: antenna A, antenna B, and VSS. This is in order to switch the resonant frequency (tuned and detuned) by shorting and un-shorting the element between antenna B and VSS. In the MCRF452, the antenna B is internally connected to the second internal 50 pF capacitor between antenna B and VSS. See Figure 1 for various external circuit configurations for each device.

The resonant frequency of the tag is determined by the LC component combination between antenna A and VSS. The circuit must be tuned precisely to the reader's carrier frequency for best read range performance.

Microchip's 13.56 MHz devices are designed to send data with 100% modulation with the appropriate external circuit configuration. The modulation depth is determined how much the tag's coil voltage is changed when it sends data from "Hi" to "Lo" or vice versa. In the 13.56 MHz devices, this is directly related to the separation between tuned and detuned frequencies. The detuned frequency is the result of shorting the frequency switching component between the antenna B and VSS. This component value is typically optimized between one-third to one-half the total L or C value. For example, three turns between antenna A and antenna B, and one turn between antenna B and VSS for a tag made of a four-turn spiral inductor. If the shorting element (between antenna B and VSS) is a capacitor, the same value of the capacitor can be chosen for the element between antenna A and B for simplicity.

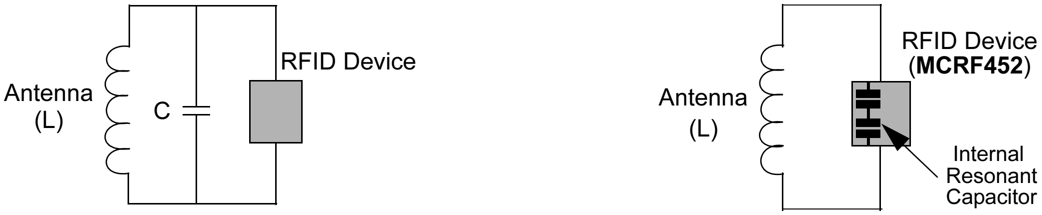
The COB for MCRF355 and MCRF450 include two identical 68 pF capacitors in series, externally to the device. The capacitor C1 is connected between antenna A and B, and C2 is between antenna B and VSS.

The MCRF452 COB does not require external capacitors since the device has two internal capacitors.

The MCRF452 is the best choice for the COB in a sense of unit COB production cost. However, for the highest performance, the MCRF450 is recommended.

Various circuit configurations for each device are shown in Figure 1.

FIGURE 1: PASSIVE RFID TAG CONFIGURATION

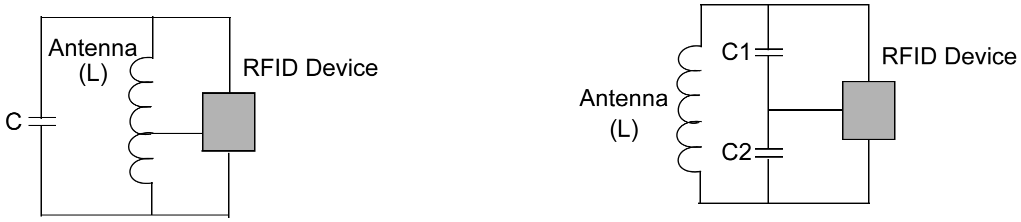


a) Configuration for 125 kHz RFID devices (**MCRF200 and MCRF250**)

b) Configuration for **MCRF452**.

c) Configuration for COB (**MCRF200/250, MCRF355, MCRF450, MCRF452**)

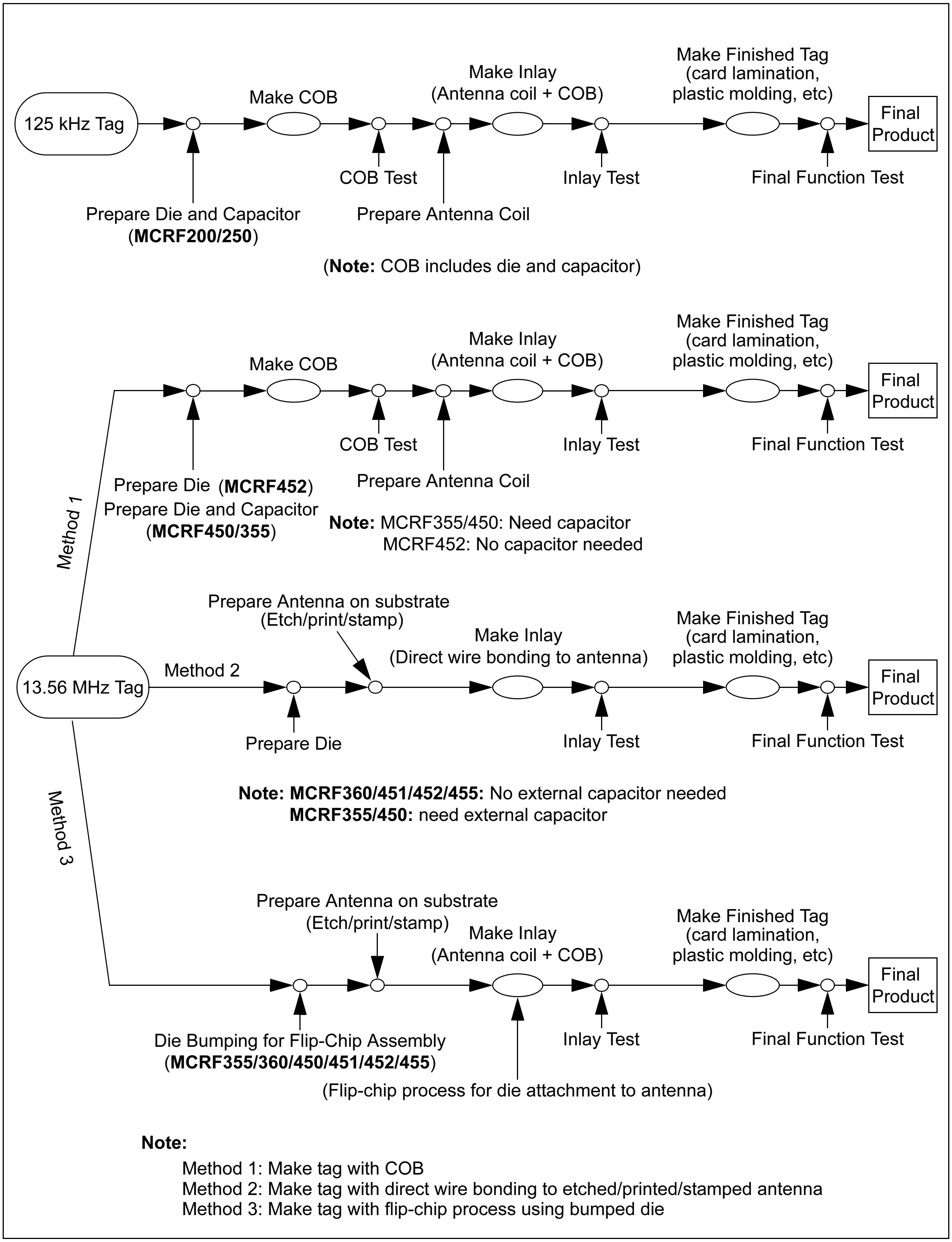
d) Configuration for 13.56 MHz RFID devices with internal resonant capacitor. (**MCRF360/ MCRF451/455**)



e) Configuration for 13.56 MHz RFID devices with no internal resonant capacitor (**MCRF355 and MCRF450**)

f) Configuration for 13.56 MHz RFID devices with no internal resonant capacitor. C1, C2 and L are external components. (**MCRF355 and MCRF450**)

FIGURE 2: TAG ASSEMBLY PROCESS



Note:

Method 1: Make tag with COB
Method 2: Make tag with direct wire bonding to etched/printed/stamped antenna
Method 3: Make tag with flip-chip process using bumped die

DIE LAYOUT AND EXTERNAL ANTENNA CIRCUITS FOR MCRF DEVICES

Table 3 shows internal resonant capacitance of the 13.56 MHz MCRF devices and their inductance requirements. The external circuit configuration for these devices are shown in Figure 1. The MCRF452 includes two 50 pF internal capacitors in series (C1: between antenna A and B, C2: between antenna B and V_{SS}). The device shorts and un-shorts C2 when it sends data “Hi” and “Lo”, respectively. The MCRF452 needs only two connection points (antenna A and V_{SS}) to external antenna. When the MCRF452 is used for the COB, it does not require the extra capacitor. The MCRF452 is a good candidate for both direct die attachment and COB. Tag assembly processing steps for various methods are shown in Figure 7.

The MCRF451, MCRF455 and MCRF360 requires three connection points to the external antenna (antenna A, antenna B, V_{SS}). These devices can be used effectively for direct die attachment (wire bonding or flip-chip) to the antenna.

Here is the summary for the 13.56 MHz devices:

For direct die attachment to antenna: MCRF 355, MCRF360, MCRF450, MCRF451, MCRF452, MCRF455.

