Signal Processing and Applications in RFID Technology

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Outline

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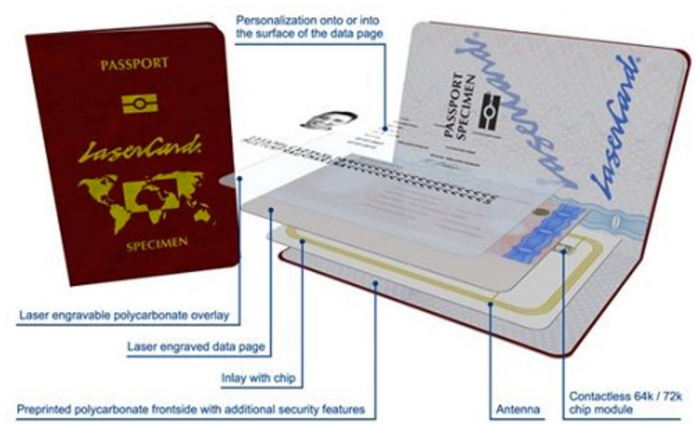
2. Mapping the System
3. Approach
4. Design
5. Signal Generation
6. Summary
7. Applications and Next Steps

1. www.dir.indiamart.com: accessed on 26 Oct. 2017

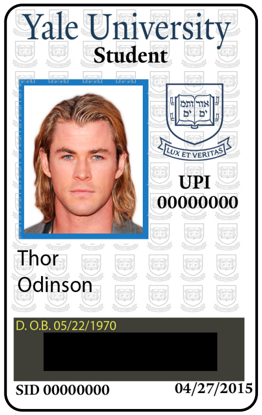
Introduction

- Radio-Frequency Identification (RFID) technology is widely used:
  - Asset management
  - Tracking of goods
  - Tracking of persons or animals
  - Contactless payment systems
  - E-Passports
  - Timing sporting events
  - Tracking and billing processes



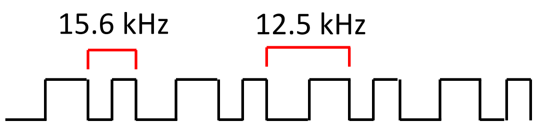
1. City A.M. News, www.cityam.com: accessed on 17 Oct. 2017
2. Leader Products, www.leaderproducts.com.au: accessed on 17 Oct. 2017
3. J&C Services, www.jclao.com: accessed on 17 Oct. 2017

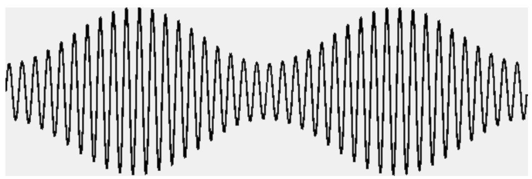
Mapping the System



Passive Sender

Subcarrier Modulated Wave





Carrier Wave

011100101100

Active Receiver

1. Receiver sends out 125 KHz carrier wave

2. Sender (ID card, in this case) amplitude-modulates that wave using a frequency shift-keyed signal

3. Receiver detects modulated subcarrier wave and deciphers ID code

Barcodes Inc., www.barcodesinc.com: accessed on 17 Oct. 2017

Approach: Mimic Reader and Writer

Reader specifications:

1. Deliver a repeatable, unique ID number for a given RFID tag
2. Wirelessly communicate with RFID tags from a distance of 2-5 cm

