# Using Mobile Phone's Audio Interface for Making of a Magnetic Stripe Card Reader

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In the fulfillment of the requirements for award of the degree

**Master of Technology (Hons.)**

**In**

**VISUAL INFORMATION PROCESSING AND EMBEDDED SYSTEMS**

**By**

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**[08EC3511]**

**Under the guidance of**

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**INDIAN INSTITUTE OF TECHNOLOGY, KHARAGPUR**
**APRIL, 2013**

# CERTIFICATE

This is to certify that the project titled "***Using Mobile Phone's Audio Interface for Making of a Magnetic Stripe Card Reader***" is a bonafide record of the work carried out by **Mr. Nalin Gupta, Roll No. 08EC3511**, under my supervision and guidance for the partial fulfillment of the requirements for the degree of Master of Technology in Electronics and Electrical Communication Engineering during the academic session 2012-2013 in the Department of Electronics and Electrical Communication Engineering, Indian Institute of Technology, Kharagpur.

Date:

Place:

**Prof. S. Mukhopadhyay**

**Electronics and Electrical Communication Engineering**

**IIT Kharagpur**

# ACKNOWLEDGEMENT

I would like to express my deepest gratitude toward Prof. S. Mukhopadhyay, Department of Electronics and Electrical Communication Engineering for offering me the opportunity to work on this project and guiding me through it. I am indebted to Sir for his invaluable guidance, constant motivation, and kind co-operation during my project work. Without his support and encouragement, I would have never been able to produce such a work.

I would also like to extend my sincere thanks to my friend A. Srinivas Reddy, Department of Electrical Engineering, IIT Kharagpur for his unflinching support and technical inputs in completing the project.

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**IIT Kharagpur**

# Contents

# Abstract

The project describes an innovative credit/debit card reader device which can conveniently read the magnetic information stored on the black stripe of a credit/debit card and convey it reliably for uses in retail stores. The device can be used in conjunction with smart phones to act as mobile POS (Point of Sale) device. It can be used by small and medium size merchants and mobile vendors for accepting credit/debit cards from their customers while having the convenience of carrying a small 1 sq. inch card reader instead of a former bulky one. As such, this small credit card reader device has the potential to unlock fortunes for many of the merchants, who are currently crippled with the costly and bulky credit/debit card reader devices.

The card reader device comprises of a read head to produce a waveform in response to the card swiping action against the read head. The generated waveform is set to a particular voltage using a simple voltage divider circuit and is then fed to the microphone input line of the mobile phone through the headset port. Once received into the mobile phone, the analog waveform is converted into digital bitstream from which data is extracted into the human readable form and presented to the end user. An advanced version of this, having the encryption feature in-built into the reader has also been discussed.

# Introduction

Plastic cards having a magnetic stripe embedded on one side of the card are prevalent in everyday commerce. These cards are used in various transactions such as to pay for purchases by using a credit card, a debit card, or a gasoline charge card. When the card is swiped through an electronic card reader at the checkout counter at a merchant's store, the reader will usually use its built-in modem to dial the number of a company that handles credit authentication requests. Once the account is verified and an approval signal will be sent back to the merchant to complete a transaction.

Although magnetic stripe cards are universally used by merchants there is no way for an individual to take advantage of the card to receive a payment from another individual (who is not a merchant) by swiping the card through a simple reader attached to his cell phone. For example, one individual may owe person money for a debt, but one way to pay the debt is to provide cash or a check.

It would be convenient to be able to use a credit card or a debit card to pay off the debt. In addition, it is advantageous for an individual to make payment to another individual or merchant by swiping his magnetic stripe card through a reader connected to a mobile phone.

Therefore, it would be desirable to have a simple card reader device that would allow an individual to read the data stored on a magnetic stripe card and use that to make a transaction. The present study presents such a simple card reader which when plugged into the audio port of any mobile phone allows one to read and accept credit/debit cards.

# Literature Review

## Present Day Card Readers

Credit/debit card terminals origin roots back to 1930 when the first Manual Imprinters were developed. Since then, however not much innovation has happened in design and manufacturing aspects of credit/debit card terminals. Some of the most popularly used card processing terminals prevalent in the market are:

(a) (b) (c)

**Figure 1: Dial-Up terminals. (a) Verifone, the first modern card swiping machine. (b) Hypercom, the main competitor of Verifone. (c) Lipman, the wireless processing terminal, but having the same bulky form factor.**

The portable credit card terminals which offered a built-in swipe, keypad and printer, as well as a signature screen suffered from multiple limitations such as:

1. They have to be connected via a wired network
2. If you need wireless transactions, you have to connect to wireless LAN through 802.11b/g Wi-Fi (which is available only in limited places)

As such, the obvious benefit of processing secure payments anywhere with wireless technology was counteracted with the compulsory requirement of having a Wi-Fi hot spot.

## How a Magnetic Stripe Card works

Credit/debit cards have a magnetic stripe on one side. These cards are used in various transactions (mostly over the counter) such as to pay for purchases, at gasoline stations and to transact business with a bank through the use of an ATM (Automated Teller Machine).

The magnetic stripe card is capable of storing data by modifying the magnetism of magnetic particles embedded in the stripe. The data stored on the magnetic stripe is read by swiping the stripe through the POS terminal slot. The analog waveform thus generated is passed through a process known as decoding to convert analog to digital signals.

Conventional magnetic stripe card readers are comprised of relatively simple sensing components as well as the more costly and complex decoding and communication components. It is typical in a magnetic stripe card to locate the magnetic stripe 0.223 inches from an edge of the card with the stripe being 0.375 inches wide. The magnetic stripe contains up to three tracks of digital data with each track being 0.110 inches wide.

The elemental parts of a magstripe are ferromagnetic particles about 20 millionths of an inch long, each of which acts like a tiny bar magnet. These particles are rigidly held together by a resin binder. These particles are actually permanent bar magnets with two stable polarities.

An un-encoded magstripe is actually a series of North-South magnetic domains. The adjacent North (N) and South (S) fluxes merge, and the entire stripe acts as a single bar magnet with North and South poles at its ends. Particles in an un-encoded Magnetic Stripe look like this:

….-N-S.N-S.N-S.N-S.N-S.N-S.N-S.N-S-….

However, if a S-S interface is created somewhere on the stripe, the fluxes will repel, and we get a concentration of flux lines around the S-S interface (same with N-N interface). *Encoding* consists of creating S-S and N-N interfaces, and *reading* consists of detecting them. The S-S and N-N interfaces are called *flux reversals*. An encoded magstripe is therefore just a series of flux reversals (NN followed by SS followed by NN).

A *solenoid* called **read head** is used to detect these flux reversals. The read head operates on the principle of electromagnetic reciprocity: current passing through a solenoid produces a magnetic field at the gap; therefore, the presence of a magnetic field at the gap of a solenoid coil will produce a current in the coil. The strongest magnetic fields on a magstripe are at the points of flux reversals. These are detected as voltage peaks by the reader, with +/- voltages corresponding to NN/SS flux reversals.

**Magstripe --->** -------NN--------SS--------NN---------SS--------

**Voltage ---->** ...........+…..........-..............+..............-……..

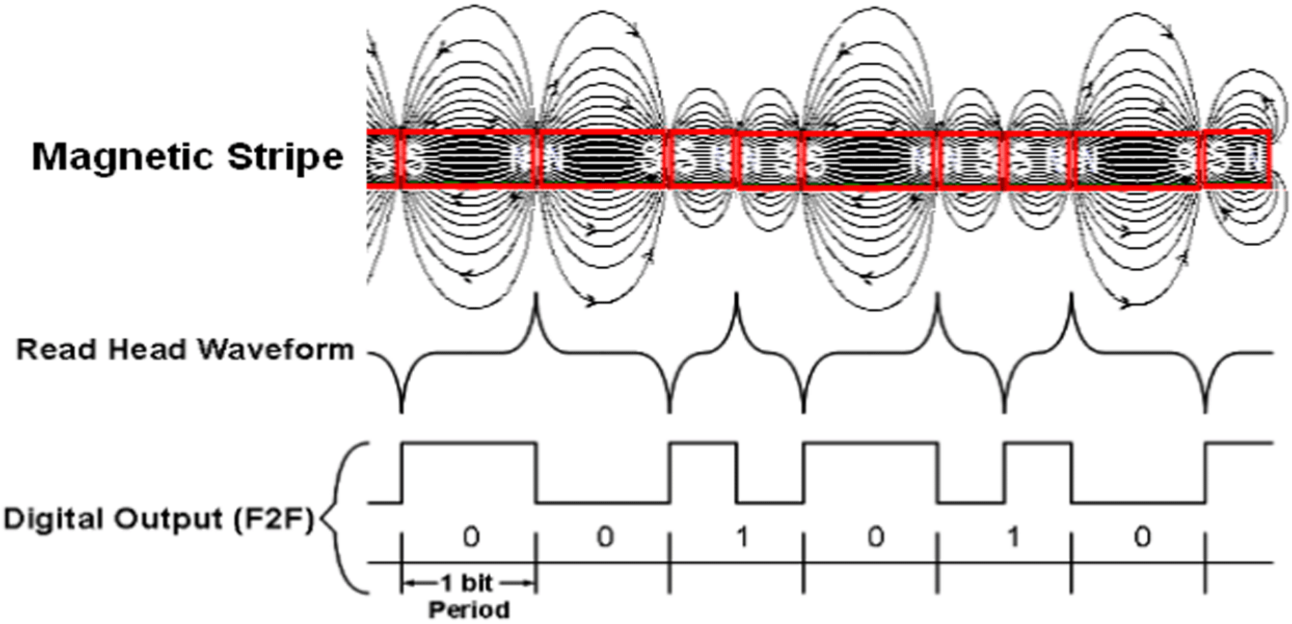
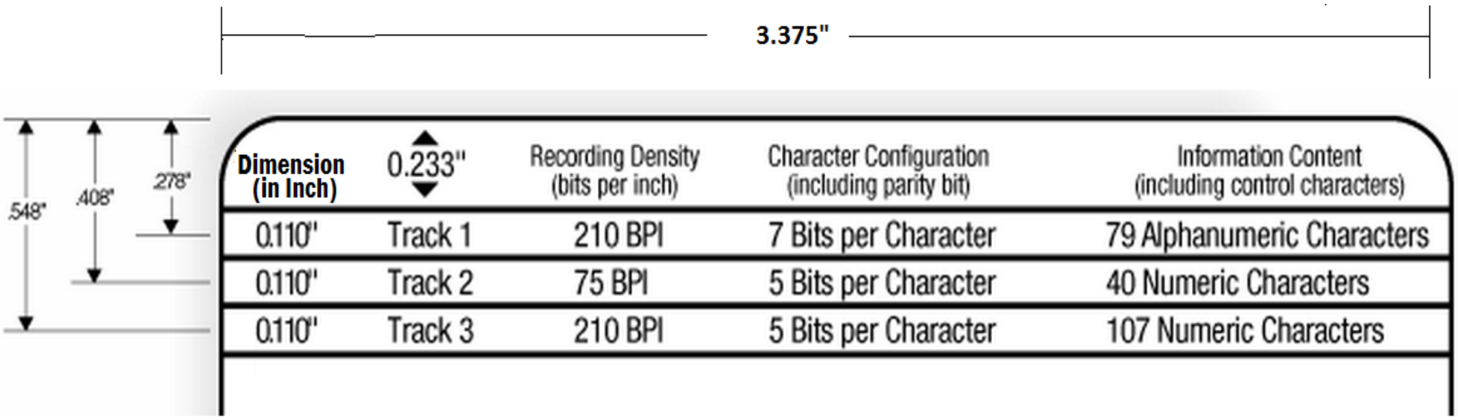


