

FeliCa Reader/Writer RC-S441C and RC-S445C

- Users Manual -
(Version 2.10)

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1 Definition

In this document, following words are used in the following sense.

Controller - An external computer, a gate controller or an equivalent equipment directly connected to Reader/Writer through specified wired interface.

Reader/Writer - The equipment, specified in this document, for Sony Remote Card System : *FeliCa*.

Card - A Contactless Smart Card for Sony Remote Card System : *FeliCa*

2 General

2.1 Basic Specification

Table 1 shows *Reader/Writer* "RC-S44x" models. RC-S445 has dual CPUs and external memories for sub CPU. RC-S441 is a single CPU type same as the models RC-S430 and RC-S480.

Reader/Writer consists of 3 parts – an *antenna board*, an *RF/control board* and the *cable* that connects the *antenna board* and the *RF/control board*. There are 2 antenna types called Type C and E (see Chapter 6).

Model No.	CPU	Memory	Antenna Type	Serial Interface	Connector Type
RC-S445C/6L	Dual	Flash 4Mbyte SRAM 0.5Mbyte	C	RS485A RS232C	Right angle
RC-S441C/6L	Single	-	C	RS485A CMOS	Straight
RC-S441E/6L			E		Right angle

Table 1 *Reader/Writer* RC-S44x models

2.1.1 Dimensions

The dimension of each type are described in Chapter 6.

The tolerance is $\pm 0.5mm$.

2.1.2 Specification Table

Communication with Card

(Common)

carrier frequency: 13.56MHz ($\pm 50ppm$)

modulation bandwidth: $\pm 300kHz$ (-30dB relative to carrier level)

radiation level: less than $4500\mu V/m$ at 10m (Type C Antenna)

1000 $\mu V/m$ at 10m (Type E Antenna)

300 $\mu V/m$ at 10m (Type B Antenna)

Communication method: half-duplex, CRC16

(ISO type C)

data transfer rate : 211.875kbps

modulation: Receive - ASK, Manchester Coding

Transmit - ASK(8-14%), Manchester Coding

modulation bandwidth: $\pm 300kHz$ (-30dB relative to carrier level)

(ISO type B)

[Note] ISO/IEC document 14443 on the type B protocol was not published at the design stage of these Reader/Writer. The design was made according to then the newest available documents as described below.

ISO/IEC JTC1/SC17 CD 14443-2 document N1433 (22.10.1998)

ISO/IEC JTC1/SC17 2nd CD 14443-3 document N1475R (28.2.1999)

data transfer rate : 106 *kbps*

modulation: Receive - ASK, BPSK(sub carrier 847.5kHz)

Transmit - ASK(8-14%), NRZ

modulation bandwidth: $\pm 100\text{kHz}$ (-30dB relative to carrier level, 106 *kbps*)

Power Supply (see Chapter 6)

Digital Processing Unit (DPU)

Main: CXD8680R (designed by Sony)

Clock Frequency = 13.56MHz

CXD8680R has a 32 *bit* CPU core, 8 *kbyte* ROM, 3 *kbyte* SRAM, 2 *kbyte* Block Erasable Flash Memory and 4×32 *kbyte* Flash Memory inside.

Sub: 32 *bit* CPU MC68340 (RC-S445)

Clock Frequency = 13.56MHz

External Memory

RC-S445: 4 *Mbyte* Flash Memory and 500 *kbyte* SRAM

Controller Interface (serial interface)

number of ports : 1 (one)

signal level : RS485 and CMOS logic level (5V) for RC-S441C/E

: RS485 and RS232C for RC-S445C

baud rate for operation: 7.2*kbps* ~ 1.2288*Mbps*

(7.2, 8.192, 9.6, 14.4, 16.384, 19.2, 28.8, 32.768, 38.4,
57.6, 65.536, 76.8, 115.2, 131.072, 153.6, 230.4, 262.144,
460.8, 524.288, 921.6, 1048.576, 1228.8 *kbps*)

: 50*bps* ~ 115.2*kbps* (Sub CPU)

communication method : half-duplex, check sum

2.1.3 Encryption Technique

All communications to and from the *Card*, with the exception of Polling Command, are encrypted.

All the communications to and from the *Controller*, with the exception of the Attention Command, are encrypted.

Two kinds of Encryption algorithm, Single-DES 56*bit* and Triple-DES 56*bit* can be applied.

3 Reader/Writer Operation

3.1 Connection with Controller

The pin assignment is described in Chapter 6.

3.2 Transaction Overview

3.2.1 Communication Protocol

There are two communication protocols, namely, data link level and application level protocol.

Either ACK or NACK packet is returned in every packet transfer. ACK indicates a successful transfer, NACK means unsuccessful.