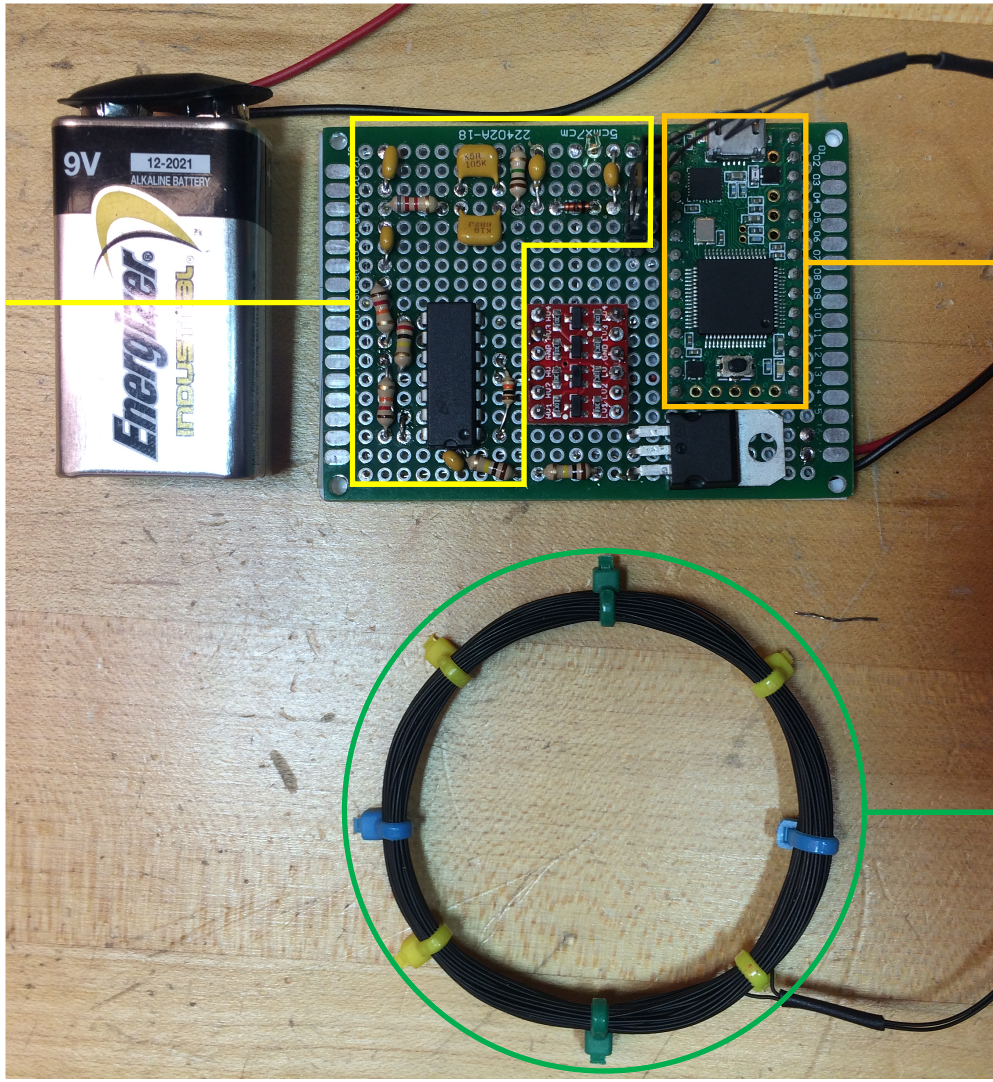
Writer specifications:

