

# muxPi

## revision v1.4



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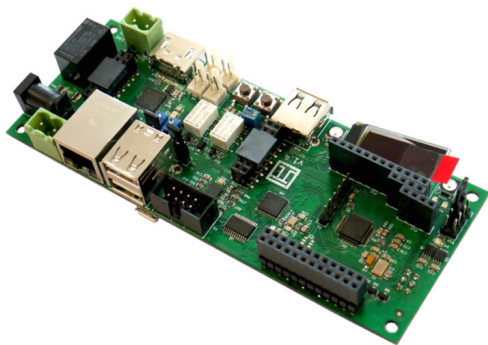
## Product description

MuxPi is a product mainly for developers and testers with the need of automating everyday tasks. It comes with help providing ease of use, distribution and connectivity. MuxPi is an open hardware device consists of two main parts:

- Main board
- NanoPi NEO

MuxPi might be considered as some kind of motherboard for NanoPi NEO SBC but it can operate without NanoPi NEO. However, in such a scenario its functionality is heavily reduced.

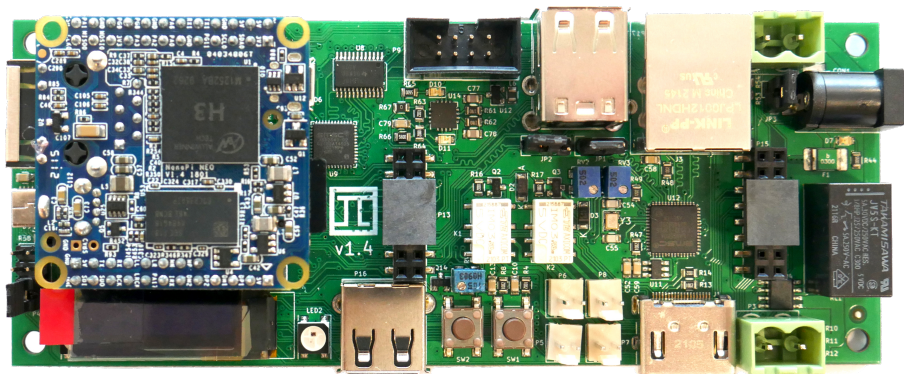
The primary purpose of the muxPi board is to enable fully remote work with devices being tested, where hardware setup can be separated from the developer. The main advantage of this board is a large number of various interfaces, making muxPi very versatile testing board.





## **muxPi elements**

- 3x USB port - additional host connectors,
- 1x Ethernet port (output) - DUT connection,
- 1x HDMI port - EDID writing feature,
- 1x microUSB port - NanoPi NEO debug UART0,
- 1x IDC 2x4pin header - SPI/SD card adapter,
- 1x UART 2x4pin header - DUT serial connection,
- 1x USB-M 1x5pin header - Samsung mobiles connection,
- 1x Atiny 2x3pin header - development header,
- 1x Cortex-M0 1x6pin header - development header,
- 4x DyPers - dynamic jumpers (2x 2-channels),
- 2x push buttons,
- 128x32 OLED display,
- 2x RGB LEDs,
- 6x monochrome LEDs - two of them are general purpose LEDs,
- SD-Reader socket - connected to SD multiplexer,
- 4x 1x2pin jumpers - various board features control,
- 2x add-on headers - additional shield connection,
- 1x PWR DC Jack 5.5/2.1 mm - muxPi power supply,
- 2x PWR connectors - DUT power (input/output),
- relay - DUT's power control.