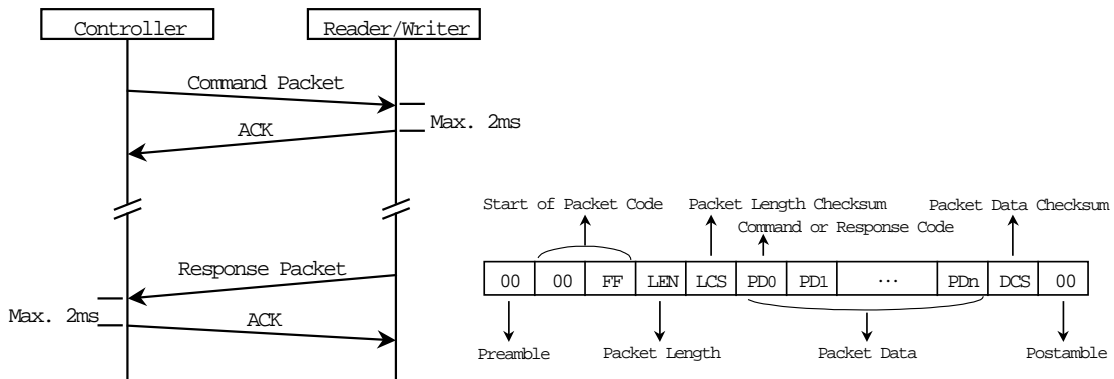


Fig. 1 : Communication Protocol and Packet Structure

3.2.2 Re-sending Protocol

Reader/Writer supports the re-sending procedure in Controller interface. Re-sending handling is triggered or required in the two cases below :

1. NACK packet is returned.
2. Neither ACK nor NACK response comes. (time out)

Controller should re-send the same packet within 5ms after receiving NACK or detecting time out.

3.2.3 ACK / NACK Packet

ACK / NACK packet format is as follows :

ACK : LEN = 00h & LCS = ffh without Packet Data part and DCS

NACK : LEN = ffh & LCS = 00h without Packet Data part and DCS

3.2.4 Mutual Authentication

Mutual Authentication is a process that is performed between Controller and Reader/Writer to authenticate each other mutually in order to avoid the fraud usage.

This authentication is based on the following elements :

1. two 8byte (64bit) keys
2. three pass authentication model (ISO 9758)
3. cryptography algorithm mentioned in section 3.2.5.

3.2.5 Encryption and Decryption

The cryptography algorithm is used for the following three stages :

1. mutual authentication between *Controller* and *Reader/Writer*
2. mutual authentication between *Reader/Writer* and *Card*
3. commands and data encryption through *Reader/Writer*

4 Communication Commands

4.1 General

In this section, the communication commands between *Controller* and *Reader /Writer* are described.

Table 2-4 shows all commands between *Controller* and general *Reader/Writer*. All commands are categorized into 3 groups as follows :

1. *Reader/Writer* internal operation command
2. *Card* operation command
3. *Card* management command

Card management command group is for issue *Reader/Writer* and not for general *Reader/Writer* .

4.2 Reader/Writer Internal Operation Command

4.2.1 Attention Command

Attention Command enables *Reader/Writer* and *Controller* to recognize each other and is the only command available before the authentication completes. The main purpose of this Attention Command is to recognize its partner before authentication and to force *Reader/Writer* to be in the idle state.

4.2.2 Authentication 1 Command

Authentication 1 Command enables *Controller* to authenticate *Reader/Writer*.

4.2.3 Authentication 2 Command

Authentication 2 Command enables *Reader/Writer* to authenticate *Controller*.

4.2.4 Disconnect Command

Disconnect Command is for *Controller* to terminate the communication with *Reader/Writer*.

4.2.5 Change Reader/Writer Access Key Command

Change *Reader/Writer* Access Key Command performs alteration of the access keys, which are stored in *Reader/Writer* for the mutual authentication between *Controller* and *Reader/Writer*.

Command	Command Code	Response Code
Attention	00h	01h
Authentication 1	02h	03h
Authentication 2	04h	05h
Disconnect	06h	07h
Change Reader/Writer Access Key	20h	21h
Self-Diagnosis	40h	41h
Check Firmware Version	44h	45h
Change Communication Mode	46h	47h
Kill Module	4ah	4bh
Reader/Writer Reset	4ch	4dh
Firmware Maintenance	52h	53h

Table 2 : *Reader/Writer* Internal Operation Command

Command	Command Code	Response Code
Polling	80h	81h
Request Service	82h	83h
Request Response	84h	85h
Mutual Authentication	86h	87h
Read Block	88h	89h
Write Block	8ah	8bh
Release	8eh	8fh
Read Without Encryption	98h	99h
Write Without Encryption	9ah	9bh

Table 3 : *Card* Operation Command

Command	Command Code	Response Code
Register Issue ID	c0h	c1h
Register Area	c2h	c3h
Register Service	c4h	c5h
Register Manufacture ID	e0h	e1h
Card Self-Diagnosis	f0h	f1h

Table 4 : *Card* Management Command

4.2.6 Self-Diagnosis Command

Self-Diagnosis Command activates self-diagnosis test of *Reader/Writer*. After the Diagnosis completion, *Reader/Writer* sends back the test result.

