

The very smart card: a plastic pocket bank

Credit cards with computer chips in them allow users to give merchants detailed financial information without contacting central banks

You have been flying for 14 hours.

Now you've arrived in Tokyo, but it's raining and your Burberry is still at home, half the world away. Not even raincoats come cheap in this expensive city. Can you remember which of your credit card accounts can stand the jolt?

Not to worry: the novel credit card in your pocket will tell you the current status of your bank and credit accounts. Its miniature computer keeps tabs on them, and your private code lets you pop the figures up on its display. It will even convert the amounts to yen, since your bank loaded the card with the prevailing exchange rates for the currencies you expect to use.

Ready to buy. *Ikura desu ka?* How much do I owe you? You enter the price of your purchase on the keypad, and the amount is displayed with a question mark. You and the merchant agree it is correct, and you press YES. The card itself immediately displays the approval code for your purchase. *Arigato.* Thank you.

An ultrathin personal terminal

Until now, even IC-based "smart cards" have only partially streamlined systems for making payments with charge or cash cards. Unlike plain plastic cards, smart cards can determine the eligibility and creditworthiness of an account. But they must still interact with vast communication networks and relatively expensive transaction support systems to determine an account's "open to buy" status—the credit allowed to that particular account. The promise of smart cards has always been strangled by their umbilical link to other computer systems.

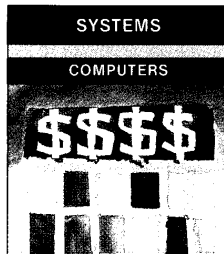
Enter the SuperSmart Card, a powerful new credit-card-sized computer that fits into your wallet. It holds the promise of taking over many of the jobs of transaction-support systems, redistributing vast amounts of data-processing work.

This June, Visa International Inc. began field tests of these multipurpose cards, which it developed jointly with Tokyo's Toshiba Corp. The tests, now under way in Japan and the United States, will expand to five regions of the world. San Francisco-based Visa International operates the world's largest payments system: it issues nearly half the major cards, and its 156 million cardholders account for 45 percent of the volume in the card payment business. Visa also operates the world's largest network of electronic cash machines, nearly 28 000 in 24 countries. Processing rates may reach 150 transactions per second in the busy season before the Christmas holiday.

The new card acts as a multipurpose pocket terminal. It gives users instant "open to buy" status and lets them prove their identity in credit transactions with firms large and small worldwide. It supplies banking services, acting as a stand-alone cash card, passbook, and point-of-sale card, as well as the key to automated teller machines (ATMs).

In conjunction with Nippon Telegraph & Telephone Corp.

Hiro Shogase Toshiba Corp.



(NTT), the cards can be used in Japan to dial telephone numbers automatically and pay for ticket reservations made over the phone. To top things off, the card also serves as a clock, calculator, and notepad. It can even be used to store personal medical records and approve hospital admittance without agonizing delays for paperwork.

Earlier smart cards needed to interact with peripheral equipment and usually required online processing, because they had no I/O devices built in. The memory chips embedded in smart cards varied with the application and included read-only memory (ROM), programmable ROM (PROM), and ever larger amounts of random-access memory (RAM).

Although it is the same size as a conventional plastic card, a very smart card contains a display and a keyboard, and can be programmed. Its simple interface uses either the keyboard or six metal contacts for a card-reader and printer. Software is loaded or altered through a dedicated personalizing system at the issuing bank. High-speed encryption safeguards the card's internal and external security.

Cards now being tested in Japan contain 8K bytes of memory. Credit data—including issuer's and cardholder's identification, expiration date, credit balance, and transaction log—take roughly 1.2K bytes. The memo pad, which can store up to 99 memos, occupies 1.8K bytes; 3.0K bytes are devoted to telephone service; and ticket reservation data takes 2.0K bytes.

Open questions

Current field tests of the very smart card in Japan go beyond merely validating an upgraded card. They put on trial the key component of the next generation of consumer data-processing systems, subjecting its technology to unprecedented demands for reliability and security. The tests will show whether the new card can resolve the technical, security, economic, and user issues