Figure 2: The principal behind the magnetic stripe on a credit card

The ISO/IEC standard 7811, which is used by banks, specifies:

- Track one is 210 bits per inch (bpi), and holds 79 6-bit plus parity bit characters.
- Track two is 75 bpi, and holds 40 4-bit plus parity bit characters.
- Track three is 210 bpi, and holds 107 4-bit plus parity bit characters.



| Dimension (in Inch) | 0.233" | Recording Density (bits per inch) | Character Configuration (including parity bit) | Information Content (including control characters) |
|---|---|---|---|---|
| 0.110" | Track 1 | 210 BPI | 7 Bits per Character | 79 Alphanumeric Characters |
| 0.110" | Track 2 | 75 BPI | 5 Bits per Character | 40 Numeric Characters |
| 0.110" | Track 3 | 210 BPI | 5 Bits per Character | 107 Numeric Characters |

Figure 3: ISO 7811 specifications for a magnetic stripe card

To process a credit card, typically only tracks one and two are sufficient. Track three is a read/write track (which includes an encrypted PIN, country code, currency units and amount authorized), but its usage is not standardized among banks.

### Track 1 format:

The information on track 1 is contained in two formats: **A** and **B.**

- **Start sentinel** - one character
- **Format code="B"** - one character (alpha only). **"A"** is reserved for proprietary use.
- **Primary account number** - up to 19 characters
- **Separator** - one character
- **Country code** - three characters
- **Name** - two to 26 characters
- **Separator** - one character
- **Expiration date or separator** - four characters or one character

- **Discretionary data** - enough characters to fill out maximum record length (79 characters total). Might contain CVV number.
- **End sentinel** - one character
- **Longitudinal redundancy check** (LRC) - one character LRC is a form of computed check character.

**Track 2 format:**

The format for track 2, developed by the banking industry, is as follows:

- **Start sentinel** - one character
- **Primary account number** - up to 19 characters
- **Separator** - one character
- **Country code** - three characters
- **Expiration date or separator** - four characters or one character
- **Discretionary data** - enough characters to fill out maximum record length (40 characters total)
- **LRC** - one character

For example, a Master Card with the Number on front of card as “1111 2222 3333 4444”, and with Expiration date “12/99” will be stored as:

**Track 2 (BCD, 75 bpi)** ;1111222233334444=99121010000000000000?

**Track 1 (ALPHA, 210 bpi)** %B1111222233334444^PUBLIC/JOHN^9912101xxxxxxxxxxxxx?

The card reader presented in this project is tuned to read the Track 2 of a magnetic stripe card.

## Encoding of Magnetic Stripe Card:

The most common technique used for encoding of magnetic stripe card is Biphase Mark Code (BMC), also known as Differential Manchester Encoding. In Differential Manchester encoding, each bit period is divided into two half-periods: clock and data. The clock half-period always begins with a transition from low to high or from high to low. The data half-period makes a transition for one value and no transition for the other value. One version of the code makes a transition for 0 and no transition for 1 in the data half-period; the other makes a transition for 1 and no transition for 0. Thus, if a "1" is represented by one transition, then a "0" is represented by two transitions and vice versa, making Differential Manchester a form of frequency shift keying. Either code can be interpreted with the clock half-period either before or after the data half-period.

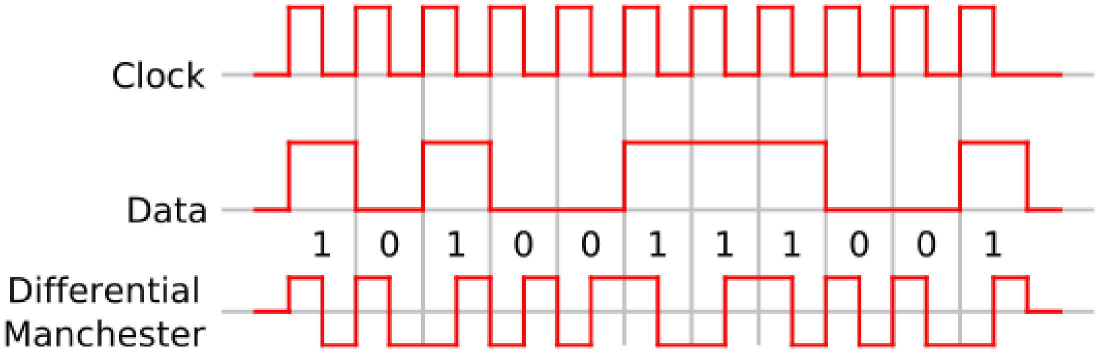


Figure 4: An example of Differential Manchester encoding: data before clock and 0 means transition.

The characteristics of a Differential Encoding which make it a preferred technique for encoding a magnetic stripe card are:

1. A transition is guaranteed at least once every bit, allowing the receiving device to perform clock recovery.

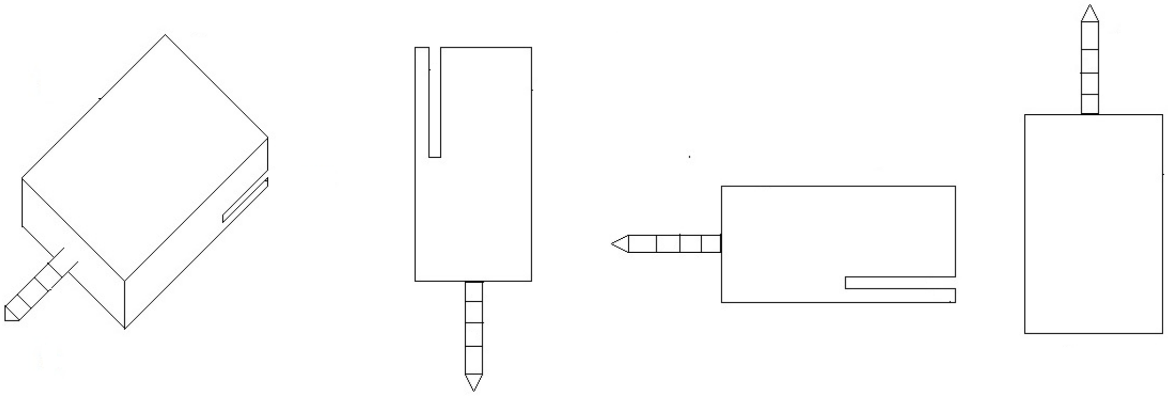
2. Detecting transitions is often less error-prone than comparing against a threshold in a noisy environment (for example, during card swipe).
3. Unlike with Manchester encoding, only the presence of a transition is important, not the polarity. Differential coding schemes will work exactly the same if the signal is inverted. This allows card to be swiped wither from left-to-right or from right-to-left.
4. If the high and low signal levels have the same voltage with opposite polarity, coded signals have zero average DC voltage, thus reducing the necessary transmitting power and minimizing the amount of electromagnetic noise produced by the transmission line.

## The Analog Card Reader

The analog card reader is the simplest form of such a mobile magnetic stripe card reader. It contains a read head which when swiped against the magnetic stripe of a card, generates an analog waveform which is representative of the card data stored on the magnetic stripe card. This waveform is then de-amplified using a simple voltage divider and send into the mobile phone through its microphone input line. A mobile application pre-installed on the receiving mobile phone receives these analog signals, converts the input signal stream into bits (0s and 1s) and subsequently into human readable ASCII characters. The processed information may then be used for, say, making payments at a merchant’s shop.

The analog card reader does not require any power source. The analog signals generated due to the swiping action are directly sent to the microphone input of the phone (after bringing the voltage under a suitable level using de-amplifier circuit).

The figure below shows the diagrammatic view of the illustrative embodiments of the present invention; and is followed by a pictorial representation of how the product will be used by people.



detail.

Figure 5: (a) Perspective view (b) Side perspective view (c) Side view (d) Front view.

Figure 6: An Image showing the use of portable card reader when plugged into the companion mobile phone

## Reading the Magnetic Stripe Card Data

As explained in above section, the read head is essentially a solenoid which converts the magnetic fluctuations (caused by the flux reversals during the card swipe) into electrical signals. The same read head is also used in old days Tape recorders to play the real cassettes. The read head used in this study is shown in the picture below, and was purchased from the local radio shop.

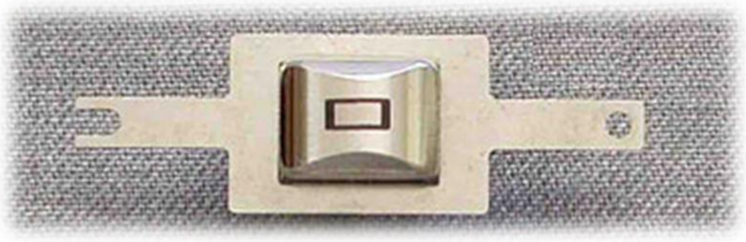


Figure 7: Read head for reading the magnetic stripe card.

A single track read head has two output pins for +ve and –ve voltages. Since the data is encoded using Differential Manchester Encoding scheme, it is not necessary to know the polarity of the sent signal since the information is not kept in the actual values of the voltage but in their change: in other words it does not matter whether a logical 1 or 0 is received, but only whether the polarity is the same or different from the previous value. Because of this reason, any output pin can be assumed to have +ve polarity. This output pin is connected to the microphone input of the TRS connector via a resistor, while the other pin is directly shorted to the ground of the TRRS connector.

All present day mobile phones use a 3.5 mm audio jack/plug, also known as TRRS connector, to output audio to headphones and to receive input from a microphone.