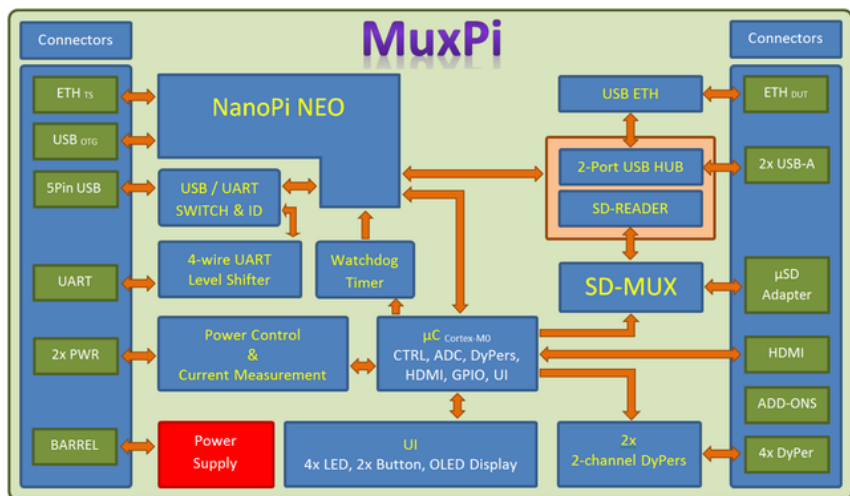




# Product features

## Key features

- Compatibility with NanoPi NEO,
- remote control over power supply for a DUT (via a relay or dedicated pins),
- measuring the current consumption of a DUT,
- providing a DUT connection (UART, USB, ETH, microSD card) to a remote location over Ethernet,
- SD card multiplexing,
- flashing and controlling Samsung mobile devices over a dedicated USB interface,
- writing EDID to a DUT over HDMI connection,
- 4x dynamic jumpers,
- additional user interface (display, push buttons, LEDs).





## Connection with muxPi

Communication with the muxPi device can be achieved through:

- serial connection debug UART0 (addon header **P13**)
- serial connection debug UART0 (micro USB connector **P10**)

## Connection with Device Under Test

MuxPi board can achieve communication with Device Under Tests in many ways:

- Ethernet - onboard USB-ETH converter,
- USB OTG - NanoPi built-in port,
- USB Host - up to 3 onboard USB host connectors,
- Serial (UART) interface - UART header with an adjustable voltage level.



## SD card multiplexing

One of the most anticipated muxPi's feature is switching or flashing a microSD card without the need of ejecting the card itself. For this purpose, it is required to use special IDC <--> microSD adapter cable shown in the figure below.



Simply connect adapter's IDC cable to the 2x4pin IDC socket (**p9**) and microSD card adapter to the target device card socket. Attach target microSD card to the card reader (**j2**) located at the bottom side of the board.

| Command | Description                                      |
|---------|--------------------------------------------------|
| mux ts  | Connect microSD card to a card reader (muxPi)    |
| mux dut | Connect microSD card to external connector (DUT) |
| dut     | Connect microSD card and power to DUT            |
| ts      | Connect microSD card and power to TS             |

After a successful connection between NanoPi and card reader/external connector user can mount or flash microSD card freely - it is visible as `/dev/sda` device. Communication with STM32 Cortex-M0 muxPi controller is described in [STM32 microcontroller](#) section.



## Audio/video capturing

The muxPi board is capable of grabbing the Audio/Video signal from Device Under Test. To achieve this approach, additional equipment (**LKV373a** HDMI Extender), software (VLC with correct params) and kernel version (NanoPi kernel).

Required steps are presented in [this](#) video.



# Specification

## ATiny10 microcontroller

ATiny10 is an 8-bit AVR RICS-based microcontroller, which combines 1KB ISP flash memory, 32B SRAM and four general purpose I/O lines. The main and only purpose of this component is a watchdog function for NanoPi NEO platform.

## STM32 microcontroller

Built-in low-power STM32F030C6T6 ARM Cortex-M0 is a 32-bit microcontroller based on RISC architecture with core operating at a 48 MHz frequency. MuxPi's Cortex-M0 must be flashed with a particular firmware developed especially for muxPi purposes. Firmware upgrade can be done directly through NanoPi via a serial connection with a microcontroller. However, our product is already fully prepared with actual Cortex-M0 firmware on board.