Defining terms

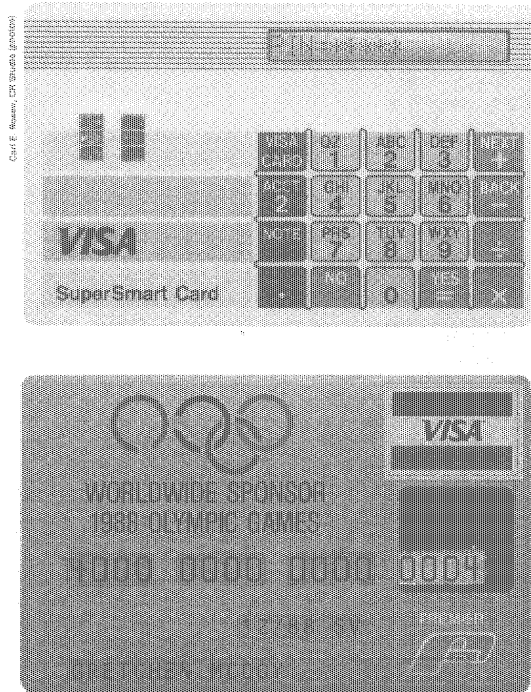
Data exchange protocol: the format and syntax used to transfer data between different computer and communications systems.

Dynamic memory management: a process by which data stored in memory pages is swapped into and out of main memory as needed.

Encryption algorithm: a set of coding procedures built into a SuperSmart Card that safeguards access to the information contained in its memory.

"Open to buy": the credit available to a customer's credit-card or charge-card account.

Smart card: a credit or cash card that contains some processing ability; smart cards are less "intelligent" than very smart cards, and require information from a centralized network to tell a user what credit is available for an account.



ahead, such as:

- Will the thin batteries, ultrathin very large-scale integrated (VLSI) circuits, and complex displays developed for the card function reliably even in hostile environments like wallets and pocketbooks, amid magnetic fields and static electricity?
- Can the same card perform equally well in stand-alone usage and linked to terminals for updating and/or transactions?
- Because debit cards are in effect preloaded with money, are the cards' internal records sufficiently secure?
- Since very smart cards cost more to make than smart cards, will their added features and benefits justify their extra cost to the issuing bank and/or the card user?
- What kinds of people are willing to learn how to use a card that performs multiple functions for a variety of services?

Easy and friendly

Ease of learning and ease of use will be two of the field test evaluations. To a user, the new card's programs appear friendly, helpful, and no more complex than a few keystrokes prompted and confirmed by a liquid-crystal display (LCD).

With one keystroke, the cardholder selects one of several accounts. After the user has entered a personal identification number (PIN) and transaction amount on the keyboard, a card program verifies the PIN, checks the account balance, deducts the amount spent, and stores it in memory. Meanwhile, the card computes and displays a unique approval code [Fig. 1]. The cardholder completes the transaction by showing the approval code on the card's display to the sales clerk, or by stating the code if the sale takes place over the telephone.

Whereas other cards demand queries to one or more remote databases to establish creditworthiness, a very smart card must be able to approve its own transactions because the issuing bank has previously loaded it with records of guaranteed worth. Its generation of an approval code can be used to prove identity over the telephone. If, for example, someone called his banker to arrange a transfer of millions of yen, or tens of thousands of dollars, he might be asked to enter a string of random numbers into

the card as if they were a transaction amount and to read back the approval code it computed. Given a correct answer, the banker would assume the card is being operated by someone who knows the PIN, and would tell the caller how to enter the transfer request. The card also provides other conveniences, including currency conversion [Fig. 2].

Inside the card

The essential technology of the new card consists of 10 components, many of which were newly developed for this application [Fig. 3]. The central processing unit (CPU) is a high-density VLSI circuit with low power dissipation. It contains an 8-bit microprocessor, 16K bytes of ROM, 8K bytes of data memory, a real-time clock and calendar, the keyboard interface, the controller for a transducer that emulates magnetic-stripe signals, and data encryption circuitry to support high-speed encryption and authentication. The use of Toshiba's Super Integration computer-aided design system drastically shortened the development times of the ICs used.

The 8K-byte data memory is a CMOS static RAM that can be written to and read from with low power and low voltage. The card's LCD is a row of sixteen 5-by-7-dot matrixes that show alphanumeric characters and symbols.

In most transactions, cardholder information is recorded by a terminal that reads a magnetic stripe or mechanically imprints the characters embossed on the card. Although a very smart card is thin (0.76 millimeter) and stuffed with technology, it was designed to survive repeated impacts by a mechanical imprinter.

During development, the decision was made to keep the new cards compatible with conventional magnetic-stripe card readers. Earlier versions of the card malfunctioned with a magnetic stripe close to the circuitry, but one was needed to function with ATMs.