4.2.7 Check Firmware Version Command

Check Firmware Version Command is used for checking the version of *Reader/Writer* firmware.

4.2.8 Change Communication Mode Command

Change Communication Mode Command performs the following changes : baud rate, logic level interface(non-inverted or inverted), encryption on/off, time-out.

4.2.9 Kill Module Command

Kill Module Command is used for killing the specified module within *Reader/Writer*.

4.2.10 Reader/Writer Reset Command

Reader/Writer Reset Command executes the initialization routine.

4.2.11 Firmware Maintenance Command

Firmware Maintenance Command is used for updating the firmware within *Reader/Writer*.

4.3 Card Operation Command

4.3.1 Polling Command

Polling Command enables *Reader/Writer* to give a call to *Card* and to detect existence of *Card* by the response from *Card*.

4.3.2 Request Service Command

Request Service Command enables *Reader/Writer* to check whether the specified service code is registered to *Card* or not. In case that the specified service is registered to *Card*, key version of the service is available by the response from *Card*.

4.3.3 Request Response Command

Request Response Command enables *Reader/Writer* to check which mode *Card* is in. There are 4 modes, 'before Authentication', 'after Authentication 1', 'after Authentication 2' and 'after Register xxx Command (see 4.4 Card Management Command)'.
'

4.3.4 Mutual Authentication Command

Mutual Authentication Command activates the mutual authentication procedure between *Reader/Writer* and *Card*.

4.3.5 Read Block Command

Read Block Command activates *Reader/Writer* to read the specified block data from *Card* after the mutual authentication between the *Reader/Writer* and *Card* has been established successfully.

Read Block Command enables a Service Provider with successful mutual authentication to read blocks that this Service Provider has the right to access.

With one Read Block Command, up to 8 block can be read simultaneously. If more than 8 blocks should be read, more than one Read Block Command shall be called separately.

The response of Read Block Command is a 1byte Read result and Block Data that has been read. In the Read result, a 1byte consequence of one block Read is given in 1bit. As there are up to 8 blocks, 1byte is enough to record all the Read consequence.

4.3.6 Write Block Command

Write Block Command activates *Reader/Writer* to write the specified block data to *Card* as new data after the mutual authentication between *Reader/writer* and *Card* has been established successfully.

With one Write Block Command, up to 8 block can be written simultaneously. If more than 8 blocks should be written, more than one Write Block Command shall be called separately.

The response of Write Block Command is a 1byte Write result. In the Write result, a 1byte consequence of one block Write is given in 1bit. As there are up to 8 blocks, 1byte is enough to record all the Write consequence.

The purse operation can be performed with Write Block Command.

4.3.7 Release Command

Release Command enables *Card* to be released from established communication sequence with *Reader/Writer*.

4.3.8 Read Without Encryption Command

Read Without Encryption Command activates *Reader/Writer* to read the specified block data from *Card* without the mutual authentication between the *Reader/Writer* and *Card*. Read Without Encryption Command can be applied only to blocks which service code is registered security-free.

The number of blocks that can be read simultaneously and the response of Read Without Encryption Command are the same as those for Read Block Command (see 4.3.5).

4.3.9 Write Without Encryption Command

Write Without Encryption Command activates *Reader/Writer* to write the specified block data to *Card* without the mutual authentication between the *Reader/Writer* and *Card*, however can be applied only to blocks which service code is registered security-free.

The number of blocks that can be write simultaneously and the response of Write Without Encryption Command are the same as those for Write Block Command (see 4.3.6).

4.4 Card Management Command

The commands described in this section are for issue *Reader/Writer* and not for general *Reader/Writer*.

4.4.1 Register Issue ID Command

Register Issue ID Command makes it possible to register Issue ID(IDi) , Issue Parameter(PMi), System Code and Area 0000 Key to *Card*, and also makes it to erase other services and to initialize Memory Allocation Information in *Card*.

4.4.2 Register Area Command

Register Area Command makes it possible to register new Area and the parameters of new Area to *Card*, which are Service Code Range, Available Block Number and Area Key.

4.4.3 Register Service Command

Register Service Command makes it possible to register new Service and the parameters of new Service to *Card*, which are Service Code, Block Number and Service Key.

4.4.4 Register Manufacture ID Command

Register Manufacture ID Command makes it possible to register Manufacture ID(IDm) , Manufacture Parameter(PMm), System Code, System Key and Area 0000 Key to *Card*, and also makes it to clear Issue ID of *Card*.

In order to execute Register Manufacture ID Command, Manufacture ID must be all 00h. This means that Register Manufacture ID Command is effective to *Card* once for all.

4.4.5 Card Self-Diagnosis Command

Card Self-Diagnosis Command activates self-diagnosis test of *Card*. After the Diagnosis completion, *Card* sends back the test result.

5 Fundamental Specifications

5.1 Operating Temperature

-20 to 85°C

Compliant to IEC 68-2-2 Part 2 Test Bd and IEC 68-2-1 Part 2 Test Ad, with duration 16 hours.