It is responsible for low-level actions and is only a slave for NanoPi NEO. List of features accessible through Cortex-M0:

- Device Under Test power control via relay (power on|off|tick)
- setting HDMI hotplug on/off and serving EDID data through HDMI connector
- setting DyPers states
- connecting microSD card to external connector (DUT) or card reader on muxPi board
- controlling 2x RGB LEDs and OLED display
- reading ADC (1 or 2) channels values and/or voltage
- reading current consumption of DUT
- reading buttons state
- controlling USB-M interface
- setting external UART voltage from 0 to 5V
- resetting watchdog



To communicate with STM32 microcontroller it is required to enable UART2/3 on nanoPi NEO system and open serial connection through UART3 visible as `/dev/ttyS2` using `minicom` or `screen` software.

Output from `help` command sent to STM32 Cortex-M0:

```
help    --- This help
version --- Display version of the firmware
echo    --- Get (no arguments) or set ('on' or 'off') echo on serial "console":
          echo [on|off]. The default value is on.
power   --- Get (no arguments) or set ('on' or 'off') or switch off and on
          ('tick') power supply for DUT: power [on|off|tick]
hdmi     --- Get (no arguments) or set ('on' or 'off') HDMI HOTPLUG pin:
          hdmi [on|off]
dyper   --- Get (no second argument) or set ('on' or 'off') DyPer state:
          dyper 1|2 [on|off]
mux      --- Connect microSD card to external connector DUT or card reader (ts):
          mux [dut|ts]
dut      --- Connect microSD card and power to DUT: dut
ts       --- Connect microSD card and power to TS: ts
led      --- Get (no second or third argument) or set ('R G B') color of led
          (1 | 2), ex: led 1 255 0 255
clr      --- Clear oled display
text     --- Print text on the OLED display: text x y color content
draw     --- Draw an object on the OLED display: draw object x1 y1 [x2 y2],
          objects are:
          - point x y color - draws one point at given coordinates
          - line x1 y1 x2 y2 color - draws line between given coordinates
          - rectangle left top width height color - draws line between given
            coordinates
          - circle x y radius color - draws line between given coordinates
          color must be 'on', 'off' or 'inv'
adc      --- Print current adc value of all (if no arguments are given) or one
          specified channel, ex: adc 1
voltage  --- Print current voltage [mV] of all (if no arguments are given) or one
          specified channel, ex: voltage 1
current  --- Print current current [mA] being consumed by DUT
lthor    --- Get (no second argument) or set state of lthor control signals:
          - lthor switch [usb|uart] - redirect DUT's USB wires to NanoPi's 'usb'
            or 'uart'
          - lthor id [usb|uart] - switch DUT's USB to 'usb' or 'uart' mode
          - lthor vbus [on|off] - switch DUT's VBUS 'on' or 'off'
          - lthor combo [usb|uart] - make DUT and MuxPi USB work in 'usb' or
            'uart' mode - no get function
key      --- Get current state of given key or both if no key number is given:
          key [1|2]
uart     --- Get current value of UART voltage or set if a new value is given
          [in millivolts]
```



## NanoPi headers

The muxPi has three headers supported by NanoPi NEO platform:

- NanoPi NEO 2x12 pin female header (**P14**) straight type 2.54mm pitch.

| Description      | Pin # | Pin # | Description      |
|------------------|-------|-------|------------------|
| SYS_3V3          | 1     | 2     | VDD_5V           |
| I2C0_SDA         | 3     | 4     | VDD_5V           |
| I2C0_SCL         | 5     | 6     | GND              |
| GPIOG11          | 7     | 8     | UART1_TX/GPIOG6  |
| GND              | 9     | 10    | UART1_RX/GPIOG7  |
| UART2_TX/GPIOA0  | 11    | 12    | GPIOA6           |
| UART2_RTS/GPIOA2 | 13    | 14    | GND              |
| UART2_CTS/GPIOA3 | 15    | 16    | UART1_RTS/GPIOG8 |
| SYS_3.3V         | 17    | 18    | UART1_CTS/GPIOG9 |
| SPI0_MOSI/GPIOC0 | 19    | 20    | GND              |
| SPI0_MISO/GPIOC1 | 21    | 22    | UART2_RX/GPIOA1  |
| SPI0_CLK/GPIOC2  | 23    | 24    | SPI0_CS/GPIOC3   |



