Payment card technology:
A guide for non card-manufacturing experts

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Abstract

Contactless payments are on the rise in the US, and many issuers have started the migration of their portfolios to contactless-enabled cards. As for any technology transition it is important to ask: Is the technology safe, secure and reliable? Will it enhance the customer experience? Can the migration costs be lowered and how? Is the supply chain reliable and agile?

The answer to these questions is largely dependent on the choice of contactless technology used for card production, and it is worth looking under the hood.

This white paper looks into the different technologies available today, and aims at offering supply-chain stakeholders the knowledge to make the right technology decisions for their business and for their customers.

We believe “Coil on Module”, which combines the benefits of inductive coupling and universal card antenna design, is the most effective solution for dual interface card construction, payment brand approval processes and daily use by consumers. This technology assures the fastest time to market, the highest quality, longest life, lowest cost and greatest manufacturing efficiency.
Payment card evolution

It has been almost 25 years since the card payment industry began to use Integrated Circuit (IC) cards that complied with EMV® (Europay, MasterCard, Visa) specifications. By 2017, EMV®-compliant cards accounted for nearly two-thirds of all card-based transactions worldwide, with penetration in many regions surpassing 90%. Members of the US Payments Forum reported in July 2018 that chip-on-chip transactions reached approximately 57%, or 60% of payment volume. Importantly, nearly 90% of cards in use today in the US are chip-enabled, indicating that EMV® transactions will continue to grow as the reader infrastructure buildout is completed.

With global adoption of EMV® Payment Acceptance, the conditions are set for the next major evolution of the payment card industry. This is the move to contactless payment, which promises to broaden card use by delivering improved user experiences and new payment use cases that are convenient, reliable and secure. To support this transition, card suppliers and issuers are required to support previous card technology, including contact-based and magnetic stripe, as well as the new contactless interface.

The value of dual interface cards

Several developments underlie the value proposition for contactless enabled payment cards. The first is the widespread adoption of contactless EMV® payment acceptance. The second is the advent of new payment devices like smartphones or wearables that require a communication technology that is independent of the form factor. The third is the transition to card acceptance for new types of payment applications, including transit.

As the EMV® transition accelerated, it has been reported that consumers and merchants generally perceive that transaction times for contact-based EMV® compliant cards are longer than transactions with older magnetic stripe technology. The user and merchant experience with contactless transactions is perceived to be faster, typically just one-third the time needed for a contact card transaction.

In addition to improving the perceived speed of transactions, contactless technology is seen as complementary to the adoption of NFC-based mobile payment technology. Both have a similar “tap to pay” benefit for both consumers and merchants.

In the U.S. today, there are two main EMV®-compliant card implementations.

› Contact-based cards contain a chip packaged within a module that must be inserted into a card reader such as an ATM or POS terminal (based on ISO/IEC 7816 standard).

› Dual-interface cards contain a single packaged chip module that supports both contact and contactless (using short-range, low power radio frequency signal) communications (based on ISO/IEC 14443 standard).

This paper compares the available technologies for producing dual-interface contactless cards. Pure contactless cards (no contact interface) and hybrid cards (which combine a contact-based chip and a separate contactless chip/antenna in the same card) represent a small and declining share of the payment market and are not considered in this document. Likewise, more costly specialty cards (e.g. with dynamic CVV, with fingerprint sensor, wallets etc.) are not discussed.

Finally, contactless is also seen as an essential element in multi-purpose and multi-application payment cards\(^4\). This is a particularly exciting and far reaching development. There are existing contactless infrastructures that support a great number of diverse applications, such as public transportation, hospitality, loyalty, building access, education,..

In public transportation, New York's Metropolitan Transportation Authority will begin its transition to contactless fare payment in late-2018 with installation of the technology in 500 subway turnstiles and 600 buses. The MTA plans for all buses, subway stations and the Long Island and Metro North rail terminals to be served by 2020.\(^5\) New York officials are licensing infrastructure technology to support the new system from Transport for London, which adopted the technology earlier this decade and now reports that 17 million trips per week are paid for with contactless.\(^6\)

For transit, dual interface cards offer great benefits to passengers (convenience of using your payment card or mobile phone at the turnstile), and Transit Agencies (fewer ticket vending machines).

Other applications like hotel key cards, access badges or student IDs leverage the same contactless standard protocol, ISO14443, as Payment or transit cards.