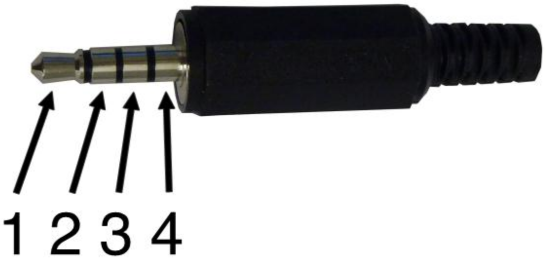


Figure 8: Pin-out diagram of a headset plug

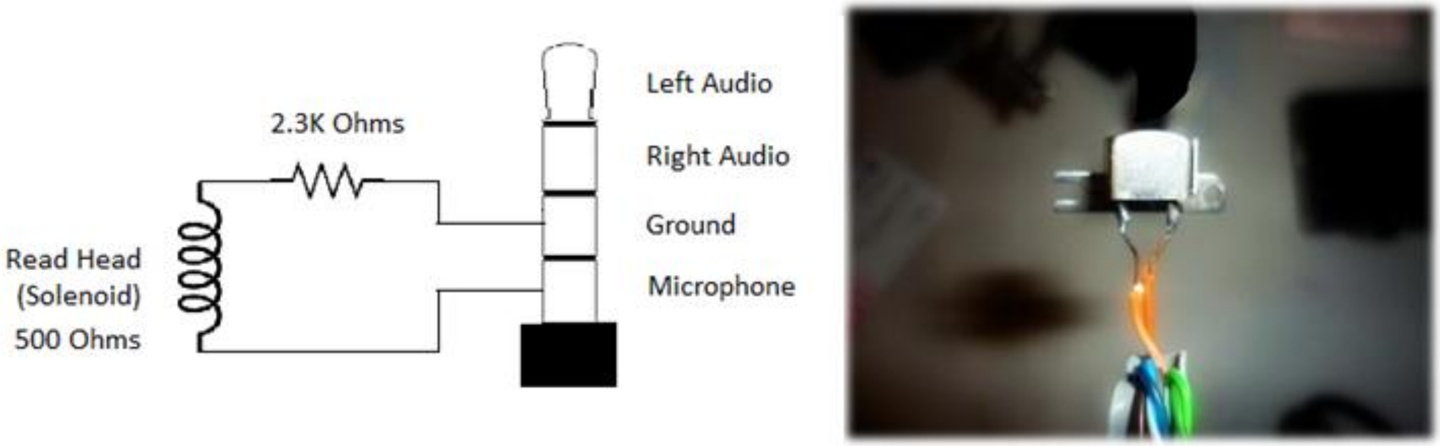
The TRRS plug connections are: (1) left earphone (tip), (2) right earphone (ring), (3) common/ground (ring), and (4) microphone (sleeve). The measured impedance of the iPhone headset between the left (or right) ear-phone and common is 33 Ohm. The measured impedance between the microphone and common is approximately 2.2K Ohm. The headset plug can be a TRS (Tip, Ring, and Sleeve) connector also known as audio jack, headset plug, phone plug or mini-stereo connector, and can be plugged into the headset or into the microphone input plug of mobile phones. For the working of this card reader, only the microphone and ground are required.

## The circuit diagram:

The circuitry of the headset set of mobile phones of different companies is different, and is well documented in [6]. In this study, Samsung Galaxy S5830i model was used as the companion device for the card reader.

To detect and use an external audio input, the Samsung Galaxy S5830i needs to see about 2.8K ohms impedance between the microphone and ground pins. This impedance will automatically disable the internal microphone in the phone, and the phone will start listening to the mic input from the headset port. To connect the output from a PC or other audio device (such as a card reader in this case) into the phones mic input, we need to add a 2.8K ohm resistor in series. For phones of other models, this value of resistance might be different, and has to be found out either experimentally for by referring to the spec-sheet such as in [6].

The resistance between the two output pins of the read head was found to be 500 Ohms. Thus, to achieve the overall impedance of 2.8K Ohms, only 2.3K Ohms resistor had to be connected in series, as shown in the following diagram.



(a)

(b)

Figure 4: (a) The circuit diagram of Analog Card Reader. (b) The image of the presented card reader

## Decoding the Read Waveform Containing Card Data

Once the card data starts coming through the microphone input line of the mobile phone, it is sampled at a high frequency. Any frequency from 11 KHz to 192 KHz works, however, by experimentation, 48 KHz seemed to be optimal. The incoming sampled data is stored locally in .PCM format, which is later processed to extract information in human readable format. A .PCM file is a standard format to store the audio files (the analog waveform coming via the microphone input of the mobile phone is treated as an audio input). A typical .PCM file containing card data for a full swipe looks like one shown in figure 10:

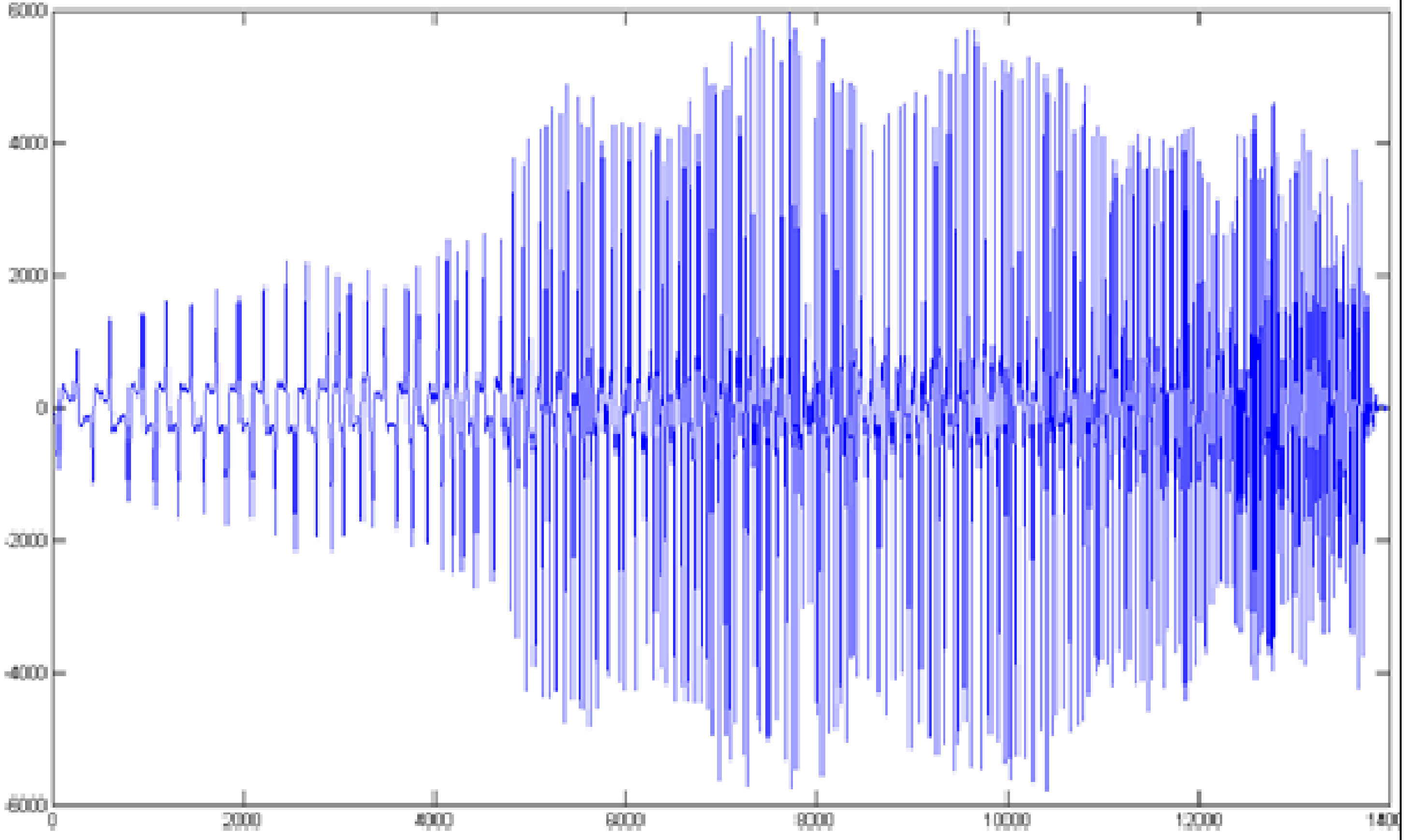


Figure 5: A .PCM file containing the card data of a full swipe.

The zoomed-in view of the waveform generated by the read head is shown below:

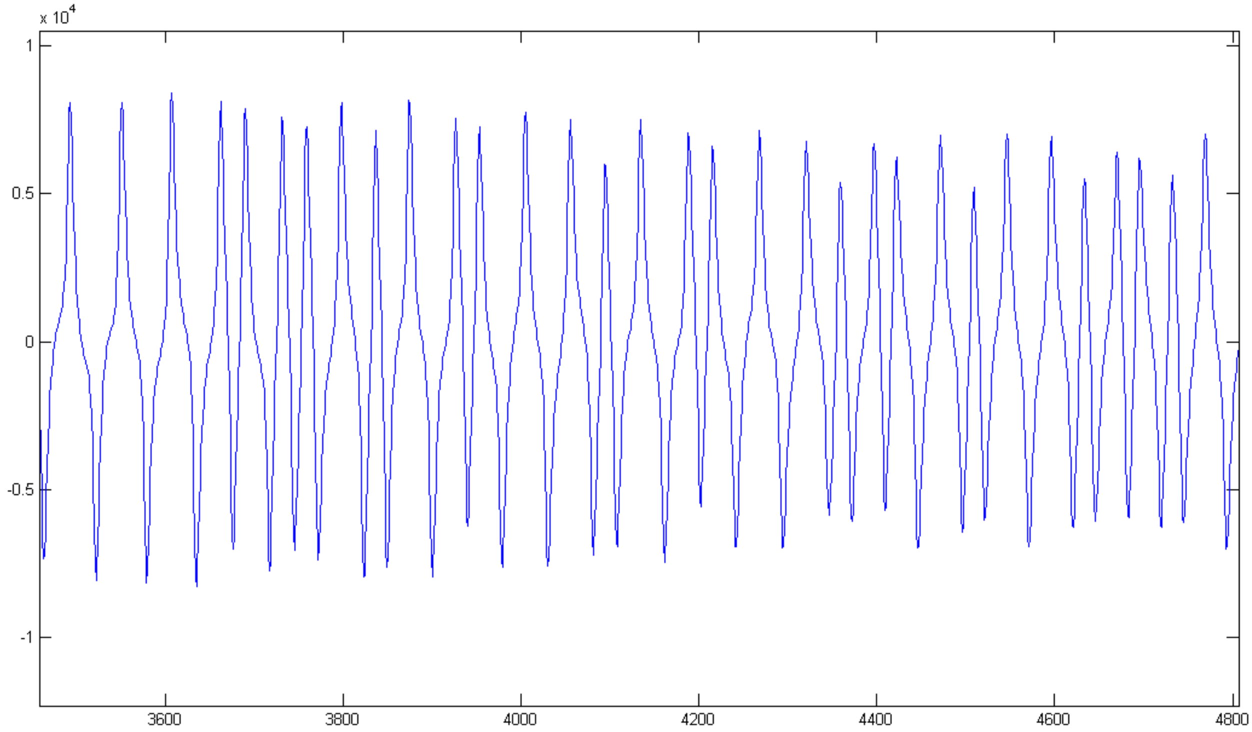


Figure 11: A zoomed in view of a part of the analog waveform read by the read head

The amplitude of the waveform in the above image is representative of the swiping speed. More the swiping speed, greater is the amplitude at that instant. Note that the algorithm is robust against the swiping speed in the sense that speed may increase or decrease during a swipe without affecting the result. Exactly how is done, is explained in the later sections.