5.2 Storage Temperature

-40 to 85°C

Compliant to IEC 68-2-2 Part 2 Test Bb and IEC 68-2-1 Part 2 Test Ab, with duration 72 hours.

5.3 Humidity

Compliant to IEC 68-2-3 Part 2 Test Ca, with duration 4 days.

5.4 Cold and Heat Shock

Compliant to IEC 68-2-1 Part 2 Test Aa, with temperature -20°C and duration 2 hours, and IEC 68-2-2 Part 2 Test Ba, with temperature 70°C and duration 2 hours.

5.5 Shock

Compliant to IEC 68-2-27 Part 2 Test Ea, severity 60g, duration 11ms.

5.6 Vibration

Compliant to IEC 68-2-6 with respect to the following parameters :

- Frequency Range : 10Hz to 500Hz
- Vibration Severity : 3gn
- Sweep rate : 1 octave per minute
- Endurance by sweeping : 20 sweep cycles for each X,Y and Z axis.

5.7 Spurious Emissions

Compliant to MPT 1339 clause 4.1.3 ; FCC Regulation Part 15.225 and Part 15.209 ; and EC(EU) I-ETS 300 330 clause 7.2.1.3.

5.8 Bump

Compliant to IEC 68-2-29 Part 2 Test Eb, severity 40gn, duration 6ms and 4000 bumps.

5.9 Electrostatic Discharge

Compliant to IEC 801-2, with severity level 3 (Test Voltage Air discharge : 8kV).

5.10 Multiple Card

The *Reader/Writer* allows addressing and authentication of up to four *Cards* in the communication area. Each *Card* will only respond to commands intended for it and only one *Card* can be addressed in a single command.

5.11 Anti-Collision

Reader/Writer supports anti-collision of multiple cards.

6 Reader/Writer Specification Table

6.1 Type C Reader/Writer

6.1.1 Type C Reader/Writer Specification Table

- Model No. RC-S441C/6L and 445C/6L

General model No. "RC-S441" or "RC-S445" is printed on the RF/Control board (see Fig.2-1 and 2-2). "Type C" means antenna type shown in Fig.6 and it is marked on "C" as in Fig.2. A mark on numerals 1-6 (it is 1 in Fig.2-1 and 2-2) indicates the installed software version.

RC-S441

A	B	C	D	E	F
1	2	3	4	5	6

Fig.2-1

RC-S445

A	B	C	D	E	F
1	2	3	4	5	6

Fig.2-2

Fig.2 : Printed Model No. (Type C)

- Operating Distance : 100mm (Card : RC-S832)
 - The *Reader/Writer* is adjusted by the combination of the RF/Control board and the antenna board, both of which shall have the same serial number labels to maximize the operating distance, and therefore, the operating distance cannot be assured by the different combination of the boards.
 - The antenna board and the RF/Control board shall be placed more than 30mm apart to prevent decrease of the operating distance more than 10mm, i.e. to obtain more than 90mm operating distance. In case of adjusting the variable capacitor on the RF/Control board to maximize the output level, the minimum distance between the boards is improved to 15mm . (see Fig. 3)
 - In the effective operating scope of the antenna, there shall be nothing that generates electric or magnetic noise. Neither shall there be an electric or magnetic shield or reflection.
 - Emission from another *Reader/Writer* affects the operating distance. In operating plural *Reader/Writers* simultaneously, it is desirable for antenna boards to be separated more than 70cm each other in order to keep the 100mm operating distance. However, *Reader/Writers* can be operated under less than 70cm separation each other with no problem except for decrease of the operating distance.

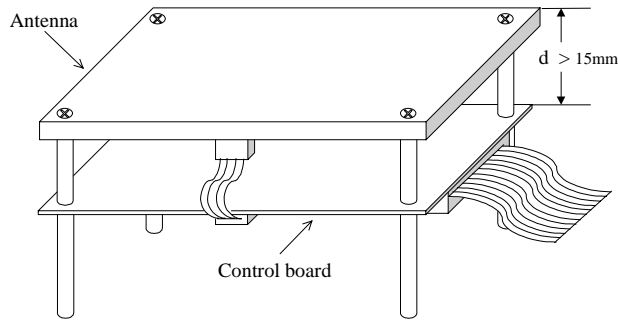


Fig.3 : Example of Antenna Placement (Type C)

- Interface Connector

RC-S441C/6L: Methode 1100-12-110-01 (straight)

RC-S445C/6L: Methode 1100-12-110-02 (right angle)

The interface connector is a 10-pin connector located at the right edge of the RF/Control board which is shown in the schematic drawing of Fig.7. The pitch of connector pins is 2.54mm. The most upper connector pin is No. 1. Pin assignment of the connector is shown in Fig. 4 and Table 5.

