# 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

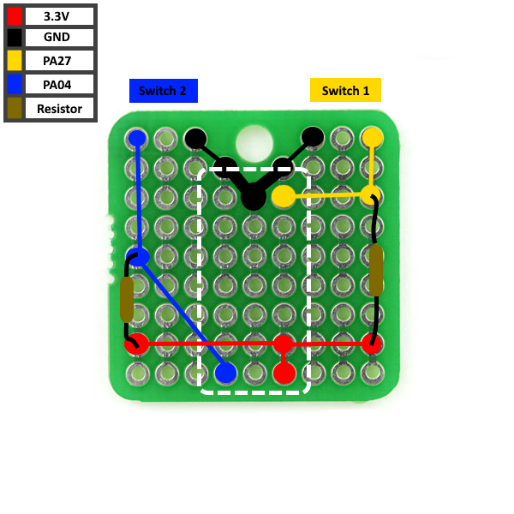
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### Concept 6: Breadboard

* [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

* [Adafruit Rotary Trinkey](https://www.adafruit.com/product/4964)
* Total cost: $13.9

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. Hook-Up Wire x 1: $1.05
5. Filament Cost: ~ $0.5

## 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. 3D Printed
   * Unit cost: $10.2 ($13.9 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 | $13.9 | $13.9 | $13.9 | N/A |

The breadboard concept introduces challenges for makers with assembly process as the solder pads of breadboard pins are not large enough for solder to make connection with solder pads of the Trinkey board. The breadboard concept would require special tools to drill/cut the breadboard. This would make the assembly process complex for most makers and could result in mis assembly of the unit.

The concept selected is to look at offering both the 3D Printed and Dual-Version 1 options, so that a maker can utilize the 3D Printed 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 3D Printed 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