Before the input stream can be used to extract the information, it is processed to remove the noise. One very simple and effective way of removing the noise is to define a silence threshold and remove all samples with amplitude less than that silence level. Apart from this, there is a capacitance effect which is seen in the starting few samples of the waveform, as shown in figure 12. This is tackled by simply neglecting the initial few samples of the input stream.

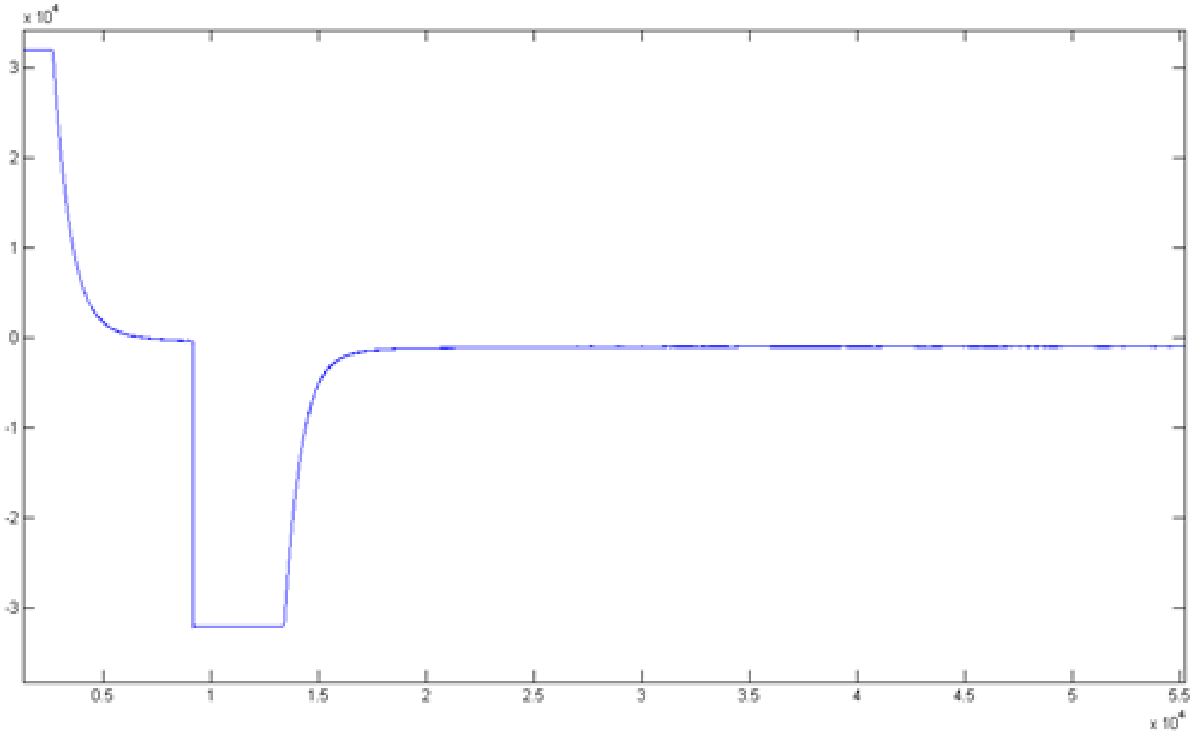


Figure 7: A zoomed in view of the starting part of the analog waveform, showing the capacitive effect in the beginning of the swipe

To get the bits from such a stream, we have three overall steps:

- Find the location of each peak in the stream.
- Decode the frequency of the peaks to output bits 0 and 1.
- Decode the bit set to human readable ASCII characters

The following sections describe these steps one by one.

## Finding the location of the peaks:

To find the locations of the peaks, the waveform and an offset of it are taken, and their mutual points of intersection are determined. During this process, intersections over a certain number (threshold) are ignored. The threshold is to eliminate intersects that occur around 0 (zero) amplitude. There will typically be more than one intersection found per peak. Intersects of the two waveforms are marked by blue crosses in the figure 13.

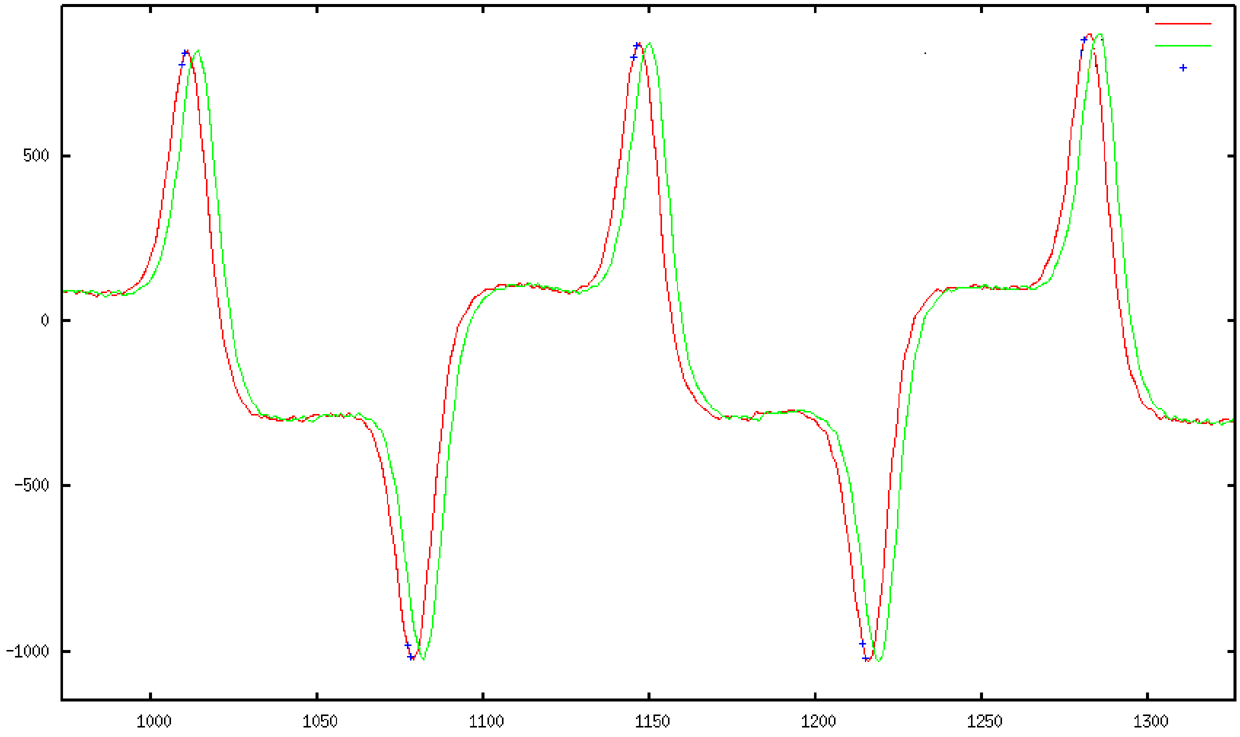


Figure 8: Red color: Original waveform. Green Color: Waveform with offset. Intersections are marked in blue color

It is observed in some situations that the little hump before the actual peak results in several intersects. To take this into consideration, we simply group the intersections detected by amplitude polarity. For instance, in the above picture, the first positive amplitude two blue crosses around sample 1010 would be a group. The second group would be the two negative amplitude crosses around sample 1075, and so forth. Once we have a group, one can pick the highest absolute value of amplitude, and reliably assume this is the true peak.

## Decoding the peak frequency to 0s and 1s

We use the information obtained upon determining the peak locations to decode the stored data into zeros (0) and ones (1). Referring back to the magnetic stripe track encoding standard, we know that:

- Beginning and end of stream are padded with 0s.
- Stream is self-clocking. The padding 0s tells the clock speed to be set while traversing the stream.
- A zero bit occurs when the distance between peaks is a full cycle. A one bit appears when there are two peaks in the full cycle (Differential Manchester Encoding)

Going through the list of peaks and determining the difference between them produces a valid bitstream of 0s and 1s. As the stream progresses, the clock speed will reduce significantly. Since it happens gradually, for better prediction, the clock speed is recalculated after every cycle by counting the number of samples between two consecutive peaks.

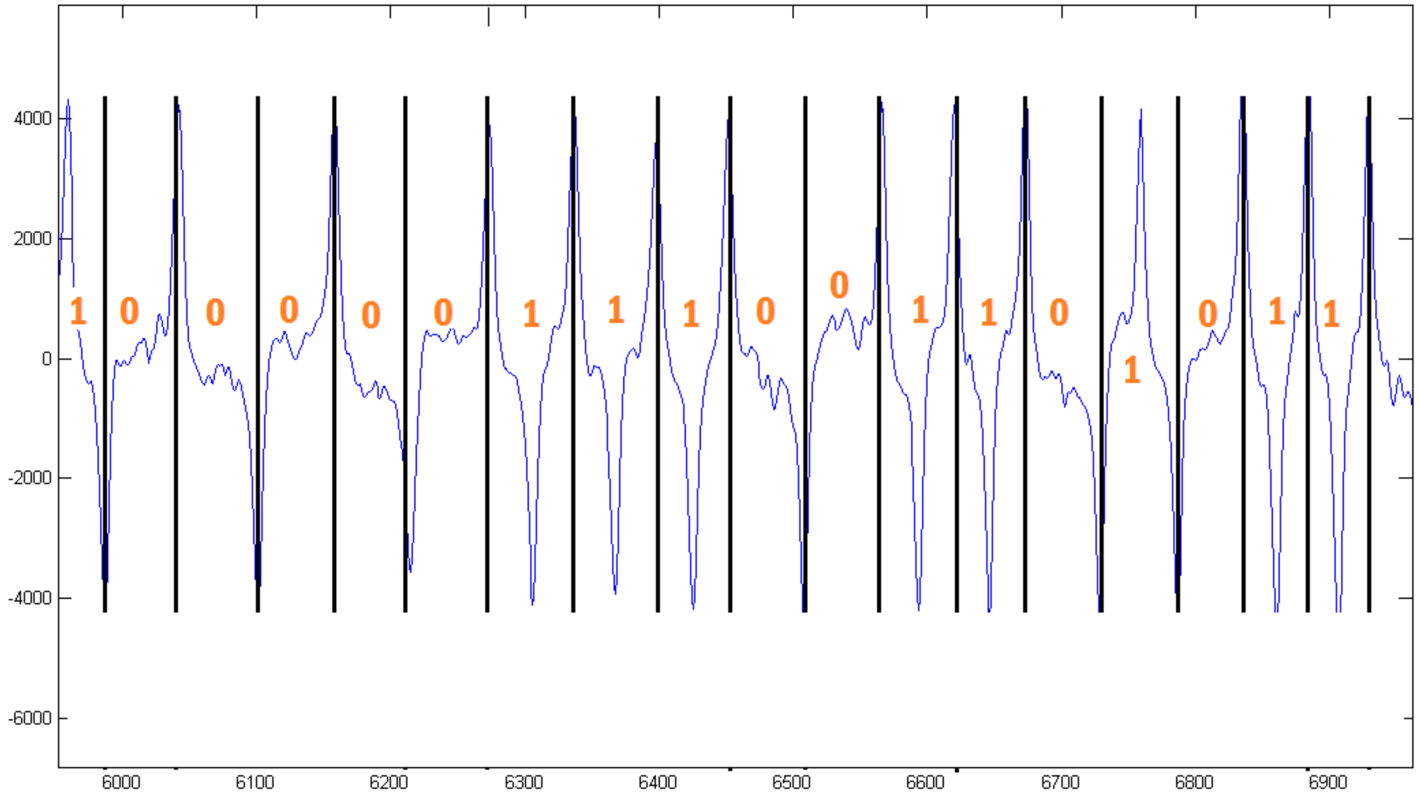


Figure 9: Decoding the waveform into 0s and 1s

At the end of this process, the card data is decoded to a bitstream as follows:

```
0000000000000000110100110100001110010000111001111000010000100010001010101101
0110111001001000000101000010000011111001011000100100111000001000000010000110
0001111110011000000000000000000000000000000000000000000000000000000000000000
00000000000000000
```