For COB: MCRF355, MCRF450, MCRF452.

TABLE 1: 13.56 MHZ DEVICE FEATURES

Devices	Programming	Anti-collision	Memory	Internal Resonant Capacitor	Read Range	Application	Availability
MCRF355	Contact or factory programming	Yes (typically 20 tags/second and as many as 50 tags/second)	154 bits	No	up to 1.5 meters	Multiple reading of tags, book store and library book ID, toys/gaming tools, airline baggage tracking, access control and asset tracking	Die, wafer, wafer on frame, bumped, SOIC, PDIP
MCRF360				100 pF			
MCRF450	Contactless	Yes (read all energized tags)	1K bits	No		Multiple reading and writing of tags, book store and library applications, toys/gaming tools, airline baggage tracking, access control, asset tracking and inventory management	
MCRF451				95 pF			
MCRF452				30 pF			
MCRF455				50 pF			

TABLE 2: 125 KHZ DEVICE FEATURES

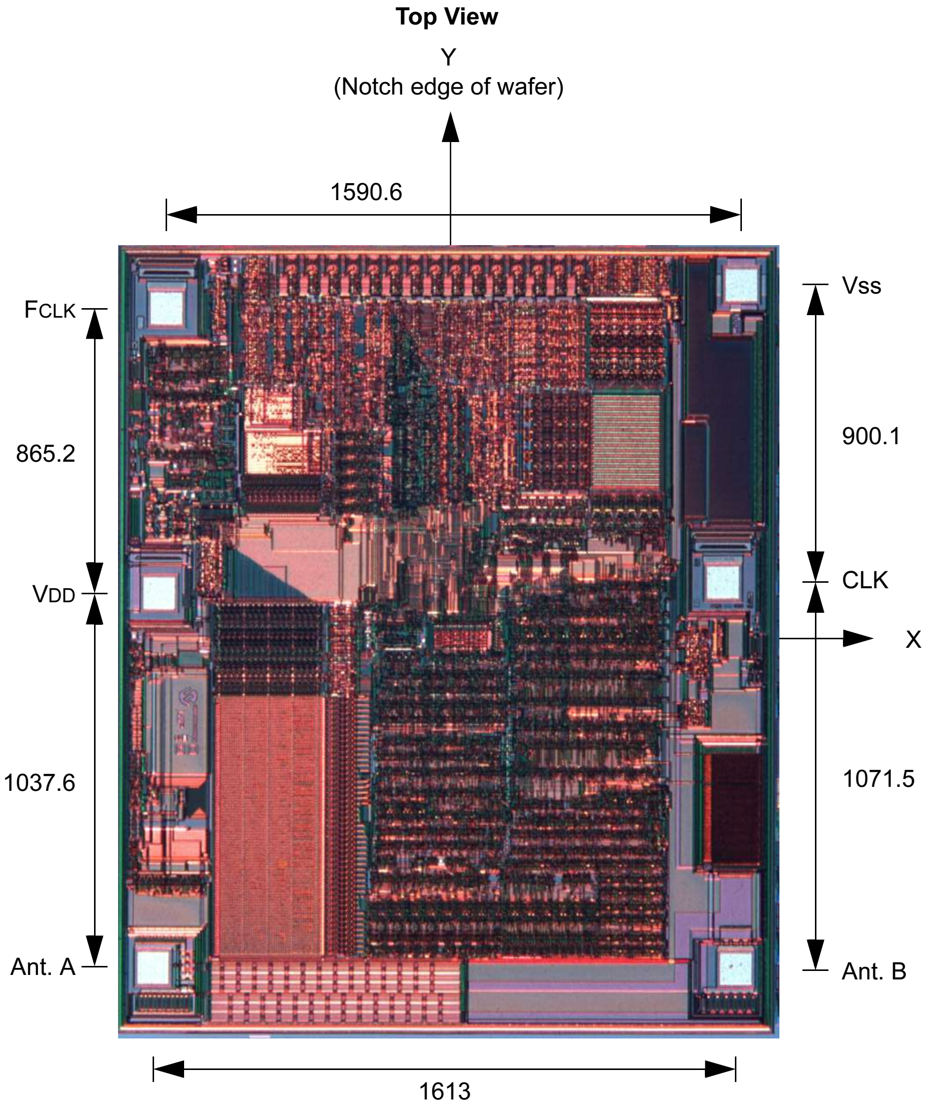
Devices	Programming	Anti-collision	Memory	Applications	Availability
MCRF200	OTP contactless or factory programming	No	128 bits	Access control, animal tagging, ISO 11784/11785 FDX-B, compatible to most of existing RFID devices (FSK, ASK, PSK options)	Die, wafer, wafer on frame, SOIC, PDIP, COB
MCRF250	OTP contactless or factory programming	Yes	128 bits	Multiple tagging applications	
MCRF202	Factory or contact programming	Yes	128 bits	Sensing application with external sensor input pin	Die, wafer, wafer on frame, SOIC, PDIP

TABLE 3: INTERNAL RESONANT CAPACITANCE OF 13.56 MHZ MCRF DEVICES

Device Name	Resonant Capacitance (Antenna A to Vss)	External Inductance Requirement for 13.56 MHz tag	Connection to External Antenna Circuit or COB Lead Frame	Reference
MCRF450	3.5 pF (Parasitic Input Capacitance)	Depending on external capacitor value	Antenna A, B, VSS pads	This device requires three connections to an external circuit. Good for both COB and direct die attachment.
MCRF451	95 pF ±10%	1.45 μH ±10%	Antenna A, B, and VSS pads	This device requires three connections to an external circuit. Good for direct wire bonding on etched antenna.
MCRF452	30 pF ±10%	4.591 μH ±10%	Antenna A and VSS pads	This device requires only two antenna connections. Good for both direct die attachment and COB.
MCRF455	50 pF ±10%	2.76 μH ±10%	Antenna A, B, and VSS pads	This device requires three connections to an external circuit. Good for direct wire bonding on etched antenna.
MCRF360	100 pF ±10%	1.4 μH ±10%	Antenna A, B, and VSS pads	This device requires three connections to an external circuit. Good for direct wire bonding on etched antenna.

Note: The internal capacitance value for bumped die is about 1 pF higher than the unbumped die’s capacitor.

FIGURE 3: MCRF450/451/452/455 DIE LAYOUT



Note: Coordinate units are in µm.
See MCRF45X Data Sheet for die mechanical dimensions.

Die size before saw:	**Die size after saw:**	**Bond pad size:**
1904.0 µm x 2340.8 µm	1840.5 µm x 2277.3 µm	89 µm x 89 µm
1.904 mm x 2.3408 mm	1.8405 mm x 2.2773 mm	0.089 mm x 0.089 mm
74.96 mil x 92.16 mil	72.46 mil x 89.66 mil	3.5 mil x 3.5 mil

Ant. Pad A: Connected to antenna coil L1.

Ant. Pad B: Connected to antenna coils L1 and L2 for MCRF450/451/455, not connected for MCRF452.

VSS: Connected to antenna coil L2 (VSS = substrate).

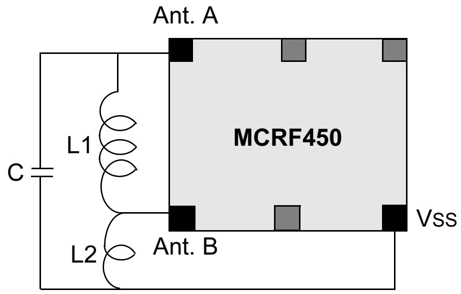
FCLK: For device test only. Leave floating or connect to VSS.

CLK: Connect to VSS.

VDD: For device test only. Leave floating.

FIGURE 4: EXTERNAL CIRCUIT CONFIGURATION FOR DSTEMP

(a) Two inductors and one capacitor



L1 > L2 **Note:** Substrate = Vss

$$f_{tuned} = \frac{1}{2\pi\sqrt{L_T C}} \qquad f_{detuned} = \frac{1}{2\pi\sqrt{L_1 C}}$$

L_T = Total antenna inductance between Ant. A and Vss

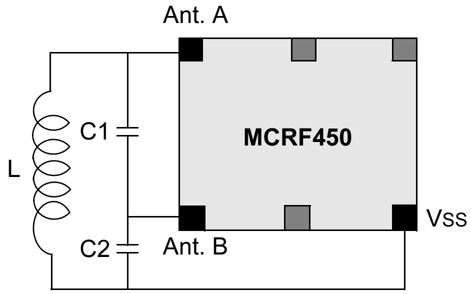
$$L_T = L_1 + L_2 + 2L_M$$

Where: L_M = mutual inductance of L1 and L2

$$L_M = K\sqrt{L_1 L_2}$$

K = coupling coefficient of two inductors ($0 \leq K \leq 1$)

(b) One inductor and two capacitors



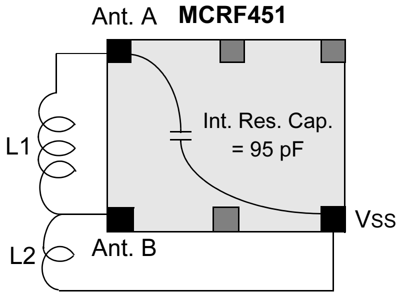
C1 ≥ C2 **Note:** Substrate = Vss

$$f_{tuned} = \frac{1}{2\pi\sqrt{L_T C_T}} \qquad f_{detuned} = \frac{1}{2\pi\sqrt{L C_1}}$$

$$C_T = \frac{C_1 C_2}{C_1 + C_2}$$

Note: Input parasitic capacitance between Antenna A and Vss pads = 3.5 pF. See application notes, AN710 and AN830 for antenna circuit design.