## NanoPi headers

- NanoPi NEO 1x12 pin female header (**P11**) straight type 2.54mm pitch:

| Description                       | Pin # |
|-----------------------------------|-------|
| VDD_5V                            | 1     |
| USB-DP1                           | 2     |
| USB-DM1                           | 3     |
| USB-DP2                           | 4     |
| USB-DM2                           | 5     |
| GPIOL1/I <sup>2</sup> C-RX        | 6     |
| SPDIF-OUT/GPIOA17                 | 7     |
| PCM0_SYNC/I <sup>2</sup> S0_LRC   | 8     |
| PCM0_CLK/I <sup>2</sup> S0_BCK    | 9     |
| PCM0_DOUT/I <sup>2</sup> S0_SDOUT | 10    |
| PCM0_DIN/I <sup>2</sup> S0_SDIN   | 11    |
| GND                               | 12    |

- UART-NPN (UART-0) 1x4pin female header (**P19/P12**) straight type 2.54mm pitch:

| Description | Pin # |
|-------------|-------|
| GND         | 1     |
| VDD_5V      | 2     |
| UART_TXD0   | 3     |
| UART_RXD0   | 4     |



## Cortex-M0 header

Cortex-M0 header (P1) is a 1x6pin header straight type 2.54mm pitch. This header is for development purpose only.

| Description | Pin # |
|-------------|-------|
| 3V3         | 1     |
| SWCLK       | 2     |
| GND         | 3     |
| SWDIO       | 4     |
| NRST        | 5     |
| NC          | 6     |

## ATiny header

ATiny header (P18) is a 2x3pin female header straight type 2.54mm pitch. This header is for development purpose only.

| Description | Pin # | Pin # | Description |
|-------------|-------|-------|-------------|
| TPI_DATA    | 1     | 2     | 5V          |
| TPI_CLK     | 3     | 4     | NC          |
| TPI_RST     | 5     | 6     | GND         |



## Jumpers

There are 5 jumper headers on muxPi board:

- USB/ETH 1x3pin (**JP1** and **JP2**)
  - first two pins are jumped - USB lines are connected to add-on connector,
  - last two pins are jumped - USB lines are connected to USB-ETH converter,
  - none of the pins are jumped - only upper socket of the double USB connector is activated.

**NOTE1:** The upper socket of double USB-A connector must be left empty if USB<->ETH is selected or add-on connector is selected and something is connected to these data lines on the add-on!

**NOTE2:** Both jumpers must be placed in the same position!

- VDD 1x2 pin (**JP3**)
  - pins jumped - **VDD** and **3V3** are always on,
  - pins opened - **VDD** and **3V3** are controlled by NanoPi.

**NOTE1:** If there is no particular need then leave this jumper open

**NOTE2:** For example, VDD jumper allows to power STM32 Cortex-M0 without NanoPi NEO

- BOOT MODE 1x2 pin (**JP4**)
  - pins jumped - STM32F030C6T6 microcontroller BOOT MODE is set to **Execution mode**,
  - pins opened - STM32F030C6T6 microcontroller BOOT MODE is controlled by PL\_GPIO1 (NanoPi NEO pin board: 7 / WiringNP pin: 7), where high state sets BOOT MODE to **Flashing mode**.
- ADC1 1x2pin (**JP5**)
  - pins jumped - **ADC1** is connected to reference voltage divider.



## DyPers

DyPer is an abbreviation for "Dynamic jumPer" and is a small, electromagnetic relay which is controllable by software. The muxPi board consists of 2 DyPers with 2 channels each:

- DP1 CH1 (**p5**),
- DP1 CH2 (**p6**),
- DP2 CH1 (**p7**),
- DP2 CH2 (**p8**).

