Hey! So this is not a full tutorial, it's just a quickstart guide while we do more research into RFID/NFC. There's a lot of info here but not everything is explained in detail. We hope to fill out the tutorial but there's not a lot of good information about NFC so it's taking a bit of time!
Breakout Wiring

This part of the tutorial is specifically for the Breakout board. We show how to use it with SPI. The breakout also supports TTL serial and I2C but we don't have a tutorial for using it that way as SPI is the most cross-platform method to communicate.

If you're using the shield, check the next page

Wiring the Breakout for SPI

The PN532 chip and breakout is designed to be used by 3.3V systems. To use it with a 5V system such as an Arduino, a level shifter is required to convert the high voltages into 3.3V. If you have a 3.3V embedded system you won't have to use the shifter of course!

To begin, we'll solder in the header to the breakout board. You'll need two small 3-pin pieces of header and one 8-pin piece. You can break these off of a large piece.
Solder the two small pieces to the **SEL0** and **SEL1** pads. These are interface selectors for the chip. Depending on how the jumpers are inserted the chip will talk in TTL serial, i2c or SPI. Also solder a strip to the end so you can plug it into a breadboard.

Wire up the 4050 level shifter chip to the Arduino as shown. The notch in the 4050 is at the 'top' in this image:

- Arduino digital pin 2 is connected to 4050 pin 9 (orange wire)
- Arduino digital pin 3 is connected to 4050 pin 11 (yellow wire)
- Arduino digital pin 4 is connected to 4050 pin 14 (green wire)

On the breakout board:

- **3.3Vin** is connected to the Arduino 3.3V pin
- **SCK** is connected to 4050 pin 10 (orange wire)
- **MISO** is connected to Arduino pin 5 (blue wire)
- **MOSI** is connected to 4050 pin 12 (yellow wire)
- **SSEL** is connected to 4050 pin 15& (green wire)
• **GND** connects to Arduino **ground** (black wire)

Also connect 4050 pin #1 to **3.3V** and pin #8 to **ground**.

Click to see a larger image. The red power wire should be connected to the **3.3v** pin on the Arduino!

Also, we need to select SPI as the interface so on **SEL1** place the jumper in the **ON** position. for **SEL0** place the jumper in the **OFF** position.

That's it! Later on you can change what Arduino pins you are using but for the beginning test we suggest matching our wiring.

If you are using the breakout in I2C mode, you will also need to add two 1.5K pullups on the SCL/SDA lines, since the breakout and the Arduino don't include the pullups. Simply solder or add a 1.5K resistor between SCL and 3.3V, and SDA and 3.3V, and then connect the breakout as you normally would.
Shield Wiring

Solder the Headers
The first step is to solder the headers to the shield. Cut the header strip to length and insert the sections (long pins down) into an Arduino. Then place the shield on top and solder each pin.

Using the Adafruit NFC Shield with I2C
The Adafruit NFC shield is designed to be used using the I2C by default. I2C only uses two pins (Analog 4 and 5 which are fixed in hardware and cannot be changed) to communicate and one pin as an 'interrupt' pin (Digital 2 - can be changed however). What is nice about I2C is that it is a 'shared' bus - unlike SPI and TTL serial - so you can put as
many sensors as you'd like all on the same two pins, as long as their addresses don't collide/conflict. The Interrupt pin is handy because instead of constantly asking the NFC shield "is there a card in view yet? what about now?" constantly, the chip will alert us when a NFC target comes into the antenna range.

The shield is drop-in compatible with any Classic Arduino (UNO, Duemilanove, Diecimilla, etc using the ATmega168 or '328) as well as any Mega R3 or later.

**Mega R2 Arduinos work as well but you need to solder a wire from the**
(https://adafruit.it/aUS)SDA (https://adafruit.it/aUS) and (https://adafruit.it/aUS)SCL (https://adafruit.it/aUS) pin holes to the
Mega's I2C pins on Digital #20 and #21 (https://adafruit.it/aUS)

**Using with the Arduino Leonardo and Yun**

The IRQ pin is tied to Digital pin #2 by default. However, on the Arduino Leonardo and Yun, digital #2 is used for I2C which will not work. If using with a Leonardo or Yun, cut the trace between the IRQ pin and Digital #2 and solder a wire from IRQ pin to Digital #4 or higher. Then change the example code so the the IRQ pin is declared as the new pin (say #6) not #2

Here are some photos of setting the IRQ pin to digital 6. First, use a sharp hobby knife to cut the trace from IRQ to 2

Solder a wire from IRQ to #6
Arduino Library

Which Library?

In the past there were two separate Arduino libraries for using the Adafruit NFC boards. One library supported the breakout over a SPI connection, and the other library supported the breakout or shield over an I2C connection. However both of these libraries have been merged into a single Arduino library, Adafruit-PN532 (https://adafru.it/eHi).

The Adafruit PN532 library has the ability to read MiFare cards, including the hard-coded ID numbers, as well as authenticate and read/write EEPROM chunks. It can work with both the breakout and shield using either a SPI or I2C connection.

Library Installation

Download the Adafruit PN532 library from github (https://adafru.it/aSX). Uncompress the folder and rename the folder Adafruit_PN532. Inside the folder you should see the Adafruit_PN532.cpp and Adafruit_PN532.h files. Install the Adafruit_PN532 library folder by placing it in your arduinosketchfolder/libraries folder. You may have to create the libraries subfolder if this is your first library. You can read more about installing libraries in our tutorial (https://adafru.it/aYG).

Restart the Arduino IDE. You should now be able to select File > Examples > Adafruit_PN532 > readMifare sketch.

If you're using the NFC breakout with a SPI connection that uses the wiring shown on previous pages you can immediately upload the sketch to the Arduino and skip down to the Testing MiFare (https://adafru.it/kAc) section.

If you're using the NFC shield, or are using the breakout with an I2C connection then you must make a small change to configure the example for I2C. Scroll down to these lines near the top of the sketch:

```cpp
// Uncomment just _one_ line below depending on how your breakout or shield is connected to the Arduino:

// Use this line for a breakout with a SPI connection:
Adafruit_PN532 nfc(PN532_SCK, PN532_MISO, PN532_MOSI, PN532_SS);

// Use this line for a breakout with a hardware SPI connection. Note that the PNS32 SCK, MOSI, and MISO pins need to be connected to the Arduino's hardware SPI SCK, MOSI, and MISO pins. On an Arduino Uno these are SCK = 13, MOSI = 11, MISO = 12. The SS line can be any digital IO pin.
Adafruit_PN532 nfc(PN532_SCK);  

// Or use this line for a breakout or shield with an I2C connection:
Adafruit_PN532 nfc(PN532_IRQ, PN532_RESET);
```

Change them so the second line is uncommented and the first line is commented. This will configure the sketch to make the library use I2C for communication with the NFC shield or breakout. The modified code should look like:
Then upload the example to the Arduino and continue on. Note that you need to make a similar change to pick the interface for any other NFC example from the library.