1. Precisely encode ID number using frequency shift-keying (FSK)
2. Modulate carrier wave at a level of 100 mV

Design: Reader

Subcarrier Wave Detector

- Peak-detects ASK modulation
- Removes noise
- Amplifies signal



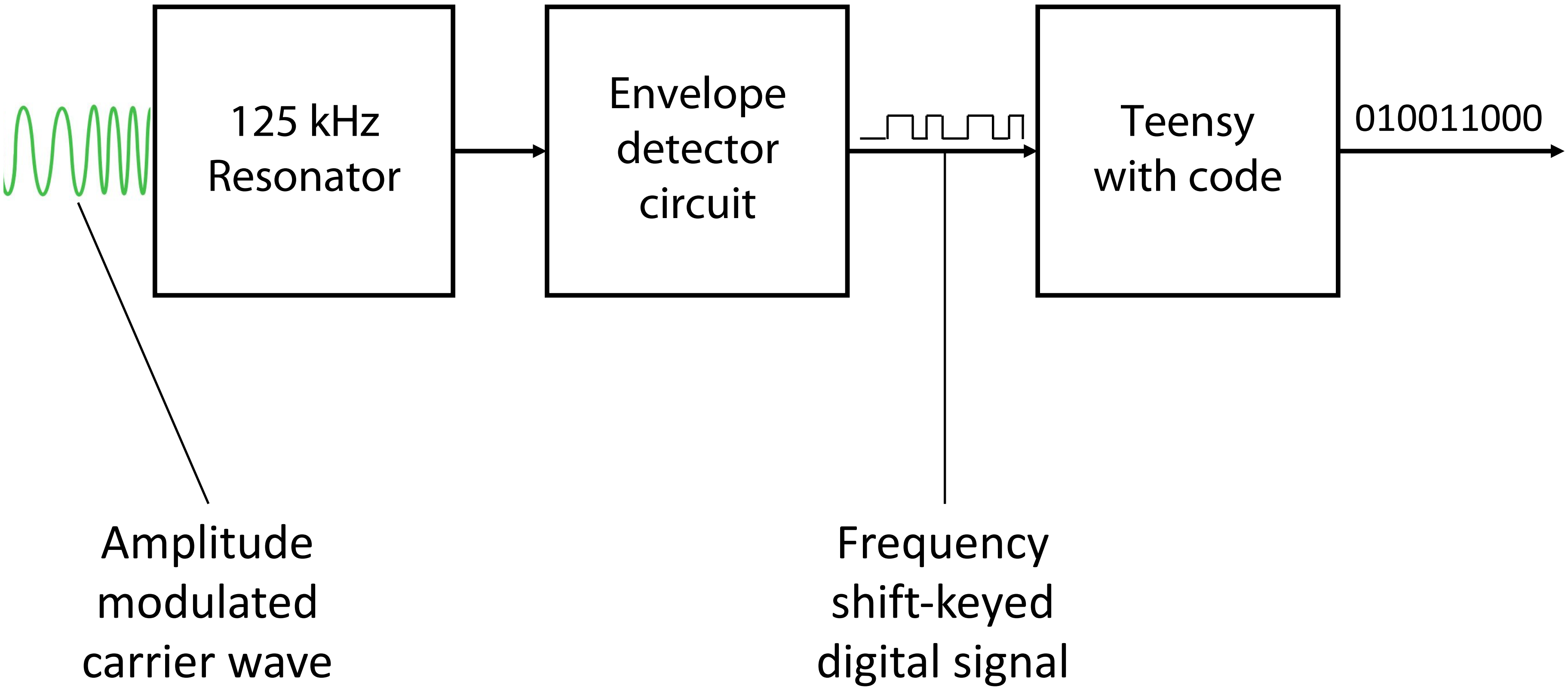
Teensy 3.2 Microcontroller

- Generates 125 KHz carrier wave
- Decodes FSK modulation

Inductive Coil

- Tuned to resonate at 125 KHz

Reader Block Diagram

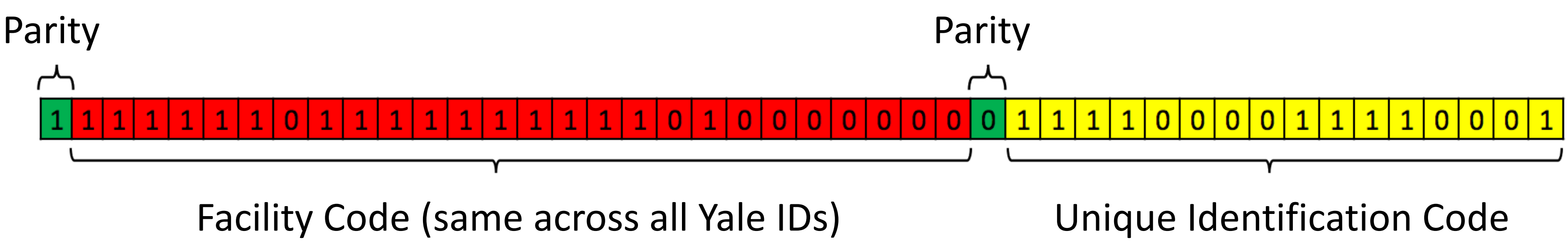


Results

- Reader successfully returned the same ID number every time for a given card
- Decoding process verified that the original data was indeed encoded by the following two methods:
  - Decimation (multi-bit encoding)
  - Manchester encoding