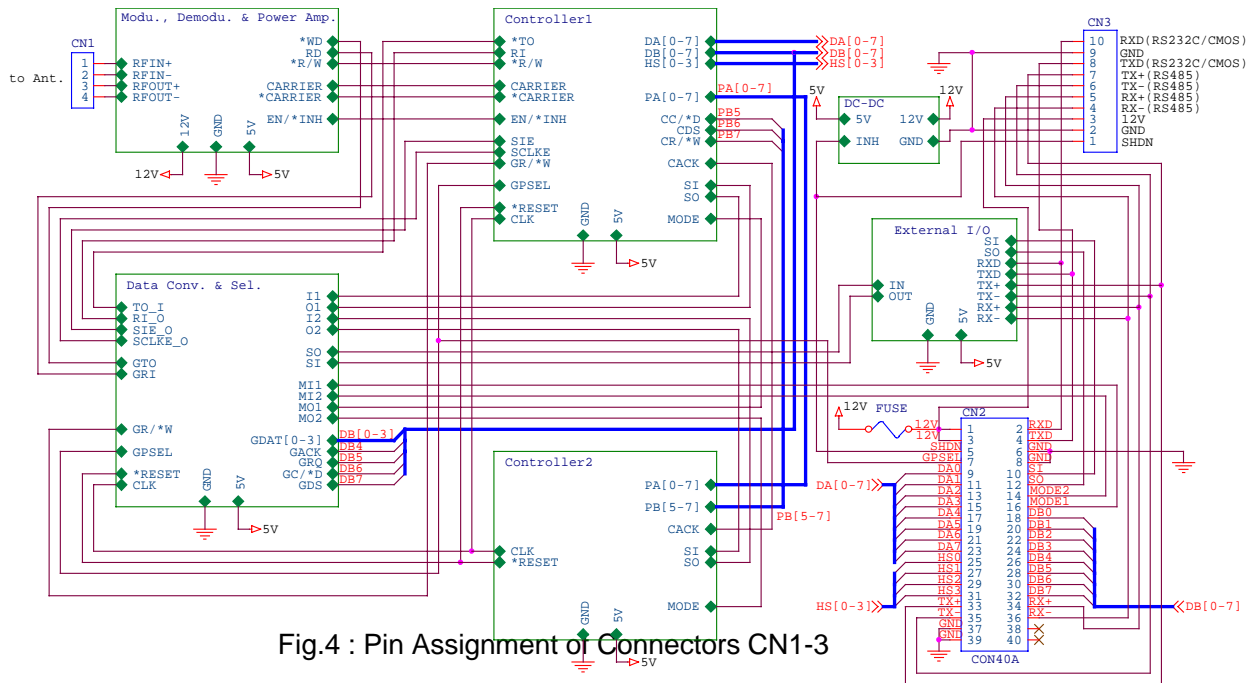


Fig.4 : Pin Assignment of Connectors CN1-3

Pin No.	1	2	3	4	5	6	7	8	9	10
Pin Assignment	SHDN	GND	DCIN	RX-	RX+	TX-	TX+	TXD	GND	RXD

Table 5 : Pin Assignment of Interface Connector CN3

- External Interface
 - serial 1 port: RS-485A and CMOS logic level (5V) for RC-S441C
 RS485A and RS232C for RC-S445C
 software selectable, non-inverted or inverted, and baud rate
 (default setting : non-inverted, 115.2kbps)
 - Common pins are assigned for RS-232C and CMOS logic level. CMOS logic level can be available instead of RS232C for RC-S445C by mounting 2 resistors R46-47 and removing 2 resistors R52-53 which are located near the right, lower corner of the RF/Control board as shown in Fig.5.