They can switch signals up to 0.5A. Both channels are switched simultaneously (on/off) with the same command. The channels are separated galvanically.

| Command     | Description       |
|-------------|-------------------|
| dyper       | Get DyPers states |
| dyper 1 on  | Set DyPer1 on     |
| dyper 1 off | Set DyPer1 off    |
| dyper 2 on  | Set DyPer2 on     |
| dyper 2 off | Set DyPer2 off    |

## SD adapter header

SD adapter header (**p9**) is an IDC 2x4pin header straight type 2.54mm pitch. The connector is used for microSD card connection with DUT or card reader located on the muxPi bottom side.

| Description | Pin # | Pin # | Description |
|-------------|-------|-------|-------------|
| DAT2        | 1     | 2     | DAT3        |
| CMD         | 3     | 4     | VDD         |
| CLK         | 5     | 6     | GND         |
| DAT0        | 7     | 8     | DAT1        |

Instruction on how to operate SD adapter through muxPi is described in the [SD card multiplexing](#) section.



## UART header

UART header (P4) is a 2x4pin male header straight type 2.54mm pitch. It is used for serial communication between muxPi and Device Under Test. It is possible to set the desired voltage level with the help of onboard voltage generator (range is from 0 to 5000mV). Device powered from **Vloc** pin must not draw more than 50mA.

| Description | Pin # | Pin # | Description |
|-------------|-------|-------|-------------|
| DUT RX      | 1     | 2     | VCC         |
| DUT TX      | 3     | 4     | Vloc        |
| DUT CTS     | 5     | 6     | NC          |
| DUT RTS     | 7     | 8     | GND         |

- DUT RX - receiver data line,
- DUT TX - transmitter data line,
- DUT CTS - Clear To Send (hardware handshake),
- DUT RTS - Ready To Send (hardware handshake).

**NOTE:** RX, TX, CTS, RTS lines are already crossed on board!

- **vcc** - DUT power pin (if DUT lacks power pin then attach jumper between **Vloc** and **VCC** pins),
- **Vloc** - local voltage pin - voltage can be generated internally on MuxPi through Cortex-M0 (command `uart 3300` sets UART voltage to 3.3V),
- **NC** - not connected,
- **GND** - ground.



## USB and ETH connectors

- 1xUSB (P16) is a type A USB Host interface derived directly from NanoPi NEO platform. The power supply of this port is not switchable and is always present.
- 2xUSB (P17) is an additional type A USB Host interface connected to NanoPi NEO through onboard USB HUB USB2640.
- ETH (J3) is a standard RJ45 connector with built-in LEDs and transformer. Port is connected to LAN9500A ETH-USB converter which is connected to USB HUB.

**NOTE:** ETH and upper USB of double USB socket share the same USB channel from USB HUB. For more information refer to [Jumpers](#) section.

- USB-M header (J5) is a 1x5pin female header straight type 1.27mm pitch. It is used for communication with Samsung mobile devices.

| Description | Pin # |
|-------------|-------|
| USB D-      | 1     |
| USB D+      | 2     |
| ID          | 3     |
| VBUS        | 4     |
| GND         | 5     |

- **USB D-** - USB data line,
- **USB D+** - USB data line,
- **ID** - pin controllable by ID switch connected with 1M potentiometer,
- **VBUS** - switchable 5V power line,
- **GND** - ground.

Additional UART/USB switch allows mobile USB data lines redirection to USB (NanoPi) or UART (DUT).



## Addon headers

muxPi has built-in 2 addon headers for extension capabilities:

- left addon (P13):

| Description | Pin # | Pin # | Description |
|-------------|-------|-------|-------------|
| 5V          | 1     | 2     | VDD         |
| 5V          | 3     | 4     | 3V3         |
| I2C0 SDA    | 5     | 6     | I2C0 SCL    |
| DBG UART TX | 7     | 8     | DBG UART RX |
| USB B+      | 9     | 10    | USB B-      |
| USB A+      | 11    | 12    | USB A-      |
| GND         | 13    | 14    | GND         |
| GND         | 15    | 16    | NC          |

- 5V - power supply - not switchable - always present,
- 3V3 - switchable (controlled by NanoPi) 3.3V power supply,
- I2C0 SDA - I2C0 SDA line connected to NanoPi,
- I2C0 SCL - I2C0 SCL line connected to NanoPi,
- DBG UART TX - UART0 (debug) of NanoPi,
- DBG UART RX - UART0 (debug) of NanoPi,
- USB B+/-, USB A+/- USB host lines connected to NanoPi through USB HUB,
- GND - ground lines,
- NC - not connected.



