STM32 based USB to MIDI or RS-232 Interface

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This is a DIY construction manual for a small USB to MIDI(or RS-232) interface based on the **STM32F042F6** microcontroller (20 pin TSSOP). Hard – and firmware fit for **STM32F070F6** (20 pin TSSOP) processors too, except the USB synchronized system clock (no quartz oscillator).

Alternatively a functionally equivalent device can be built on a Veroboard as a kind of shield (or better say "base board") for the **STM32L053-, the STM32F411, the STM32F446 and the STM32L476 Nucleo-64 modules.** This solution is less elegant but takes less "technological skills". Detailled description see below.

Though a number of SMD parts is used, technology is held as simple as possible. The prototype board is bathroom made and freehand assembled.

The interface is "full speed USB2.0" grade. USB class selection between MIDI and CDC class (= virtual COM port for RS-232) is made by a jumper near the USB socket (may be connected to a switch). The 5V supply is scaled down by a linear low drop regulator to 3.3V which supplies the complete board except the serial output driver (total supply current about 26 - 30mA, depending on operation conditions).

The basic mode of operation is "transparent" bidirectional transfer of a byte stream. A simple combined MIDI and RS-232 port hardware is provided on the board with separately wired connectors. Depending on the activated USB class, the device works as a standard MIDI interface or as an external RS-232 port. A dual LED signals presence of power and data flow.

Two rows of pinheads (or socket arrays, as user prefers) are provided in the middle of the PCB, which break out all I/O pins of the microcontroller for additional tasks or "shields".

Supported by the provided firmware, up to 6 potentiometers and 1 pushbutton (or no potentiometers and 7 pushbuttons) can be installed there to trigger user programmable MIDI messages laid over the "transparent" data transfer.

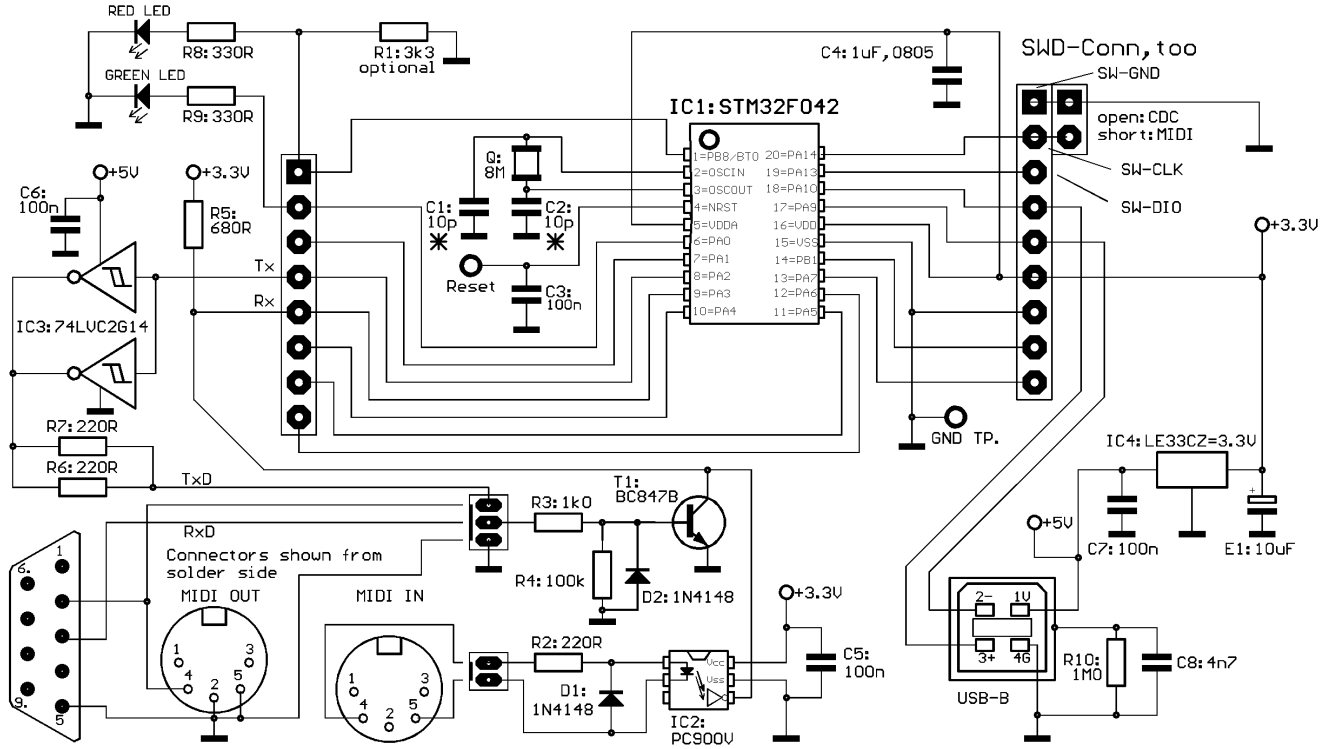
The board is preferably programmed with ST-LINK, which is connected to the upper 3 pins of the pinhead next to the USB connector. Wires for power and reset are not necessary. Alternatively, but less comfortably, the module can be programmed with the STM Flash Loader via the on board RS232 connector. Unfortunately the loader supports only USART1, which is not directly available because USB is mapped on these pins. A workaround is shown below.