For card issuers, these applications add convenience, more transactions and thus broadens portfolio utilization. Consumer behavior has already shown that contactless capability may help move a card to “top-of-wallet” status, creating incremental revenue for issuers.\(^7\)

In short, the benefits of contactless produce a positive feedback loop; a great consumer experience leads to greater usage, which creates incremental revenue and improves portfolio utilization for issuers. The result is that while contactless-capable cards are not yet extensively used in the U.S., this is about to change. ABI Research estimates that growth will jump from just 25.7 million units shipped in 2016 to 57.6 million in 2018, and then 179.4 million shipped in 2021.\(^8\) The question then for card manufacturers is how to produce cards that meet operating requirements, are reliable over the expected lifetime of the card and are competitively priced.

\(^4\) Pure EMV® cards that are also accepted on transit networks are “multi-purpose”. EMV® cards that have an additional transit application implemented for a specific transit network are “multi-application”.


What’s in your card?

The payment card manufacturing process for a payment card with contact chip is relatively simple at first glance: a card body that meets the ISO standard (dimensions, thickness etc.) and is assembled by laminating several layers of PVC. A cavity is then milled at a specific location (in the upper left part of the card) and a chip module is inserted and glued into the card. The card is then personalized; the customer’s name is embossed or printed and the chip is programmed with the payment account information and secret keys for the security features. When inserted into a card reader, contact between the chip module and the chip reader inside the payment terminal enables communication.

For a dual interface card, the module is upgraded with a chip that supports contactless communication using very low-power RF. At least one additional production step during card manufacturing is needed: an antenna is inserted in the card body during the lamination process before milling and embedding of the chip. While the added step and materials make contactless cards more expensive to produce than contact-only cards, other markets have demonstrated the benefits of the technology far outweigh the cost. As we shall see, the choice of dual interface technology also affects the cost to issue the card and the complexity of the supply chain.
Dual interface card technologies

As noted above, a dual interface card must support two methods of communication with a card reader. It requires an electrical contact to physically interface with the card reader, and an antenna to support the radio frequency (RF) communication needed for the contactless interface. The antenna is an inlay in the plastic body of the card which, in turn, requires a link to the chip module in the card.

The two ways to implement the “module to antenna link” are pictured here. They are Direct Connect, which uses a galvanic, physical connection, or a technique known as Inductive Coupling.

With Direct Antenna Connect, the module is physically connected to the antenna using micro-soldering, polymer bumps, silver glue or other connection technologies. In the case of Inductive Coupling, the connection is made through radio frequency. Although the end results look similar, there are significant differences between the approaches. Both technologies can lead to an excellent quality level, however in case of Direct Antenna Connect this will require higher investments & several process optimizations compared to Inductive Coupling.

There are two quality-related sensitive points to be considered with Direct Antenna Connect.

- **A physical connection can break** if the card quality is not optimized. When going through a mail-sorting machine, or bent when sitting on a wallet, a card is subject to bending and torsion that results in high stress on the connection. If card manufacturing processes and quality are not well managed by the card embedder this stress may lead to the connection breaking, making the card inoperable in contactless mode. Inductive Coupling has no physical connection that can be broken with this technology it is easier to reach a high quality level with less manufacturing effort.

- **Electrostatic Discharge (ESD) can damage the card, or the payment terminal.** Specifically in cold and dry climates and without counter measures on the card or on the chip, an electrical charge can accumulate and be dissipated via the module to the reader, with possibly destructive consequences. Inductive Coupling has a lower risk of ESD damage compared to Direct Connect technology, which allows ESD discharge to flow freely between the card body, antenna and module.

Coil on Module from Infineon is based on a flip chip module design optimized for thicker card body structure. Thinner lamination can lead to early tear (exposure of the back side of the module) of the card. Payment card thickness is set by ISO standards at 760 µm (1/32 in, about 31 mils). Most of the chip card module designs in the market are 580 µm thick, leaving just 180µm. “Coil on Module” assembly is just 32 0µm thick.