Testing MiFare

In the serial monitor, you should see that it found the PN532 chip. Then you can place your tag nearby and it will display the 4 byte ID code (this one is 0xAE 0x4C 0xF0 0x6C) and then the integer version of all four bytes together. You can use this number to identify each card. Recently NXP made so many cards that they actually ran through all 4 bytes ($2^{32}$) so the number is not guaranteed to be absolutely unique. However, the chances are extremely slim you will have two cards with the same ID so as long as you aren’t using these cards for anything terribly important (like money transfer) its fine to use the number as a unique identifier.
Python & CircuitPython

It's easy to use the PN532 breakout and shield with Python and CircuitPython, and the Adafruit CircuitPython PN532 (https://adafruit.it/DJz) module. This module allows you to easily write Python code that reads and writes data from and to RFID/NFC tags.

You can use this breakout with any CircuitPython microcontroller board or with a computer that has GPIO and Python thanks to Adafruit_Blinka, our CircuitPython-for-Python compatibility library (https://adafruit.it/BSN).

CircuitPython Microcontroller Wiring

First assemble a PN532 breakout or shield exactly as shown on the previous pages.

Here's an example of wiring a Feather M0 to the breakout with I2C:

- Board 3V to breakout 3.3V
- Board GND to breakout GND
- Board SCL to breakout SCL
- Board SDA to breakout SDA
- Board D6 to breakout RSTOUT_N

I2C requires external pull ups on SCL and SDA!

You must set the jumpers to enable I2C on your PN532!

For I2C:

- SEL0 = ON
- SEL1 = OFF

Here's an example of wiring a Feather M0 to the breakout using SPI:

- Board 3V to breakout 3.3V
- Board GND to breakout GND
- Board MISO to breakout MISO
- Board MOSI to breakout MOSI
- Board SCK to breakout SCK
- Board D5 to breakout SSEL

You must set the jumpers to enable SPI on your PN532!

For SPI:

- SEL0 = OFF
- SEL1 = ON

Here's an example of wiring a Feather M0 to the breakout using UART:
You must set the jumpers to enable UART on your PN532! For UART:

- SEL0 = OFF
- SEL1 = OFF

You must set the jumpers to enable I2C on your PN532! For I2C:

- SEL0 = ON
- SEL1 = OFF

Here's an example of wiring a Metro M0 to the shield using I2C:

Assemble the shield as shown in the previous pages, and plug into your Metro M0.

This breakout is designed to work with I2C, SPI and UART, however I2C AND UART DO NOT WORK RELIABLY ON RASPBERRY PI. If you're using the PN532 with Raspberry Pi, use SPI!

Here's the Raspberry Pi wired with SPI:
You must set the jumpers to enable SPI on your PN532!
For SPI:

- SEL0 = OFF
- SEL1 = ON

We don't recommend using I2C, but here's the Raspberry Pi wired with I2C:

You must set the jumpers to enable I2C on your PN532!
For I2C:

- SEL0 = ON
- SEL1 = OFF

We don't recommend using UART, but here's the Raspberry Pi wired with UART:
CircuitPython Installation of PN532 Library

Next you'll need to install the Adafruit CircuitPython PN532 (https://adafru.it/DJz) library on your CircuitPython board.

First make sure you are running the latest version of Adafruit CircuitPython (https://adafru.it/Amd) for your board.

Next you'll need to install the necessary libraries to use the hardware--carefully follow the steps to find and install these libraries from Adafruit's CircuitPython library bundle (https://adafru.it/zdx). Our introduction guide has a great page on how to install the library bundle (https://adafru.it/ABU) for both express and non-express boards.

Remember for non-express boards like the, you'll need to manually install the necessary libraries from the bundle:

- adafruit pn532.mpy
- adafruit_bus_device

Before continuing make sure your board's lib folder or root filesystem has the adafruit pn532.mpy, and adafruit_bus_device files and folders copied over.

Next connect to the board's serial REPL (https://adafru.it/Awz) so you are at the CircuitPython >>> prompt.

Python Installation of PN532 Library

You'll need to install the Adafruit_Blinka library that provides the CircuitPython support in Python. This may also require enabling I2C on your platform and verifying you are running Python 3. Since each platform is a little different, and Linux changes often, please visit the CircuitPython on Linux guide to get your computer
Once that's done, from your command line run the following command:

- `sudo pip3 install adafruit-circuitpython-pn532`

If your default Python is version 3 you may need to run 'pip' instead. Just make sure you aren't trying to use CircuitPython on Python 2.x, it isn't supported!

CircuitPython & Python Usage

To demonstrate the usage of the breakout we'll initialize it and read the ID from a tag using the board's Python REPL.

Run the following code to import the necessary modules and assign the reset pin to a digital pin on your board. We've used D6:

```python
import board
import busio
from digitalio import DigitalInOut
from adafruit_pn532.i2c import PN532_I2C
reset_pin = DigitalInOut(board.D6)
```

On Raspberry Pi, you must also connect a pin to P32 "H_Request" for hardware wakeup. This avoids I2C clock stretching.

```python
req_pin = DigitalInOut(board.D12)
```

Initialise the I2C object:

```python
i2c = busio.I2C(board.SCL, board.SDA)
pn532 = PN532_I2C(i2c, debug=False, reset=reset_pin, req=req_pin)
```

Now we can start interacting with NFC/RFID tags using the following functions:

- `get_firmware_version` - Get the latest firmware version.
- `SAM_configuration` - configure the PN532 to read MiFare cards.
- `read_passive_target` - Wait for a MiFare card to be available and return its UID when found.
- `call_function` - Send specified command to the PN532 and expect up to `response_length` bytes back in a response.
- `mifare_classic_authenticate_block` - Authenticate specified block number for a MiFare classic card.
- `mifare_classic_read_block` - Read a block of data from the card.
- `mifare_classic_write_block` - Write a block of data to the card.
- `ntag2xx_read_block` - Read a block of data from the card.
- `ntag2xx_write_block` - Write a block of data to the card.

First, we'll verify the PN532 is connected and check the firmware.

```python
ic, ver, rev, support = pn532.get_firmware_version()
print('Found PN532 with firmware version: {}.{}. Format(ver, rev))
```
Now we're going to configure the PN532 to read MiFare cards. Then we'll wait for a card to be available and print the UID.

First we check to see if a card is available. While we're waiting we'll print \cdot to the serial output so we know it's still looking. If no card is found, we continue looking. When a card is found, we print the UID.

```
>>> ic, ver, rev, support = pn532.get_firmware_version()
>>> print(f'Found PN532 with firmware version: {ver}.{rev}'.format(ver, rev))
Found PN532 with firmware version: 1.6
```

Touch a MiFare card to the breakout!

```
pn532.SAM_configuration()
while True:
    uid = pn532.read_passive_target(timeout=0.5)
    print('.', end='', flush=True)
    if uid is None:
        continue
    print('Found card with UID:', [hex(i) for i in uid])
```

That's all there is to reading the UID from a card with CircuitPython and the PN532! For more information, check out the documentation [here](https://adafru.it/DJA).