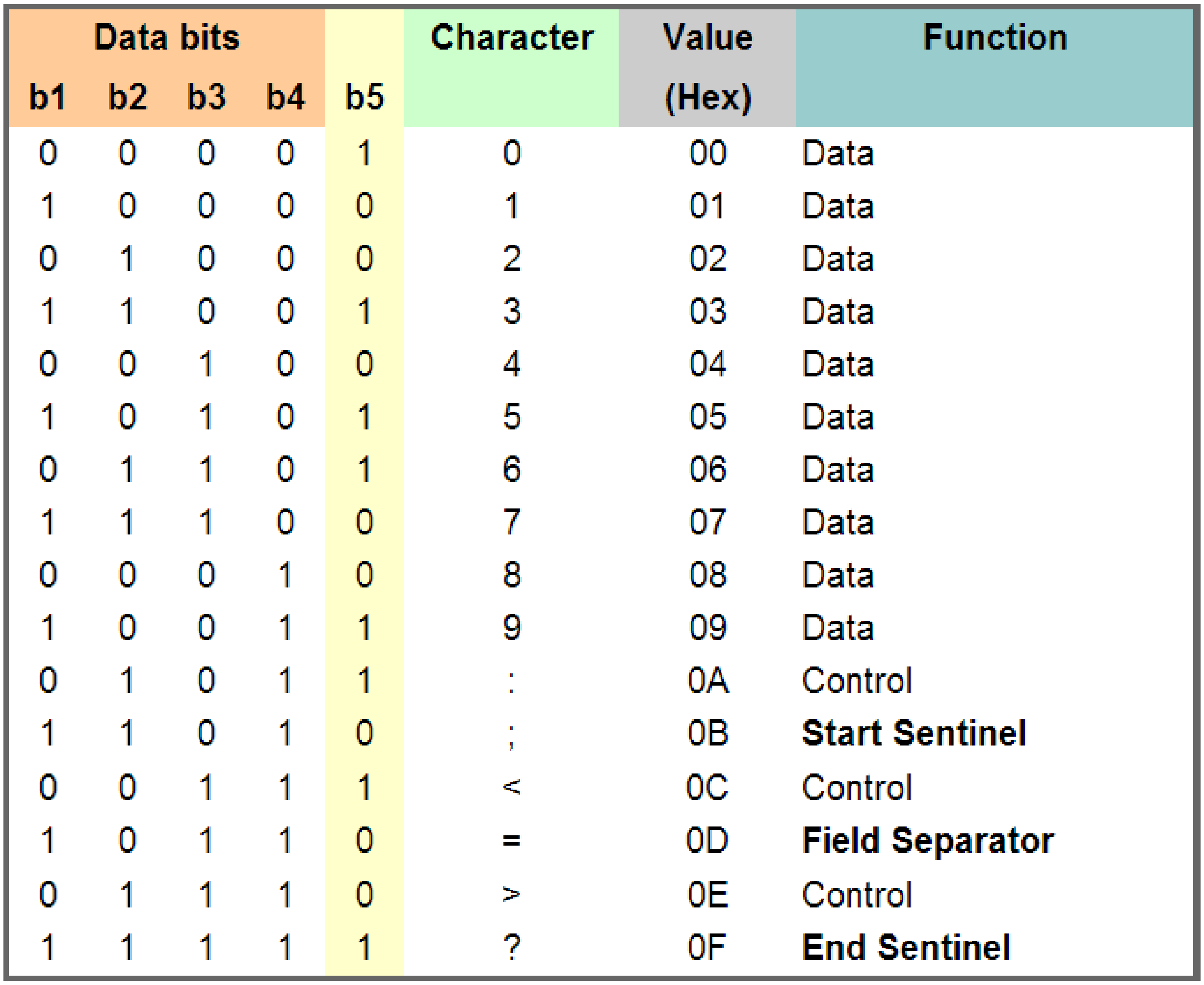
## Decoding the Bit Set to Human Readable ASCII Characters

To decode this bitstream into the human readable characters, we will have to follow the look up table provided by ISO 7810 for Track 2. Track 2 data is written in ANSI/ISO BCD format, which contains 5 bit, 4 data bits + 1 parity bit (odd). The data is read least significant bit first. The character set contains 16 characters, 10 alphanumeric, 3 framing/field characters and 3 control/special characters. The format for Track 1 is different and can be referred at [5]. The table for track 2 is reproduced in figure 15 for this example. Following this table, we are ultimately left with the decoded data which looks like this:

**;6030374425663402297=1912001?**

The following information is interpreted from the above data string (referring to the track 2 data format):

| | |
|---|---|
| Card Number: | **6030374425663402297** |
| Expiry date: | **12/19** (December 2019) |



| Data bits | | | | | Character | Value | Function |
|---|---|---|---|---|---|---|---|
| b1 | b2 | b3 | b4 | b5 | | (Hex) | |
| 0 | 0 | 0 | 0 | 1 | 0 | 00 | Data |
| 1 | 0 | 0 | 0 | 0 | 1 | 01 | Data |
| 0 | 1 | 0 | 0 | 0 | 2 | 02 | Data |
| 1 | 1 | 0 | 0 | 1 | 3 | 03 | Data |
| 0 | 0 | 1 | 0 | 0 | 4 | 04 | Data |
| 1 | 0 | 1 | 0 | 1 | 5 | 05 | Data |
| 0 | 1 | 1 | 0 | 1 | 6 | 06 | Data |
| 1 | 1 | 1 | 0 | 0 | 7 | 07 | Data |
| 0 | 0 | 0 | 1 | 0 | 8 | 08 | Data |
| 1 | 0 | 0 | 1 | 1 | 9 | 09 | Data |
| 0 | 1 | 0 | 1 | 1 | : | 0A | Control |
| 1 | 1 | 0 | 1 | 0 | ; | 0B | **Start Sentinel** |
| 0 | 0 | 1 | 1 | 1 | < | 0C | Control |
| 1 | 0 | 1 | 1 | 0 | = | 0D | **Field Separator** |
| 0 | 1 | 1 | 1 | 0 | > | 0E | Control |
| 1 | 1 | 1 | 1 | 1 | ? | 0F | **End Sentinel** |

Figure 10: Table showing the data standard followed while writing the information onto the magnetic stripe card

## Flowchart:

Having described the procedure from starting to end, here is the flowchart summarizing the flow of these individual techniques for reading the magnetic stripe card data.

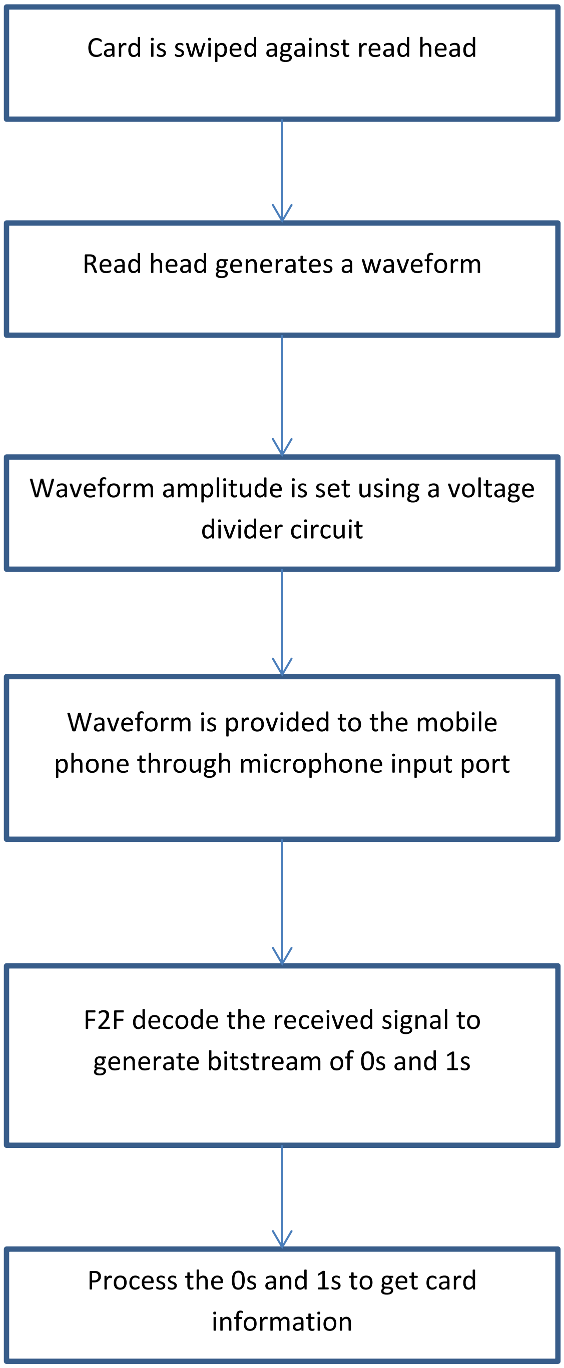


**Figure 11: Flowchart explaining the steps involved in reading a magnetic stripe card using the presented card reader and a companion app**