So, a small, very thin magnetic-head transducer emulates the signals of a normal magnetic-stripe card as it is swiped over the heads of a card reader. It employs thin-film technology commonly used for hard-disk magnetic heads. In Japan, field tests continue on this card. The version used by Visa in other tests has a magnetic stripe, however. To make it less conspicuous and more pleasing esthetically, this stripe is not brown-black but gold.

Clearly power consumption was a major design consideration

The future for self-contained transaction cards

The attraction of secure personal electronic funds transfer in the United States is beginning to extend beyond automated teller machines (ATMs) and payments to stores, restaurants, and gasoline stations. Electronic delivery of funds has long been common in France, where payrolls are transferred to employees' banks and funds made available for withdrawal by bankcard or credit card, including smart card versions.

Because very smart cards improve protection against fraud and reduce the communications and administrative costs of stand-alone use, new niches can be projected from recent smart card tests:

- In Minnesota, 9000 welfare clients will receive benefits from ATMs. Many of these people would ordinarily be considered outside the payment infrastructure because they have no bank accounts.
- The U.S. Navy is about to test shipboard ATMs made by NCR Corp., Dayton, Ohio, as a way to reduce long lines of crew members waiting to cash paychecks.
- U.S. Marines in boot camp are issued not only rifles but also smart cards, acceptable on base for goods and services.
- Because a U.S. Department of Agriculture experiment with online debit smart cards for food stamp recipients proved slow and costly, it is considering offline cards for such transactions.

—Evan Herbert, Contributing Editor



Carl E. Rosen, CNI Studio (photos)

[1] The SuperSmart Card flashes date and time when turned on. When an account is selected, the holder's personal identification number (PIN) is requested. The display confirms the keystrokes without revealing the actual PIN. Users may review the amount available in an account ("open to buy") and previous purchases. When a new transaction amount is keyed in and shown to a store clerk, the user confirms the entry with the YES key. The card then uses the amount, PIN, and date to compute and display a unique authorization code for this transaction. The clerk enters the code in the store register and on the receipt.

for the very smart card. With a specially developed thin-paper 3-volt lithium battery and CMOS VLSI circuit technology for the chips, a card will last at least two years, with an average life of three years, assuming 10 transactions a month plus card use for other functions.

So thin a card, handled or stored in wallets or pockets, might bend enough to damage the components inside it. The rigid card structure adopted survives the International Standards Organization's bending property standard, which requires the card to function with a distortion of 20 mm over its length and 10 mm over its width. This goal was achieved with the aid of a computer-aided design system for structure and layouts, and assembly methods tailored to handling extremely small parts.

Finite-element analysis was used to evaluate the card bending pressures and thermal effects, and components were then laid out to mitigate the effects of force and heat. The printed-circuit board used can squeeze five conductor lines into 1 mm.

Because the card is only 0.76 mm thick, conventional techniques of wire-bonding for chip terminals and printed boards were not precise enough to control the shape or height of the wiring loops. Toshiba developed software that controls loop shape during the unique wire-bonding method used for low-loop, high-density laser welding.

Surge absorbers protect the card's circuitry from the effects of static electricity generated by wool, silk, or synthetic fabrics. They even accommodate the eel skin desirable for very thin and very expensive wallets and credit card holders. The most vulnerable points of entry for static electricity are the exposed card contacts; the surge arrestors are located just behind them.

When a bank issues a very smart card, it writes information

into memory and embosses the face of the card. Conventional punch and die methods of embossing seemed likely to damage the card's electronics, so new embossing technology was developed: clear plastic pads are formed on the front panel of the card by the manufacturer, and then the issuing bank uses a computer numerically controlled (CNC) engraving unit to mill the pads into alphanumeric characters giving cardholder name, card number, expiration date, and so on.

Keeping it secure

Most of the safeguards inherent in the card stem from its enhanced microprocessing capabilities. These let the card use a sophisticated encryption algorithm to make some memory conditionally accessible through PINs or code words. Toshiba believes that this algorithm is even proof against any attempt at fraud made through the metallic contacts that let outside devices read to and write from the card.

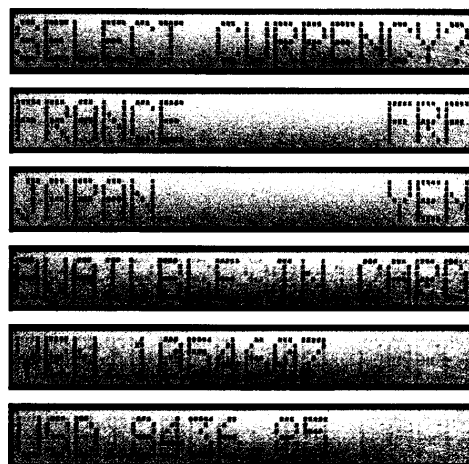
This concern for security characterizes every stage in the card's life cycle. Confidentiality is required of the card issuer, manufacturer, cardholder, and service provider. Access to the card's data areas is controlled by a group directory; each area may be accessed only after the code unique to each directory is specified. A code may be a combination of a PIN and/or authentication keys, to be entered by users or the issuing bank.

