In March 2007, interoperation started between JR East’s Suica and the PASMO IC card service of major private railways and buses and subways. Increased added value for Suica cards will thus be required to differentiate the service from PASMO and to expand Suica businesses. We therefore have to study adding an information display function to the Suica card as provided with the Mobile Suica service for mobile phones to create and offer new services for customers who do not use Mobile Suica. Those new services include a ticketless service using electronic tickets, expanding Suica use to in-station shopping and services using perks such as coupons shown on the display and providing individualized information to customers.

In adding a display function to an IC card such as Suica, the prominent data rewriting method is contactless (where users only need to touch the data reader), rather than contact method (where users need to insert the card to the reader). Reasons for that are user convenience and maintenance cost. We are therefore carrying out development of a Suica card with a display that can rewrite the displayed data by contactless communication. This article will introduce that development.

1 Introduction

In March 2007, interoperation started between JR East’s Suica and the PASMO IC card service of major private railways and buses and subways. Increased added value for Suica cards will thus be required to differentiate the service from PASMO and to expand Suica businesses. We therefore have to study adding an information display function to the Suica card as provided with the Mobile Suica service for mobile phones to create and offer new services for customers who do not use Mobile Suica. Those new services include a ticketless service using electronic tickets, expanding Suica use to in-station shopping and services using perks such as coupons shown on the display and providing individualized information to customers.

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2 Electronic Paper Technology

To make Suica cards more convenient by adding a display function, hassles such as changing the battery need to be eliminated. So, we are carrying out development in electronic paper technology that enables semi-permanent displayed data retention without using power. In order to mount electronic paper to an IC card without power supply, power consumption for display data rewriting must be reduced as much as possible. Of the multiple types of electronic paper available, we applied a cholesteric LCD in the test as that features display data retention (memory) and less power consumption for data rewriting (Fig. 1).

We have already developed a display module for Suica cards separate from the actual card and a prototype system to show the information stored in the Suica card on that display via a controller PC (Fig. 2). The system uses the 13.56 MHz band for communication between the controller and the display module, the same bandwidth as for Suica.

3 Development of the First Prototype

We have already developed a display module for Suica cards separate from the actual card and a prototype system to show the information stored in the Suica card on that display via a controller PC (Fig. 2). The system uses the 13.56 MHz band for communication between the controller and the display module, the same bandwidth as for Suica.
Considering that the display module will be built into Suica cards in future, we developed a display module that is about the same size as an IC card. Furthermore, we chose a display size that enables the amount of information on a single ticket to be shown (Fig. 3 and 4), in addition to showing the remaining balance, so the cards can be used as electronic tickets.

In the initial-stage prototype module, we succeeded in data rewriting by contactless communication using no batteries, but such a long data rewriting time meant optimization of the system configuration and the internal circuit was an issue that still needed to be handled in the future.

In the second-stage prototype, we combined the display module and the IC card. Fig. 6 shows the system configuration. The display controller sends the data to the reader/writer, and the reader/writer transfers it to the prototype card by wireless communication. The reader/writer also supplies rewriting power to the prototype card.

For the outer size, we chose the normal IC card size of 85.6 mm width and 54.0 mm height, and set the thickness at approx. 3 mm (Fig. 7). For the display, we used electronic paper as in the initial-stage prototype.

### Measurement of displayed data rewriting time
We measured the total displayed data rewriting time of the initial-stage prototype as shown in Fig. 5. The results were approx. 4 sec. for balance amount display and approx. 11 sec. for electronic ticket display (Table 1).

### Display specs
- Size: 36.8 mm (W) × 28.5 mm (H)
- Display colors: Four colors of white, black, light blue, and orange
- Display characters and letters: Hiragana and Katakana (Japanese phonetic characters), Kanji (Chinese characters), and alphanumeric
- Display character count: 10 digits × 10 lines

We applied a dot matrix display rather than a segment display to allow freer display of future coupons and maps that will include content other than numbers and letters. Since the material must be flexible, we selected a film type.

Display color is a combination of four colors: light blue and orange in addition to black and white. Black and white are mandatory. But we decided to use light blue and orange also because adding a reddish warm color heightens contrast and since those two colors have high visibility against white.
Card system configuration of the second-stage prototype

Fig. 8 illustrates the block configuration in the card system of the second-stage prototype, and Fig. 9 shows the appearance of the second-stage prototype. Both stored fare data communication and display data communication use communication with a FeliCa Dual chip. FeliCa is a contactless IC card technology from Sony. A FeliCa Dual chip can launch either a contactless interface (a communication function to transmit the data stored in the chip to the reader/writer without contact) or a contact interface (a communication function to transmit the data stored in the chip through contact terminals), but the contactless interface and the contact interface launch at the same time. So, switching to operation by the contact interface after operation by the contactless interface is necessary, and this switching done by control by a CPU. First, contactless interface communication is ended by cutting the power to the antenna off, and then the control CPU starts contact interface communication.