## The Android App

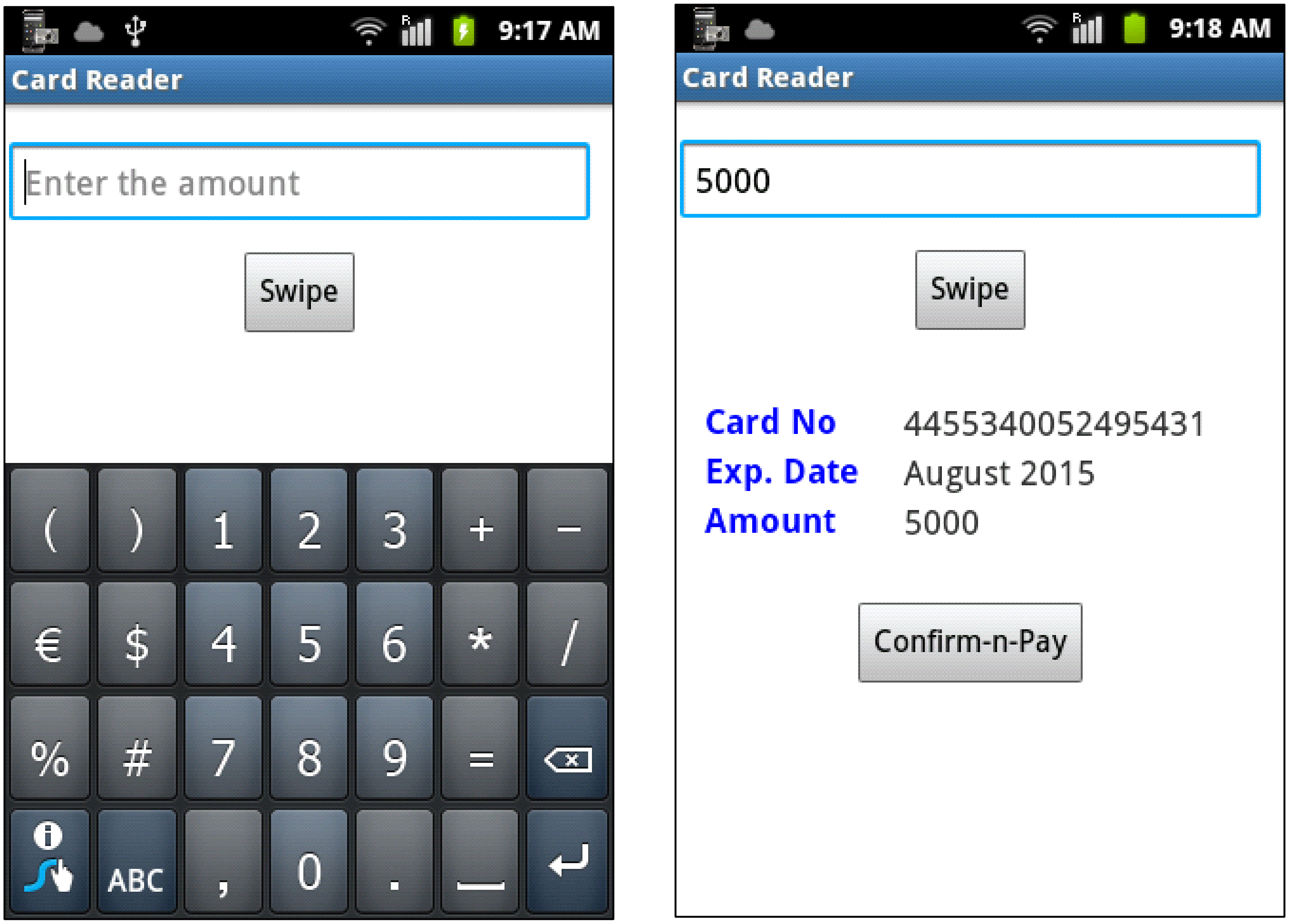
The companion mobile device had an application running on it to retrieve the card data from the analog waveform generated by read head and transmitted to the phone via the headset port. In this project, the application was written for Android 2.3.6 (GingerBread) platform in Java language.

The algorithm behind the code contained in the application has been explained in the above sections. Essentially, the app detects the presence of an external microphone input by checking against the expected impedance for the same. If detected, it turns down the internal mic and starts listening to the signal coming from the microphone input line of the headset port. The analog signal received is sampled at user specified frequency (48KHz in this case) in Microphone_mono input mode. The other mode, Microphone_stereo is not required here. The sampled audio signal which is representative of the data stored in the magnetic stripe card is stored in .PCM file format. This file is later read into an input buffer which is then processed inside the android application.

In this app, a very specific application of such a card reader was shown. The app was meant to be used by merchants who want to accept credit / debit card from their customers. This is how it works: The merchant plugs in the card reader into the 3.5mm headset port of his mobile phone, and then opens up the application. He then enters the amount he wishes to charge into the text field, and clicks on the ‘swipe’ button. As soon as the swipe button is clicked, the app starts listening for the signals. The merchant then swipes the card through the slot provided into the card reader taking note that the black colored magnetic stripe should face the read head. Upon successful swipe, the card data gets displayed on the screen along with the entered amount. The merchant then clicks on the ‘confirm’ button to finish off the transaction. If the swipe is not successful, he gets a message declaring a bad swipe and requesting him to swipe the card once again (after pressing the ‘swipe’ button).

## Results, Images and Screenshots

Figure 12: (Top) The anolog card reader made for this study. (Bottom) The card reader plugged into the mobile phone



5000

| | |
|---|---|
| **Card No** | 4455340052495431 |
| **Exp. Date** | August 2015 |
| **Amount** | 5000 |

Figure 13: Screenshots of the mobile app. (Left) The screen where the merchant enters the amount to be charged from the customer. (Right) The screen showing the read card number, expiry date and the amount to the merchant..

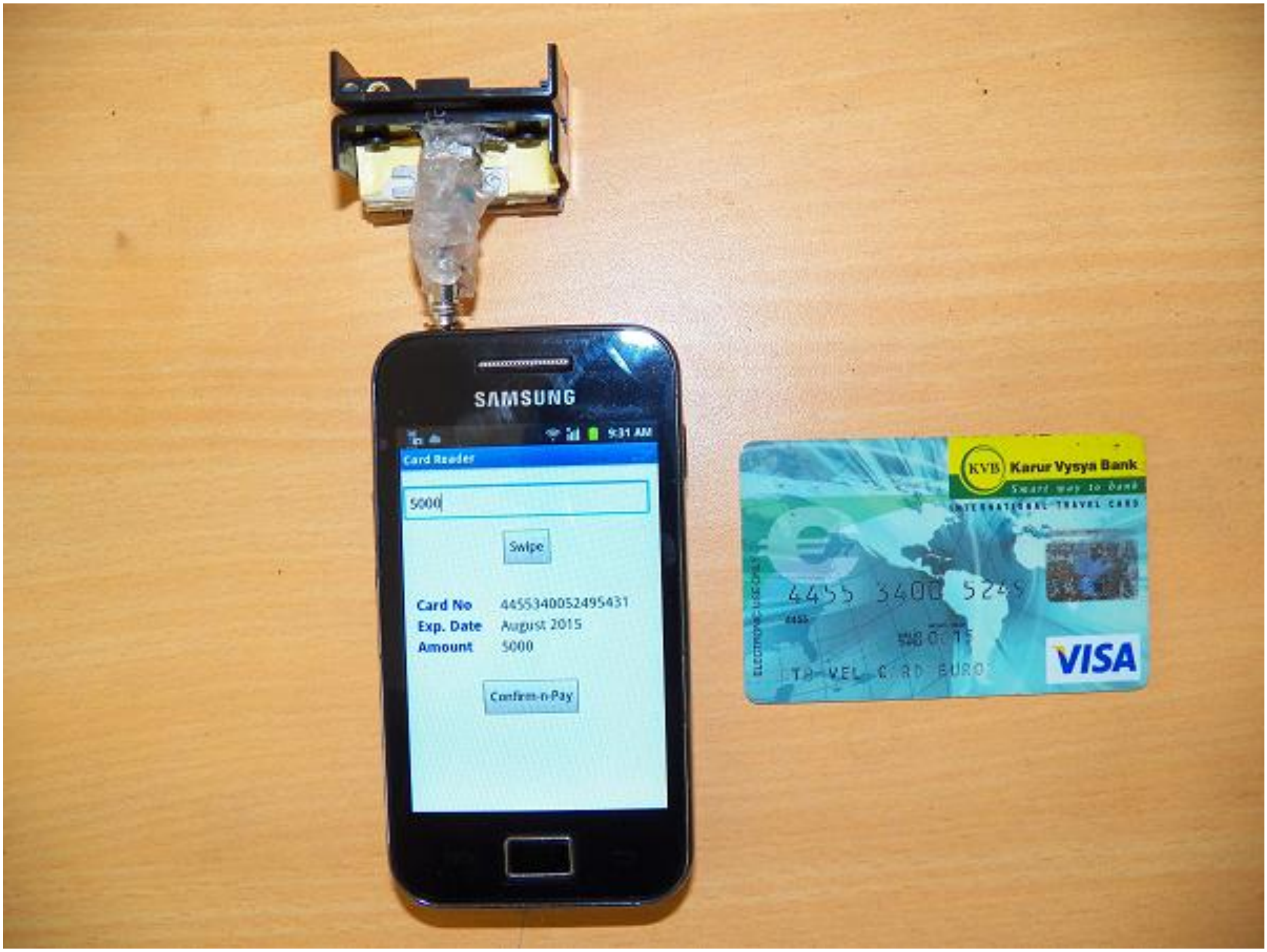
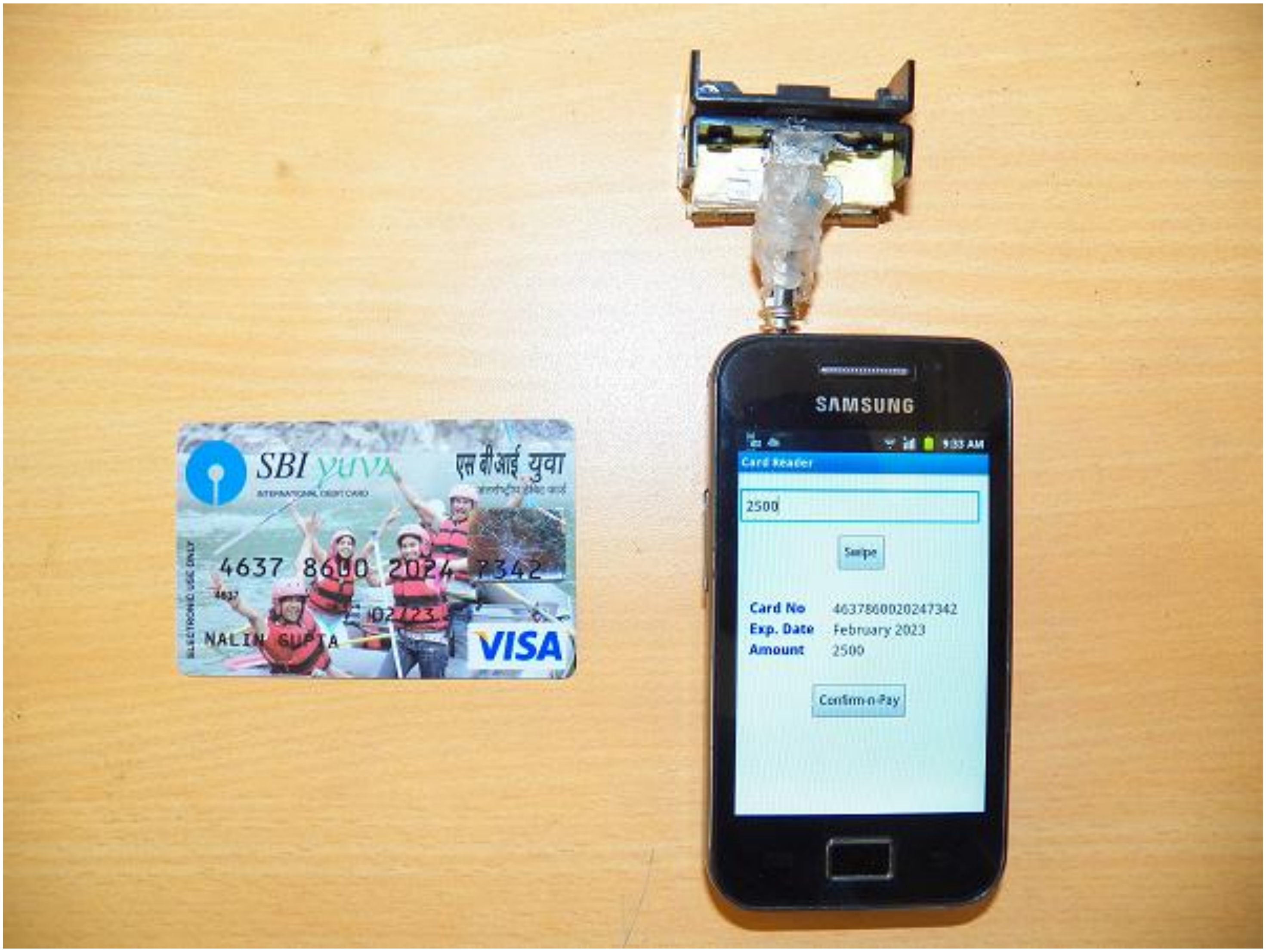


