Ecard
一卡通

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This project aims to use stm32 microcontroller to realize the simulation function and information transmission of NFC card as well as the display and update function of specific information. The simulation function of NFC cards allows users to use Ecard instead of physical cards to perform various operations, such as access control, payment, membership, etc. The Bluetooth picture transmission function allows users to send pictures to the microcontroller using their mobile phones and display or store them on the microcontroller. The main technical difficulty of this project is how to implement the NFC card simulation and Bluetooth transmission protocols and algorithms, and how to optimize the performance and stability of the system.

Keywords: STM32, NFC ,Android app, Circuit Design

1 Background and Relative work

The e-ink screens we use have a variety of applications and capabilities, here are some papers supporting our work. Literature [1] designed an electronic ink screen display system based on STM32. The system can read peripheral text documents, display text and pictures in real time, and can also accept user single-point or multi-point touch screen control.
Literature [2] designed a wireless electronic tag based on an electronic ink screen, which can be remotely controlled through the user's mobile phone terminal. The basic functions of our NFC have also been studied by many scholars.
Literature [3] analyzes the technical principles of NFC and compares the differences between NFC and other communication technologies. The application modes and application fields of NFC are analyzed, and the application prospects of each mode are proposed.
In the literature [3], there is an IoT intelligent identification system based on NFC card simulation. This paper uses communication simulation technology to collect card information, so that NFC technology can be widely used.
We also have Bluetooth technology. Literature [4] proposed that in the context of information technology, Bluetooth technology has been widely used in the information transmission process of electronic sensors. The short-range data transmission of Bluetooth technology is very fast and is independent of position and orientation, so the cables laid during the acquisition process of the sensing electronics can be efficiently transmitted.
Bluetooth technology allows devices to transmit within a small range. Document [5] introduces the structure and application of the Bluetooth wireless communication module HC-05.
Based on the pairing settings of the Bluetooth module, the application of two Bluetooth modules to realize the data transmission of clock display between two microcontrollers is analyzed, and wireless communication between the microcontrollers is realized. Literature [6] realizes communication between microcontrollers through Bluetooth.
Literature [7] mainly studies the application and display of related electronic ink screens under NFC communication technology. The system includes 5 parts: power module, electronic ink screen display, Chinese font module, NFC near field communication module and STM32 main controller module. It can parse Chinese character encoding and convert it into dot matrix data to complete NFC module reading and writing, power control, screen refresh, and font reading.
Literature [8] mainly studies and analyzes the technical background, working principle, and various application modes of NFC. and application occasions.
Literature [9] conducted in-depth research on the issue of NFC antenna structure optimization and performance improvement. The main work is to explore the close coupling performance of NFC antennas. This paper simulates and analyzes the coupling performance of various antennas, focusing on the performance of different NFC antennas. Come out with the performance and find out which NFC antenna is suitable for mobile devices.
The main article in literature [10] uses the NXP PN532 NFC chip as the core to design and implement a reader and writer that transmits data through Bluetooth and designs the Android terminal. The software design part is mainly divided into NFC and Bluetooth module program design, PC host computer software design, and mobile phone application design.

2 System structure design

Fig. 1 shows the system structure design diagram.

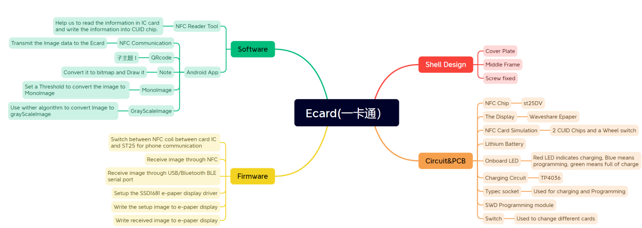

Fig. 1 System structure design

2.1 Circuit principle.

Regarding the choice of MCU, we originally planned to use ESP32 with built-in Wi-Fi and Bluetooth, but ESP32 was relatively too big, so we finally chose the STM32L0 series MCU. Fig. 2 is the overall schematic diagram of our circuit.

