# Introduction

The goal is to create a low-cost switch interface that can be alternative to commercial options. The device needs be able to perform the main functions that is offered in alternative devices.

# Research

**Commercial alternatives**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Device | Company | Inputs | Information | Cost ($US) |
| [Swifty](https://orin.com/access/swifty/) | Origin Instruments | * 2 - Stereo Jack (Requires splitter ) | * Splitter is sold separately : $10 * USB Extension : $10 | $99 |
| [Tapio](https://www.orin.com/access/tapio/) | Origin Instruments | * 2 - Stereo Jack (Requires splitter ) | * iPad and iPhone Switch Interface | $120 |
| [Tecla Shield](https://www.iaccessibility.com/accessories/switches/index.cgi/product?ID=41) | Tecla | * 2 mono jacks + 4 way Joystick d-pad | * Discontinued? * 9-pin DB connection for joysticks |  |
| [Hitch 2](https://www.especialneeds.com/shop/assistive-technology/switches/switch-interfaces/hitch-2.html) | Ablenet | * 4 | * Ability to program one to four keystrokes of your choice * 9-pin DB connection for joysticks | $120 |
| [JoyCable](https://thinksmartbox.com/product/joycable/) | Thinksmartbox | * 2 | * [Up to 2 switches](https://thinksmartbox.com/wp-content/uploads/2016/07/JoyCable-manual-July-2016-web-2.pdf) | £99.00 or $118 |
| [Crick USB Switch Box](https://www.cricksoft.com/us/crick-usb-switch-box) | Crick Software Inc. | * 4 | * Works on Windows and Mac computers * **Crick Software application** | $160 |

**DIY Alternatives**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Device | Creator | Inputs | Information | Cost ($US) |
| [Enabled Controller Mini](https://makersmakingchange.com/project/enabled-controller-mini/) | Milador | * 4 input jacks and 2-axis analog input | * Morse code mode * Morse mouse mode * Gaming firmware | $40 |
| [ATMakers KeySwitch](https://makersmakingchange.com/project/keyswitch/) | ATMakers | * 5 | * Low memory issue with the selected MCU * Gaming firmware | $40 |
| [FAIO Multiplexer](https://makersmakingchange.com/project/faio-multiplexer/) | Milador | * 4 | * Morse code mode * Morse mouse mode * Gaming firmware | $55 |

# Requirements

## Goals

|  |  |
| --- | --- |
| **ID** | **Description** |
| G01 | Cost Effective (Low cost comparing to alternative options) |
| G02 | Easy to use |
| G03 | Easy to assemble |
| G04 | Minimal size |

## Functional Requirements

|  |  |
| --- | --- |
| **ID** | **Description** |
| F01 | The device shall have one or more input channels. |
| F02 | The device shall send output data via USB HID to the host device. |
| F03 | The device shall be compatible with switch control software. |
| F04 | The device switch shall incorporate minimal input protection. |
| F05 | The device latency shall not exceed 50 milliseconds. |
| F06 | The device shall support visual feedback for user interactions. |
| F07 | The device shall not consume more than 20 mA of current from the USB port. |
| F08 | The device shall be able to perform Mouse button, joystick button and keyboard emulation. |
| F09 | The device shall weigh less than 25 grams. |
| F10 | The device shall be smaller than 50mm x 40mm x 20mm. |

## Non-functional Requirement

|  |  |
| --- | --- |
| **ID** | **Description** |
| NF01 | Shall look professional with tight tolerance on case size. |
| NF02 | Input ports should be legibly labelled for easy identification |

## Constraints

|  |  |
| --- | --- |
| **ID** | **Description** |
| C01 | Shall be able to be built as a single unit for ≤ $40 CAD |
| C02 | Shall be easily manufacturable by a moderately skilled maker |

# Ideation

The initial idea was to add a custom PCB to an existing, small-sized commercially available microcontroller board.

There are a few other ways this could be accomplished:

* Using components with a proto board and breadboard-friendly 3.5 mm jacks
* Using components in a 3D printed jig / 3d printed PCB
* Using panel mount switch jacks mounted in a 3d printed enclosure

# Conceptual Design

## Components

### Dev Board/MCU

The TRINKEY board is a great low-cost option to design the switch interface based of it, as it offers the basic requirement for creation of a switch interface. Trinkey offer one to three GPIO’s and a built-in RGB LED in a small footprint (USB Flash Stick size).