In RS-232 operation, a special configuration mode can be activated. Here, for use as USB virtual COM port baud rates 9600, 19200, 38400 , 57600, 115200, 230400 plus MIDI (31250) are user configurable. **These baud rates are configurable independently for MIDI (USB MIDI class, Jumper set) too.** With the extended baudrate options, the device is useful as a data bridge between RS-232 and MIDI "worlds". Furthermore user specific USB Vid/Pid are configurable as well as MIDI messages to be triggered by pushbuttons or potentiometers. The user setup is stored nonvolatile in the microcontroller flash.

Hardware for STM32F042

For easy reproduction with simple tools, the hardware is built on a single layer PCB with a small number of jumper wires. Thickness and spacing of the printed wires are designed for hobbyist technologies. Assembly is made with a mixture of through hole and SMD parts.

Schematic diagram:



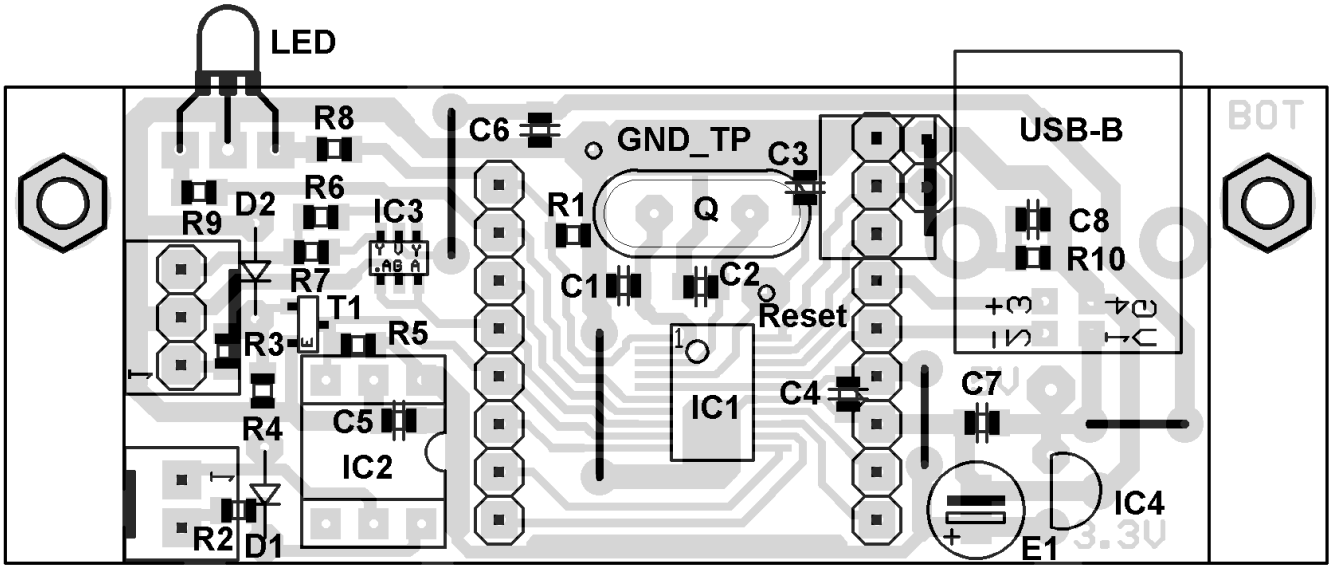
The serial output driver of the actual hardware version is equiped with a 74VHC2G14 push-pull MOS driver. This improves noise immunity of long RS-232 cables with respect to previous hardware. Crosstalk from the serial input (0 Volt out voltage, RS-232 'Mark' state) happened sometimes with the high side driver of the previous hardware.