Making data template-dependent

To reduce the data size, we made templates for the images to be displayed on the card. We developed templates to display the ticket data of a single train and the ticket data of two trains, depending on whether or not there is a train change. That was done under the assumption that the cards will be used as electronic tickets.

Fig. 10 shows an image of the actual electronic ticket (for a single train).

While compression efficiency differs depending on the data details, we reduced 4,800 bytes of data before compression to approx. 1,600 – 1,800 bytes for the electronic ticket for a single train and to approx. 1,900 – 2,400 bytes for the electronic ticket for two trains.

Measurement of the displayed data rewriting time

We measured the displayed data rewriting time of the second-stage prototype as shown in Fig. 12. The result was a reduction of the time required for ticket display of the initial-stage prototype by about half (Table 1), to approx. 4.3 sec. (Table 2).

Measurement of power consumption

In research on adding a display to a Suica card, power consumption of the card must be minimized because the card has no own power supply. We therefore measured the power consumption required for rewriting the displayed data.

![Flow of data](image)

Fig. 8 Block Configuration in Card System of Second-Stage Prototype

![Appearance of the Second-stage Prototype](image)

Fig. 9 Appearance of the Second-stage Prototype

![Template Image](image)

Fig. 10 Template Image (for a Single Train)

![Sample Electronic Ticket Display](image)

Fig. 11 Sample Electronic Ticket Display (for a Single Train)

![Measurement of the Displayed Data Rewriting Time](image)

Fig. 12 Measurement of the Displayed Data Rewriting Time (Second-Stage Prototype)

| Table 2 Measurement of the Communication Time (Second-stage Prototype) |
|--------------------------|--------|--------|--------|
| Data size                | (A)    | (B)    | (C)    |
| One train (approx. 1,780 bytes) | 1.9 s  | 2.4 s  | 4.3 s  |
| Two trains (approx. 2,100 bytes) | 2.4 s  | 2.2 s  | 4.6 s  |
The measurement results (Table 3) clarified that the control CPU (microcomputer) and the display consume a total of 70 mW and FeliCa consumes 20 mW when rewriting the displayed data.

The display module constantly consumes approx. 30 mW, when high voltage is applied. Since the high voltage generator and the voltage divider consume only minor power of less than 1 mW, most of that 30 mW would be consumed at the display module. The boosting efficiency of the high voltage generator is approx. 75%, so actual power consumption at the display is approx. 22 mW. We thus need to further improve the power efficiency of the display module that still consumes much power.

Table 3 Power Consumption per Block

<table>
<thead>
<tr>
<th>Block</th>
<th>Power consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Display with high voltage on</td>
<td>30 mW (3.3V 9 mA)</td>
</tr>
<tr>
<td>Display in operation, including voltage boosting and dividing</td>
<td>60 mW (3.3V 18 mA)</td>
</tr>
<tr>
<td>Microcomputer (minimum value)</td>
<td>20 mW (3.3V 6 mA)</td>
</tr>
<tr>
<td>FeliCa</td>
<td>20 mW (3.3V 6 mA)</td>
</tr>
</tbody>
</table>

5 Examination of a Lower-Cost Version

We studied using electronic paper for the card in the initial- and second-stage prototypes, but electronic paper is still expensive to use for cards. So, we examined a version using a low-cost LCD for the display (Fig. 13).

Signal shielding might occur due to increased number of parts if using a solar cell for the display power, and that might affect processing at the ticket gate. Therefore, we tested the affect on communications that the added display module, solar cell and circuit board have (Fig. 14).

●Measurement test
1) Standard sequence processing time
2) Communication distance for polling commands

As shown in Table 4, we confirmed that there is no difference between a FeliCa card (a card mounted with the same chip as used for Suica cards) and a prototype display card for the standard sequence (equivalent to the processing of a Suica card) processing time (Fig. 14).

We did find, however, that the communication distance for polling commands (response to communications) is shorter than that of the FeliCa card by approx. 30% (Fig. 15). Compared to a FeliCa card, the newly added items (LCD, solar cell, circuit board and power charging coil) would cause inhibition. We have to investigate what items affect communications and in what way and develop countermeasures for that.

Table 4 Standard Sequence Processing Time

<table>
<thead>
<tr>
<th>Card</th>
<th>Strong current R/W</th>
<th>Light current R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Close contact 96.5 mm away</td>
<td>Close contact 96.5 mm away</td>
</tr>
<tr>
<td>FeliCa</td>
<td>109.38</td>
<td>352.00</td>
</tr>
<tr>
<td>Prototype card</td>
<td>109.39</td>
<td>352.00</td>
</tr>
</tbody>
</table>

Fig. 15 Communication Distance for Polling Commands

6 Conclusion

We have worked for approx. two years on R&D for adding a display function to Suica cards. In that work, we confirmed that a card without batteries could display data information with contactless communication alone. In the future, we are planning to carry out functional tests mainly on signal interference and other affects on Suica functions, cost and specifications (size, thickness and bending strength).

*FeliCa is a registered trademark of Sony Corporation.