To replenish a card's "open to buy" line of credit after bills are paid, issuing banks furnish each cardholder with a unique code in the monthly statement. Typically, a statement would contain a bill for credit transactions during the past month, plus a string of numbers to be keyed into the card on the assumption that the user has paid the current bill.

That code allows a bank to set or reset usage limits according to the user's payment behavior. Or it might suspend use of a savings or checking account when it is emptied of cash. World travelers who do not catch up with their statements as they draw down their accounts can take the very smart card to any member bank in the Visa association. Updating information is downloaded from the issuing bank through the Visa communication network to a member bank's chip reader.

Although the data exchange protocol for IC cards to communicate with read/write devices has not been standardized by the ISO, the card employs a subset of the ISO 1745 and ISO 2629 that are used for ordinary online communication systems.

The card's software structure enables it to be programmed for



[2] A very smart card can convert its user's base currency—here U.S. dollars—into foreign currencies, using rate tables entered by the issuing bank. The available amount is then displayed in local currency.

a variety of applications. Its operating system manages the hardware to control power and shut off the battery after the keyboard has been inactive for an arbitrary period of time. For security, the display is controlled under certain conditions, such as keyboard entry of a PIN, when a star rather than an actual number confirms each keystroke.

As on more conventional cards, the information is protected by a PIN. At certain stages of operation, a very smart card simply will not work unless the correct PIN is verified by an access control software module in the security management program.

Moreover, such important data as currency conversion rates are guarded by specially encrypted data called a message authentication code (MAC). Unless the MAC is correctly entered, this data held in the card cannot be modified.

Features providing security against forgery and unauthorized modification of information within the card are part of a progressive manufacturing process that starts in Toshiba's factory and ends in the personalization centers of Visa member banks [see "Automating issuance," below].

Despite these safeguards, technology cannot fully protect users against their own carelessness or stupidity. Any card is vulnerable if lost or stolen with its PIN. Banks warn against recording PINs where they can be associated with cards; now they are moving toward real-time updates to merchants' "hot card" lists. But the new card's ability to generate approval codes does not relieve merchants of the obligation to check such lists.

Field tests in Japan

The stand-alone features of the card will simplify the ways that earlier multi-application cards had to be used. Recent field tests of multi-application smart cards in Japan illustrate the potential for the SuperSmart Card in Visa's current global field trials.

Field trials began in December 1986 in Park City Kanazawa

Hakkei, a residential area of the southern part of Yokohama, Kanagawa. The participants were Mitsui Bank/Sangin Credit, Saikaya Department Store, Nippon Petroleum, Mitsui Life Insurance, Taisho Marine Insurance, and Toshiba. This system allows 300 smart-card holders to shop in department stores without leaving home, and to make cashless gasoline station purchases. Through an inquiry terminal at Mitsui Bank, the card can be used to obtain insurance information, property value analysis, even biorhythm information.

For home shopping, Sangin Credit issues cards to customers who have opened accounts for repayment at Mitsui Bank; cardholders can receive broadcasts of Saikaya Department Store's catalog on local cable television and may order by telephone.

The deliveryman enters the purchase amount into a handheld terminal on arrival at a customer's home. If it is correct, the customer inserts the card into the terminal, enters a PIN, and confirms the transaction details displayed on the terminal. Then the transaction is recorded in the customer card and in the terminal memory; the terminal also prints out a paper receipt. Purchases are billed by the department store to Sangin Credit and subsequently by Sangin to the cardholder, who must settle the account by depositing the required amount in Mitsui Bank for transfer to Sangin Credit.

Use of the smarter card for home shopping, however, eliminates the terminal used during delivery. When placing the order, the cardholder generates an "electronic signature"—an authentication code unique to that transaction—which he or she provides to the store verbally on the telephone. A clerk then enters this code into a terminal without further delay for approval.

