THE UNIVERSITY of TULSA

*Electrical and Computer Engineering*

# USB-Enabled Capacitive Touch Keypad

Project Requirements

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# Revision History

| Date | Version | Author | Description |
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# Customer Approval

| **Name** | **Role** | **Signature of Approval** | **Approval Date** |
|---|---|---|---|
| Adam Dyer | Engineer | *Adam Dyer* | November 18, 2021 |
| Nathan Hutchins | Customer | *Nathan Hutchins* | November 18, 2021 |

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# Abstract

This report will go over the hardware and software design requirements of the project to create a USB-Enabled Capacitive Touch Keypad. This device will be a 4x3 keypad without any physical buttons on it. Instead, the "buttons" will be in the form of capacitive touch sensors hidden under the top face of the keypad. Touching the face of the keypad above a touch sensor will act as if you had pressed a physical button located there. This will result in a very sleek and novel device that has no obvious buttons on it yet functions exactly as if it did. There will also be small LED's hidden under the top face of the keypad that will illuminate when the "button" is pressed, further enhancing its appearance and aesthetic and also functioning as an indicator that the button press was detected. A pair of Arduino Nano's will control the capacitive sensors themselves and relay that information to a NUCLEO-STM32F411RE Microcontroller Development Board. It will take the information from the Arduino's and turn them into keystrokes corresponding to which button on the keypad was pressed. The Nucleo will also present itself as a keyboard, and will be able to plug into any computer and act as a connected keyboard. In short, pressing a button on the capacitive sensing keypad will have that character appear on the connected computer as if you had typed that character on the computer itself.

# Nomenclature

| | |
|---|---|
| Nucleo | The NUCLEO-STM32F411RE Microcontroller Development Board |
| LED | Light Emitting Diode |
| USB | Universal Serial Bus |
| SPI | Serial Peripheral Interface Communication Protocol |
| $I^2C$ | Inter-Integrated Circuit Communication Protocol |

# Chapter 1

# Introduction

## 1.1 Introduction

Capacitive sensing is a technology that can detect and measure anything that is conductive. Capacitive sensing technology is what makes modern day touchscreens on devices like smartphones, tablets, and e-readers possible. While these types of capacitive sensor touchscreens are quite complicated, the basic principle of a capacitive touch sensor is relatively straightforward. Imagine a piece of metal foil that is connected to a pin of a microcontroller. Because the human body is conductive, when you touch your finger to this piece of metal foil it will change it's capacitance. Detecting this change in capacitance using the microcontroller allows that piece of metal foil to function as a simple push button.

However, you do not necessarily need to make physical contact with the metal foil. With a sensitive enough setup, you are able to detect the presence of a finger above the metal foil without actually having the finger physically touch the foil. The exact range of detection varies depending on many factors and can range from needing to make physical contact with the sensor to being able to detect a finger from over a foot away. This ability to detect a finger without having the finger make physical contact with the sensor is the basic working principle behind this project.

Another technology that will be implemented in this project is USB On-The-Go. This is a communication protocol that allows devices to communicate with each other over USB and function as both a host and a peripheral. The NUCLEO-STM32F411RE Development Board is USB On-The-Go enabled. This means that it can act both as a host to receive programming instructions from a computer and as a peripheral to send information back to the computer.

## 1.2 Objective

The objective of this project is to combine the capacitive sensing technology and USB-On-The-Go features to create a capacitive touch keypad that will be able to connect to any computer as a keyboard. This means that the capacitive touch keypad will appear to any computer as a connected keyboard, able to send keystroke information to the computer and having those characters appear on the screen as if you typed them yourself.

## 1.3 Customer

Dr. Nathan Hutchins is the intended customer of this project. He is a Professor of Electrical and Computer Engineering at the University of Tulsa, and the instructor of ECE-2263 Embedded Systems in C. This project is designed to fulfill the requirements of the Final Project for ECE-2263. This project will be assessed and graded by Dr. Hutchins and other faculty members.

## 1.4 Design Team

### 1.4.1 Engineering Manager/Lead Engineer

Adam Dyer will be the Engineering Manager and Lead Engineer on this project. He is currently a first-year undergraduate student at the University of Tulsa majoring in Computer Engineering. He will be the only team member and thus responsible for the entire project, including hardware and software design and construction, assembly, testing, documentation, and presentation.

# Chapter 2

# Project Requirements

## 2.1 Hardware Requirements

### 2.1.1 Keypad Layout

The keypad will be designed as a standard 4x3 keypad, meaning it will have four rows and three columns of buttons. See Figure 2.1 for the layout of the buttons. Each button will have a corresponding touch sensor associated with it.