This means that the backside lamination thickness jumps up to 44%, from 180 µm to 440 µm (7.2 to 10.4 mils), by using this module technology. This improves the overall reliability of the card, as well as its aspect (the back side of a thicker module can be seen through a thin lamination layer if the embedder does not have accurate manufacturing tolerances to realize an appropriate backside layer).
Direct connection of modules introduces an extra soldering step in the production process. This may require:

› **Capital investment in tooling.** Soldering a module to an antenna requires specific equipment
› **Reduction in supply chain flexibility** compared to contact card manufacturing due to required dedicated equipment and processes
› **Reduction in manufacturing throughput & incremental yield loss due to physical connection** if the process is not mastered & optimized by the embedder
› **Additional cost of consumable material** (e.g. solder paste)

### Antenna design and optimization

As noted earlier, the dual interface card also requires an antenna for external communications with payment terminals. Achieving reliability in low-power RF communications is an engineering challenge, particularly in the environments where a payment card is used. This means that the combination of Module + Antenna + Card Body assembly is critical. There are three specific areas of concern:

› **Maximizing the energy transfer between the antenna and reader.** Here the key parameters are the Resonant Frequency (ISO/IEC 14443 specification of 13.56MHz) and the Q factor of the antenna, which gives an indication of the RF performance. The antenna design (layout and material) is naturally a key factor, as is the card body material, which affects the resonant frequency and Q factor. For instance, an antenna designed and optimized for a standard PVC card may not be optimal when using a metallic foil.

› **Maximizing the energy transfer between the antenna and the module.** The key parameter to control is the impedance matching between the module and the antenna. A mismatch results in loss of energy transferred between the antenna and the module.

› **Optimizing the mechanical and visual design.**

An antenna must be sturdy enough to resist bending and torsion tests, must not degrade in performance over time, must be compatible with 4-line card embossing, avoid ghosting where the antenna shows through the card (unless it is part of the artwork), etc.
Design impact of antenna materials

As of today mainly two types of antennas are used in dual interface cards, Aluminum etch (Al-etch) and embedded copper wire (Cu-wire). In high volumes Al-etch antennas are slightly cheaper and impedance matching can be accomplished by “tuning” capacitors that can be cut by laser, which is not possible with Cu-wire antennas. Cu wire antennas are the state of the art technology for cards with direct antenna connection. Alternatively to AL etched Cu-wire antennas have better performance, have a more discreet appearance (very fat traces of Aluminum are needed to match the low resistance of copper) and more importantly can be easily attached to a PVC inlay. The Cu wire embedding technology has also more flexibility in manufacturing and allows faster adoption to customized antenna sheet designs in comparison to AL etched antenna technology. Figure 2 shows how Al-etch antennas are made on PET(1) inlays, which do not adhere well to the PVC(2) card body. A special interface (glue) is needed, which adds to cost, increases the inlay thickness and can lead to delamination.

(1) Polyethylene Terephthalate  
(2) Polymerizing Vinyl Chloride

Another consideration when choosing between Al-etch or Cu-wire is from card design perspective the color matching of the different layers of the card. A Cu-wire antenna can be mounted on a PVC inlay that matches the card body color to produce a seamless edge. This is not the same for PET, which can’t be color-matched to the PVC body. The PET base material with thin Al-etch on both sides is typically transparent, so a match to the PVC color(s) of the card is not possible. The payment card will show a transition from the PVC layers to the clear PET.
Matching antenna and module

We’ve discussed the benefits of Inductive Coupling and the Infineon “Coil on Module” solution, and we’ve reviewed key parameters related to the antenna design and materials. This lets us examine the topics of matching the antenna and module for construction of a card with the best possible performance and reliability.

A proper impedance matching between the card antenna and module antenna is critical to the good contactless performance of the card. There are two ways to do the matching; one is to match the antenna to a given module, and the other one is to match the module to the antenna based on defined design criteria for Module and card antenna.

Matching the antenna to a given module has significant drawbacks:
› The antenna must be redesigned by the antenna vendor for every new module, which adds time and cost
› An industrialized solution for trimming of antennas (e.g. laser cutting of capacitors) as of today is only realized with Al-etch antennas, which are only available on PET inlays.