FIGURE 5: EXTERNAL CIRCUIT CONFIGURATION FOR DSTEMP



L1 > L2 **Note:** Substrate = Vss

Internal Resonant Capacitor (Cres_100) = 95 pF

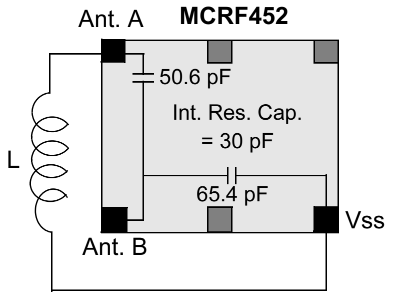
L1: External Antenna Coil A

L2: External Antenna Coil B

$$f_{tuned} = \frac{1}{2\pi\sqrt{(L_T)(95\times10^{-12})}} \qquad f_{detuned} = \frac{1}{2\pi\sqrt{(L_1)(95\times10^{-12})}}$$

L_T = Total antenna inductance between Ant. A and Vss

FIGURE 6: EXTERNAL CIRCUIT CONFIGURATION FOR DSTEMP

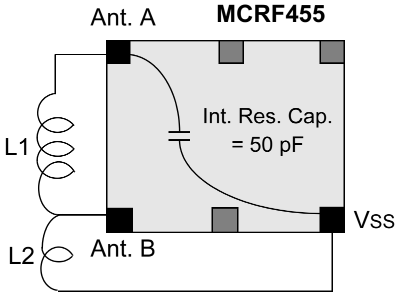


Note: Substrate = VSS

Internal Resonant Capacitor between Ant. A and Vss pads:
CRES_2_50 + parasitic capacitor = 30 pF

$$f_{tuned} = \frac{1}{2\pi\sqrt{(L)\,30\times10^{-12}}} \qquad f_{detuned} = \frac{1}{2\pi\sqrt{(L)50.6\times10^{-12}}}$$

FIGURE 7: EXTERNAL CIRCUIT CONFIGURATION FOR MCRF455



L1 > L2 **Note:** Substrate = VSS

L1: External Antenna Coil A
L2: External Antenna Coil B

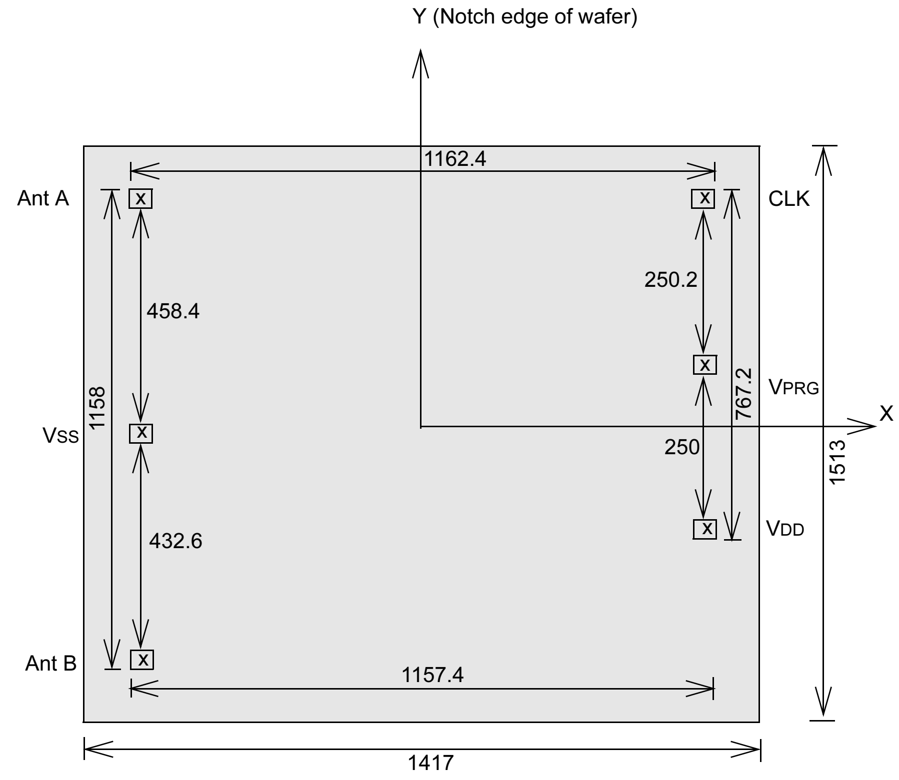
Internal Resonant Capacitor (Cres_50) = 50 pF

$$f_{tuned} = \frac{1}{2\pi\sqrt{(L_T)\,50\times10^{-12}}} \qquad f_{detuned} = \frac{1}{2\pi\sqrt{(L_1)\,50\times10^{-12}}}$$

L_T = Total antenna inductance between Ant. A and VSS

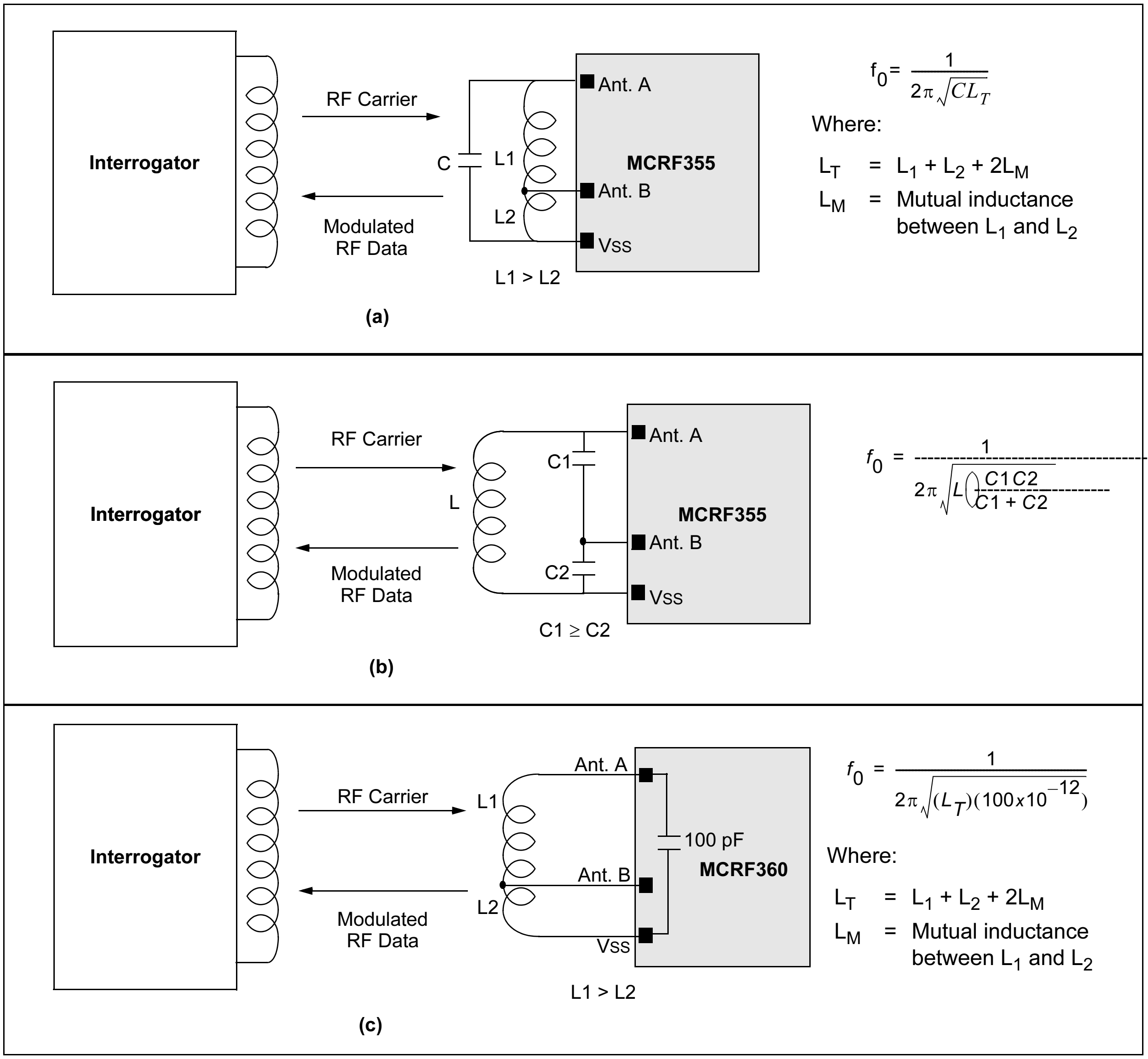
Note: See application notes AN710 for antenna circuit design of Figure 4 through Figure 7.