Insights: Reader

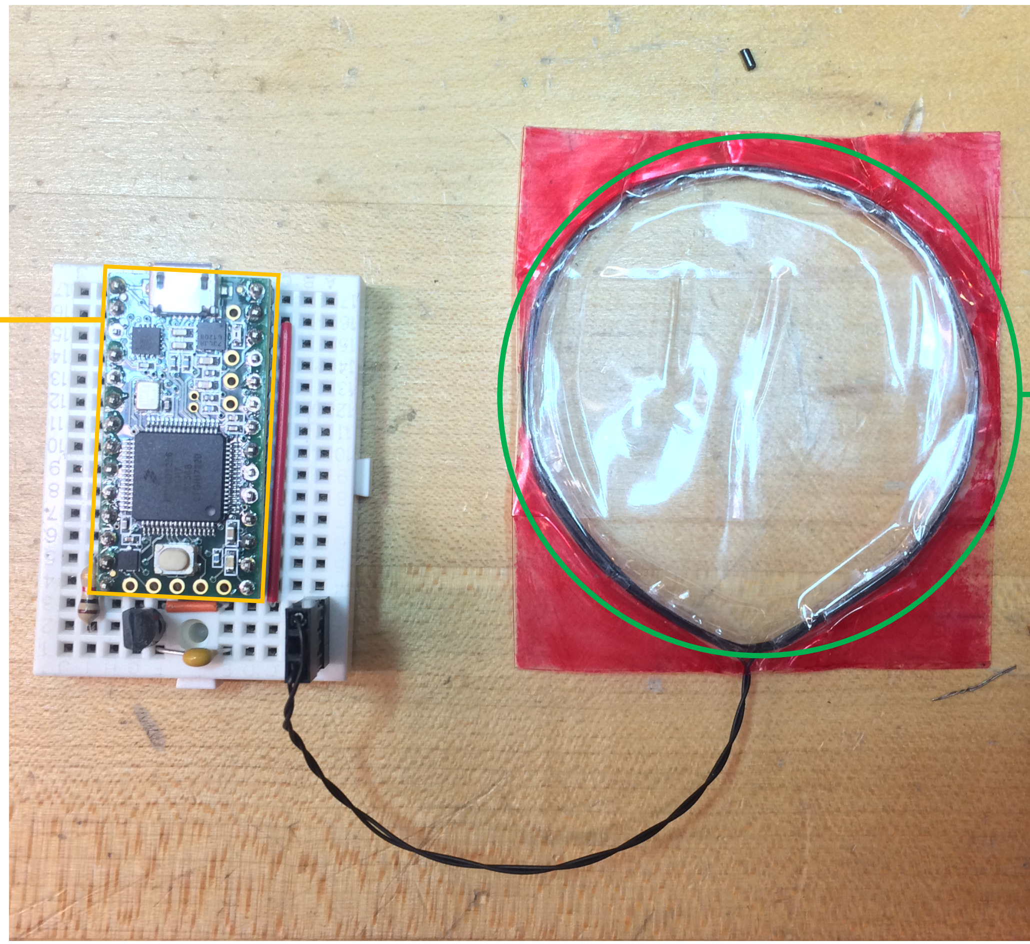
- Yale maintains a proprietary, unencrypted RFID format
  - Student codes were 44 bit instead of the standard 26
- ID codes looked very similar, as expected