We saw earlier that the use of PET inlays have several negative consequences:
› Cost/complexity of assembly (PET to PVC adhesion)
› Potential for delamination
› Ghosting effect (large antenna traces showing through the card lamination)
› Costly and complex color-matching

Matching the module to the card antenna based on defined design criteria offers significant advantages:
› The burden of impedance matching during module development is on the module supplier
› A “universal antenna” is designed and certified and will operate with any module that is specified to meet the known impedance requirement for that antenna. This reduces the complexity during card production and simplifies the stock management significantly
› Is compatible to Cu-wire antennas on any material, in particular PVC and polycarbonate to match the card body. Additionally, “mono-block” PVC or solid polycarbonate cards can be built, thus eliminating the risk of delamination and ghosting.
Certification process

Certification of payment cards is a complex and lengthy process. EMVCo, which maintains the global specification, has a set of processes surrounding the chip module functionality, security and applications support. Each of the Payment Networks mirrors that certification process. Additionally, the Payment Networks have additional certification processes that aim at guaranteeing performance of the card and minimizing card failures that can be costly and negatively impact the brand.

For manufacturers of dual interface cards, any new card construction must undergo testing since each combination Module + Antenna Inlay + Card Body is unique. Certification testing and approval takes about three months, if no issue is found. This testing is conducted by Test Laboratories accredited by the Payment Networks (such as APPLUS, CTC, FIME), often followed by a final test and approval cycle by the Payment Network.

When a card embedder certifies their card for first time this creates pre-certified antenna / module / card body combination based on the embedding technology used (Direct connect or Inductive coupling) which is valid for this card embedder only. Depending the Payment Network used, when this card manufacturer utilizes such pre-certified combinations without change to the card construction or the embedding technology, the certification will be limited to a paperwork process.
Comparative summary

As card issuers in the US accelerate the adoption of contactless payment, we need to consider the best technologies to produce dual interface cards. The right technology can help deliver flexible, cost-effective, reliable manufacturing of higher quality dual interface cards.

The key decision criteria summarized in Table 1 include: Card Design, Contactless Performance, Cost of Ownership, Quality and Reliability, and Supply Chain Flexibility.

<table>
<thead>
<tr>
<th>Table 1: Dual interface decision criteria</th>
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<tr>
<th>Criteria</th>
<th>Description</th>
<th>Classic approach</th>
<th>Inductive coupling #1</th>
<th>Inductive coupling #2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Direct antenna connect</td>
<td>Antenna to module matching</td>
<td>Module to antenna matching</td>
</tr>
<tr>
<td>Card design</td>
<td>No ghosting</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Shallow milling cavity</td>
<td>* depends on card manufacturing tolerance</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>4-line embossing</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Metal foil and metal cards</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Contactless performance</td>
<td>Passes EMVCo and Payment Network tests</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Cost of ownership</td>
<td>No tooling investment at card manufacturer</td>
<td></td>
<td>✓</td>
<td>✓</td>
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<tr>
<td></td>
<td>Use same manufacturing line/process as contact cards</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Same milling and embedding throughput as contact cards</td>
<td>Impact of the antenna connection step that may be major if not optimized</td>
<td>Minor to no (if optimized) impact of the RF frequency check after milling &amp; after embedding</td>
<td>Minor to no (if optimized) impact of the RF frequency check after milling &amp; after embedding</td>
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<tr>
<td></td>
<td>No yield loss due to physical connection</td>
<td>* depends on card manufacturer optimization</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Quality and reliability</td>
<td>Same ESD robustness as contact cards</td>
<td>* depends on card manufacturing quality</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>No Field failures due to broken antenna connection</td>
<td>* depends on card manufacturer optimization &amp; quality</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Supply chain flexibility</td>
<td>Antenna supply from multiple vendors</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Use same manufacturing line/process as contact cards</td>
<td></td>
<td>✓</td>
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Conclusion: a low risk, cost effective migration to dual interface is possible

Whenever making a technology decision, as a consumer or a professional, it is useful to follow the following guiding principles:

› Select a standard, non-proprietary technology, with a track record of security and reliability
› Leverage existing processes, tools, and equipment
› Ensure availability and long life cycle, flexible and reliable supply chain
› Look for unique features and opportunities to differentiate

These principles apply to the selection of a dual interface technology for the next generation of contactless-enabled payment cards. As we have seen above, not all dual interface technologies are equal; some will require more efforts than others will. The selected dual interface technology will impact, positively or negatively, every step of a card life cycle: from card design to certification, production, personalization and in-field maintenance.

A careful look at the available technologies shows that inductive coupling technologies offer significant advantages and benefits over traditional methods of soldering the chip/module to the antenna for card embedders starting with dual interface manufacturing.

We have also seen that an inductive coupling technology using a universal card antenna design, such as "Coil on Module" offers additional benefits that make it the optimal choice in every respect.