The Japanese field trials of the multi-application very smart card are called the Vista project (for Visa integrated services with telemarketing access). Trials were first conducted within Toshiba, NTT, and issuing banks. In the public test, cardholders of

Automating issuance

Tight security shrouds the distributed stages of personalizing a SuperSmart Card at the issuing bank. The data file for each card combines such Visa data as account number and issuer with the issuing bank's data: the cardholder's accounts and limits, base currency, and conversion tables.

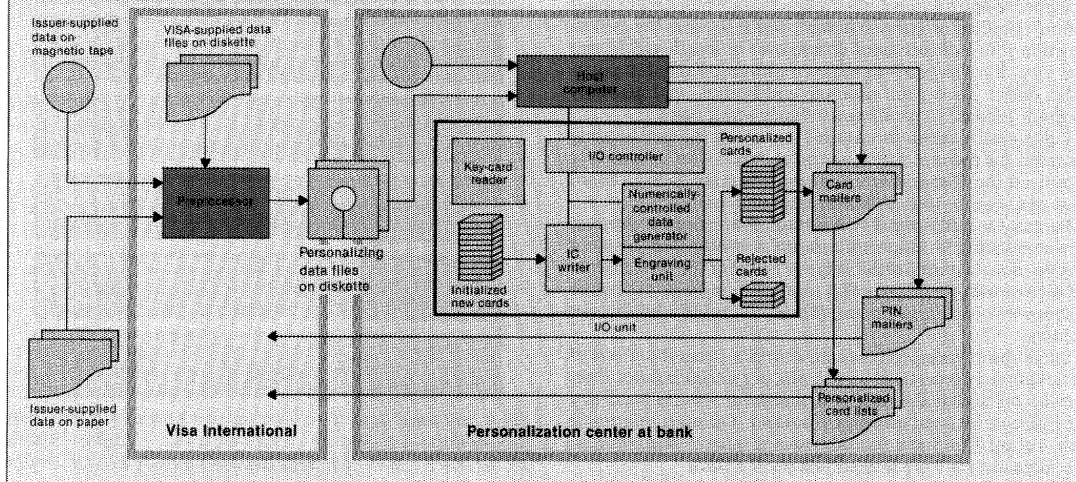
Authorization codes permit the personalizing machine to enter applications and data into dedicated parts of card memory through the card's electrical contacts. Without the proper codes, some of this information—such as the initial amount available—cannot be modified after it is loaded. Visa contends that the security of the new cards will be hard to compromise because no entity in the overall system (Visa,

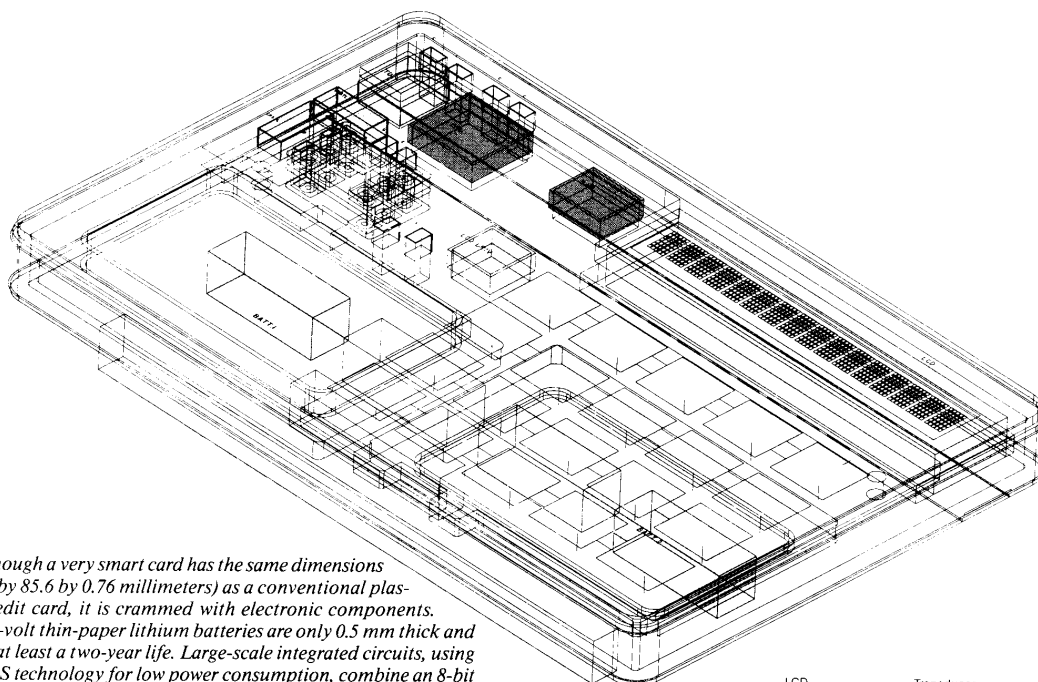
the card manufacturer, or units of the issuing bank) will have all the keys needed to modify such data.