FIGURE 8: MCRF 355/360 DIE LAYOUT



Die size before saw:	**Die size after saw:**	**Bond pad size:**
1417 µm x 1513 µm	1353.8 µm x 1450.34 µm	89 µm x 89 µm
55.79 mil x 59.57 mil	53.3 x 57.1 mil	3.5 mil x 3.5 mil

FIGURE 9: EXTERNAL ANTENNA CIRCUITS FOR MCRF355 AND MCRF360



$$f_0 = \frac{1}{2\pi\sqrt{CL_T}}$$

Where:

L_T = $L_1 + L_2 + 2L_M$

L_M = Mutual inductance between L_1 and L_2

$$f_0 = \frac{1}{2\pi\sqrt{L\left(\frac{C1C2}{C1 + C2}\right)}}$$

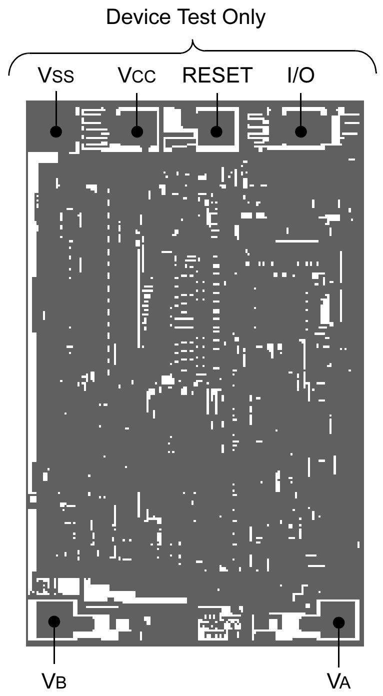
$$f_0 = \frac{1}{2\pi\sqrt{(L_T)(100x10^{-12})}}$$

Where:

L_T = $L_1 + L_2 + 2L_M$

L_M = Mutual inductance between L_1 and L_2

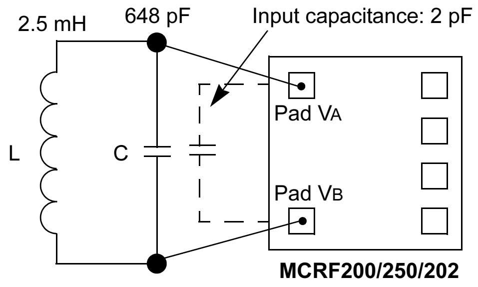
FIGURE 10: DIE LAYOUT OF THE MCRF200/280



VA, VB: Antenna connection
VSS, VCC, RESET, I/O: Do not connect to antenna.

Die size before saw:	**Die size after saw:**	**Bond pad size:**
1121.5 μm x 1738.4 μm	1059.18 μm x 1673.86 μm	89 μm x 89 μm
44.15 mil x 68.44 mil	41.7 x 65.9 mil	3.5 mil x 3.5 mil

FIGURE 11: EXTERNAL ANTENNA CONFIGURATION FOR MCRF200/250/202



$$f_{res} = = \frac{1}{2\pi\sqrt{LC}} \qquad 125\ \text{kHz}$$

COB FOR 13.56 MHZ AND 125 KHZ DEVICES

Microchip offers two COB package types from two different vendors: (a) IOA2 made by International Semiconductor Technology Inc. (IST) in Taiwan, and (b) WORLD II and WORLD III types made by HEI Inc. in the USA. Similar COB packages are also available from Kiho Electronics Ltd in Korea, Dynacard Ltd and Hong Woei Inc in Taiwan, and Hana Microelectronics and Century Electronics Inc in Thailand.

Tables 4 and 5 show various COBs and their internal capacitor values. The capacitors for the COB are made with silicon oxide with less than 5% tolerance.

To be used for the ISO Standard 7810 and 7816-1 (85.6 mm x 54 mm x 0.76 mm) card, the typical COB thickness is about 0.4 mm. Figures 12 and 13 show IOA2 and WORLD II COB package types, respectively.

The inductance requirements for Microchip's COBs are shown in Tables 4 and 5. Inductance calculations of various tag configurations are shown in Microchip's Application Note AN710. Additional detailed tag and coil design methods are also available from Microchip Technology Inc.

TABLE 4: COB FOR 13.56 MHZ DEVICES

COB Name	COB Type	COB Thickness	Resonant capacitance (Antenna A to Vss)	External Inductance Requirement for 13.56 MHz tag	COB Manufacturer
MCRF450/7M	IOA2	0.40 mm	41 pF ±5%	3.36 µH ±5%	International Semiconductor Technology (IST) in Taiwan
MCRF355/7M	IOA2	0.40 mm	41 pF ±5%	3.36 µH ±5%	International Semiconductor Technology (IST) in Taiwan
MCRF355/6C	WORLD II	0.41 mm	42 pF ±5%	3.28 µH ±5%	HEI Inc. in USA
MCRF452	IOA2 WORLD III	0.40 mm	30 pF ±10%	4.591 µH ±10%	Available from IST and HEI Inc.

Note: All COBs except MCRF452 use a dual silicon capacitor made by Quick Sil Inc.