**Full Example Code**
This example shows connecting to the PN532 with I2C (requires clock stretching support), SPI, or UART. SPI is best, it uses the most pins but is the most reliable and universally supported. After initialization, try waving various 13.56MHz RFID cards over it!

```python
import board
import busio
from digitalio import DigitalInOut

# NOTE: pick the import that matches the interface being used

from adafruit_pn532.i2c import PN532_I2C
# from adafruit_pn532.spi import PN532_SPI
# from adafruit_pn532.uart import PN532_UART

# I2C connection:
i2c = busio.I2C(board.SCL, board.SDA)

# Non-hardware
#pn532 = PN532_I2C(i2c, debug=False)

# With I2C, we recommend connecting RSTPD_N (reset) to a digital pin for manual hardware reset
reset_pin = DigitalInOut(board.D6)
# On Raspberry Pi, you must also connect a pin to P32 "H_Request" for hardware wakeup! this means we don't need to do the I2C clock-stretch thing
req_pin = DigitalInOut(board.D12)
pn532 = PN532_I2C(i2c, debug=False, reset=reset_pin, req=req_pin)

# SPI connection:
spi = busio.SPI(board.SCK, board.MOSI, board.MISO)
cs_pin = DigitalInOut(board.D5)
pn532 = PN532_SPI(spi, cs_pin, debug=False)

# UART connection
uart = busio.UART(board.TX, board.RX, baudrate=115200, timeout=100)
pn532 = PN532_UART(uart, debug=False)

ic, ver, rev, support = pn532.get_firmware_version()
print('Found PN532 with firmware version: {0}.{1}'.format(ver, rev))

# Configure PN532 to communicate with MiFare cards
pn532.SAM_configuration()

print('Waiting for RFID/NFC card...')
while True:
    # Check if a card is available to read
    uid = pn532.read_passive_target(timeout=0.5)
    print('.', end=''

    # Try again if no card is available.
    if uid is None:
        continue

    print('Found card with UID:', [hex(i) for i in uid])
```
NFC (Near Field Communication)

NFC (Near Field Communication) is a set of short-range (typically up to 10cm) wireless communication technologies designed to offer light-weight and secure communication between two devices. While NFC was invented by NXP (Phillips at the time), Nokia and Sony, the main body behind the NFC 'standard' today is the NFC Forum (https://adafru.it/aSy), who are responsible for publishing and maintaining a variety of standards relating to NFC technology.

NFC operates at 13.56MHz, and is based around an "initiator" and "target" model where the initiator generates a small magnetic field that powers the target, meaning that the target does not require a power source. This means of communication is referred to as Passive Communication, and is used to read and write to small, inexpensive 13.56MHz RFID tags based on standards like ISO14443A. Active communication (peer-to-peer) is also possible when both devices are powered, where each device alternately creates its own magnetic field, with the secondary device as a target and vice versa in continuous rotation.

Passive Communication: ISO14443A Cards (Mifare, etc.)

While the PN53x family of transceivers from NXP are compatible with a number of 13.56MHz RFID card standards, by far the most popular standard is ISO14443A. A variety of manufacturers produce ISO14443A compatible cards or chips, but the most common are based around the Mifare family from NXP. Mifare Classic and Mifare Ultralight are probably the most frequently encountered and useful for basic projects, though many tags with improved security and encryption also exist (Mifare DESFire, etc.). All of the tags sold at adafruit.com are Mifare Classic 1K, meaning that they contains 1K (1024 bytes) of programmable EEPROM memory which can be read and modified in passive mode by the initiator device (the PN532).

While all ISO14443A cards share certain common characteristics on the highest level (defined by the four part standard), each set of Mifare chips (Classic, Ultralight, Plus, DESFire, etc.) has it's own features and peculiarities. The two most common formats are described below.

- **Mifare Classic** (https://adafru.it/cl7): These cards are extremely common, and contain 1K or 4K of EEPROM, with basic security for each 64 byte (1K/4K cards) or 256 byte (4K cards) sector.
- **Mifare Ultralight** (https://adafru.it/cl7): Contains 512 bytes of EEPROM, including 32-bits of OTP memory. These tags are inexpensive, often come in sticker format and are are frequently used for transportation ticketing, concert tickets, etc.

Active Communication (Peer-to-Peer)

Active or "Peer-to-Peer" communication is still based around the Initiator/Target model described earlier, but both devices are actively powered and switch roles from being an Initiator or a Target during the communication. When one device is initiating a conversation with the other, it enables it's magnetic field and the receiving device listens in (with it's own magnetic field disabled). Afterwards, the target/recipient device may need to respond and will in turn activate it's own magnetic field and the original device will be configured as the target. Despite two devices being present, only one magnetic field is active at a time, with each device constantly enabling or disabling its own magnetic field.

ToDo: Add better description of active mode, but I need to test it out a bit first myself!

NFC Data Exchange Format (NDEF)

The NFC Data Exchange Format (NDEF) is a standardised data format that can be used to exchange information between any compatible NFC device and another NFC device or tag. The data format consists of NDEF Messages and
NDEF Records. The standard is maintained by the NFC Forum and is freely available for consultation but requires accepting a license agreement to download (https://adafru.it/aSA).

The NDEF format is used to store and exchange information like URIs, plain text, etc., using a commonly understood format. NFC tags like Mifare Classic cards can be configured as NDEF tags, and data written to them by one NFC device (NDEF Records) can be understood and accessed by any other NDEF compatible device. NDEF messages can also be used to exchange data between two active NFC devices in "peer-to-peer" mode. By adhering to the NDEF data exchange format during communication, devices that would otherwise have no meaningful knowledge of each other or common language are able to share data in an organised, mutually understandable manner.

The NDEF standard includes numerous Record Type Definitions (RTDs) that define how information like URIs should be stored, and each NDEF device, tag or message can contained multiple RTDs. Standard RTD definitions are described in "NFC Record Type Definition (RTD) Specification" maintained by the NFC Forum.

*NDEF Overview (https://adafru.it/cl7):* This page offers a more detailed explanation of NDEF, including how Mifare Classic cards can be used to store NDEF messages.

**NOTE:** The dedicated NDEF page is still a work in progress and some information is currently incomplete.

**Reading**

For more details about NFC/RFID and this chip we suggest the following fantastic resources:

- RFID selection guide (https://adafru.it/Cc3) - a lot of details about RFID in general
- Nokia's Introduction to NFC (https://adafru.it/aSD) - a lot of details about NFC in general
- NXP S50 chip datasheet (https://adafru.it/aSE) , the chip inside MiFare classic tags
- NXP PN532 Short Form Datasheet (https://adafru.it/aSF)
- NXP PN532 Long Form Datasheet (https://adafru.it/aSG)
- NXP PN532 User Manual (https://adafru.it/aSH)
- NXP PN532 App Note (https://adafru.it/Cc4)
- Using PN532 with libnfc (https://adafru.it/aSJ)
- NFC Glossary (https://adafru.it/aSK)
MiFare Cards & Tags

MiFare is one of the four 13.56MHz card ‘protocols’ (FeliCa is another well known one) All of the cards and tags sold at the Adafruit shop use the inexpensive and popular MiFare Classic chipset

MiFare Classic Cards

MiFARE Classic cards come in 1K and 4K varieties. While several varieties of chips exist, the two main chipsets used are described in the following publicly accessible documents:

- MF1S503x Mifare Classic 1K data sheet (https://adafru.it/aSL)
- MF1S70yyX MIFARE Classic 4K data sheet (https://adafru.it/aSM)

MiFare Classic cards typically have a 4-byte NUID that uniquely (within the numeric limits of the value) identifies the card. It's possible to have a 7 byte IDs as well, but the 4 byte models are far more common for Mifare Classic.

EEPROM Memory

Mifare Classic cards have either 1K or 4K of EEPROM memory. Each memory block can be configured with different access conditions, with two seperate authentication keys present in each block.