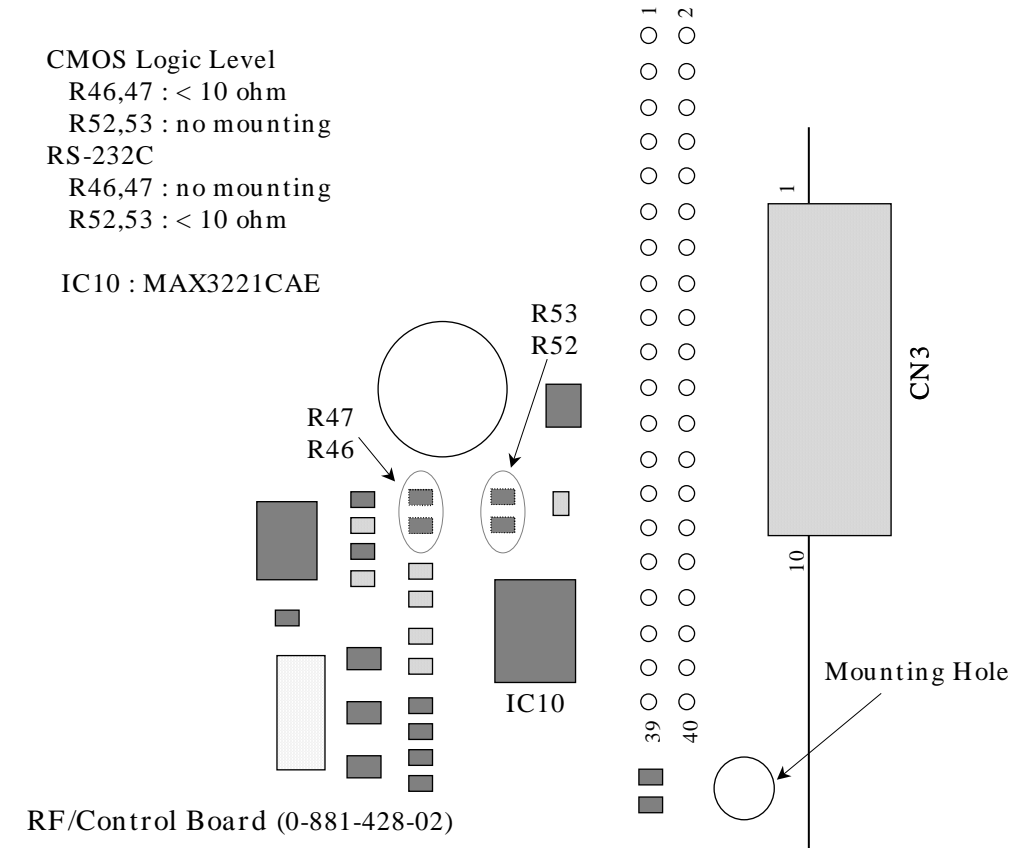


Fig.5 : Placement of Parts for RS-232C or CMOS Interface

- Dimensions (see Fig.6 and Fig.7)
 - antenna: 104mm × 67mm × 6mm
 (PCB thickness 1mm, connector height 5mm)
 - RF/Control board: 104mm × 67mm × 10.5mm (PCB thickness 1mm)
 - cable: length 120mm
- Mounting Holes (see Fig.6 and Fig.7)
 - antenna : M3 × 4, clearance 8mm
 - RF/Control board : M3 × 4, clearance 7mm
- Power
 - voltage: DC12V (shall be applied to DCIN of CN2)

voltage allowance: +4V, -0.5V

current: < 400mA

voltage ripple allowance: 100mV (peak-to-peak)

The Reader/Writer can be operated in the voltage range of 8-11.5V and the voltage ripple > 100mV, however operating distance cannot be assured in such condition.

6.1.2 Type C Reader/Writer Schematic Drawing

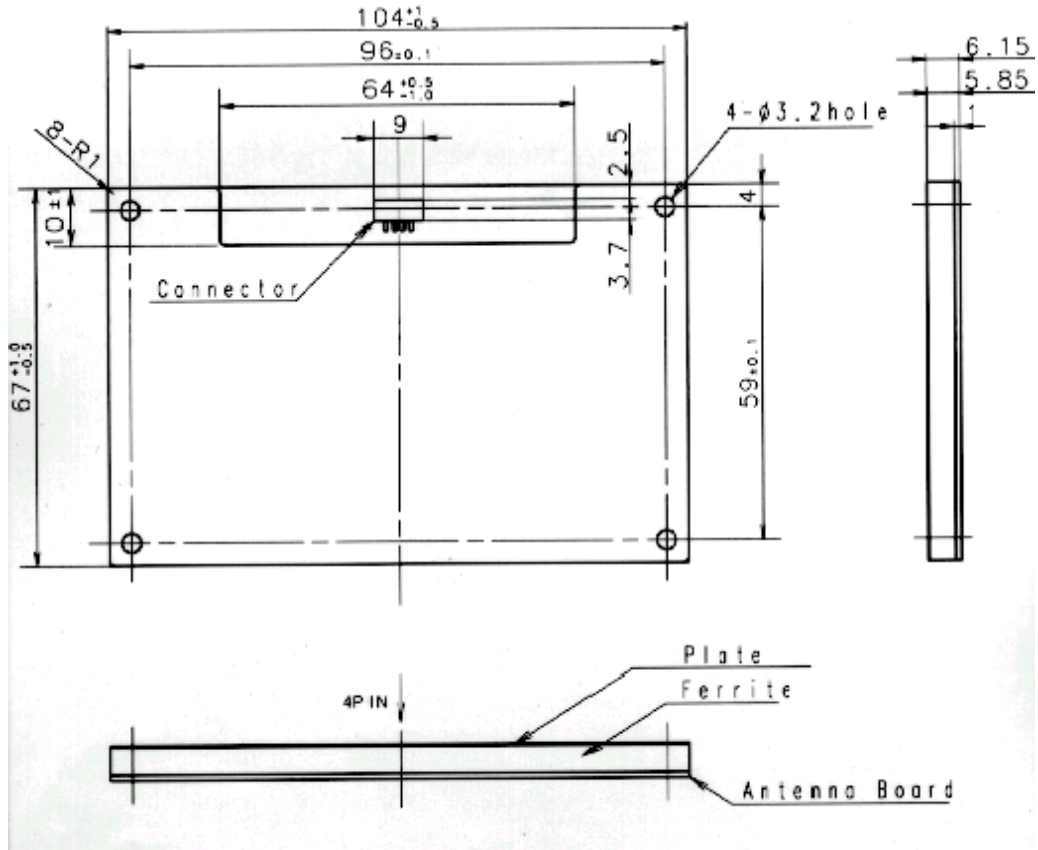


Fig.6 : Antenna Board (Type C)