The board can be assembled without or with quartz Q plus capacitors C1,C2

(see special firmware. Without quartz, the STM32F042 HSI oscillator is active USB synchronized. With quartz, the board can be operated standalone as a MIDI stompbox with pushbuttons and pots - battery powered, no USB). The STM32F070 processor is not provided with the feature HSI synchronisation by USB, so it must be operated with quartz Q !

Assembly:

This assembly drawing is shown from the **solder side**!
All SMD resistors and capacitors are size 0805.



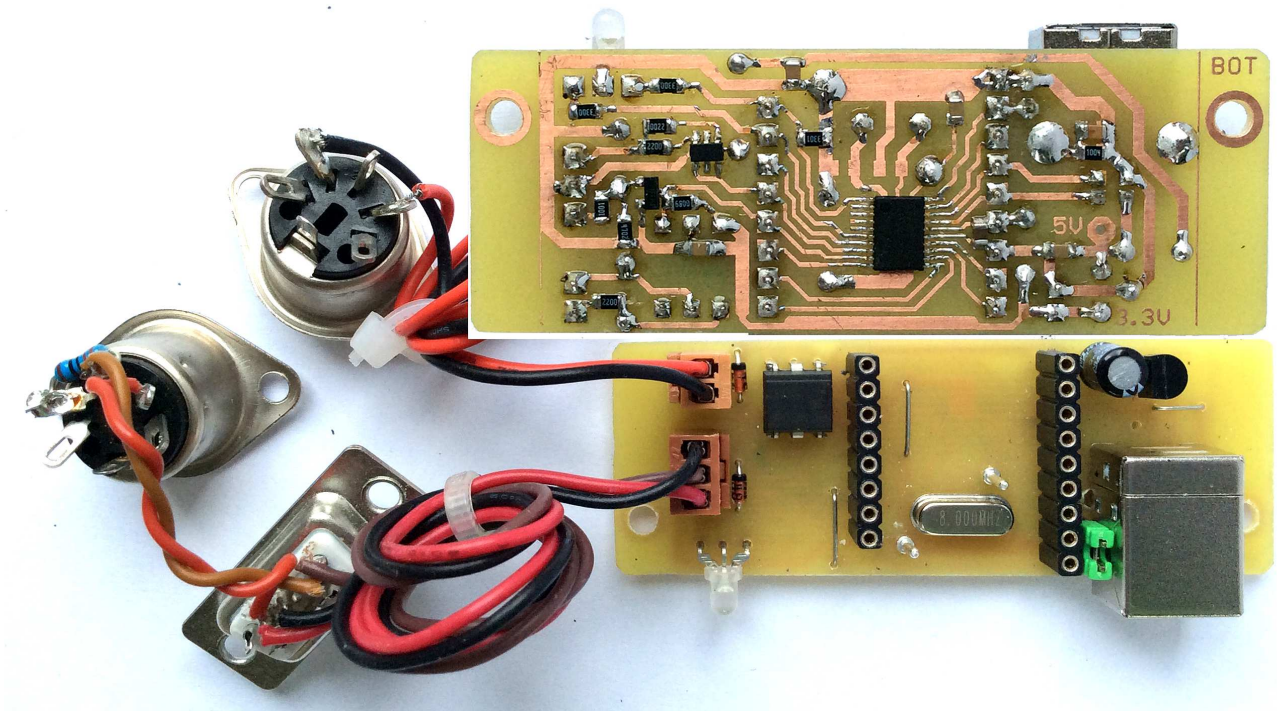
If Q is assembled, most times the quartz oscillator works best, when C1 and C2 are not assembled. So it is recommended not to solder C1 and/or C2 and perform a first test with the assembled board. If the oscillator won't start reliably then, first try 1=C2=4.7pF or one capacitor with 10 pF.

The LED has to be mounted with the flattened side towards the PCB to get the colors as described in the text.

R1 is only necessary to pull the BOOT0 (PB8) pin down if the leakage current of the LED is not sufficient.
The Reset pin is only necessary for programming via USART.

Special parts: (suppliers are for example. Components are available from others, too)

IC1: STM32F042F6P6, STM32F070F6P6 source: www.tme.eu, Mouser, RS Components, Farnell
IC2: PC900V, source Conrad 184098
IC3: 74LVC2G14GV (SOT23-6 or SOT457 case pitch0.95mm), source Reichelt
IC4: 3.3 V regulator LE33CZ, source Conrad 1185305
Q:standard quartz HC49, 8.000 MHz.
Frequencies 4.000,6.000,12.000,16.000 MHz may be used, hex codes are in the BIN volume of source.ZIP.
No quartz option is available only for STM32F042.
LED: V-L-115-WEGW, source Conrad 187496. Flattened side directed to PCB for correct colors.
Other dual red/green LED types may be used, but then values of R8 and R9 have to be adjusted
Optocoupler: PC900V, source: Conrad 184098
C4: Murata High Cap, source: Reichelt X7R-G0805 1,0/25
connectors for MIDI/RS-232: source Reichelt PS 25/2G BR, PS 25/3G BR. Connectors may be soldered directly.