The Trinkey is offered in following versions:

1. [Adafruit NeoKey Trinkey](https://www.adafruit.com/product/5020)
   * + - Digikey Link: <https://www.digikey.ca/en/products/detail/adafruit-industries-llc/5020/14307382>
       - Cost: $10 CAD
       - Pros:
         * USB NeoPixel Mechanical Key Switch
         * LED Visible from top and bottom
         * One Touch pad
         * Factory code is compatible with Switch control on Android
       - Cons:
         * One GPIO
         * No exposed ground pad (Needs to use pull down)
2. [Adafruit Rotary Trinkey](https://www.adafruit.com/product/4964)
   * + - DigiKey Link: <https://www.digikey.ca/en/products/detail/adafruit-industries-llc/4964/14307384>
       - Cost: $10
       - Pros:
         * 2 Analog pins and 1 digital pin exposed which can be used as three GPIO’s
         * One Touch pad
         * Power and ground pads exposed
       - Cons:
         * Factory code is not compatible with switch control software
         * LED Visible from bottom side
3. [Adafruit Proximity Trinkey](https://www.adafruit.com/product/5022)
   * + - Digikey Link: <https://www.digikey.ca/en/products/detail/adafruit-industries-llc/5022/15222465>
       - Cost: $14 CAD
       - Pros:
         * Two Touch pads
         * Two RGB LEDs on top side
       - Cons:
         * Factory code is not compatible with switch control software
         * No Exposed GPIO’s
         * No exposed power and ground pad

This is not a suitable option because there are no solder pads readily accessible to connect a switch easily.

Both the Adafruit NeoKey Trinkey and the Adafruit Rotary Trinkey could be used to create a switch interface. The Adafruit Rotary Trinkey was selected for the following reasons:

1. Ability to use 2 switches
2. Ground pad is exposed.
3. The rotary switch has thru hole connections that make it easier to connect the switch jacks.

### 3.5 mm Input Jack Options

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 3.5 mm Jack | SJ1-3533NG | SJ1-3535NG | MJ-3536N | SJ-43514 | STX-3120-3B |
| Type | Stereo (3 Conductor, TRS) | Stereo (3 Conductor, TRS) | Mono | Stereo (4 Conductor, TRRS) | Stereo (3 Conductor, TRS) |
| Cost (CAD$) | 1.9 to 1.92 | 1.93 to 1.96 | 1.37 to 1.39 | 1.45 to 1.47 | 1.15 to 1.16 |
| Availability | 689,251 from Digikey, 21,251 from Mouser | 109,033 from Digikey, 5,468 from Mouser | 22,746 from Digikey, 8,534 from Mouser | 28,000 from Digikey, 27,750 from Mouser | 4,467 from Digikey, 5,220 from Mouser |
| Manufacturer | CUI Devices | CUI Devices | CUI Devices | CUI Devices | Kycon, Inc. |
| Dimensions | 14(+4) mm x 8.2mm x 12.3mm | 14(+4) mm x 8.2mm x 12.3mm | 15.8(+3) mm x 10mm x 10mm | 11(+3) mm x 4.9mm x 5mm | 10.5(+3.5) mm x 12mm x 10mm |
| Number of Sets | 1 | 1 | 1 | 1 | 1 |
| Number of Positions | 3 Conductors, 3 Contacts | 3 Conductors, 5 Contacts | 2 Conductors, 3 Contacts | 4 Conductors, 4 Contacts | 3 Conductors, 3 Contacts |
| Voltage - Rated | 12VDC | 16VDC | 12VDC | 12VDC | N/A |
| Current Rating | 1A | 1A | 1A | 1A | N/A |
| Internal Switch | None | 2 Switches | Single Switch | None | None |
| ProtoBoard Friendly | None | None | None | None | Yes |
|  | SJ1-3533NG | SJ1-3535NG | MJ-3536N | SJ-43514 | STX-3120-3B |

Trinkey doesn’t provide enough pins to support jack internal switch (touch pad may not be a reliable method to provide additional input)

SJ-43514 is a reliable and low-cost option.

### Hardware pullup

Hardware pullup can be added as an optional feature

### Mounting Hole

A single M3 mounting hole to provide additional support for the enclosure.