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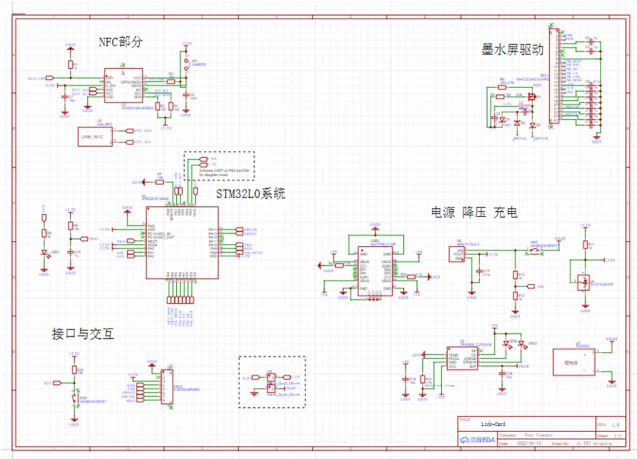

Fig. 2 Overall schematic diagram

2.2 NFC.

The circuit diagram was drawn according to the data sheet on the official website. The ST25 is shown in Fig. 3, and the ST95 is shown in Fig. 4. Because ST95 is too complicated and the functions provided are relatively unimportant, we gave up ST95 and chose ST25. The LINK_NFC shown in Fig. 3 is the package of the dial switch and coil, connecting two CUID chips.

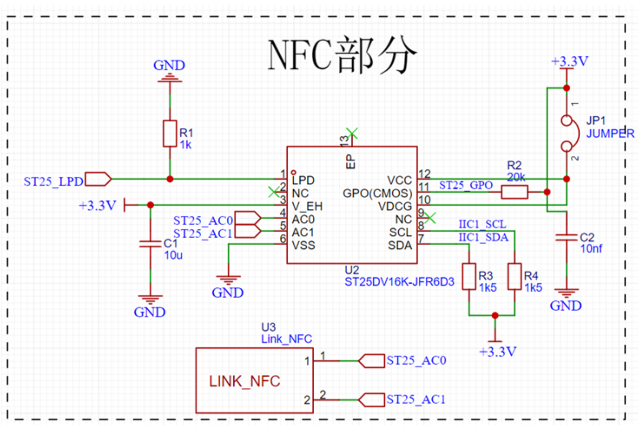

Fig. 3 NFC part

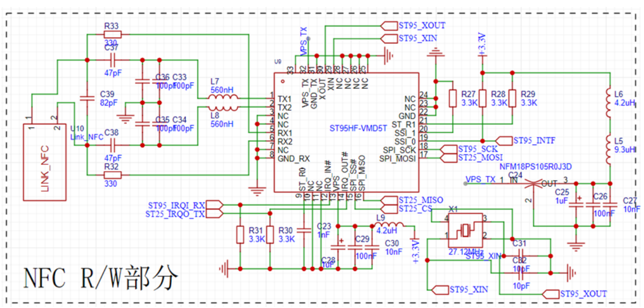

Fig. 4 NFC R/W part

2.3 E-paper driver.

As shown in Fig. 5, the Ink Screen has a 24-pin FPC connector, where we need to place some functions that support the e-paper driver IC of the component. The SSD1681 driver chip communicates with the microcontroller through SPI. Electronic paper requires a higher voltage to work, so L1 and Q1 are used to form a charge pump circuit.

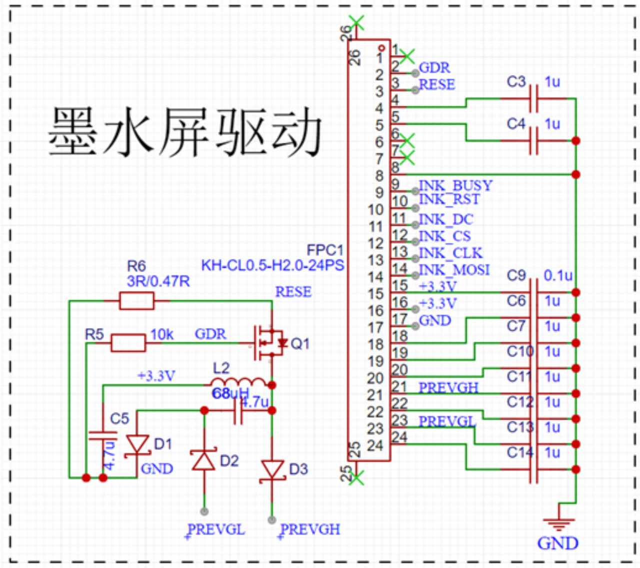

Fig. 5 E-paper Driver

2.4 Battery.

As shown in fig. 6, we built the MCU and device power supply from a Li-polymer battery using an AMS1117 linear regulator and a 2.5V Zener regulator, and then used a TP4056 charge controller IC to charge the battery from a USB-C interface. We used TL431 to detect the voltage in preparation for subsequent display of battery power.