Design: Writer 1

Teensy 3.2 Microcontroller

- Generates FSK encoded signal based on stored card ID number



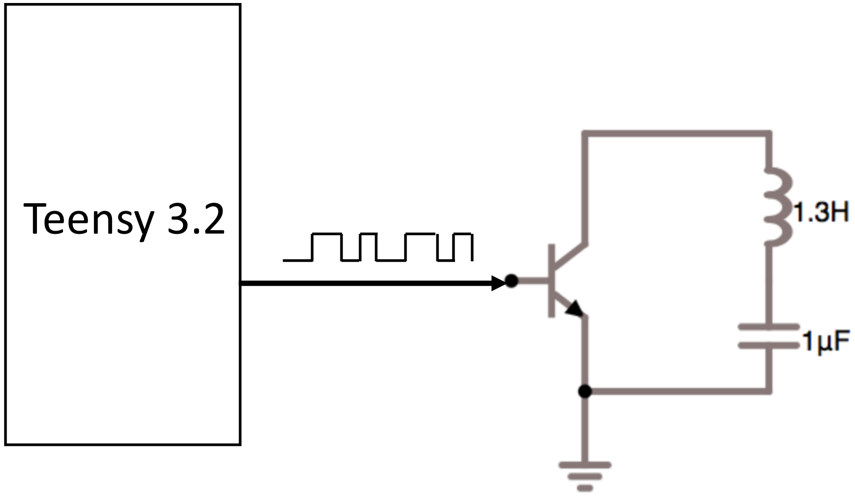
Inductive Coil

- Tuned to resonate at 125 KHz

Schematic of Writer

Teensy 3.2 Microcontroller

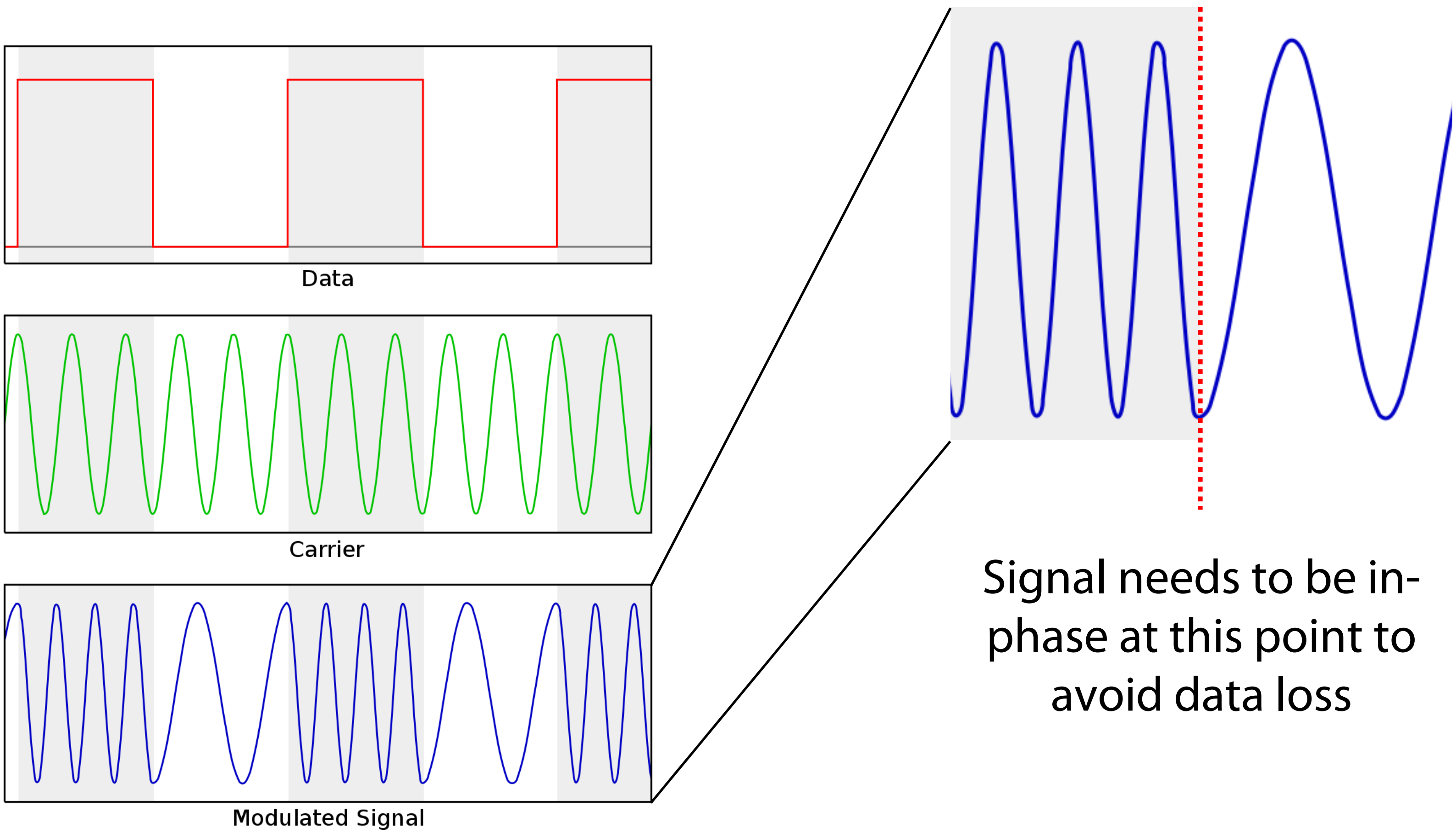
- Generates FSK encoded signal based on stored card ID number