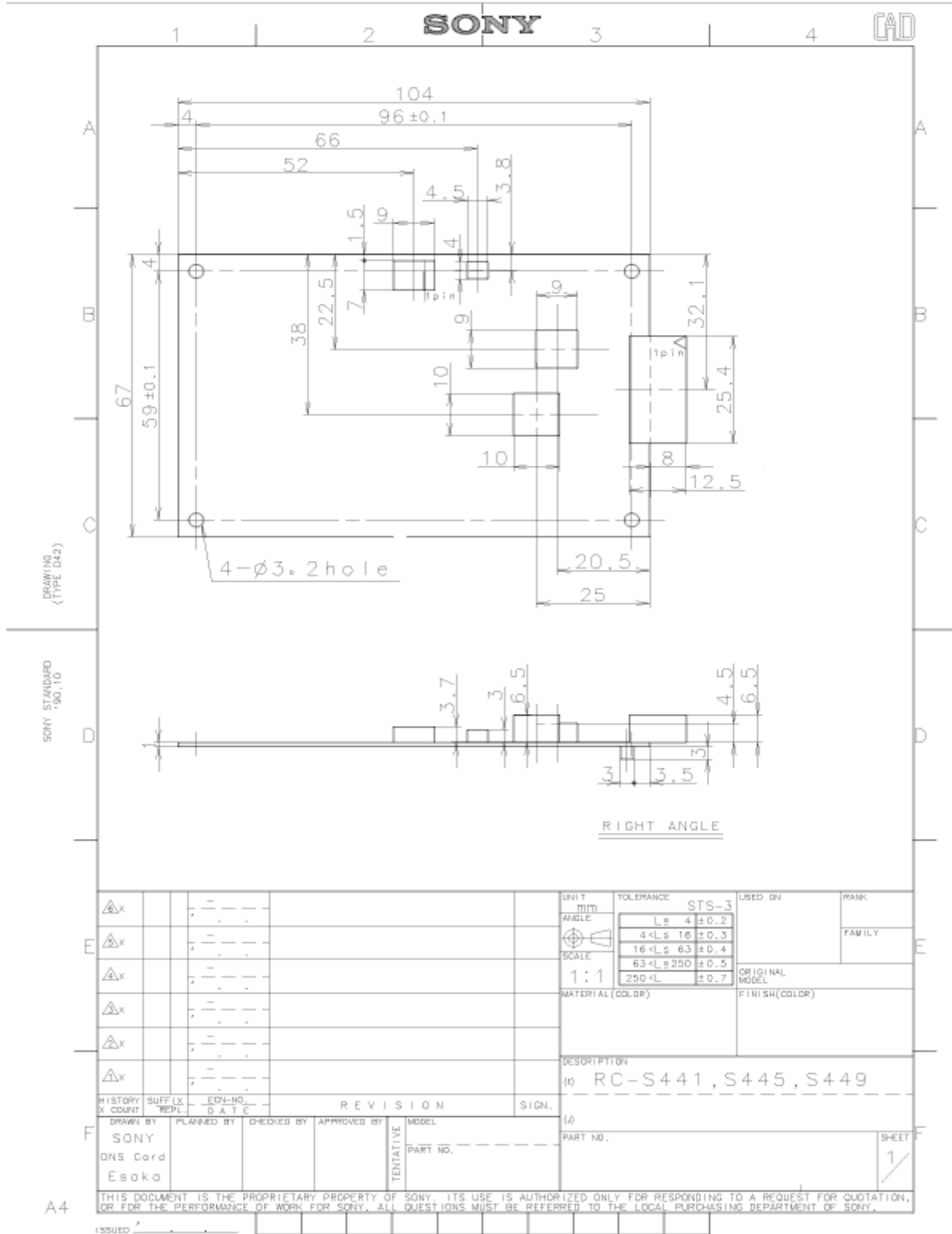


Fig.7 : RF/Control Board

6.2 Type E Reader/Writer (Limited Model)

6.2.1 Type E Reader/Writer Specification Table

- Model No. : RC-S441E/6L
General model No. "RC-S441" is printed on the RF/Control board (see Fig.8). "Type E" means antenna type shown in Fig.9 and it is marked on "E" as in Fig.8. A mark on numerals 1-6 (it is 1 in Fig.8) indicates the installed software version.