Figure 14: A VISA debit card along with the read data shown by the app



2500

**Card No** 4637860020247342
**Exp. Date** February 2023
**Amount** 2500

Figure 15: Another VISA debit card along with the read data shown by the app

## The Encrypted Magnetic Card Reader

In order to ensure the safety of the card data, it becomes imperative to use encryption technologies before transmitting any data through the headset port. However, as soon as we talk about including encryption, the device becomes a whole lot more complex and involves a much more circuitry and IC chips. For example:

- A microcontroller to encrypt the data
- An ASIC to decode the F2F encoded waveform (a typical low power embedded microcontroller does not has enough memory to do decoding operation)
- A battery to power the IC and ASIC
- An amplifier to amplify the read head waveform (in mV) to 3.3 V (taken as input by ICs)
- A lot of resistors and capacitors to filter the noise

The new encrypted card reader device comprises of a read against which the magnetic stripe card is swiped by the user. The read head senses the data stored on the magnetic stripe and produces an Analog waveform representative of the data stored on the magnetic stripe.

A decoder circuit which may be an Application Specific IC (ASIC) such as Singular M3-2200G F2F Decoder IC is used just after the read head for converting the waveform into digital bit stream. The output of such a F2F decoder IC is a data line and a clock line containing the +ve and –ve voltage levels and their corresponding clock duration. Both these data lines are sent to the microcontroller which then convert the digital bit stream into a digital data representative of the data on magnetic stripe and encrypts it. The encrypted data is then transferred to the mobile phone through the microphone input line of the headset plug. Once inside the mobile phone, the data is decrypted, converted into human readable form and presented to the user for any further use.