Mifare Classic cards are divided into section called sectors and blocks. Each "sector" has individual access rights, and contains a fixed number of "blocks" that are controlled by these access rights. Each block contains 16 bytes, and sectors contains either 4 blocks (1K/4K cards) for a total of 64 bytes per sector, or 16 blocks (4K cards only) for a total of 256 bytes per sector. The card types are organised as follows:

- **1K Cards** - 16 sectors of 4 blocks each (sectors 0..15)
- **4K Cards** - 32 sectors of 4 blocks each (sectors 0..31) and 8 sectors of 16 blocks each (sectors 32..39)

4 Block Sectors

1K and 4K cards both use 16 sectors of 4 blocks each, with the bottom 1K of memory on the 4K cards being organised identically to the 1K models for compatability reasons. These individual 4 block sectors (containing 64 bytes each) have basic security features are can each be configured with seperate read/write access and two different 6-byte authentication keys (the keys can be different for each sector). Due to these security features (which are stored in the last block, called the Sector Trailer), only the bottom 3 blocks of each sector are actually available for data storage, meaning you have 48 bytes per 64 byte sector available for your own use.

Each 4 block sector is organised as follows, with four rows of 16 bytes each for a total of 64-bytes per sector. The first two sectors of any card are shown:

<table>
<thead>
<tr>
<th>Sector</th>
<th>Block</th>
<th>Bytes</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>3</td>
<td>[Access Bits] [Access Bits] [Access Bits] [Access Bits]</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>0</td>
<td>[KEY A] [KEY B] [KEY C] [KEY D]</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>1</td>
<td>[KEY A] [KEY B] [KEY C] [KEY D]</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>2</td>
<td>[KEY A] [KEY B] [KEY C] [KEY D]</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>[KEY A] [KEY B] [KEY C] [KEY D]</td>
</tr>
</tbody>
</table>

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https://learn.adafruit.com/adafruit-pn532-rfid-nfc
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Sector Trailer (Block 3)
The sector trailer block contains the two secret keys (Key A and Key B), as well as the access conditions for the four blocks. It has the following structure:

<table>
<thead>
<tr>
<th>Sector Trailer Bytes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15</td>
</tr>
<tr>
<td>[ Key A ] [ Access Bits ] [ Key B ]</td>
</tr>
</tbody>
</table>

For more information in using Keys to access the clock contents, see Accessing Data Blocks further below.

Data Blocks (Blocks 0..2)
Data blocks are 16 bytes wide and, depending on the permissions set in the access bits, can be read from and written to. You are free to use the 16 data bytes in any way you wish. You can easily store text input, store four 32-bit integer values, a 16 character uri, etc.

Data Blocks as "Value Blocks"
An alternative to storing random data in the 16 byte-wide blocks is to configure them as "Value Blocks". Value blocks allow performing electronic purse functions (valid commands are: read, write, increment, decrement, restore, transfer).

Each Value block contains a single signed 32-bit value, and this value is stored 3 times for data integrity and security reasons. It is stored twice non-inverted, and once inverted. The last 4 bytes are used for a 1-byte address, which is stored 4 times (twice non-inverted, and twice inverted).

Data blocks configured as "Value Blocks" have the following structure:

<table>
<thead>
<tr>
<th>Value Block Bytes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15</td>
</tr>
<tr>
<td>[ Value ] [ ~Value ] [ Value ] [ A ~A A ~A ]</td>
</tr>
</tbody>
</table>

Manufacturer Block (Sector 0, Block 0)
Sector 0 is special since it contains the Manufacturer Block. This block contains the manufacturer data, and is read-only. It should be avoided unless you know what you are doing.

16 Block Sectors
16 block sectors are identical to 4 block sectors, but with more data blocks. The same structure described in the 4 block sectors above applies.
Accessing EEPROM Memory

To access the EEPROM on the cards, you need to perform the following steps:

1. You must retrieve the 4-byte NUID of the card (this can sometimes be 7-bytes long as well, though rarely for Mifare Classic cards). This is required for the subsequent authentication process.

2. You must authenticate the sector you wish to access according to the access rules defined in the Sector Trailer block for that sector, by passing in the appropriate 6 byte Authentication Key (ex. 0xFF 0xFF 0xFF 0xFF 0xFF 0xFF for new cards).

3. Once authentication has succeeded, and depending on the sector permissions, you can then read/write/increment/decrement the contents of the specific block. Note that you need to re-authenticate for each sector that you access, since each sector can have its own distinct access keys and rights!

Note on Authentication

Before you can do access the sector's memory, you first need to "authenticate" according to the security settings stored in the Sector Trailer. By default, any new card will generally be configured to allow full access to every block in the sector using Key A and a value of 0xFF 0xFF 0xFF 0xFF 0xFF 0xFF. Some other common keys that you may wish to try if this doesn't work are:

```
0xFF 0xFF 0xFF 0xFF 0xFF 0xFF
0xD3 0xF7 0xD3 0xF7 0xD3 0xF7
0xA0 0xA1 0xA2 0xA3 0xA4 0xA5
0xB0 0xB1 0xB2 0xB3 0xB4 0xB5
0x4D 0x3A 0x99 0xC3 0x51 0xDD
0x1A 0x98 0x2C 0x7E 0x45 0x9A
0xAA 0xBC 0xCC 0xDD 0xEE 0xFF
0x00 0x00 0x00 0x00 0x00 0x00
0xAB 0xCD 0xEF 0x12 0x34 0x56
```

Example of a New Mifare Classic 1K Card

The follow memory dump illustrates the structure of a 1K Mifare Classic Card, where the data and Sector Trailer blocks can be clearly seen:

```
[--------------------------Start of Memory Dump--------------------------]  
32 15 [-------KEY A-------] [Access Bits] [-------KEY B-------] Sector Trailer 32 
... 2 [ Data ] Data ] Data ] Data ] Data 
1 [ Data ] Data ] Data ] Data ] Data 
0 [ Data ] Data ] Data ] Data ] Data 

[--------------------------End of Memory Dump--------------------------]  
```

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MiFare Ultralight Cards

MiFare Ultralight cards typically contain 512 bits (64 bytes) of memory, including 4 bytes (32-bits) of OTP (One Time Programmable) memory where the individual bits can be written but not erased.

MF0ICU1 MiFare Ultralight Functional Specification (https://adafru.it/aSN)

MiFare Ultralight cards have a 7-byte UID that uniquely identifies the card.

EEPROM Memory

MiFare Ultralight cards have 512 bits (64 bytes) of EEPROM memory, including 4 byte (32 bits) of OTP memory. Unlike Mifare Classic cards, there is no authentication on a per block level, although the blocks can be set to "read-only" mode using Lock Bytes (described below).

EEPROM memory is organised into 16 pages of four bytes eachs, in the following order:

<table>
<thead>
<tr>
<th>Page</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Serial Number (4 bytes)</td>
</tr>
<tr>
<td>1</td>
<td>Serial Number (4 bytes)</td>
</tr>
<tr>
<td>2</td>
<td>Byte 0: Serial Number</td>
</tr>
<tr>
<td></td>
<td>Byte 1: Internal Memory</td>
</tr>
<tr>
<td></td>
<td>Byte 2..3: Lock bytes</td>
</tr>
<tr>
<td>3</td>
<td>One-time programmable memory (4 bytes)</td>
</tr>
<tr>
<td>4..15</td>
<td>User memory (4 bytes)</td>
</tr>
</tbody>
</table>

Here are the pages and blocks arranged in table format:
Lock Bytes (Page 2)

Bytes 2 and 3 of page 2 are referred to as "Lock Bytes". Each page from 0x03 and higher can individually locked by setting the corresponding locking bit to "1" to prevent further write access, effectively making the memory read only.