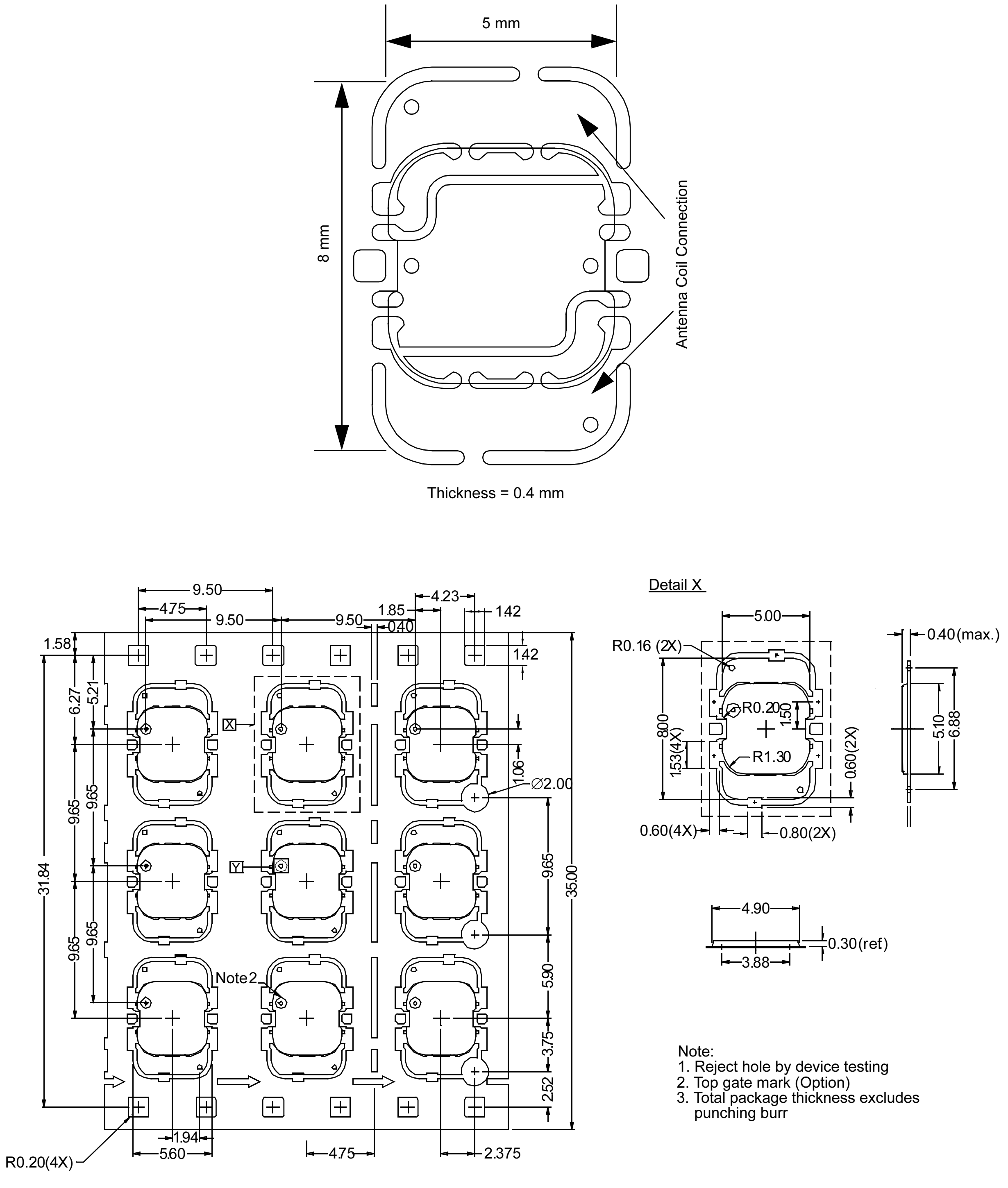
TABLE 5: COB FOR 125 KHZ DEVICES

COB Name	COB Type	COB Thickness	Resonant capacitance (Antenna A to Vss)	External Inductance Requirement for 125 KHz tag	Manufacturer
MCRF200/1M	IOA2	0.40 mm	1000 pF ±5%	1.62 mH ±5%	International Semiconductor Technology (IST) in Taiwan
MCRF200/3M	IOA2	0.4 mm	330 pF ±5%	4.91 mH ±5%	International Semiconductor Technology (IST) in Taiwan
MCRF200/1C	World II	0.41 mm	1000 pF ±5%	1.62 mH ±5%	HEI Inc. in USA
MCRF200/3C	World II	0.41 mm	330 pF ±5%	4.91 mH ±5%	HEI Inc. in USA
MCRF250/1M	IOA2	0.40 mm	1000 pF ±5%	1.62 mH ±5%	International Semiconductor Technology (IST) in Taiwan
MCRF250/3M	IOA2	0.4 mm	330 pF ±5%	4.91 mH ±5%	International Semiconductor Technology (IST) in Taiwan
MCRF250/1C	World II	0.41 mm	1000 pF ±5%	1.62 mH ±5%	HEI Inc. in USA
MCRF250/3C	World II	0.41 mm	330 pF ±5%	4.91 mH ±5%	HEI Inc. in USA

FIGURE 12: IOA2 COB PACKAGE TYPE

FIGURE 13: WORLD II COB PACKAGE TYPE

FIGURE 14: IOA2 COB PACKAGE



Note:
1. Reject hole by device testing
2. Top gate mark (Option)
3. Total package thickness excludes punching burr

13.56 MHZ TAG WITH DIRECT DIE ATTACHMENT ON TO ANTENNA

All 13.56 MHz devices can be used effectively for low cost smart label applications. These smart labels are made by direct die attachment to the antenna. The attachment can be achieved with direct wire bonding or flip-chip method. For the flip-chip, the die's pad must be bumped with proper material such as gold. Since the 13.56 MHz tag needs only a few uH of inductance, the antenna is easily made on a thin dielectric substrate with a few spiral turns of metallic traces. The antenna is mostly etched with copper or aluminum material on a thin paper-like substrate.

The choice of etched, printed, or stamped antenna is a trade-off between cost and performance. For a 13.56 MHz tag, the Q factor of the antenna is very important for long read range applications. The Q factor is inversely proportional to the resistance of the antenna trace. It has been determined that the etched antenna is less resistive and inexpensive than the printed antenna with conductive material. However, for a very large antenna size (greater than 4” x 4”), both etching and stamping processes waste too much unwanted material. Therefore, printed or wired antennas should be considered as an alternative.

Microchip offers gold-bumped die and wafers for the flip-chip process. Table 6 shows the bump specifications of the Microchip products. The bumped wafer from Microchip has an extra polyimide passivation layer (3 µm thickness). This extra dielectric layer prevents possible electrical shorting between the bare die and the antenna circuit.

Figure 15 shows an example of a MCRF355/360 tag with direct die attachment (wire bonded) on to the etched antenna trace. The resonant capacitor is not required for the MCRF360 device. The contact programming pads shown are used to program the device in the Contact mode for customers who need to program the tag after assembly.

The MCRF45x devices are programmed contactlessly by an interrogator. External capacitor is not required for the MCRF451, MCRF452, and MCRF455 devices.

Inductance calculations of various tag configurations are shown in Microchip’s Application Note, AN710.

TABLE 6: BUMP SPECIFICATIONS

Bumped Pad (MCRF45X)	Four corner pads (FCLK, VSS, Antenna B, Antenna A)
Bumped Pad (MCRF355/360)	All 5 pads
Other area except the bumped pads	Covered by polyimide
Thickness of polyimide	3 µm
Bump Material	>99.9% pure Au
Bump Hardness	After Anneal: 35 - 75 Knoops Before Anneal: 90 Knoops
Bump Shear Strength	5.6 gm/mil sq at height 7 µm @50 µm/sec
Bump Height	25 µm ±3 µm
Bump Height Uniformity	Within a die: ±1 µm Within a wafer: ±2 µm Wafer to wafer: ±3 µm
Bump Size	103 x 103 µm
Under Bump Metallization	UBM TiW

FIGURE 15: EXAMPLE OF DIRECT WIRE BONDING OF MCRF355/360 ON TO THE ANTENNA

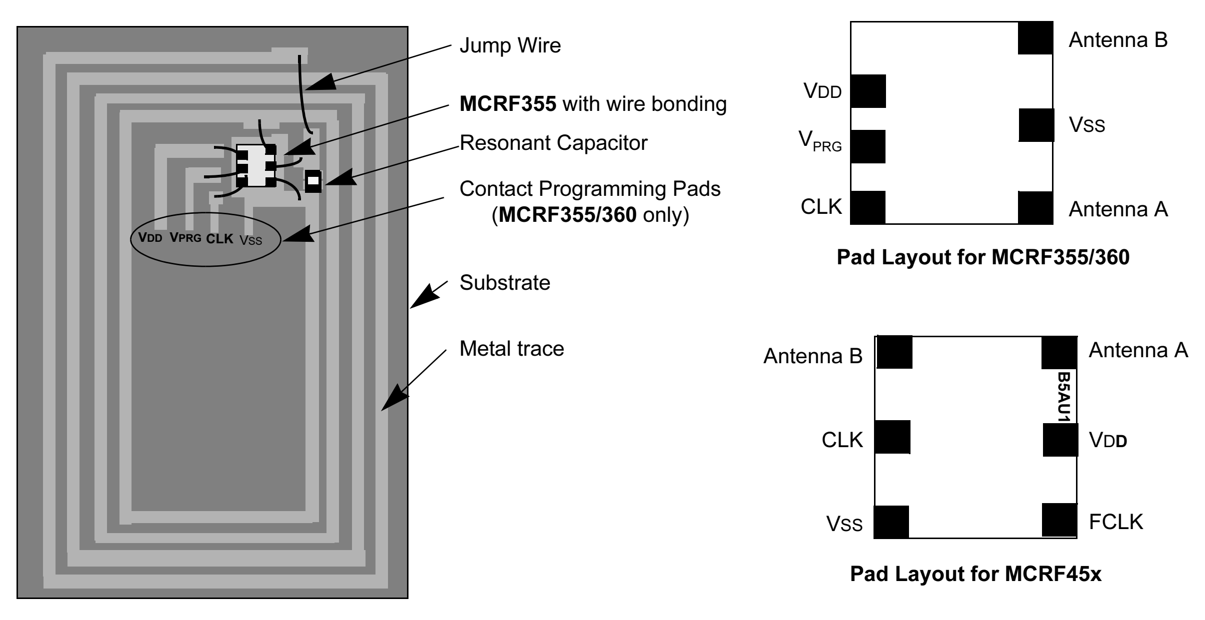
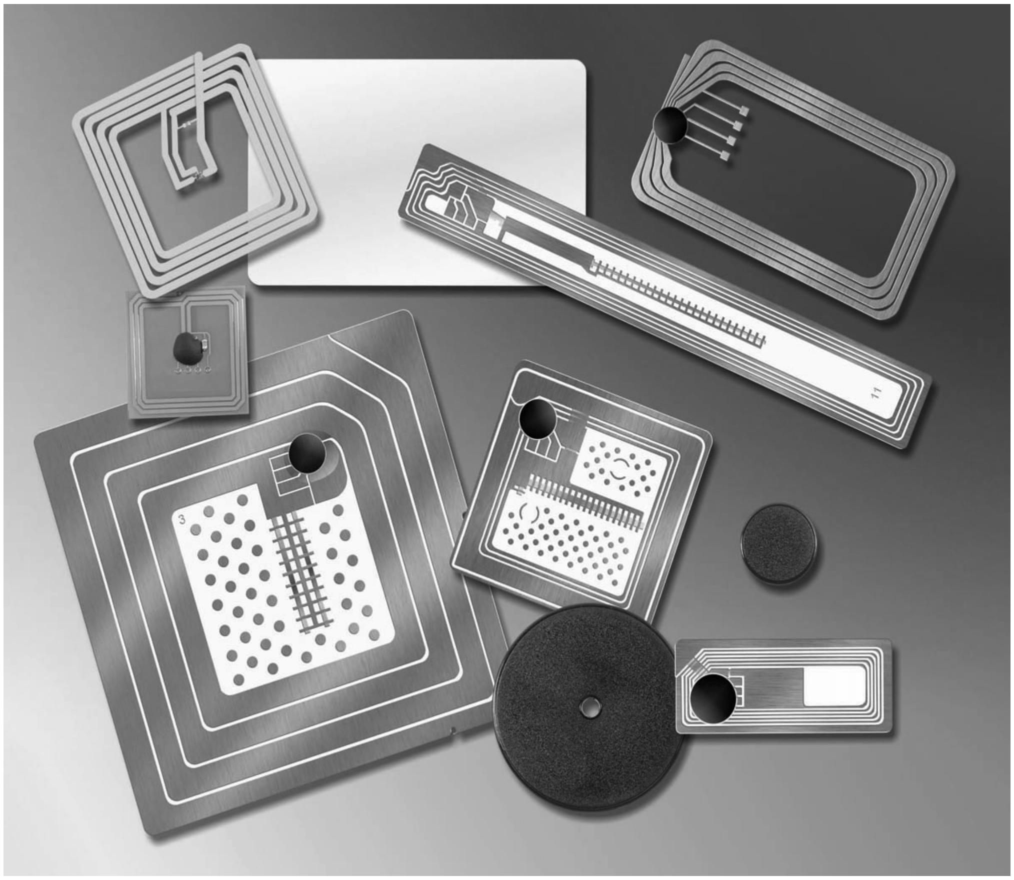