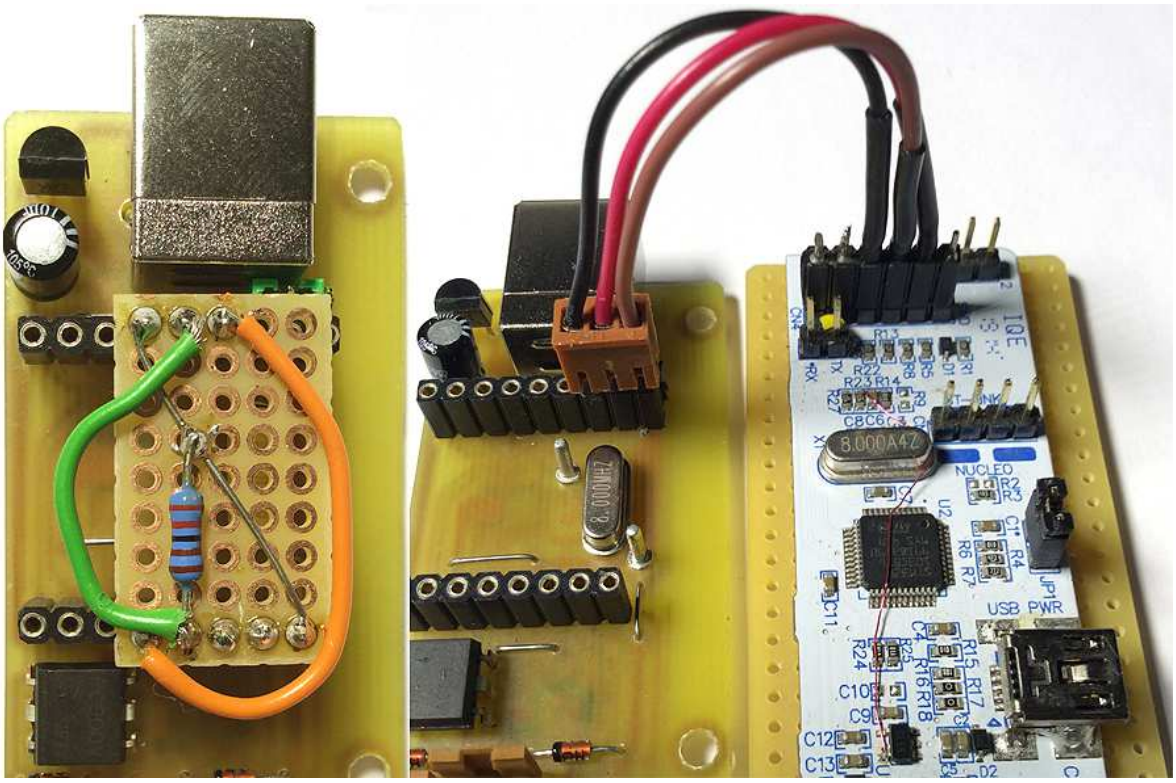
Programming

STM provides two quite useful but different programming tools.

Very comfortable programming is possible with the ST-LINK hardware and software. Instead of buying a dedicated ST-LINK module it is recommended to get a STM Nucleo-64 module, which can be configured as programmer. It is less expensive and additionally it may be used for other experiments with STM32 microcontrollers. How to program external parts with the Nucleo, read its manual. A special driver packet must be downloaded from the STM website and installed. When the programmer is used standalone and the programming software sends a problem like "no target voltage", connect the 3.3V output (pin next to text U1) of

the regulator (5 pins) on the ST-Link part with R23 (4.7 kOhm, pad directed towards the SWD connector) to pretend a supply voltage of the programmed device.

Build a short programming adaptor (see picture below, wire length max 25 cm)**:**
--- connect the 2nd pin of the Nucleo SWD connector (counted from the side towards the Mini USB connector) with pin PA14 of our board.
--- connect the 3rd pin with Ground of our board.
--- connect the 4th pin with pin PA13 of our board.
These pins are broken out at the socket array near the USB connector, order see schematic.
--- start the ST-LINK software. Click item "Connect" of the "Target" menue. After some seconds, a screen with the connection report and a listing should appear. In seldom cases it is necessary to reset our board for a moment while you connect it with ST-LINK. When you are connected, select "Program&Verify" from the "Target" menue and upload the hex code. After programming, remove the programming adaptor.