Inductive Coil

- Tuned to resonate at 125 KHz

Motivation: Characteristics of FSK



Signal needs to be in-phase at this point to avoid data loss

Frequency Shift-Keying, Wikimedia Commons: accessed on 10 Dec. 2017

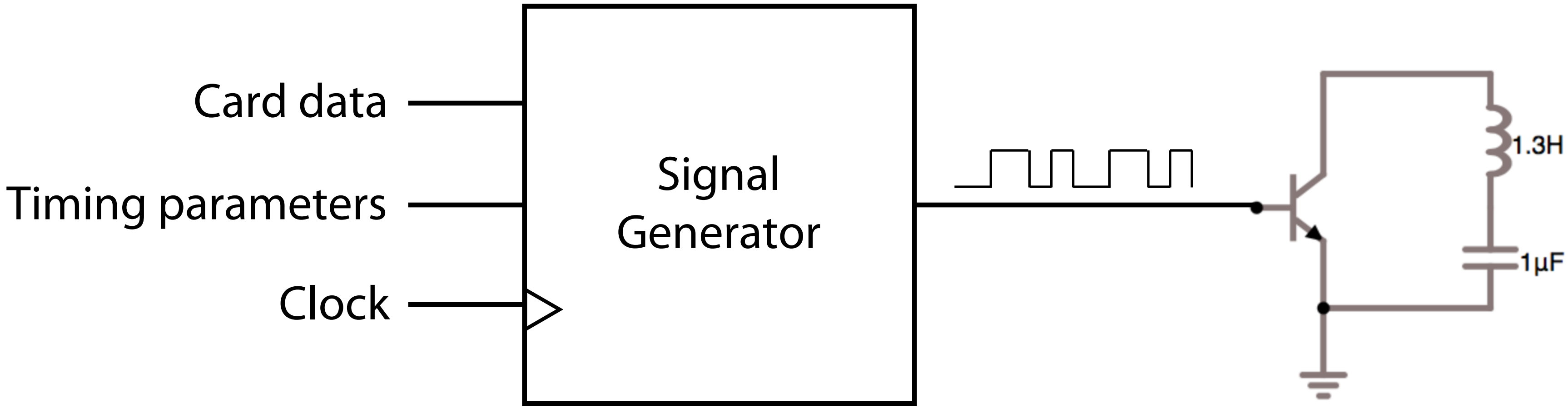
Signal Generator: Motivation

Problem: Microcontrollers are bad for high frequency, time-dependent applications

Goal: Develop a more efficient method for performing basic high frequency and time sensitive operations