For more information on the lock byte mechanism, refer to section 8.5.2 of the datasheet (referenced above).

OTP Bytes (Page 3)

Page 3 is the OTP memory, and by default all bits on this page are set to 0. These bits can be bitwise modified using the MiFare WRITE command, and individual bits can be set to 1, but can not be changed back to 0.

Data Pages (Page 4-15)

Pages 4 to 15 are can be freely read from and written to, provided there is no conflict with the Lock Bytes described above.

After production, the bytes have the following default values:

<table>
<thead>
<tr>
<th>Page</th>
<th>Byte Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1 2 3</td>
</tr>
<tr>
<td>4</td>
<td>0xFF 0xFF 0xFF 0xFF</td>
</tr>
<tr>
<td>5..15</td>
<td>0x00 0x00 0x00 0x00</td>
</tr>
</tbody>
</table>

Accessing Data Blocks

In order to access the cards, you must following two steps:

1. 'Connect' to a Mifare Ultralight card and retrieve the 7 byte UID of the card.
2. Memory can be read and written directly once a passive mode connection has been made. No authentication is required for Mifare Ultralight cards.

Read/Write Lengths

For compatibility reasons, "Read" requests to a Mifare Ultralight card will retrieve 16 bytes (4 pages) at a time (which corresponds to block size of a Mifare Classic card). For example, if you specify that you want to read page 3, in reality pages 3, 4, 5 and 6 will be read and returned, and you can simply discard the last 12 bytes if they aren't needed. If you
select a higher page, the 16 byte read will wrap over to page 0. For example, reading page 14 will actually return page 14, 15, 0 and 1.

"Write" requests occur in pages (4 bytes), so there is no problem with overwriting data on subsequent pages.
About the NDEF Format

NDEF (NFC Data Exchange Format)

The NFC Data Exchange Format (NDEF) is a standardised data format that can be used to exchange information between any compatible NFC device and another NFC device or tag. The data format consists of NDEF Messages and NDEF Records. The standard is maintained by the NFC Forum and is freely available for consultation but requires accepting a license agreement to download (https://adafrui.it/aSA).

The NDEF format is used to store and exchange information like URIs, plain text, etc., using a commonly understood format. NFC tags like Mifare Classic cards can be configured as NDEF tags, and data written to them by one NFC device (NDEF Records) can be understood and accessed by any other NDEF compatible device. NDEF messages can also be used to exchange data between two active NFC devices in "peer-to-peer" mode. By adhering to the NDEF data exchange format during communication, devices that would otherwise have no meaningful knowledge of each other or common language are able to share data in an organised, mutually understandable manner.

Some helpful app notes and white papers relating to NDEF are listed below:

- NFC Data Exchange Format (NDEF) Technical Specification (https://adafrui.it/aSA) (requires accepting the license terms)
- NFC Record Type Definition (RTD) Specification (https://adafrui.it/aSA) (requires accepting the license terms)
- NXP White Paper - NFC Forum Type Tags (https://adafrui.it/aSO)

NDEF Messages

NDEF Messages are the basic "transportation" mechanism for NDEF records, with each message containing one or more NDEF Records.

NDEF Records

NDEF Records contain a specific payload, and have the following structure that identifies the contents and size of the record:

```
Bit  7  6  5  4  3  2  1  0
------- ------- ------- ------- ------- ------- ------- -------
          [ MB ] [ ME ] [ CF ] [ SR ] [ IL ] [        TNF         ]
          [ TYPE LENGTH ]
          [ PAYLOAD LENGTH ]
          [ ID LENGTH ]
          [ RECORD TYPE ]
          [ ID ]
          [ PAYLOAD ]
```

Record Header (Byte 0)

The record header contains a number of important fields, including a 3-bit field that identifies the type of record that follows (the Type Name Format or TNF):

**TNF: Type Name Format Field**
The Type Name Format or **TNF Field** of an NDEF record is a 3-bit value that describes the record type, and sets the expectation for the structure and content of the rest of the record. Possible record type names include:

<table>
<thead>
<tr>
<th>TNF Value</th>
<th>Record Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x00</td>
<td>Empty Record</td>
<td>Indicates no type, id, or payload is associated with this NDEF Record. This record type is useful on newly formatted cards since every NDEF tag must have at least one NDEF Record.</td>
</tr>
<tr>
<td>0x01</td>
<td>Well-Known Record</td>
<td>Indicates the type field uses the RTD type name format. This type name is used to stored any record defined by a Record Type Definition (RTD), such as storing RTD Text, RTD URIs, etc., and is one of the mostly frequently used and useful record types.</td>
</tr>
<tr>
<td>0x02</td>
<td>MIME Media Record</td>
<td>Indicates the payload is an intermediate or final chunk of a chunked NDEF Record</td>
</tr>
<tr>
<td>0x03</td>
<td>Absolute URI Record</td>
<td>Indicates the type field contains a value that follows the absolute-URI BNF construct defined by RFC 3986</td>
</tr>
<tr>
<td>0x04</td>
<td>External Record</td>
<td>Indicates the type field contains a value that follows the RTD external name specification</td>
</tr>
<tr>
<td>0x05</td>
<td>Unknown Record</td>
<td>Indicates the payload type is unknown</td>
</tr>
<tr>
<td>0x06</td>
<td>Unchanged Record</td>
<td>Indicates the payload is an intermediate or final chunk of a chunked NDEF Record</td>
</tr>
</tbody>
</table>

**IL: ID LENGTH Field**
The IL flag indicates if the ID Length Field is preent or not. If this is set to 0, then the ID Length Field is ommitted in the record.

**SR: Short Record Bit**
The SR flag is set to one if the PAYLOAD LENGTH field is 1 byte (8 bits/0-255) or less. This allows for more compact records.

**CF: Chunk Flag**
The CF flag indicates if this is the first record chunk or a middle record chunk.

**ME: Message End**
The ME flag indicates if this is the last record in the message.

**MB: Message Begin**
The MB flag indicates if this is the start of an NDEF message.

**Type Length**
Indicates the length (in bytes) of the Record Type field. This value is always zero for certain types of records defined with the TNF Field described above.

**Payload Length**
Indicates the length (in bytes) of the record payload. If the SR field (described above) is set to 1 in the record header, this value will be one byte long (for a payload length from 0-255 bytes). If the SR field is set to 0, this value will be a 32-bit value occupying 4 bytes.

**ID Length**
Indicates the length in bytes of the ID field. This field is present only if the IL flag (described above) is set to 1 in the record header.

**Record Type**
This value describes the 'type' of record that follows. The values of the type field must correspond to the value entered in the TNF bits of the record header.

**Record ID**
The value of the ID field if an ID is included (the IL bit in the record header is set to 1). If the IL bit is set to 0, this field is omitted.