## Concepts

### Concept 1 : Mono

* [Adafruit NeoKey Trinkey](https://www.adafruit.com/product/5020)
* One switch input through pull-down resistor
* Factory code can be used
* Total cost without PCB: $11.36
* Adafruit NeoKey Trinkey x 1: $9.73
* SJ-43514 3.5mm Jack Stereo x 1: $1.48
* 4.7 kΩ 1/4W Through Hole Resistor x 1: $0.15

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### Concept 2: Dual version 1

* [Adafruit Rotary Trinkey](https://www.adafruit.com/product/4964)
* Two switch inputs through software/hardware pull-up resistor
* Low-cost option
* Total cost without PCB: $12.99

1. Adafruit Rotary Trinkey x 1: $9.73
2. SJ-43514 3.5mm Jack Stereo x 2: $1.48
3. 4.7 kΩ 1/4W Through Hole Resistor x 2: $0.15

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### Concept 3: Dual Version 2

* [Adafruit Rotary Trinkey](https://www.adafruit.com/product/4964)
* Two vertical switch inputs (Jack with 2 sets) through software pull-down resistor
* Total cost without PCB: $14.47

1. Adafruit Rotary Trinkey x 1: $9.73
2. SJ-43514 3.5mm Jack Stereo x 1: $4.44
3. 4.7 kΩ 1/4W Through Hole Resistor x 2: $0.15

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### Concept 4: Dual Version 3

* [Adafruit NeoKey Trinkey](https://www.adafruit.com/product/5020)
* Two switch inputs through software/hardware pull-up resistor
* Total cost without PCB: $12.99

1. Adafruit NeoKey Trinkey x 1: $9.73
2. SJ-43514 3.5mm Jack Stereo x 2: $1.48
3. 4.7 kΩ 1/4W Through Hole Resistor x 2: $0.15

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### Concept 5: Triple

* [Adafruit Rotary Trinkey](https://www.adafruit.com/product/4964)
* Three vertical switch inputs (Jack with 3 sets) through software pull-up resistor
* Total cost without PCB: $14.85

1. Adafruit NeoKey Trinkey x 1: $9.73
2. SJ-43514 3.5mm Jack Stereo x 1: $4.67
3. 4.7 kΩs 1/4W Through Hole Resistor x 3: $0.15

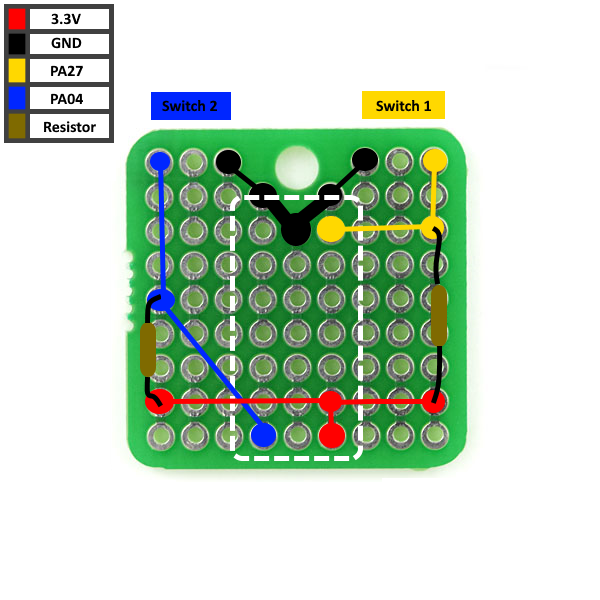
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### Concept 6: Breadboard

* [Adafruit Rotary Trinkey](https://www.adafruit.com/product/4964)
* SparkFun ProtoBoard
* Two breadboard friendly 3.5mm switch inputs through software pull-up resistor
* Total cost: $16.13

1. Adafruit NeoKey Trinkey x 1: $9.73
2. STX-3120-3B 3.5mm Jack Stereo x 2: $1.16
3. 4.7 kΩs 1/4W Through Hole Resistor x 2: $0.15
4. SparkFun ProtoBoard - Square 1" Single Sided x 1: $2.73
5. Hook-Up Wire x 1: $1.05



### Protoboard / Breadboard

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Item | Dimension | Availability | Cost $CAD | Link |
| Sparkfun - Square 1" Single Sided | 2.54mm x 2.54mm ( 9 by 9 0.1 standard spacing) | 2000 units available from Digikey and 388 from Mouser | $2.42 to $3.99 | [Digikey](https://www.digikey.ca/en/products/detail/sparkfun-electronics/PRT-08808/7387401)  [Mouser](https://www.mouser.ca/ProductDetail/SparkFun/PRT-08808?qs=WyAARYrbSnYE9naQ%252BrkzGQ%3D%3D&mgh=1&gclid=EAIaIQobChMI2YaDxsj0-QIVcgF9Ch2AewNmEAQYASABEgIwuvD_BwE)  [Sparkfun](https://www.sparkfun.com/products/8808)  [elmwoodelectronics](https://elmwoodelectronics.ca/products/8808) |
| ELEGOO Double Sided PCB Board | 20mm x 80mm to 90mm x 150mm | Amazon and AliExpress  70mm x 100mm version on [Mouser](https://www.mouser.ca/ProductDetail/Seeed-Studio/319030009?qs=SElPoaY2y5JaWFOX29wUwA%3D%3D&mgh=1) | $1.97 to $3.45  Or $0.56 per unit for 32 units | [Amazon.ca](https://www.amazon.ca/Veroboard-Stripboard-Prototype-Soldering-Compatible/dp/B072Z7Y19F)  [Aliexpress](https://www.aliexpress.com/item/1005001621976056.html) |
| Chip Quik Solder-in breadboard | 44.5mm x 17.8mm | 86 units available from Digikey and 48 from Mouser | $1.5 to $1.62 | [Digikey](https://www.digikey.ca/en/products/detail/chip-quik-inc/SBBTH1506-1/5978222)  [Mouser](https://www.mouser.ca/ProductDetail/Chip-Quik/SBBTH1506-1?qs=gjT6naH6P5K7JrxFPe%252BjSQ%3D%3D) |