FIGURE 16: EXAMPLE OF VARIOUS 13.56 MHZ RFID TAGS



COB ASSEMBLY WITH MCRF DEVICES

The purpose of the chip-on-board (COB) is to integrate the RFID device and capacitor together in the same package. The COB package is designed to protect the internal devices from external environments and is also easy for coil attachment. Besides the Microchip's IOA2 and World II types which are made on a special lead frame, it can also be made on a small PCB with an epoxy glob top. Both die and capacitor are wire-bonded together on a small PCB and covered with a black-colored epoxy material for protection. The black color protects the device from light source.

Refer to Figure 1 for the wire bond connection between the device and capacitor. Figures 18, 19, 20, and 21 show the MCRF200/250, MCRF355, MCRF452, and MCRF450 COB anatomy, respectively. The MCRF200/250 needs a capacitor. The MCRF355 and MCRF450 need dual capacitor. The MCRF452 is the same as the MCRF450, but doesn't require any capacitor. The test procedure for each COB is described in the following section.

FIGURE 17: 125 KHZ COB ANATOMY

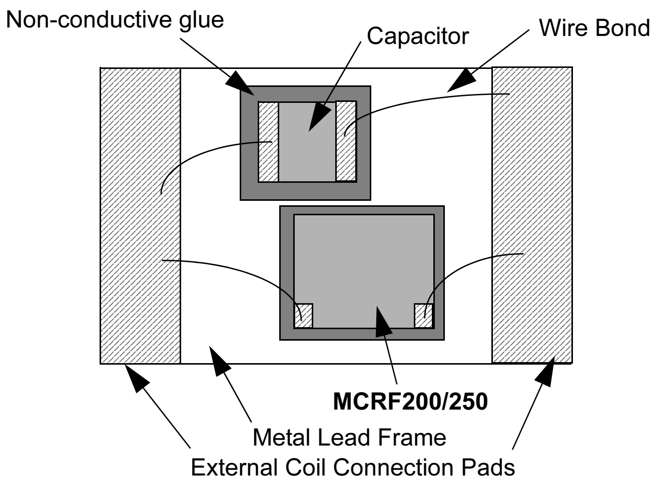


FIGURE 18: MCRF355 COB ANATOMY

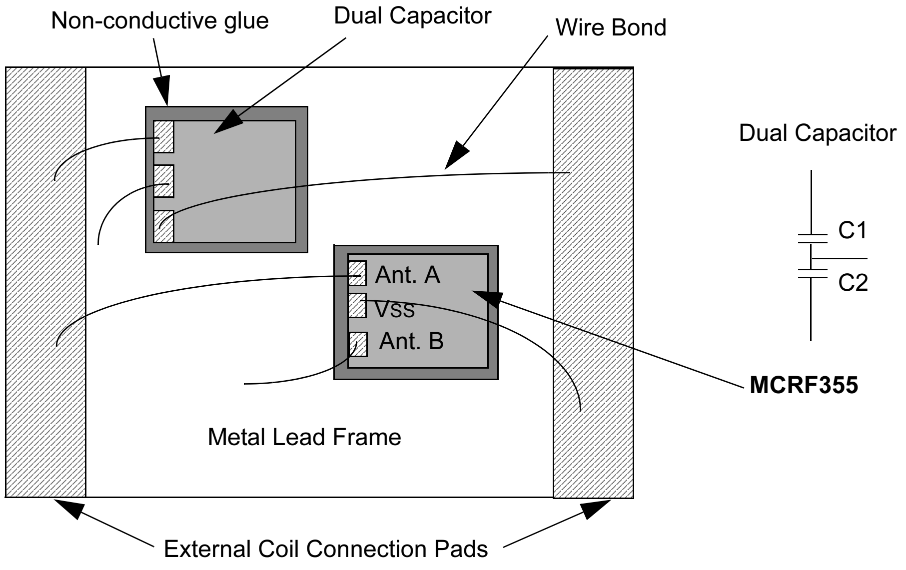


FIGURE 19: MCRF452 COB ANATOMY

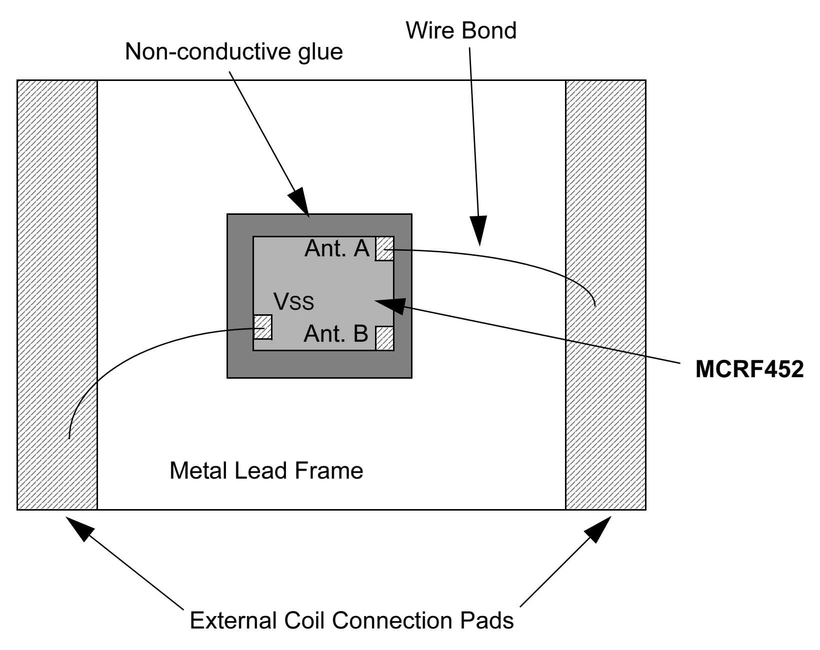
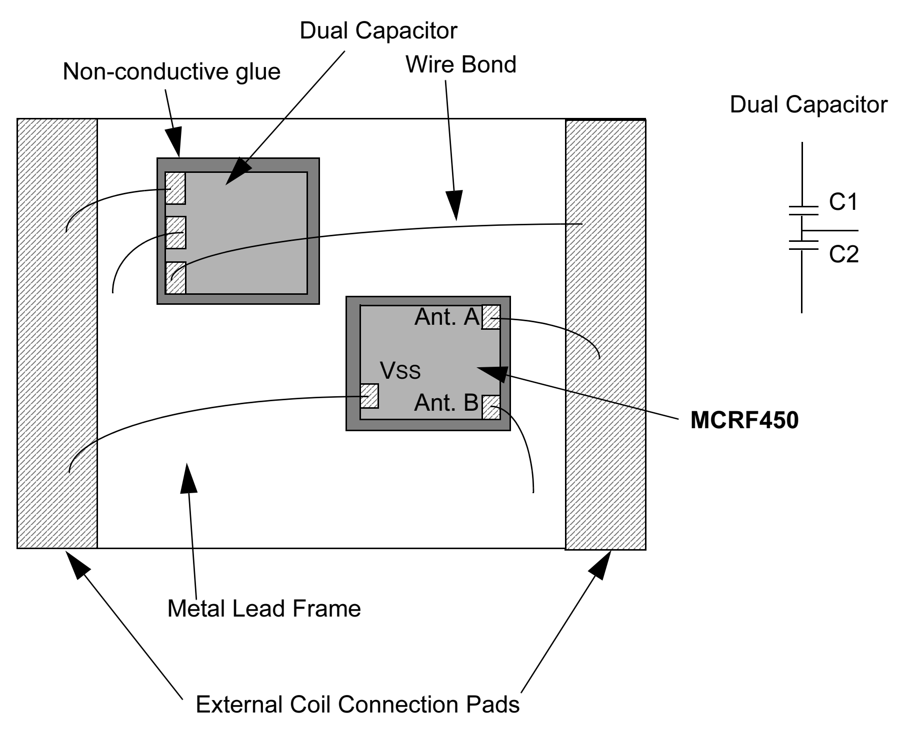


FIGURE 20: MCRF450 COB ANATOMY



COB TEST PROCEDURES

COB manufacturers test the COB during and after final assembly. The COB test typically consists of (a) open/short test and (b) function test. Most of the COB manufacturers are conducting 100% open/short test and a sample function test.