**Payload**
The record payload, which will be exactly the number of bytes described in the Payload Length field earlier.

**Well-Known Records (TNF Record Type 0x01)**
Probably the most useful record type is the "NFC Forum Well-Known Type" (TNF Type 0x01). Record types that adhere to the "Well-Defined" type are each described by something called an RTD or Record Type Definition. Some of the current Well-Defined RTDs are:

**URI Records (0x55/'U')**
The “Well Known Type” for a URI record is 0x55 ('U'), and this record type can be used to store a variety of useful information such as telephone numbers (tel:), website addresses, links to FTP file locations, etc.

URI Records are defined in the document "URI Record Type Definition" from the NFC Forum, and it has the following structure:

<table>
<thead>
<tr>
<th>Name</th>
<th>Offset</th>
<th>Size</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identifier</td>
<td>0</td>
<td>1 byte</td>
<td>See table below</td>
</tr>
<tr>
<td>URI Field</td>
<td>1</td>
<td>N bytes</td>
<td>The rest of the URI (depending on byte 0 above)</td>
</tr>
</tbody>
</table>

The URI Identifier Code is used to shorten the URI length, and can have any of the following values:
Following the URI Identifier Code is the **URI Field**. This field provides the URI as per RFC 3987 and contains the rest of the URI after the value corresponding to the URI Identifier is prepended (unless the URI ID is 0x00, in which case the complete URI will be contained in the URI Field).

### Test Records
To Do

### Smart Poster Records
To Do

### Example NDEF Records

<table>
<thead>
<tr>
<th>Value</th>
<th>Protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x00</td>
<td>No prepending is done ... the entire URI is contained in the URI Field</td>
</tr>
<tr>
<td>0x01</td>
<td><a href="http://www">http://www</a>.</td>
</tr>
<tr>
<td>0x02</td>
<td><a href="https://www">https://www</a>.</td>
</tr>
<tr>
<td>0x03</td>
<td>http://</td>
</tr>
<tr>
<td>0x04</td>
<td>https://</td>
</tr>
<tr>
<td>0x05</td>
<td>tel:</td>
</tr>
<tr>
<td>0x06</td>
<td>mailto:</td>
</tr>
<tr>
<td>0x07</td>
<td>ftp://anonymous:anonymous@</td>
</tr>
<tr>
<td>0x08</td>
<td>ftp://ftp.</td>
</tr>
<tr>
<td>0x09</td>
<td>ftps://</td>
</tr>
<tr>
<td>0x0A</td>
<td>sftp://</td>
</tr>
<tr>
<td>0x0B</td>
<td>smb://</td>
</tr>
<tr>
<td>0x0C</td>
<td>nfs://</td>
</tr>
<tr>
<td>0x0D</td>
<td>ftp://</td>
</tr>
<tr>
<td>0x0E</td>
<td>dav://</td>
</tr>
<tr>
<td>0x0F</td>
<td>news:</td>
</tr>
<tr>
<td>0x10</td>
<td>telnet://</td>
</tr>
<tr>
<td>0x11</td>
<td>imap:</td>
</tr>
<tr>
<td>0x12</td>
<td>rtsp://</td>
</tr>
<tr>
<td>0x13</td>
<td>urn:</td>
</tr>
<tr>
<td>0x14</td>
<td>pop:</td>
</tr>
<tr>
<td>0x15</td>
<td>sip:</td>
</tr>
<tr>
<td>0x16</td>
<td>sips:</td>
</tr>
<tr>
<td>0x17</td>
<td>tftp:</td>
</tr>
<tr>
<td>0x18</td>
<td>btspp://</td>
</tr>
<tr>
<td>0x19</td>
<td>btl2cap://</td>
</tr>
<tr>
<td>0x1A</td>
<td>btgoep://</td>
</tr>
<tr>
<td>0x1B</td>
<td>tcpobex://</td>
</tr>
<tr>
<td>0x1C</td>
<td>irdaobex://</td>
</tr>
<tr>
<td>0x1D</td>
<td>file://</td>
</tr>
<tr>
<td>0x1E</td>
<td>urn:epc:id:</td>
</tr>
<tr>
<td>0x1F</td>
<td>urn:epc:tag:</td>
</tr>
<tr>
<td>0x20</td>
<td>urn:epc:pat:</td>
</tr>
<tr>
<td>0x21</td>
<td>urn:epc:raw:</td>
</tr>
<tr>
<td>0x22</td>
<td>urn:epc:</td>
</tr>
<tr>
<td>0x23</td>
<td>urn:nfc:</td>
</tr>
</tbody>
</table>

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An example of a URI record is shown in "Memory Dump of a Mifare Classic 1K Card with an NDEF Record" below.

Using Mifare Classic Cards as an NDEF Tag
Mifare Classic 1K and 4K cards can be configured as NFC Forum compatible NDEF tags, but they must be organised in a certain manner to do so. The requirements to make a Mifare Classic card "NFC Forum compliant" are described in the following App Note from NXP:

AN1304 - NFC Type MIFARE Classic Tag Operation (https://adafruit.it/aSP)

While the App Note above is the authoritative source on the matter, the following notes may also offer a quick overview of the key concepts involved in using Mifare Classic cards as NFC Forum compatible 'NDEF' tags:

Mifare Application Directory (MAD)
In order to form a relationship between the sector-based memory of a Mifare Classic card and the individual NDEF records, the Mifare Application Directory (MAD) structure is used. The MAD indicates which sector(s) contains which NDEF record. The definitive source of information on the Mifare Application Directory is the following application note:

AN10787 - MIFARE Application Directory (MAD) (https://adafruit.it/aSQ)

For reference sake, the two types of MADs (depending on the size of the card in question) are defined below:

Mifare Application Directory 1 (MAD1)
MAD1 can be used in any Mifare Classic card regardless of the size of the EEPROM, although if it is used with cards larger than 1KB only the first 1KB of memory will be accessible for NDEF records.
The MAD1 is stored in the Manufacturer Sector (Sector 0x00) on the Mifare Classic card.

Mifare Application Directory 2 (MAD2)
MAD2 can only be used on Mifare Classic cards with more than 1KB of storage (Mifare Classic 4K cards, etc.). It is NOT compatible with cards containing only 1KB of memory!

The MAD2 is stored in sectors 0x00 (the Manufacturer Sector) and 0x10.

MAD Sector Access
The sectors containing the MAD1 (0x00) and MAD2 (0x00 and 0x10) are protected with a KEY A and KEY B (if you’re not familiar with this concept, consult the Mifare Classic summary elsewhere in the PN532/NFC wiki). To ensure that these sectors can be read by any application, the following common KEY A should always be used:

<table>
<thead>
<tr>
<th>Public KEY A of MAD Sectors</th>
</tr>
</thead>
<tbody>
<tr>
<td>BYTE 0  BYTE 1  BYTE 2  BYTE 3  BYTE 4  BYTE 5</td>
</tr>
<tr>
<td>0xA0   0xA1   0xA2   0xA3   0xA4   0xA5</td>
</tr>
</tbody>
</table>

The MAD sector may optionally be write-protected using KEY B if you wish to limit the ability of customers to modify the card contents. The public KEY A will ensure that they can always read the data.

Storing NDEF Messages in Mifare Sectors
NDEF messages/records may be stored in any sector of the Mifare card, other than the sector(s) use by the MAD or sectors beyond the 1K range if a MAD1 table is used.