STX-3120-3B 3.5mm jack would be idea for this concept due to it’s breadboard friendly characteristic.

### Concept 7: 3D Printed version

## Circuit Board

1. PCB (Dual Concept 1)

|  |  |  |  |
| --- | --- | --- | --- |
| **Units** | 1 | 5 | 10 |
| **Minimum order Unit** | 5 | 5 | 5 |
| **PCB Cost $US** | $2 ($2.6 CAD) | $2 ($2.6 CAD) | $2 ($2.6 CAD) |
| **Shipping Cost $US** | ~$18 ($23.5 CAD) | ~$18 ($23.5 CAD) | ~$18 ($23.5 CAD) |
| **Component Cost $US** | $9.94 ($12.99 CAD) | $49.7 ($64.95 CAD) | $99.4 ($129.9 CAD) |
| **Unit Cost $(US)** | $29.91 ($39.09 CAD) | $13.93 ($18.21 CAD) | $11.94 ($15.6 CAD) |

1. ProtoBoard
   * Unit cost: $12.34 ($16.13 CAD)

# Concept Selection

* Low cost ($10 less than Enabled controller Mini)
* Easy to assemble
* Small footprint
* Individual jacks instead of stereo jack that requires cable adapter.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Concept** | **Microcontroller** | **Inputs** | **Single Unit Cost** | **Qty 5 Unit Cost** | **Qty 10 Unit Cost** | **Size** |
| Mono | Neokey Trinkey | 1 | $37.46 | $16.58 | $13.97 | 32mm x 16.5mm x 11mm (Total: 44.7 x 16.5mm x 11mm) |
| Dual1 | Rotary Trinkey | 2 | $39.09 | $18.21 | $15.6 | 33.3mm x 29mm x 11mm (Total: 44.6 x 29mm x 11mm) |
| Dual2 | Rotary Trinkey | 2 | $40.57 | $19.69 | $17.08 | 33.8mm x 16.5mm x 31.7mm (Total: 45.1 x 16.5mm x 31.7mm) |
| Dual3 | Neokey Trinkey | 2 | $39.09 | $18.21 | $15.6 | 31.8mm x 29mm x 11mm (Total: 44.4 x 29mm x 11mm) |
| ~~Triple~~ | ~~Rotary Trinkey~~ | ~~3~~ | ~~$40.95~~ | ~~$20.07~~ | $17,46 | 41mm x 16.5mm x 42.5mm (Total: 52.3 x 16.5mm x 42.5mm) |
| Breadboard | Rotary Trinkey | 2 | $16.13 | $16.13 | $16.13 | 10mm x 10mm x 11mm (Total: 21.3 x 10mm x 11mm) |
| 3D Printed | Rotary Trinkey | 2 |  |  |  |  |

The concept selected is to look at offering both the Breadboard and Dual-Version 1 options, so that a maker can utilize the breadboard version for the least expensive option and use a custom PCB when producing quantities of 5 or more.

# Prototyping

* Mono version was fabricated and assembled using PCB.
* The Concept 2: Dual version 1 was fabricated and assembled using PCB.

# Testing

* Mono and dual versions were successfully tested with Universal Switch accessibility feature of an Android smartphone.

# Detailed Design

Concept 2: Dual version 1 was selected as the final concept due to the following reasons:

* It offers all the required features including exposed GPIO pads and ground pads
* It’s a more cost effective option compared to other PCB base concepts
* This concept has a smaller footprint compared to other concepts
* The selected Trinkey board for this concept has additional solder pads which can help with the assembly process of the device.

Diagram, schematic

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# Opportunities for Improvement

* Create the breadboard version for smaller builds of 5 or less
* Improve the software settings and use GUI based settings
* Minimize the dimensions of the case to allow easier connection for USB ports beside