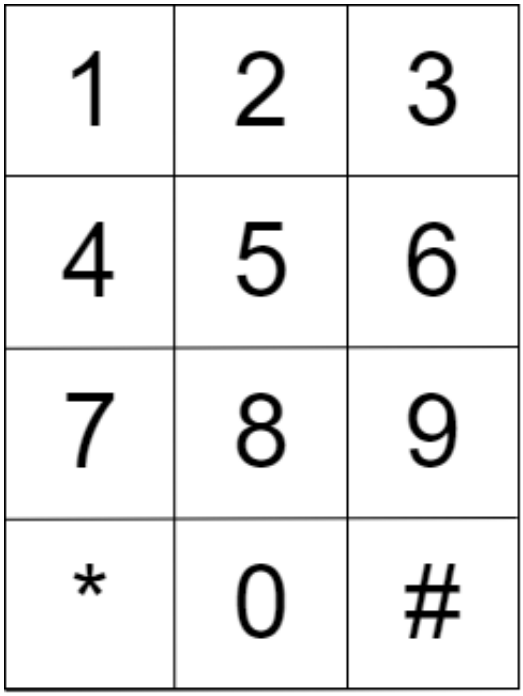


Figure 2.1: Keypad Layout

### 2.1.2 Enclosure

A key part of what makes this project interesting is the futuristic, sci-fi nature of capacitive touch sensors, since you are essentially pressing a button without actually pressing a button. As such, the overall design of the enclosure will need to be simple and sleek. The keypad itself will be encased in a white 3D-printed enclosure with some type of marking on the top face to indicate the placement of the buttons as shown

in Figure 2.1. The top face will be a smooth, solid piece of plastic. The actual metal touch sensors that will detect the button "press" will be located inside this enclosure and will not be visible on the outside. Essentially, the enclosure will look like a standard keypad without having any of the actual, physical buttons present on it.

### 2.1.3 LED Backlights

Each button will have a small LED mounted to it. This LED will be under the top face of the enclosure, directly above the metal touch sensors. Because the enclosure will be 3D-printed, the light from these LED's will be able to penetrate this top face. The purpose of these LED's is to act as indicators for when a button is pressed. When a button is pressed, the LED directly under it will turn on and illuminate that key of the keypad. This will also enhance the futuristic and sleek appearance of the keypad as described in the first part of section 2.1.2. It should be noted that these LED backlights are purely for aesthetic and ease of use, and will have no impact on the actual functionality of the device.

### 2.1.4 Microcontollers

#### Arduino Nano

Do to time constraints and the complexity of capacitive sensing, a pair of Arduino Nano's will act as an intermediary between the keypad and the Nucleo. They will only be responsible for controlling the touch sensors under each button and relying that information to the Nucleo. A pair of Arduino Nano's is used because each touch sensor will require a dedicated analog pin, and two Arduino's are needed to ensure enough analog pins are available.

#### Nucleo

The NUCLEO-STM32F411RE Development Board will act as the main microcontroller. It will receive the information about the button presses from the Arduino Nano's and relay that information to the connected computer using its built in USB-On-The-Go capabilities.

## 2.2 Software Requirements

### 2.2.1 Capacitive Sensing

The software to control and detect the capacitive touch buttons will be written in Arduino C and hosted on the pair of Arduino Nano's. It should be able to reliably detect the presence of a human finger above each button on the keypad. It needs to be sensitive enough to detect the capacitance of a human finger without it actually touching the metal touch sensors (since those sensors will be hidden under the top face of the enclosure) but robust enough to distinguish each individual button. Basically, it should detect a finger when it is directly above the button, but not detect the finger if it is over an adjacent button. The software also needs to be fast enough to handle multiple buttons being pressed in quick succession.

### 2.2.2 Communication between Arduino's and the Nucleo

The Arduino's must be able to communicate with the Nucleo. This will be implemented using either SPI or $I^2C$, and the final determination of which protocol to use will be determined later in the development period depending on which protocol presents itself as the better option. The decision on which protocol to use should have no effect on the final functionality of the device.

### 2.2.3 Nucleo and USB Communication

The software on the Nucleo must be able to receive the SPI or $I^2C$ signals coming from the Arduino's, interpret the signal to determine which button on the keypad was pressed, and relay that information to the Computer using the USB-On-The-Go protocol. Along with this, the Nucleo should present itself to the

connected computer as a keyboard so that the computer knows to interpret the information from the Nucleo as keyboard inputs and print the corresponding characters on the computer screen.