## Addon headers

- right addon (**P15**):

| Description | Pin # | Pin # | Description |
|-------------|-------|-------|-------------|
| SPI0 CLK    | 1     | 2     | SPI0 MOSI   |
| SPI0 CS     | 3     | 4     | SPI0 MISO   |
| PI GPIO 1   | 5     | 6     | PI GPIO 2   |
| PI GPIO 3   | 7     | 8     | ST GPIO 1   |
| ST GPIO 2   | 9     | 10    | ST GPIO 3   |
| ADC1        | 11    | 12    | ADC2        |
| GND         | 13    | 14    | GND         |
| GND         | 15    | 16    | GND         |

- **SPI0 CLK** - SPI0 clock line,
- **SPI0 MOSI** - SPI0 data output from master line,
- **SPI0 CS** - SPI0 chip select line,
- **SPI0 MISO** - SPI0 data output from slave line,
- **PI GPIO 1/2/3** - NanoPi NEO general purpose I/O (ports **PG11**, **PL11**, **PA17** respectively),
- **ST GPIO 1/2/3** - Cortex-M0 general purpose I/O (ports **PB3**, **PB4**, **PB5** of STM32F03C6T6 respectively),
- **ADC1/2** - analog inputs connected to ADC converter of Cortex-M0 microcontroller (ports **PA1**, **PA2** respectively, voltage range: 0 to 3.3V),
- **GND** - ground lines.



## HDMI connector

Full sized HDMI connector with connected only DDC channel wires, hot plug pin, **VCC** and **GND** pins. It is used for EDID injector into Device Under Test HDMI output. EDID writing over HDMI feature is controllable through STM32 Cortex-M0.

## Power connector

Power connector (**CON1**) is a standard barrel jack 5.5/2.1mm connector. It is used for powering the muxPi board. Recommended power supply parameters should provide 5V/2A (muxPi average power consumption should not exceed 1A).

## DUT power connectors

DUT power input connector (**P3**) and output connector (**P2**) is a 2 way, pluggable terminal socket with 5.08mm contact pitch dedicated for Device Under Test power supply. The output state is controlled through a relay. The power line is galvanically isolated from the rest of components thanks to the use of Hall effect current sensor ACS712ELCTR-05B-T (connected to the unswitchable power line). This enables DUT current measurement up to 5A.

| Command | Description                              |
|---------|------------------------------------------|
| current | Print current [mA] being consumed by DUT |



## Relay

Relay (RL1) is an electromagnetic switch for controlling Device Under Test power supply.

Technical reference:

- 1 Form A (SPST-NO) contact arrangement
- Rated coil voltage: 5V DC
- Max. carrying/switching current: 5A
- Max. switching voltage: 250VAC/150VDC
- Coil resistance: 125 Ohms
- Min. expected life: 5 000 000 operations (mechanical), 100 000 (electrical)

Relay state is controlled through the STM32 Cortex-M0 unit:

| Command    | Description     |
|------------|-----------------|
| power      | Get relay state |
| power on   | Power on DUT    |
| power off  | Power off DUT   |
| power tick | Power cycle DUT |



## User interface

muxPI builtin interactive user interface elements:

- Power LED (**D7**) - red LED indicates the presence of power supply,
- SD reader LED (**D6**) - blue LED indicating internal SD card reader activity,
- UART VCC LED (**D9**) - red LED indicating the presence of UART target voltage,
- LED 1 (**D4**) - general purpose, green LED connected directly to NanoPi NEO GPIO,
- LED 2 (**D5**) - general purpose, red LED connected directly to NanoPi NEO GPIO.

| #Pin (board) | # Pin (WiringNP) | Description | Low state "0" | High state "1" |
|--------------|------------------|-------------|---------------|----------------|
| 12           | 1                | LED 1       | LED off       | LED on         |
| 13           | 2                | LED 1       | LED off       | LED on         |