The issuing bank enters a personal identification number (PIN) into the card, and mails it to the user, but cardholders may alter the PIN at will. The bank determines how many times a PIN may be entered incorrectly before the card disables itself on the premise that someone is trying to break in. Special bank codes are required to re-enable the card.

To avoid damage to the electronics when embossing it with account number, name, and expiration date, the personalizing machine mills raised plastic tabs on the card's surface into characters.

—H.S.





[3] Though a very smart card has the same dimensions (54.0 by 85.6 by 0.76 millimeters) as a conventional plastic credit card, it is crammed with electronic components. The 3-volt thin-paper lithium batteries are only 0.5 mm thick and have at least a two-year life. Large-scale integrated circuits, using CMOS technology for low power consumption, combine an 8-bit central processing unit, 16K bytes of programmable ROM, and 8K bytes of memory on one chip. The keyboard and 16-digit dot-matrix liquid-crystal display are flexible, and the card can be distorted up to 20 millimeters lengthwise without harm. It also withstands repeated impacts from conventional mechanical imprinters. The thin-film transducer emulates conventional magnetic-stripe signals.

Visa Japan use all the regular cashcard and credit services of Visa International, plus banking, reservations, and telephone network services. Both the credit card features described and prepaid or debit card functions will be evaluated.

The novel card technology, with its CPU and larger memories, holds promise of unifying personal medical information and related insurance information, thus speeding the prolonged data taking that today precedes diagnosis and treatment. Feasibility trials, using conventional smart cards, were conducted last year at Yukiuni Yamato Hospital in Niigata under the supervision of the Ministry of Health and Welfare.

At a doctor's fingertips

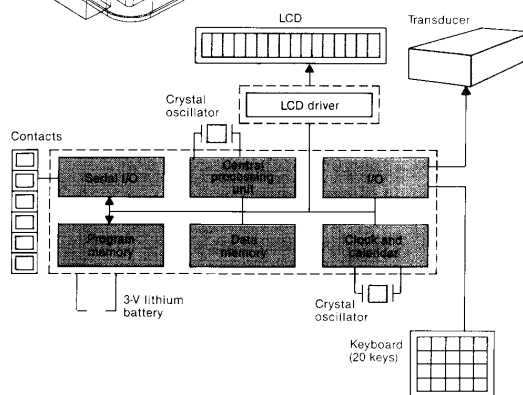
Separate cards were used for patients' records and for approval of access to those records throughout the medical information system. In this system, the hospital—not the patient—keeps the card containing a patient's medical records, such as blood type, consultations, previous diseases or surgery, and allergies.

Details of a patient's insurance information and payments are kept in another part of memory. A receptionist at a terminal records the arrival and appointment details on the card, which the patient carries into the doctor's consulting room.

There the doctor must insert a special ID card into a terminal and enter a special doctor's PIN. Only after verification of the PIN can the doctor access the information in the patient card. After diagnosis or treatment, the doctor records updated information in the patient's card and returns it to the receptionist for recording medication, insurance, and other clerical information.

To probe further

Regular updates on transaction card developments and services appear in *Card News*, published monthly for \$345 a year by



Philips Publishing Inc., 7811 Montrose Rd., Potomac, Md. 20854; 301-340-2100. A report on "IC Smart Cards—Japanese Developments and Trends" is available for \$995 from International Planning Information, 465 Convention Way, Suite No. 1, Redwood City, Calif. 94063; 415-364-9040.

The potential of smart cards for electronic funds transfer is reported in "Beating the Paper Chase," p. 9, and "Food Stamp Agency Tests Cards Instead of Coupons," p. 18, *American Banker*, April 11, 1988, published by American Banker, 1 State St. Plaza, New York, N.Y. 10004; 212-943-8200. Technical details on earlier smart cards are given in "Smart credit cards: the answer to cashless shopping," *IEEE Spectrum*, February 1984, p. 43.

About the author

Hiro Shogase is manager for strategy planning of IC card systems in Toshiba Corp.'s business machines and equipment division. He joined the company upon graduation in 1970 from Seikei University, where he studied mechanical engineering. He has served in the business machines division as deputy manager for international marketing of labor-saving devices and as manager for international marketing of banking equipment. ♦