125 kHz COB (MCRF200/250)

The 125 kHz MCRF200 and MCRF250 COB include an unpackaged RFID IC (die) and an unpackaged silicon capacitor (die). Microchip offers the COB modules with both 330 pF and 1000 pF capacitors. The COB test verifies that both die and capacitor are connected properly to the COB lead frame.

The open/short test ensures correct wire bonding from die to the COB lead frame. This open/short test does not guarantee the connection of the capacitor, however, the capacitor can be tested with a capacitance meter. If capacitance measurement is not possible, a functional test may be used instead with a proper sample size.

The MCRF200 and MCRF250 are one time contactlessly programmable (OTP) devices. Although these devices require a special pulse sequence to enable the Programming mode, an unprogrammed (blank) device could accidently enter the Programming mode with a high voltage, and lock the memory array. A voltage of less than 14 V_{PP} must be used for the unprogrammed COB test. These unprogrammed MCRF200/250 COBs must be handled carefully. However, the COB for the factory programmed device (SQTP) can use higher voltage for testing. Refer to the MCRF200 and MCRF250 data sheets for more information on contactless programming.

OPEN-SHORT TEST:

Force I_{PP} = 0.4 mA, and pass if Voltage = 7.2 V_{PP} - 8.2 V_{PP}.

FUNCTIONAL TEST:

The functional test is done by measuring the modulation signal. The COB must be attached to the coil and exposed to the tester's RF field.

The COB with a factory programmed device (SQTP) is mostly done with a reader which outputs an RF signal and measures the responses from the tag.

For the COB with a blank device (unprogrammed COB), the functional test can be done with a reader or Microchip's MCRF200 Contactless Programmer. If the reader is used for the test, the output power must be kept as low as possible. Do not exceed more than 14 V_{PP} across the COB pads. If the COB sees greater than 14 V_{PP}, it can enter the Programming mode and accidently program the COB with the RF field. The device outputs a modulation signal when the voltage across the COB is greater than 9~10 V_{PP}. The voltage should not exceed 14 V_{PP}.

When the test is performed using Microchip's 125 kHz Contactless Programmer, the customer can tell whether the device is actually blank or not.

MCRF200/MCRF250 COB Function Test Procedure.

CONTACTLESS PROGRAMMER SET-UP:

1. Prepare the microID™ Contactless Programmer and RFLab 125 kHz software on a personal computer (PC).
2. Connect 9 VDC power supply to the Contactless Programmer.
3. Connect the Programmer to your PC via RS-232 cable.
4. Run "RFLab125".
5. Click "File" from the menu on the RFLab and select "microID Programmer".
6. Select "comm port" (1,2,3, etc).

COB TEST COIL SET-UP:

1. Place the COB test coil (RFID antenna coil) on to the "Contactless Programmer" as shown in Figure 21. Make sure the coil is placed at the center of the tag placement area on the programmer.
2. You may secure the coil to the programmer with a tape if necessary.
3. Place two COB holding pins (clips or pogo pins) to the coil (see Figure 21).

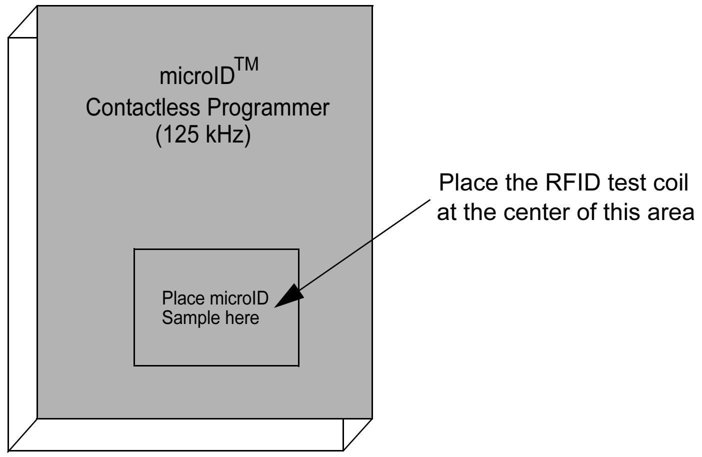
COB SAMPLE TEST

1. Connect the sample COB to the COB holder pins in the COB test coil.
2. Click the "Blank Check" button in the RFLab menu on your PC.
3. If the COB is blank (good), a green bar appears in the RFLab with a message "Device is Blank".
4. If the device is bad (or already programmed), a red bar appears with a message "Device is Not Present".

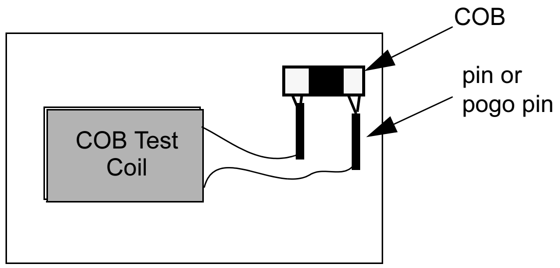
Note 1: Please contact Microchip Technology Inc. for further assistance.

2: Do not click the "Program" button unless you want to program the device. You can't reprogram the COB once it has been programmed.

FIGURE 21: 125 KHZ CONTACTLESS PROGRAMMER AND COB TEST SET-UP



(a) 125 kHz Contactless Programmer



(b) COB Test Coil Set -up

13.56 MHz COB (MCRF355, MCRF450/452)

The MCRF355 and MCRF450 COB includes a dual silicon capacitor: one capacitor (C1) between antenna A and B, and another capacitor (C2) between antenna B and VSS pads. Microchip's 13.56 MHz COB includes dual 68 pF capacitors. The dual 68 pF capacitance is chosen to match the inductance of ISO access control card type properly. Different capacitor values can be used for other types of applications.

Figures 15 and 17 show the IOA2 and WORLD II type COB package, respectively. Drawings for each COB are shown in Figures 12 and 13.

MCRF355 COB TEST:

Open/Short Test (forward and reverse excitations)

1. Force I (forward) = 20 μA, and pass if V = 0.5V~1.2V.
2. Force I (reverse) = 20 μA, and pass if V = 0.2V~0.6V.

Capacitance Measurement

1. Measure the capacitance of the COB.

Functional Test

1. The COB can be tested by monitoring the 70 kHz manchester encoded modulation. The COB outputs the data as soon as it is energized.
2. Attach the COB to a proper RFID coil (inductor) and bring the COB into the reader's RF field and measure any modulated data. The MCRF355 or MCRF355/45x reader can be used for this test.

MCRF450 AND MCRF452 COB TEST:

Open/Short Test (forward and reverse excitations)

1. Force I (forward) = 0.3 mA, and pass if V = 6V~8V.
2. Force I (reverse) = 20 uA, and pass if V = 0.2V~0.6V.

Capacitance Measurement

The MCRF450 COB requires a dual capacitor. This capacitor must be tested to see if it is properly connected to the lead frame.

The MCRF452 COB does not require an external capacitor since the MCRF452 device includes a dual 50 pF on-chip capacitor. The internal capacitor is tested at wafer probe prior to shipment. Therefore, open/short and sample function tests should be sufficient for the MCRF452 COB.

Functional Test

The COB can be tested by monitoring the 70 kHz manchester encoded modulation.

If the device is configured to Tag Talk First mode (TTF), the COB outputs its' tag ID data when it sees an FRR/FRB command, or as soon as it is energized. The default set of the device is fast read (FR bit = `1`) and Read Talk First (RTF) mode. In this case, the COB requires the FRR (if FR bit is set) or FRB (if FR bit is cleared) to initiate communication with the reader. When the COB receives the FRR or FRB command, it outputs a 32-bit tag ID with a Manchester encoded 70 kHz data rate. This test can be performed using Microchip's MCRF45x system development kit.

EFFECT ON READ RANGE DUE TO THE CAPACITANCE VARIATION FOR THE 13.56 MHZ TAG

The read range of the tag is greatly affected by tuning conditions of the antenna circuit (to the reader carrier frequency) and the Q factor of the antenna circuit. The inductance must be designed to yield minimum resistance as possible for the highest Q factor. The capacitor for both the tag and COB must be chosen to have the following criteria for the maximum read range:

1. Q factor must be greater than 100 at 13.56 MHz,
2. DC voltage rating must be greater than 50 VDC,
3. Optimum capacitance tolerance: < 5%.