When a sector is used to store NDEF records, it is referred to as an NFC Sector. As with the MAD Sector(s) described above, these sectors must always be accessible in at least read-only mode, and as such a common public KEY A also exists for NFC Sectors, though it is not the same KEY A used in the MAD sector(s):

<table>
<thead>
<tr>
<th>Public KEY A of NFC Sectors</th>
</tr>
</thead>
<tbody>
<tr>
<td>BYTE 0  BYTE 1  BYTE 2  BYTE 3  BYTE 4  BYTE 5</td>
</tr>
<tr>
<td>0xD3   0xF7   0xD3   0xF7   0xD3   0xF7</td>
</tr>
</tbody>
</table>

In order to store an NDEF Message on the Mifare Classic card, the message needs to be wrapped inside something called a TLV Block. The basic structure of a TLV Block is described below.

TLV Blocks
TLV is an abbreviation for three different fields: T for Tag Field, L for Length Field and V for Value Field. A TLV Block consist of one or more bytes, depending on which of these three fields is present. Note that the TLV Block will always be at least one byte since the T Field is mandatory in every case.

Tag Field
The Tag Field (or T Field) is the only mandatory field, and uses a single-byte to identify the type of TLV block accordingly to a pre-determined table of values:
### TLV Block Types

<table>
<thead>
<tr>
<th>Block Type</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NULL</td>
<td>0x00</td>
<td>These blocks should be ignored</td>
</tr>
<tr>
<td>NDEF Message</td>
<td>0x03</td>
<td>Block contains an NDEF message</td>
</tr>
<tr>
<td>Proprietary</td>
<td>0xFD</td>
<td>Block contains proprietary information</td>
</tr>
<tr>
<td>Terminator</td>
<td>0xFE</td>
<td>Last TLV block in the data area</td>
</tr>
</tbody>
</table>

### Length Field

The Length Field (or L Field) contains the size (in bytes) of the value field. The Length Field can be organised in two different ways, using either one or three bytes.

The one byte format simple contains a single byte value from 0x00..0xFF.

The three byte format consists of the following format:

- **Byte 0:** Always 0xFF to indicate that we are using the three byte format
- **Byte 1..2:** Can be a value between 0x00FF and 0xFFFF

Both the one byte and three byte format must be supported for NFC Forum and NDEF compatibility.

### Value Field

The Value Field (or V Field) is only present if the Length Field (described above) is present and not equal to 0x00. If the Length Field is not equal to 0, the Value Fields will contain N bytes of data in the format indicated by the T Field above.

The value field is where the payload (an **NDEF Message**, for example) is stored.

### Terminator TLV

The Terminator TLV is the last TLV block in the data area, and consist of a single byte: 0x0FE (see the TLV Block Type table above). This TLV Block in mandatory.

**Memory Dump of a Mifare Classic 1K Card with an NDEF Record**

```
[ Start of Memory Dump ]
--------------------------------- Sector 0 ---------------------------------
Block 0 3E 39 AB 7F D3 88 04 00 47 41 16 57 40 10 34 >9=Ô?..GA.WM.4.
Block 1 14 01 03 E1 03 E1 03 E1 03 E1 03 E1 03 E1 03 E1 03 E1 03 E1 ...
Block 2 03 E1 03 E1 03 E1 03 E1 03 E1 03 E1 03 E1 03 E1 03 E1 03 E1 ....
Block 3 00 00 00 00 00 00 78 77 88 C1 00 00 00 00 00 00 ......xw?Ä......
--------------------------------- Sector 1 ---------------------------------
Block 4 00 00 00 03 11 D1 01 0d 55 01 61 64 61 66 72 50 00 00 00 00 00 00 00 00 t.com...
Block 5 74 2E 63 6F 6D FE 00 00 00 00 00 00 00 00 00 00 00 00 ....N..U.adafrui
Block 6 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ....
Block 7 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ....?
--------------------------------- Sector 2 ---------------------------------
Block 8 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ....
Block 9 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ....
Block 10 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ....
Block 11 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ....?
--------------------------------- Sector 3 ---------------------------------
Block 12 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ....
Block 13 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ....
```
NDEF Records
The above example contains two records, both located in sector 1 (sector 0 contains the MAD).

Record 1
The first record on the card can be identified by looking at the first byte of block 4 in sector 1.

Every record on the Mifare card starts with the TLV Block (described above), and the first byte of the TLV Block (the Tag Field) indicates that this is a NULL Block type (value 0x00). The second byte is the Length Field, and is 0. Since there is no payload for this record (Length = 0), the third byte of the TLV block is not present (the Value Field).

This record was likely inserted when the card was first formatted to ensure that at least one record is present.

Record 2
The second record on the card starts at byte 0x02 of block 4 and continues into block 5.

Starting with the TLV Block data in the first two bytes, we can determine the following:

<table>
<thead>
<tr>
<th>Byte(s)</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>04:02</td>
<td>0x03</td>
<td>Field Type (0x03 = NDEF Message)</td>
</tr>
<tr>
<td>04:03</td>
<td>0x11</td>
<td>Length Field (17 bytes)</td>
</tr>
</tbody>
</table>

This indicates to us that the record contains an NDEF Message (value 0x03), and that the message is 17 bytes long (0x11 in hexadecimal = 17 in decimal value). This means that our NDEF message is contained in the next 17 bytes (04:04..05:04). The NDEF record can then be analysed as follows:
The final byte (block 5, byte 5), with the value OxFE, is the **TLV Terminator** and indicates that this is the end of the TLV Block.

---

**TLV Terminator**

<table>
<thead>
<tr>
<th>Byte(s)</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>04:04</td>
<td>0xD1</td>
<td>This byte is the <strong>NDEF Record Header</strong>, and indicates that this is an NFC Forum Well Known Record (0x01 in the first 3 bits), and that this is the first and last record (MB=1, ME=1), and that this is a short record (SR = 1) meaning the payload length is less than or equal to 255 chars (len=one byte).</td>
</tr>
<tr>
<td>TNF = 0x01 (NFC Forum Well Known Type)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IL = 0 (No ID present, meaning there is no ID Length or ID Field either)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SR = 1 (Short Record)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CF = 0 (Record is not 'chunked')</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ME = 1 (End of message)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MB = 1 (Beginning of message)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>04:05</td>
<td>0x01</td>
<td>This byte is the <strong>Type Length</strong> for the Record Type Indicator (see above for more information), which is 1 byte (0x55/'U' below)</td>
</tr>
<tr>
<td>04:06</td>
<td>0x0D</td>
<td>This is the payload length (13 bytes)</td>
</tr>
<tr>
<td>04:07</td>
<td>0x55</td>
<td>Record Type Indicator (0x55 or 'U' = URI Record)</td>
</tr>
<tr>
<td>04:08</td>
<td>0x01</td>
<td>This is the <strong>start of the record payload</strong>, which contains the URI Identifier (&quot;<a href="http://www">http://www</a>.&quot;) since this is a URI Well-Defined Record Type (see Well-Defined Records above). This will be prepended to the rest of the URI that follows in the rest of the message payload</td>
</tr>
<tr>
<td>04:09..05:04  ...</td>
<td>The remainder of the URI (&quot;adafruit.com&quot;), which combined with the pre-pended value from byte 04:08 yields: <a href="http://www.adafruit.com">http://www.adafruit.com</a></td>
<td></td>
</tr>
</tbody>
</table>
Using with LibNFC

LibNFC is a constantly moving target, and due to the frequent changes from one version to the next we aren’t able to offer LibNFC support ourselves for the PN532. We can only guarantee support and working code for the Arduino codebase that we maintain ourselves. The information below is our best attempt at helping you get started with libnfc and the PN532 breakout, but it may require a bit of poking and prodding on your own depending on the library version and platform you are working with. LibNFC use is, unfortunately, at your own discretion.