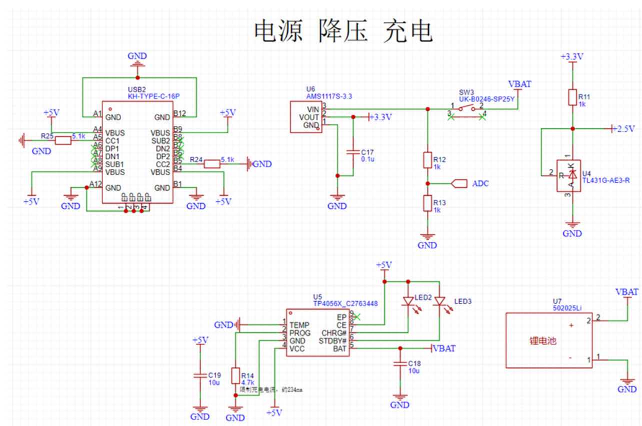

Fig. 6 Battery

2.5 Interface and interaction.

As shown in fig 7, here we use the 8pin FPC connector to program the STM32. In subsequent designs, we use a USB to serial conversion IC to be able to program the STM32 directly from the USB port.

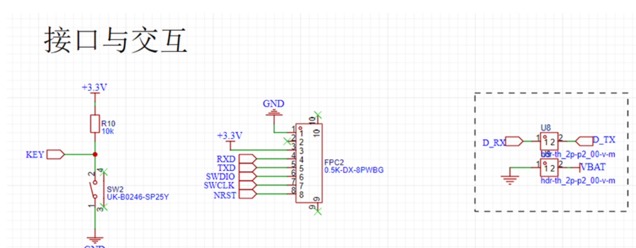

Fig. 7 Interface and interaction

2.6 PCB Design.

The final PCB rendering is shown in Fig. 8 and Fig. 9.

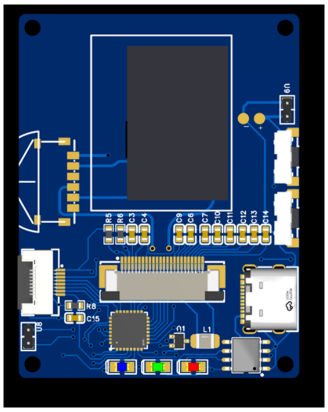

Fig. 8 PCB Design

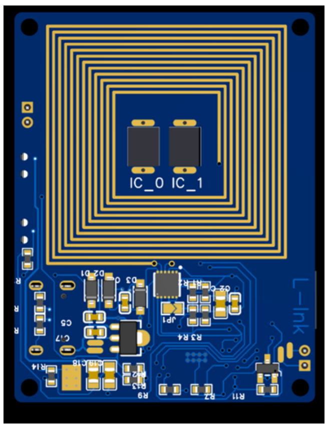

Fig. 9 PCB Design

2.7 Shell Design.

We made two versions of the shell design, and rendered the first version to show it. The first version is as shown in the picture, and the second version is as shown in the picture. Although the first version will be lighter , but personally I felt that it didn’ t look good to expose the PCB circuit to the outside, so in the end we chose the second version of the solution. The first version of the plan is shown in Fig. 10 and Fig. 11. The middle frame in the second version of the plan is shown in Fig. 12 and Fig. 13.