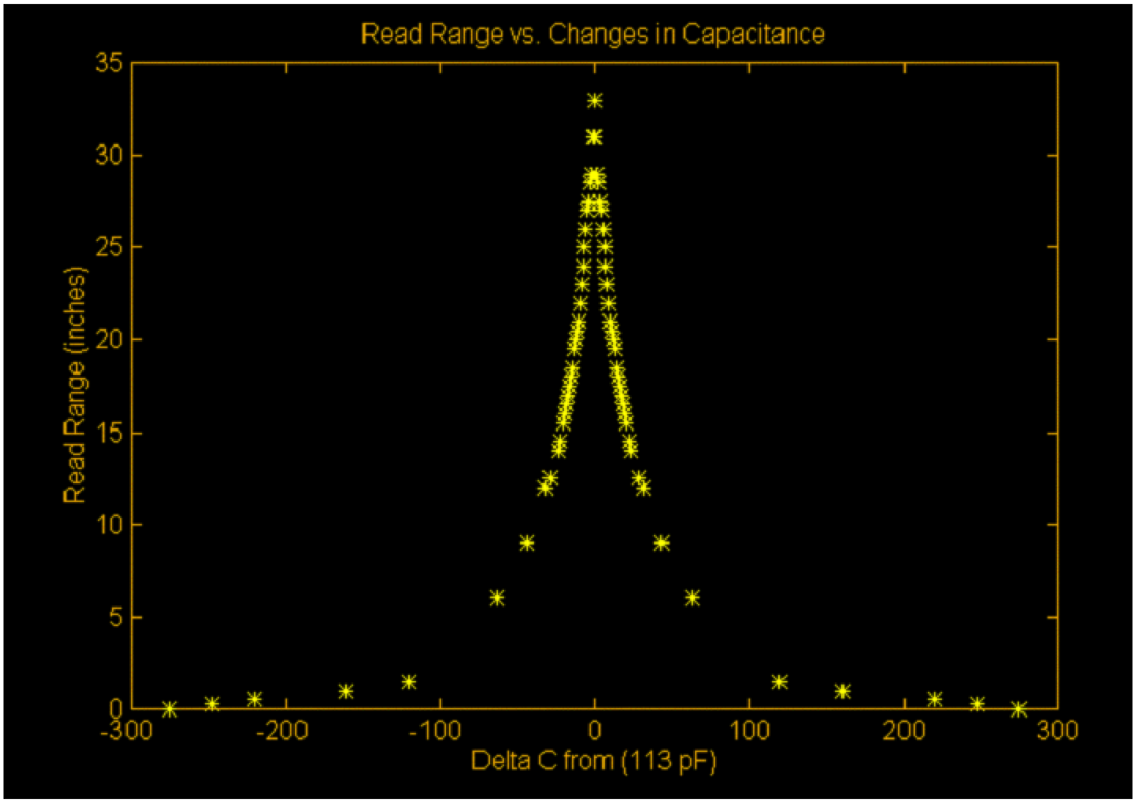
Any variation of capacitance or inductance results in a change of the resonant frequency of the tuned antenna circuit. When the circuit is detuned from the reader's carrier frequency, the tag develops less voltage. This results in a shorter read range. Table 7 shows the capacitance variation from a tuned circuit vs. resonant frequency vs. read range. Figure 22 shows the read range vs. changes in the capacitance value from its tuned circuit. A reference long range reader and tag is used for the data in Table 7 and Figure 22. The results indicate that the component variation is critical for long range applications. For example, a 10% difference in the capacitance value reduces the read range about 37% from its maximum range. It also shows that 1 pF of capacitance difference from its tuned condition reduces the read range about 1 inch from its maximum range (33 inches) that is available in a tuned condition. The data also indicates that component variation becomes less significant for short read range applications.

TABLE 7: VARIATION OF CAPACITANCE VALUE VS. RESONANT FREQUENCY VS. RESULTING READ RANGE

Capacitance Variation (pF) from Tuned Condition	Resonant Frequency (MHz)	Read Range (inches)
0	13.56	33
1	13.3896	31
1.2	13.3273	29
2.7	13.3119	28.5
3.3	13.2692	27.5
4.3	13.255	27
5.3	13.1964	26
6.3	13.1473	25
7.3	13.1055	24
8.3	13.0544	23
9.3	13.0042	22
10.3	12.9613	21
11.3	12.9151	20.5
12.3	12.8672	20
13.3	12.8221	19.5
14.3	12.7698	18.5
15.3	12.7243	18
16.3	12.6701	17.5
17.3	12.6257	17
18.3	12.5869	16.5
19.3	12.5377	16
20.3	12.4936	15.5
22.3	12.4166	14.5
23.3	12.3711	14
29.3	12.1186	12.5
31.6	12.0222	12

Capacitance Variation (pF) from Tuned Condition	Resonant Frequency (MHz)	Read Range (inches)
43.3	11.731	9
63.3	11.0744	6
120.3	9.597	1.5
160.3	8.9006	1
220.3	7.7304	0.5
247.3	7.7465	0.25
275.3	7.204	0

FIGURE 22: READ RANGE VS. CHANGES IN THE CAPACITANCE FROM ITS TUNED VALUE



REFERENCES

[1] MCRF200 Data Sheet, DS21219

[2] MCRF250 Data Sheet, DS21267

[3] MCRF355/360 Data Sheet, DS21283

[4] MCRF45X Data Sheet, DS40232

[5] Microchip Technology Inc., Appl. Note AN707, “MCRF355/360 Application Note: Mode of Operation and External Resonant Circuit”

[6] Microchip Technology Inc., Appl. Note AN710, “Antenna Circuit Design for RFID applications”

[7] MicroID^{TM} 13.56 MHz RFID Design Guide, Microchip Technology Inc., DS21299

[8] MicroID^{TM} 125 kHz RFID Design Guide, Microchip Technology Inc., DS51115

Note the following details of the code protection feature on Microchip devices:

- Microchip products meet the specification contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is one of the most secure families 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 Microchip products in a manner outside the operating specifications contained in Microchip's Data Sheets. Most likely, the person doing so is 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 products.

Information contained in this publication regarding device applications and the like is intended through suggestion only and may be superseded by updates. It is your responsibility to ensure that your application meets with your specifications. No representation or warranty is given and no liability is assumed by Microchip Technology Incorporated with respect to the accuracy or use of such information, or infringement of patents or other intellectual property rights arising from such use or otherwise. Use of Microchip’s products as critical components in life support systems is not authorized except with express written approval by Microchip. No licenses are conveyed, implicitly or otherwise, under any intellectual property rights.

Trademarks

The Microchip name and logo, the Microchip logo, KEELOQ, MPLAB, PIC, PICmicro, PICSTART and PRO MATE are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

FilterLab, microID, MXDEV, MXLAB, PICMASTER, SEEVAL and The Embedded Control Solutions Company are registered trademarks of Microchip Technology Incorporated in the U.S.A.

dsPIC, dsPICDEM.net, ECONOMONITOR, FanSense, FlexROM, fuzzyLAB, In-Circuit Serial Programming, ICSP, ICEPIC, microPort, Migratable Memory, MPASM, MPLIB, MPLINK, MPSIM, PICC, PICDEM, PICDEM.net, rfPIC, Select Mode and Total Endurance are trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

Serialized Quick Turn Programming (SQTP) is a service mark of Microchip Technology Incorporated in the U.S.A.

All other trademarks mentioned herein are property of their respective companies.

© 2002, Microchip Technology Incorporated, Printed in the U.S.A., All Rights Reserved.

Printed on recycled paper.

DNV Certification, Inc.
USA

ANSI★RAB
QMS
ACCREDITED

DNV

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 and Mountain View, California in March 2002. The Company’s quality system processes and procedures are QS-9000 compliant for its PICmicro® 8-bit MCUs, KEELOQ® code hopping devices, Serial EEPROMs, microperipherals, non-volatile memory and analog products. In addition, Microchip’s quality system for the design and manufacture of development systems is ISO 9001 certified.

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: 480-792-4338

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

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: 86-28-86766200 Fax: 86-28-86766599

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: 86-755-82350361 Fax: 86-755-82366086

China - Hong Kong SAR
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: 65-6334-8870 Fax: 65-6334-8850

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

EUROPE

Austria
Microchip Technology Austria GmbH
Durisolstrasse 2
A-4600 Wels
Austria
Tel: 43-7242-2244-399
Fax: 43-7242-2244-393

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
Steinheilstrasse 10
D-85737 Ismaning, 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
Microchip Ltd.
505 Eskdale Road
Winnersh Triangle
Wokingham
Berkshire, England RG41 5TU
Tel: 44 118 921 5869 Fax: 44-118 921-5820

10/18/02