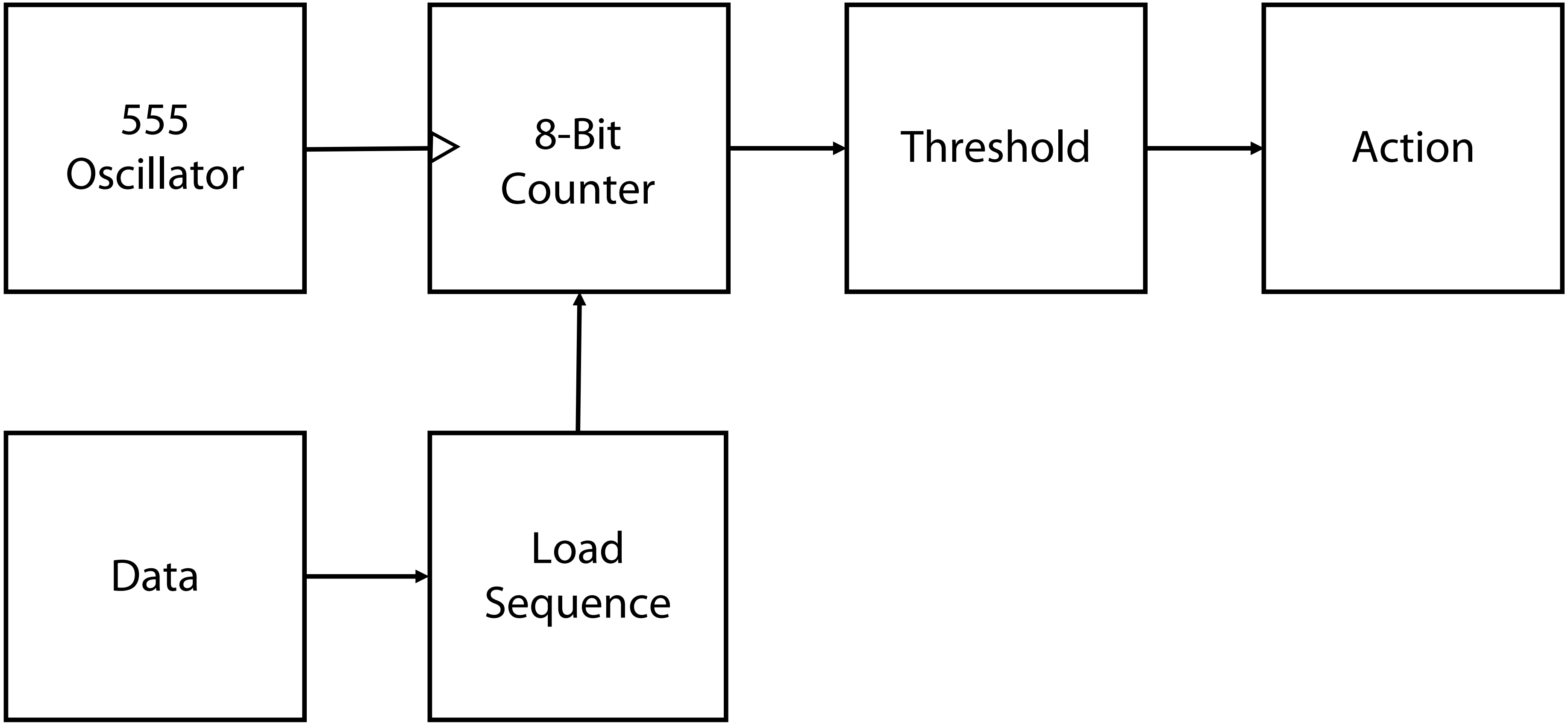
Solution: A cheap, hardware-level implementation of an algorthim that uses a data set, a parameter set, and a clock to produce an arbitrary digital function

Signal Generator



Designated hardware replaces the Teensy in order to better generate the frequency shift-keyed digital control signal

Signal Generator: Design



Creating Arbitrary Digital Signals

- Input data can be generalized to n-dimensions
  - Data set **{D}**, parameter set **{T}**, action set **{α}**, each with cardinality i
- Pulse length-formula:

$$\tau_n = \mathrm{T}_n(\Delta t)$$

- Full signal formula:

$$f(t) = \begin{cases} \alpha_1, & 0 < t < \tau_1 \\ \alpha_2, & \tau_1 < t < \tau_1 + \tau_2 \\ & \cdots \\ \alpha_n, & \sum_{i=0}^{n-1} \tau_i < t < \sum_{i=0}^{n} \tau_i \end{cases}$$

Summary and Key Points

- RFID cards send data through the processes of FSK, ASK, decimation, and Manchester encoding
- This operation is replicable using cheap, off-the-shelf components
- Microcontrollers are bad for high frequency, time-dependent applications

Applications and Next Steps

- Implementation in control systems
  - Allows for tight uncertainties in timing operations
  - Potentially draws less power than a microcontroller
- Integrate analog values with action set to further generalize the function generator

Acknowledgements

- Yale School of Engineering and Applied Science Dean’s Office

Supplemental Slides