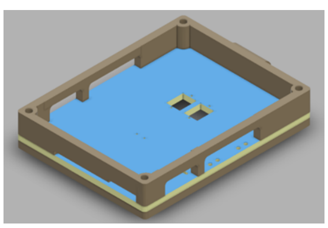

Fig. 10 Shell Design

2.8 App.

2.8.1 Card Writing.

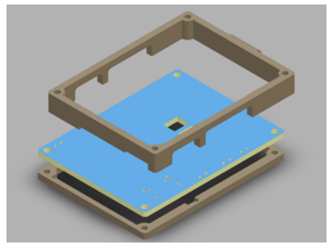

Fig. 11 Shell Design

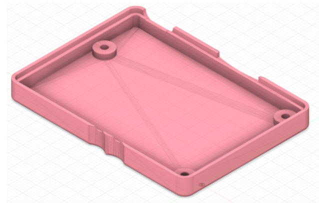

Fig. 12 Shell Design

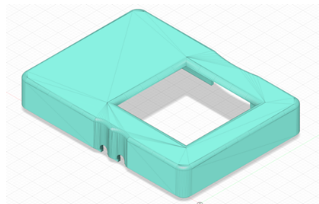

Fig. 13 Shell Design

We use the ready-made NFC Reader Tool app to read the IC card key, as shown in Fig. 19, we use the school’s campus card as an example.

Fig. 14 Card Writing App

The key shown in Fig. 19 is the default value FFFFFFFFF, which means that there is no key and reading of such a card will be relatively simple. In this way, we only need to write this information into the UID chip through ST25 to realize the card storage, and we can also directly overwrite the information on the UID to realize the rewriting of the card.

2.8.2 Display of E-paper Information.

As shown in Fig. 15, you can write directly use Zhihuijun's L-ink app.

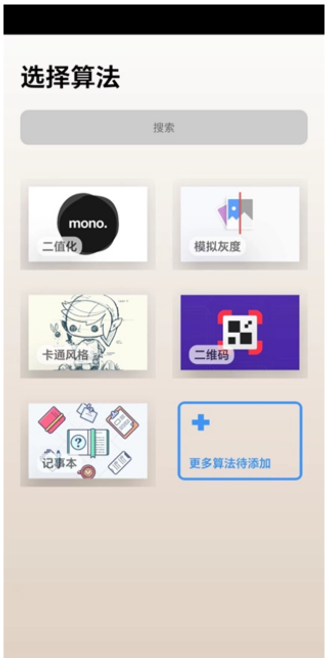

Fig. 15 Zhihuijun's L-ink app

But his project was done three years ago, and the characteristic of **Android** is that it updates and iterates very quickly, maybe every two or three months. This also means that the code of the app three years ago is extremely old and inconvenient to use. and maintenance, we will use **Compose** to reconstruct the UI interface and the **Kotlin** language to reconstruct the code, especially the part that communicates with ST25.

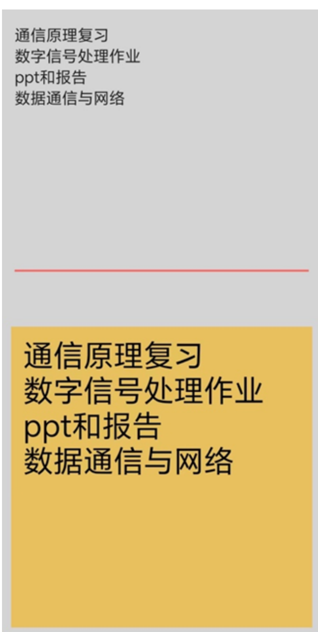

Fig. 16

Fig. 17

Fig. 18

2.8.3 Improved App.

We develop our own App in order to transmit image by NFC. In order to better introduce the function, We show the function framework in Fig. 19. We address 4 interesting functions to generate the picture.We

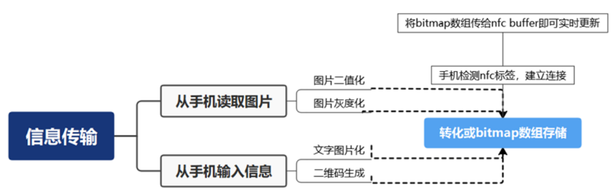

Fig. 19 App framework

We also added one more function.When we start the device，it will write the pre-loaded start-up image in NFC buffer to the display。

We hope to burn the firmware program onto the STm32 chip through a serial port. After the firmware program is burned to the chip, information can be transmitted through Bluetooth.This section receive the image over USB,which is using this interrupt service routine triggered by the UART receive. That's a routine that receives information from the serial port,everytime data is received on the USB serial port, the ISR interrupt function is called.It will pauses the cpu to run the function.then resumes cpu back to normal code execution.when we have received 5000 bytes (full image), it writes the nfcbuffer to the e-paper display.so we can send the raw image bytes over serial, and it will update the display.