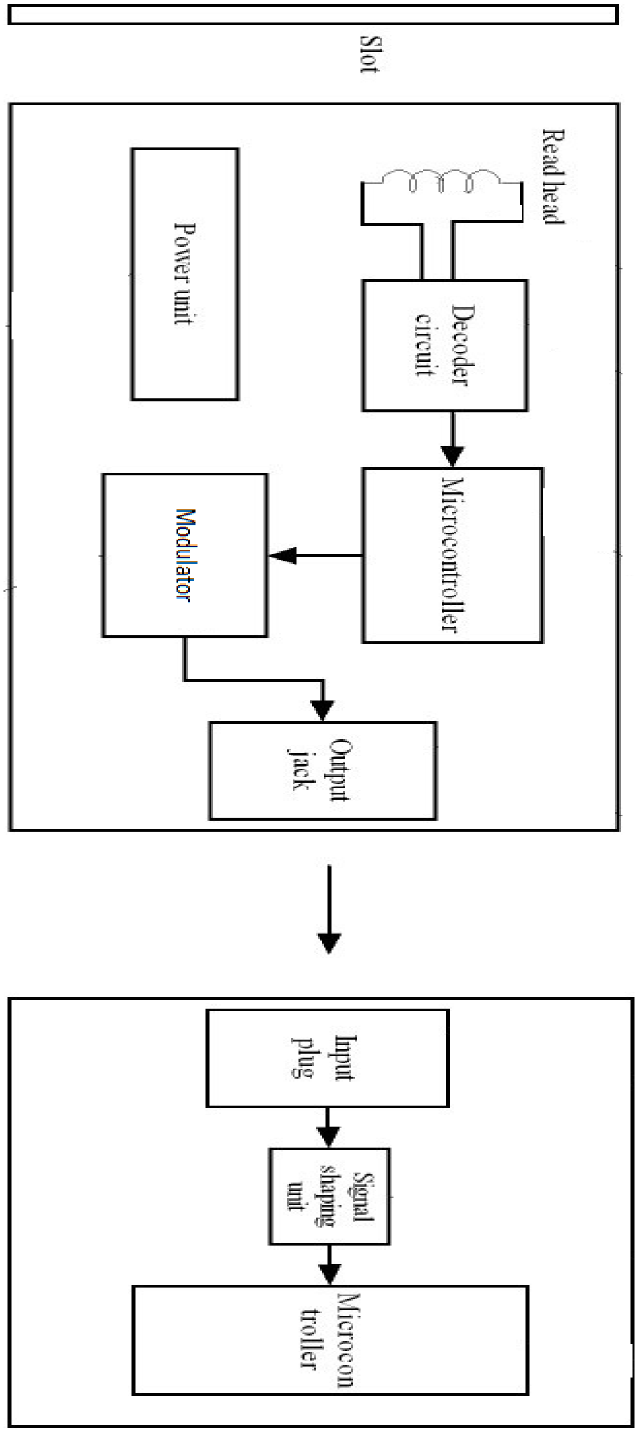


Figure 21: Block diagram of the encrypted card reader

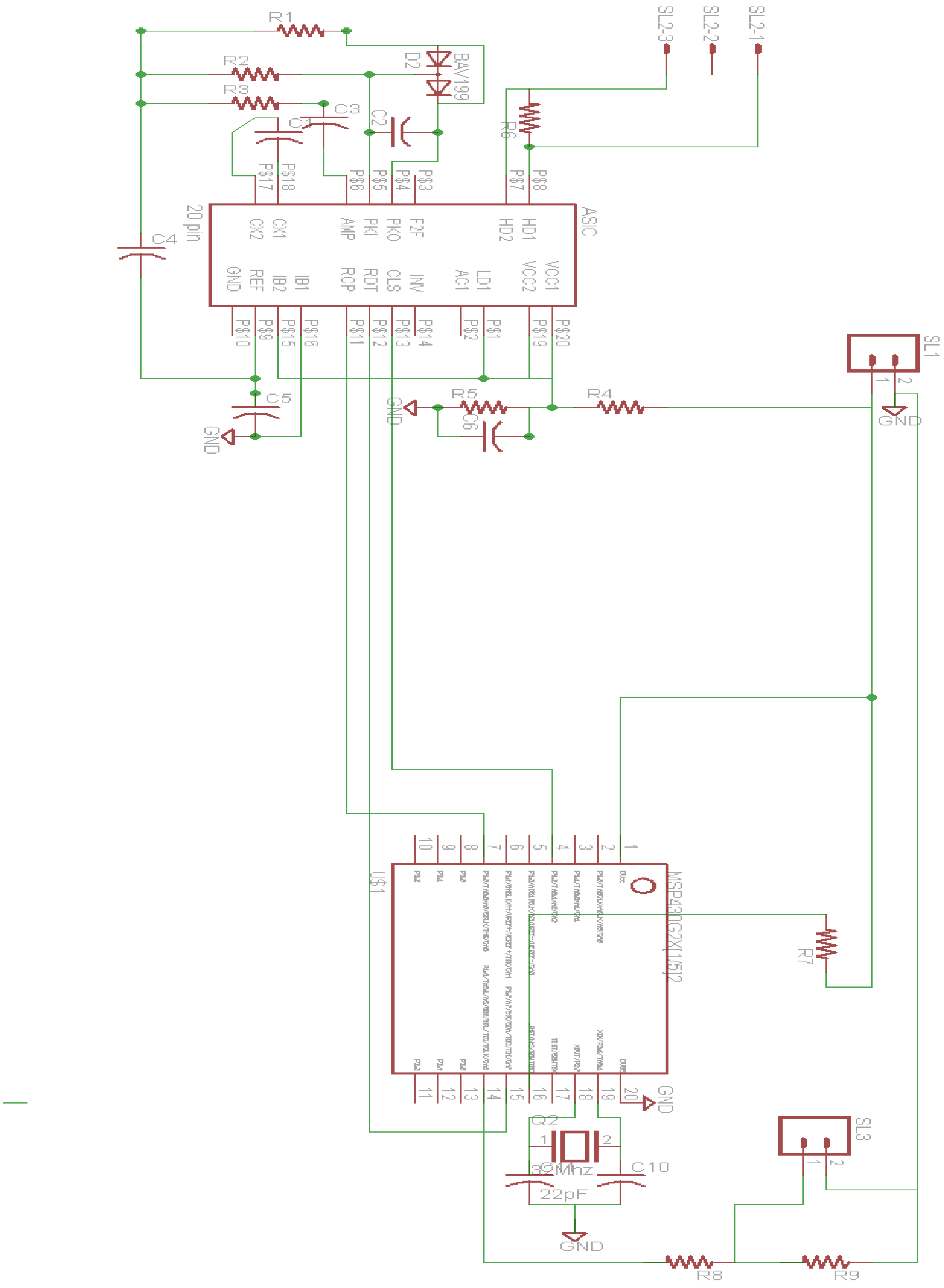


Figure 17: The schematic diagram of the board for encrypted card reader

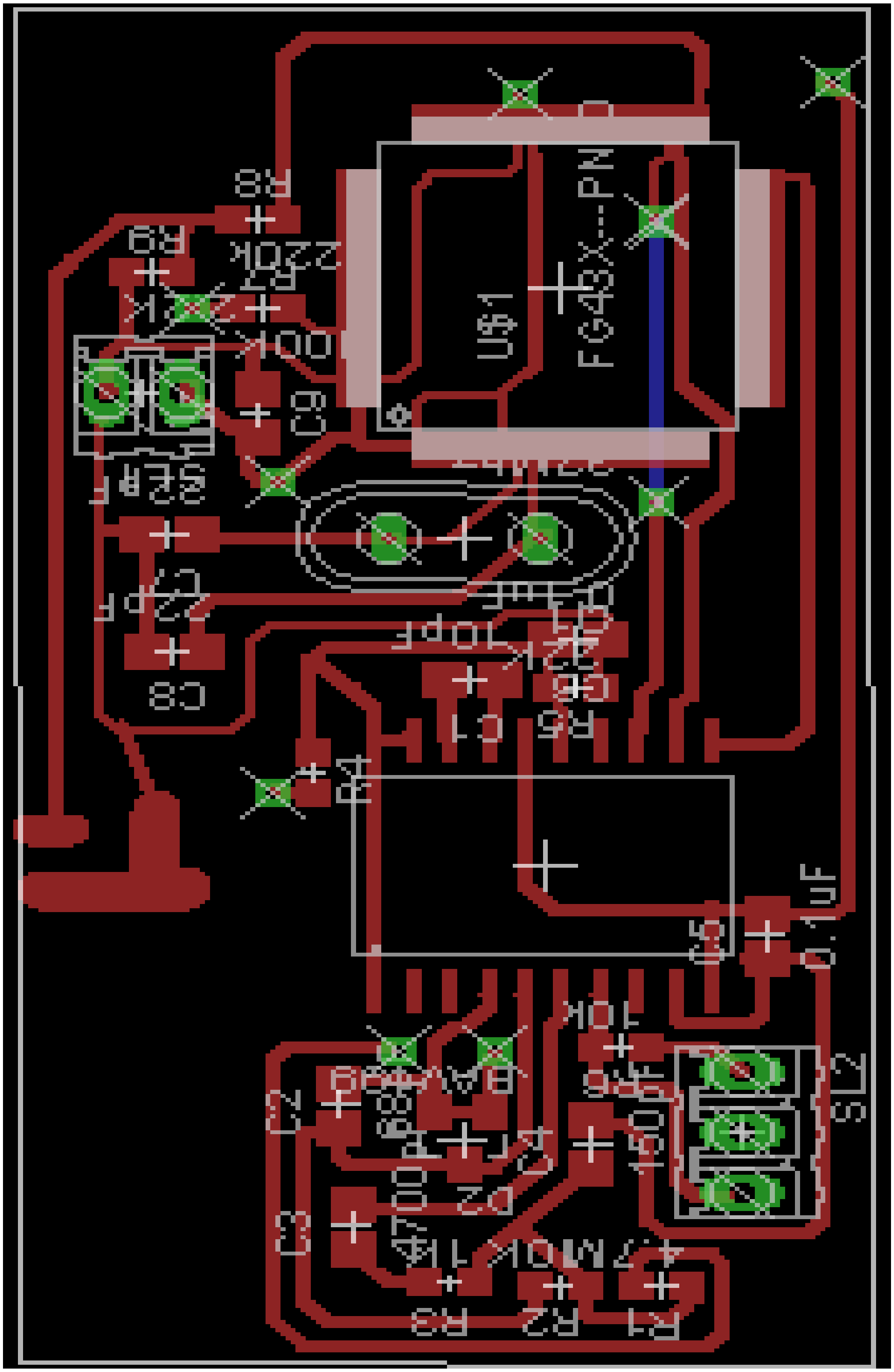


Figure 18: The PCB board file for manufacturing of PCB for the encrypted card reader

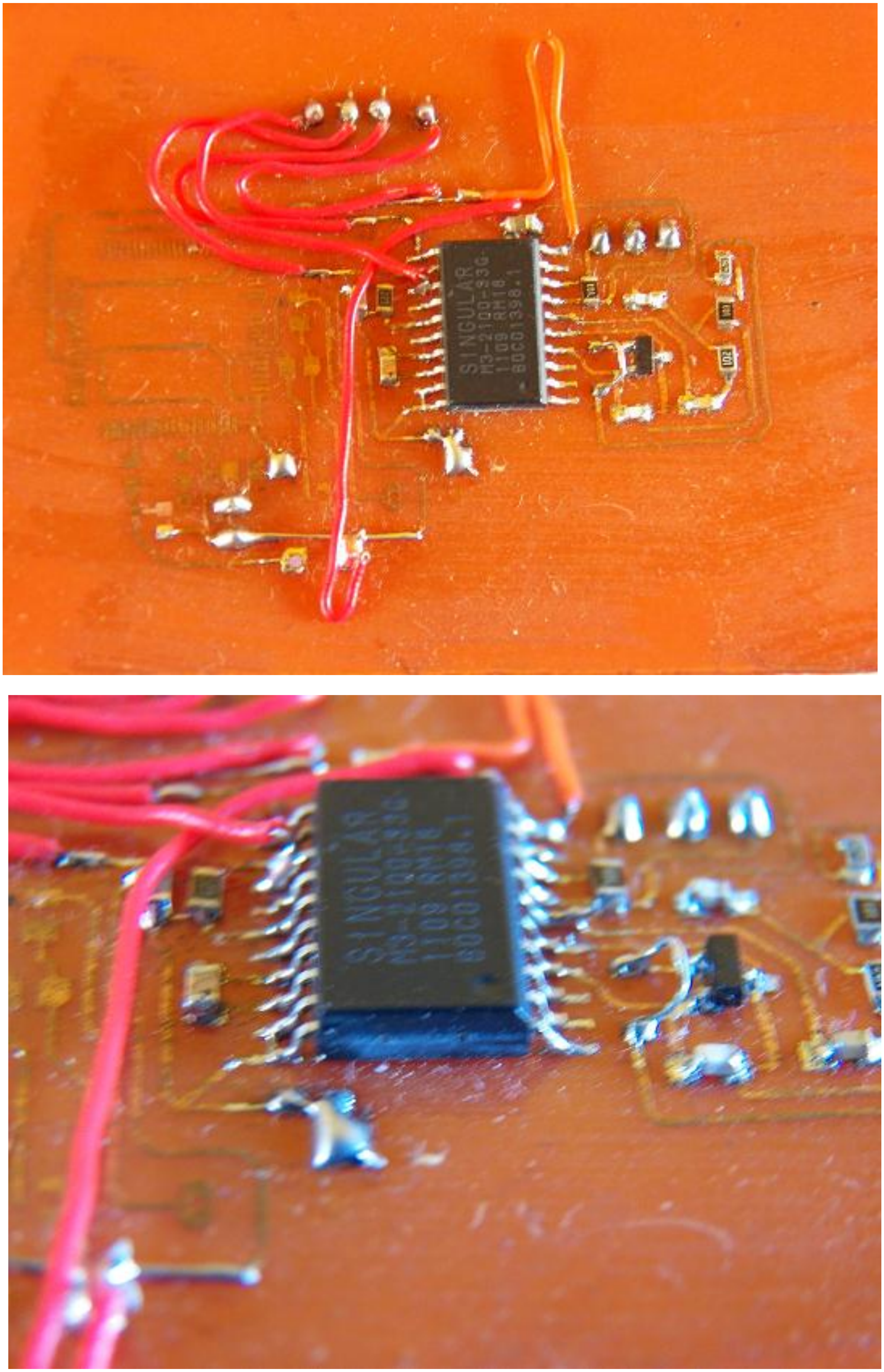


Figure 19: (Top) PCB manufactured in the lab as per the above layout. (Bottom) Zoomed view of the F2F decoder

## Discussion:

The presented product is very innovative and has a great commercial value.

1. It allows anyone (whether a small merchant or a home-based consultant) to read and accept the credit / debit cards anywhere, anytime. It’s totally portable, pocket size and works with every mobile phone.
2. It leverages the processing, display and communication units of the mobile phones, thereby making it very cheap as compared to traditional card readers.
3. The presented card reader is very low in cost. This card reader can be manufactured in less than Rs. 50 ($ 1 dollar) using off-the-shelf components.
4. This card reader does not require any battery power for the operation.
5. The presented card reader has around 80% accuracy in reading the card data.

During the course of this project, I learnt many new things, which have been summarized below

1. **Error correction techniques:** The microphone input of mobile phones is traditionally meant to transmit the voice signals in which loss of few data samples is not a serious issue. But in case of magnetic stripe card reader, loss of a single sample can result in a different output. Hence, it had to be ensured that no data is being lost during the transmission.
2. **Audio signal processing:** The analog signal coming from the microphone input line of the mobile phone is stored in .PCM format, which is a widely used format to store the audio files. This .PCM file is then processed to retrieve the card data. It also involved application of noise removal techniques for very low voltage signals (~mV range).
3. **Android Apps:** The mobile end of the magnetic card reader consists of a mobile app. The app processes the signals and displays the final result (the card number, expiry date and the card holder’s name) on the screen. The app was written in Java. I also learnt how to interface with the mobile hardware such as headset audio port.

4. **PCB Designing:** The next step of analog magnetic card reader is the digital card reader which supports encryption of the data during transmission. Such a card reader will consist of lots of smd components (resistors, capacitors etc.), smd size ASICs (Application Specific ICs) and microprocessors. All these components had to be put together on a single PCB which was custom designed and manufactured by myself during the course of this project.
5. **MSP430 programming:** MSP430 is a new type of microcontroller whose programming is different from the programming of 8051 IC and AtMega32 we had done earlier. MSP430 was used for encryption and modulating the digital data for transmission to the microphone.

The following challenges came into light during the project.

1. **Interoperability between different types of phone models:** Phones of different companies and sometimes even different models of the same company differ in the specifications of their headset port. For example, the position of microphone and ground is opposite in phones of Apple and Samsung. Similarly, the input impedance expected by the microphone of phones of different companies is different. Because of this, a lot of experiments had to be conducted on various types of phones to arrive at the best value of the resistance used in the card reader.
2. **Manufacturing a Precise casing:** The magnetic stripe card contains 3 tracks of data, each track of 2 mm wide and having different data format and encoding scheme. On the other hand, the sensor area on the read head responsible to read the data is also 2 mm wide. It was very challenging to align the two things perfectly against each other without the help of machined parts.
3. **Parameter Calibration:** The biggest challenge was in the calibration of the parameters. There are so many parameters like the silence level, silence level coefficient, waste_buffer size, max no of samples, sampling frequency etc. There is no way of automating the process of calibration; neither is it an established procedure. Fine tuning the parameters involved a lot of hit and trial and experimentation.

## Future Work:

The future work to be done in the presented card reader involves:

1. Improving the swiping accuracy of the analog card reader
2. One major drawback of the present card reader is that it is not secure. It means that anyone can write a small application in the mobile phone to tap the vital card information during its transmission through the audio jack. As such, the card data needs to be protected using some encryption techniques.
3. Making of the encrypted card reader will include fabrication of the PCB, procurement of the relevant IC chips, firmware programming and modulation techniques for transmission through audio port
4. Harvesting the energy from the audio line of the mobile phone so as to remove the dependency on the external battery for powering of the ICs
5. Developing a full working application on Android Phone with some real life use.
6. Developing apps for other mobile platforms like Symbian and iPhone

## Conclusion

Mobile phone is a versatile device. An affordable and ubiquitous plug-and-play interface for attaching sensors with its audio jack can have many applications. One such application is a simple credit card reader, which has been demonstrated in this project. If the analog signals generated by the magnetic read head are passed to the mobile phone via the audio jack, then those signals can be processed to retrieve useful card data from the magnetic stripe card. Such a device can be used by mobile merchants to accept credit / debit cards anywhere.

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