- RGB1 (**LED1**), RGB2 (**LED2**) - two general purpose RGB LEDs connected to Cortex-M0 microcontroller.

| Command     | Description    |
|-------------|----------------|
| led         | Get LEDs state |
| led 1 R G B | Set LED1 color |
| led 2 R G B | Set LED2 color |

**NOTE:** R, G, B values range from 0 to 255.



## User interface

- 128x32 OLED Display - general purpose 0.96" yellow, graphic display controllable through Cortex-M0 unit:

| Command                   | Description                                     |
|---------------------------|-------------------------------------------------|
| clr                       | clear display                                   |
| text x y color content    | print "content" on display at given coordinates |
| draw object x1 y1 [x2 y2] | draw "object" on display at given coordinates   |

**NOTE1:** Valid "objects":

- point x y color - draws one point at given coordinates,
- line x1 y1 x2 y2 color - draws line between given coordinates,
- rectangle left top width height color - draws line between given coordinates,
- circle x y radius color - draws line between given coordinates.

**NOTE2:** "color" must be **on**, **off** or **inv**

- 2x push buttons - two general purpose buttons connected to Cortex-M0 unit

| Command | Description        |
|---------|--------------------|
| key     | Get buttons states |
| key 1   | Get button1 state  |
| key 2   | Get button2 state  |



## Shopping kit

Full muxPi validation set includes:

| Category     | Description                                                     | Quantity |
|--------------|-----------------------------------------------------------------|----------|
| device       | muxPi v1.4                                                      | 1        |
| control unit | NanoPi NEO v1.31 512MB RAM version                              | 1        |
| power supply | 5V/2A (5.5/2.1 mm DC Jack)                                      | 1        |
| storage      | SanDisk 16GB microSD card (with preinstalled compatible system) | 1        |
| cables       | IDC 8-pin to microSD adapter                                    | 1        |
| connectors   | 2-ways pluggable terminal block for DUT power supply            | 2        |
| spacers      | Polyamide M3 spacers and bolts                                  | 4        |

Price: ~256 €



## Revision history

Up to date revision history can be tracked at:  
<https://github.com/SamsungSLAV/muxpi/blob/master/hw/MuxPi/changelog.txt>

### 1.4 - 2019-05-21

- Added symbol to OLED display footprint to indicate where the first pad is,
- placed P14 header on the top side,
- added descriptions for the P1, P13 and partly P15,
- added missing assembly footprints for many elements.

### 1.3 - 2018-08-14

- Added alternative power supply for NanoPi NEO debug UART<->USB converter,

Previously the converter was powered from USB cable. As it turned out it has to be powered even when it's not connected to any PC.

- Change few footprints to more convenient ones,
- Change current measurement circuitry.

### 1.2 - 2018-04-20

- Fixed footprint for NanoPi NEO debug UART converter,
- fixed (partially) current measurement circuitry,
- fixed SD-MUX power supply switching circuitry (inverted `SOCKET_SEL` signal),
- adjusted to NanoPi NEO v1.3 keeping compatibility with v1.2 and v1.1.



## 1.1 - 2018-02-01

- Added Cortex-M0 flashing from NanoPi NEO capability,
- added reverse-polarity protection,
- added USB-M circuitry,
- added voltage genreator for DUT UART,
- added NanoPi NEO debug UART converter,
- changed SD-MUX power supply switching circuitry (MOS -> PNP),
- removed one connector (TS side) for microSD flat cable.

## 1.0 - 2017-01-18 - never published

- Initial release
- Main components:
  - NanoPi NEO v1.1 and v1.2 compatible socket,
  - 4-wire UART level shifter,
  - Watchdog timer (ATtiny),
  - Power control & current measurement,
  - STM32 microcontroller handling:
    - SD-MUX module,
    - DyPers,
    - UI (OLED 128x32, 2xRGB LED, push buttons),
    - HDMI/DDC,
    - DUT's power switch,
    - DUT's power consumption measurement.
  - 2 port USB hub with integrated SD card reader
  - USB<->ETH converter,
  - SD-MUX,
  - 2x 2-channel DyPers,
  - HDMI/DDC.