There are four functions implemented by the app. Fig 20 is the overview of app.

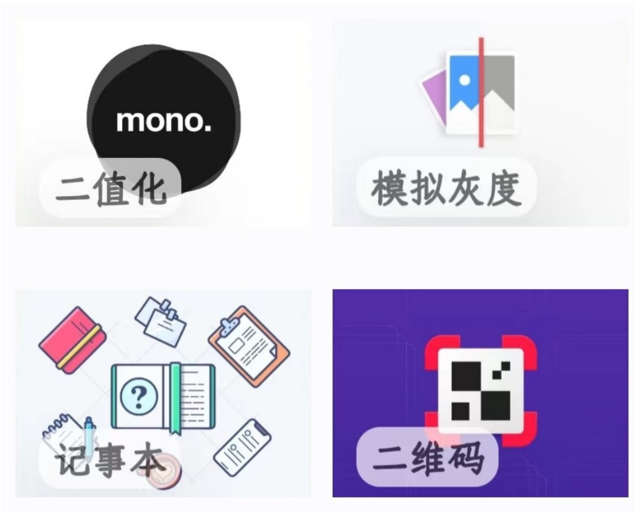

Fig. 20 App framework

- Mono image: Convert color image to black and white image and output image to ECARD. Fig 21 is an example diagram.
- Grayscale image: Use Floyd Steinberg dithering algorithm to grayscale images and output them to ECARD. Fig 22 is an example diagram.
- QRcode: Enter a paragraph of text in the text box (due to ink screen resolution limitations, it is recommended to enter no more than 143 words) and generate a QR code, then output to ECARD. Fig 23 is an example diagram.
- Notebook: Enter a paragraph of text in the text box and generate bitmap, then output. Fig 24 is an example diagram.

Fig. 21 Mono image

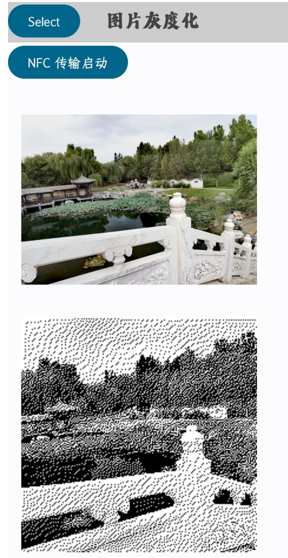

Fig. 22 Grayscale image

Fig. 23 QRcode

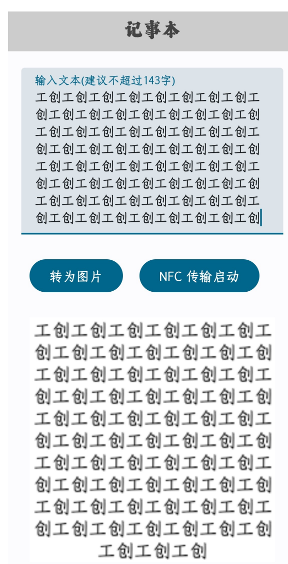

Fig. 24 Notebook

3 Firmware

The firmware performs several functions in our L-Ink card device. It runs on the STM32 MCU and is responsible for setting up all the peripheral's communication (SPI, UART), receiving images and displaying them to the E-Paper display, as well as handling NFC, Bluetooth BLE and USB communications.

3.1 Display Buffer.

In order to receive a whole image and then transfer it to he E-Paper display at once, the firmware stores a display buffer. This buffer is a char array with 5,000 bytes, or 40,000 bits; one bit for the monochrome state of every pixel of our 200 by 200 pixel display.

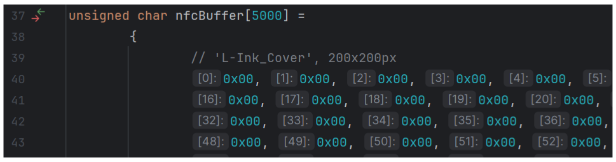

Fig. 25 Display Buffer Definition

At startup, a default image is loaded into the display buffer from flash memory. Whenever incoming data is detected, data is input into the display buffer and finally the display draw call is executed when the buffer has been filled.