RC-S441

A	B	C	D	E	F
1	2	3	4	5	6

Fig.8 : Printed Model No. (Type E)

- Operating Distance : 40mm (Card : RC-S832)
 - The *Reader/Writer* is adjusted by the combination of the RF/Control board and the antenna board, both of which shall have the same serial number labels to maximize the operating distance, and therefore, the operating distance cannot be assured by the different combination of the boards.
 - The antenna board and the RF/Control board shall be placed more than 30mm apart.
 - In the effective operating scope of the antenna, there shall be nothing that generates electric or magnetic noise. Neither shall there be an electric or magnetic shield or reflection. Type E antenna is affected by conductive material more easily than other antenna types because a ferrite block is not attached on the antenna board.
 - Emission from another *Reader/Writer* affects the operating distance. In operating plural *Reader/Writers* simultaneously, it is desirable for antenna boards to be separated more than 50cm each other in order to keep the 40mm operating distance. However, *Reader/Writers* can be operated under less than 50cm separation each other with no problem except for decrease of the operating distance.
- Interface Connector : Methode 1100-12-110-02 (right angle)
The interface connector is a 10-pin connector located at the right edge of the RF/Control board which is shown in the schematic drawing of Fig.7. The pitch of connector pins is 2.54mm. The most upper connector pin is No. 1. Pin assignment of the connector is shown in Fig. 4 and Table 5.
- External Interface
 - serial 1 port : RS-485A, CMOS logic level (5V)
software selectable, non-inverted or inverted, and baud rate
(default setting : non-inverted, 115.2kbps)
- Dimensions (see Fig.7 and Fig.9)
 - antenna: 65mm × 40mm × 6mm
(PCB thickness 1mm, connector height 5mm)
 - RF/Control board: 104mm × 67mm × 10.5mm (PCB thickness 1mm)
 - cable: length 120mm

- Mounting Holes (see Fig.7 and Fig.9)
 - antenna : M3 × 4, clearance 8mm
 - RF/Control board : M3 × 4, clearance 7mm
- Power
 - voltage: DC12V (shall be applied to DCIN of CN2)
 - voltage allowance: +4V, -0.5V
 - current: < 400mA
 - voltage ripple allowance: 100mV (peak-to-peak)
 - The *Reader/Writer* can be operated in the voltage range of 8-11.5V and the voltage ripple > 100mV, however operating distance cannot be assured in such condition.

6.2.2 Type E Reader/Writer Schematic Drawing

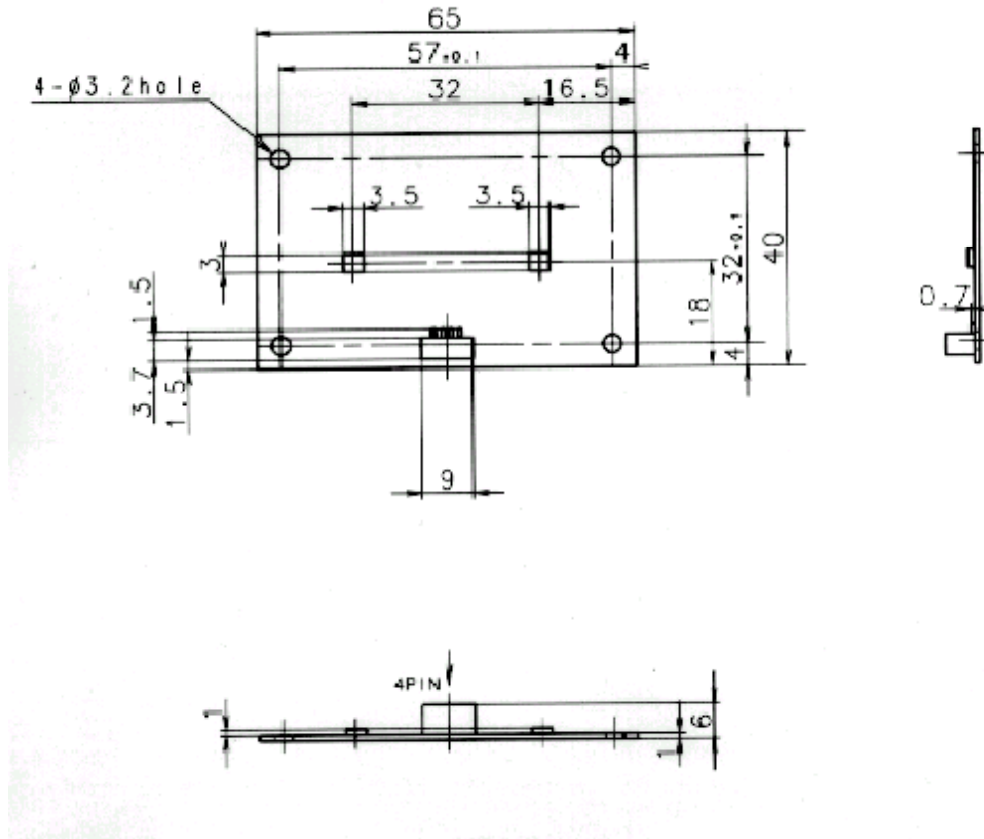


Fig.9 : Antenna Board (Type E)