Using the PN532 Breakout Boards with libnfc

LibNFC (https://adafruit.it/aSR) is a mature, cross-platform, open-source NFC library that can be easily configured to work with the PN532 Breakout Board. While Linux is probably the easiest platform to use libnfc with, it can be configured for the Mac and Windows as well, though you may need to dig around on the libnfc Community Forums for some specific details on compiling .dlls for Windows, etc.

If you want to test the PN532 Breakout Board out with libnfc, this simple tutorial should walk you through the absolute basics of compiling and configuring libnfc, and using some of the canned example SW included in the library.

LibNFC in Linux (Ubuntu 10.10 used in this example)

Step One: Download libnfc

Download the latest version of libnfc from Google Code (https://adafruit.it/aSS) (ex. "libnfc-1.4.1.tar.gz") and extract the contents of the file as follows:

```bash
$ wget http://libnfc.googlecode.com/files/libnfc-x.x.x.tar.gz
$ tar -xvzf libnfc-x.x.x.tar.gz
$ cd libnfc-x.x.x
```

Step Two: Configure libnfc for PN532 and UART

LibNFC currently only supports communication over UART, using any inexpensive USB to UART adapter like the FTDI Friend or a TTL FTDI cable. Before compiling, however, you will need to configure libnfc to include support for UART and the PN532 chipset, which can be done with the following command (executing in the folder where the above archive was unzipped):

```bash
$ ./configure --with-drivers=pn532_uart --enable-serial-autoprobe
```

Note: If you also wish to include debug output, you can add the ‘--enable-serial-autoprobe’ flag (minus the single quotes) to the configure options.
Step Three: Build and install libnfc

You can build and install libnfc with the following three commands, also run from the folder where the original archive was unzipped:

```
$ make clean
$ make
$ make install
```

Step Four: Check for installed devices

Now that libnfc is (hopefully) built and installed, you can run the 'nfc-list' example to try to detect an attached NFC board. Make sure the board is connected to the FTDI or USB/UART adapter, and that it is connected to your PC, and run the following commands:

```
$ cd examples
$ ./nfc-list
```

This should list the devices that were detected

Step Five: Poll for an ISO14443A (Mifare, etc.) Card

Next, you can use the 'nfc-poll' example to wait 30 seconds for an ISO14443A card or tag and display some basic information about this card. In the examples folder that we changed to above, run the following command:

```
$ ./nfc-poll
```

This should give you some basic information on any card that entered the magnetic field within the specified delay.
libnfccc With Mac OS X Lion

scott-42 was kind of enough to post some tips on getting libnfccc working on a Mac using an FTDI adapter. A couple simple changes to the code were required (as of v1.6.0-rc1), with the details here (https://adafru.it/aP1).

Keeping in mind the code changes mentioned above, the following steps should get libnfccc compiling and working via an FTDI type adapter and UART on Lion (using libnfccc 1.6.0.rc1):

Download and build libnfccc and configure if for PN532 UART (making the code changes above before running make):

```
wget http://libnfccc.googlecode.com/files/libnfccc-1.6.0-rc1.tar.gz
    tar -xvzf libnfccc-1.6.0-rc1.tar.gz
    cd libnfccc-1.6.0-rc1
    ./configure --with-drivers=pn532_uart --enable-serial-autoprobe
    sudo make
    sudo make install
```

If everything worked out, switch to the examples folder and see if you can find the PN532 and wait for an appropriate tag:

```
    cd examples
    /Users/kevin/libnfccc-1.6.0-rc1/examples/examples/nfc-poll
    NFC reader: pn532_uart:/dev/tty.usbserial-FTE5WWPB - PN532 v1.6 (0x07) opened
    NFC device will poll during 30000 ms (20 pollings of 300 ms for 5 modulations)
    ISO/IEC 14443A (106 kbps) target:
      ATQA (SENS RES): 00 04
      UID (NFCID1): 3e b9 6e 66
      SAK (SEL RES): 08
```

There are some dependencies to get libnfccc running, but since it isn’t an Adafruit project and we can’t really support it
directly ourselves, you will probably have better luck looking at the libnfc forums (https://adafruit.it/aST) for Mac support. There are a few active users developing on the Mac.
FAQ

Some of the more common questions on the forums related to the PN532 NFC/RFID Breakout (http://adafruit.it/364) and NFC Shield (http://adafruit.it/789).

Can I have multiple shields on one Arduino?
Can I read or write to Mifare tags with the PN532 and Adafruit Libraries?
This is all you need to start reading and writing data, and you can verify the data using one of many Android applications that support working with Mifare cards (a search for NFC will turn up plenty).

What level of NDEF support is included in the libraries?

```c
uint8_t mifareclassic AuthenticationService (uint8_t * uid, uint8_t uidLen,
                                          uint32_t blockNumber, uint8_t keyNumber,
                                          uint8_t * keyData);
uint8_t mifareclassic_ReadDataBlock (uint8_t blockNumber, uint8_t * data);
uint8_t mifareclassic_WriteDataBlock (uint8_t blockNumber, uint8_t * data);
```
Does the PN532 support peer to peer communication to talk with my smartphone?

Note: Please use the limited NDEF code with care. Formatting cards for NDEF support is currently a one way operation, and should only be performed on cards you can dedicate to NDEF use.
Does the PN532 support tag emulation?
Can the PN532 read Tag-It tags from TI?
Can I set a delay calling readPassiveTargetID()?
#include <Wire.h>
#include <Adafruit_NFCShield_I2C.h>

#define IRQ   (2)
#define RESET (3)  // Not connected by default on the NFC Shield

Adafruit_NFCShield_I2C nfc(IRQ, RESET);

void setup(void) {
  Serial.begin(115200);
  Serial.println("Hello!");

  nfc.begin();

  uint32_t versiondata = nfc.getFirmwareVersion();
  if (! versiondata) {
    Serial.print("Didn't find PN53x board");
    while (1); // halt
  }
}
Hey wait ... isn't there something funny with the SVDD pin?
Are there any special requirements to use the PN532 Breakout with the Due?
Downloads

Files

- SPI and I2C library is available from github (https://adafru.it/aSX)
- Deprecated I2C-only library is available from github (don't recommend) (https://adafru.it/aSW)
- Fritzing objects available in the Adafruit Fritzing library (https://adafru.it/aP3)
- EagleCAD PCB files for the Shield at https://github.com/adafruit/Adafruit-PN532-RFID-NFC-Shield (https://adafru.it/dik)

Datasheets

For more details about NFC/RFID and this chip we suggest the following fantastic resources:

- RFID selection guide (https://adafru.it/Cc6)- a lot of details about RFID in general
- Nokia's Introduction to NFC (https://adafru.it/qPD)- a lot of details about NFC in general
- Using PN532 with libnfc (https://adafru.it/aSJ)
- Antenna design document (https://adafru.it/qPE) Card format (https://adafru.it/qPF)

Breakout v1.6 schematic & print

(click to enlarge)
Version 1.3 schematic

(click to enlarge)