Fig. 26 Start-up Image Buffer

Notice that the firmware does no image processing, only direct transfer and display of image buffers. Additionally, the E-Paper display is monochrome, not gray-scale; though the illusion of a gray-scale display can be achieved through dithering in the sender-side (transmitter) software.

3.2 NFC Image Transfer.

In order to receive images through NFC, we utilise the ST25 Mailbox function. The Mailbox functions allows us to receive individual NFC packets with a data length of 200 bytes each. We append each incoming packet of data directly to the display buffer as well as keeping a pointer to the current buffer position. Once a whole image (5,000 bytes) is received, we send the full display buffer to the E-Paper.

Fig. 27 NFC Receive Function

3.3 USB & Bluetooth BLE Serial Image Transfer.

In addition to receiving images through NFC, our device is able to receive images through UART serial. The UART port may be connected to the on-board USB to serial converter for transfer over USB UART, or to the on-board Bluetooth low-energy to serial converter for transfer over BLE. For both cases, the receiving function is the same. First, we enable an Interrupt Service Routine (ISR) which is triggered by receiving UART data on the STM32's hardware UART interfaces. In this ISR function we read the incoming byte, append it to the display buffer and increment the display buffer pointer. Once we have received a full image buffer we may then write it to the display. Additionally, we also print the receive progress back to the sender via the serial port transmit.

Fig. 28 UART Receive Function

In practice, this means that the transmitter device must first prepare an image to be sent; by first converting it to a monochrome 200 by 200 pixel image (applying dithering as needed), then it must convert the image information into an appropriate image buffer of 5,000 bytes (representing the display pixels row-by-row), finally the raw bytes of this image buffer may be sent over USB or Bluetooth LE UART. For convenience, we store a prepared image buffer as a .bin file, which may then be simply uploaded through the UART to perform the image transfer.

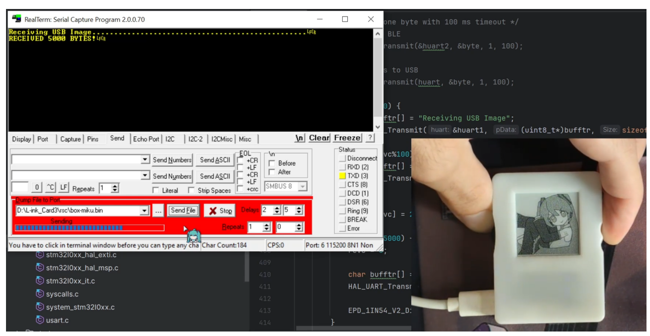

Fig. 29 UART Receive through USB

4 Distributions

Name	Circuit	Shell	Firmware	Materials	Android app
Jingdi Lei	70%	100%	23%	25%	50%
Luigi Pizzolito	30%	-	35%	16%	-
Yuluan Cao	-	-	15%	28%	50%
Ziye Li	-	-	17%	20%	-
Zenan Ji	-	-	-%	11%	-
Tianqi Kang	-	-	10%	-	-

Table 1 Distribution in different task, Materials include document and video

Name	Final Distribution
Jingdi Lei	48.35%
Luigi Pizzolito	19%
Yuluan Cao	19.5%
Ziye Li	8.4%
Zenan Ji	2.75%
Tianqi Kang	2%

Table 2

5 Cost

Table 3 is the whole cost in this Project. The total cost is ¥248.9

Material	Cost(¥)
Jialichuang consulting fee	30.9
PCB proofing and SMT cost	98
Battery	20.8
Three ink screens Li	88
Bluetooth chip	11.20

Table 3

6 Conclusions

The purpose of this project is to explore the application and potential of stm32 microcontroller in NFC card simulation and image transmission. Starting from the circuit design, we realized the integration of the NFC chip and STM32, changed the button battery of the original project into a more practical charging circuit, and optimized the PCB to make its NFC function less likely to be interfered with. After that, we designed two versions of the shell and printed the second version through 3D printing. We implemented some basic functions of the app, such as NFC reading. The expected outcome of this project is a prototype system that can realize NFC card simulation and information transmission functions, as well as a detailed technical document and test report. The significance of this project is to demonstrate the powerful functions and flexibility of stm32 microcontrollers and interesting solutions used to face difficulties in daily life, as well as to provide reference and inspiration for future research and development in related fields.

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