These photos are shot with the previous hardware version. But the procdure is the same

If no special programmer is available, the module can be programmed with the "STM FlashLoader" via the on board RS232 connector - but the ST-LINK works much better. Unfortunately the loader supports only USART1, which is not directly available because USB is mapped on these pins. The user RS-232 interface works with USART2. Following practical workaround is proposed:

First download and install the STM Flash Loader. Then build a small Veroboard as follows:
--- connect pin PB8 (red LED) with +3.3Volt (solid wire in the picture).
--- connect the TX of USART1 (= Pin PA9 = USB- pin) with TX of USART2 (PA2) (green wire in the picture). This pin has to be lifted to 3.3 Volt idle state with a pull-up resistor of about 2.2 kiloOhm (exact value is uncritical)
--- connect RX of USART1 (=pin PA10= USB+ pin) with RX of USART2 (PA3) (orange wire in the picture).

Now the device can be powered with 5 Volt via the USB connector, **but it is essential, that the USB cable is rather short and there is absolute no digital signal or other electric noise on the USB data wires!** If no USB power supply or USB power bank is available, any d.c. supply 4V up to max 5.5V can be used. Take care for correct polarity and connect it at the USB SIDE OF THE REGULATOR ! The LED on our board should light up red.

Connect the onboard RS-232 with a (real or virtual) COM port of your PC. Start the STM Flashloader software. There select the COM port number you are using and optimally 57600 Baud. Leave the other settings as proposed.

Immediately before you click "Next" at the STM Flashloader window, make a reset of our board: short the test pin in the middle of the PCB side with the Ground test pin near to the mPCB edge. When you have clicked "Next" a dialog with a green lamp symbol should appear. If so, follow the hints on the screen. Sometimes the Flashloader does not detect the microcontroller correctly, shows "STM8.." or so. Then disconnect power, restart the Flashloader and repeat the action.
If connection fails, don't resignate, check everything and repeat the action carefully. Sometimes the Flashloader is headstrong.

Installation and Operation (some commands and features are changed with respect to earlier versions)

In default state, the board is connected to a virtual COM port at the PC. This can be observed with the Windows Device Manager. When USB is connected the first time, the driver has to be installed. If you already have installed the "STM32 Virtual Com Port Driver" (is done together with the ST-LINK software), by default our board uses the same driver and will be listed under "COM and LPT ports" as "STMicroelectronics Virtual COM Port". Else download the "STM32 Virtual Com Port Driver" from the STM website and install it. You can change the COM port number under "advanced settings" in the Device Manager. Else keep the default settings. The baud rate is not relevant in this case, any works.

When a connection is made between pin PA14 and Ground (short the two pins near the USB connector), the board starts as native MIDI interface. When the USB cable is connected first, a driver gets installed automatically (Windows XP or later). In the Windows Device Manager it appears under "Audio-,Video & Game Controller" as "USB-MidiCom" or sometimes simply as "USB-Audio Device".

When the jumper is set or removed during operation, the board performs a new USB enumeration within 1-2 seconds. Unfortunately, a MIDI software or Virtual COM port on the PC has to be closed then (do it before before mode change, else deadlock !) and restarted after.

Without further configuration, the local serial I/O works as a RS-232 interface, data format 8N1 (default 115200 baud, independent of the setting at your PC) or as a native MIDI interface (with MIDI baudrate).

To get into the user setup mode during RS-232 operation, type tree times a plus "+++" within max 1 second and one second no input before and after (as known from legacy modems). A prompt "CMD>" appears. Here you can enter some single character command codes followed by numeric input as described below. All input is case independent. Wrong input is refused with a question mark "?". Then simply repeat the command. Else the interface is held quite simple, Backspace is not supported. You can leave the setup mode with comamnd 'E'.

command 'B': enter the desired serial baud rate for the serial connectors with its two leading characters: 96, 19, 31(=MIDI), 38, 57, 11 or 23. The rest is inserted automatically. Default is

115200 Baud. The new baudrate is not active before the next USB enumeration and only if stored in Flash explicitly. This setting is effective when **operated as virtual COM port**.

command 'S': same features as "B", but effective when **operated as USB-MIDI interface**. In this case, the default baud rate is MIDI.

command 'V': enter your own USB Vid as a **4 digit hex number** (leading zeroes must be typed). Then a letter "P" appears and you enter your own USB Pid the same way as a 4 digit hex number. By default the STM Vid/Pid is used, **but this is only allowed for test and evaluation inside your shack! For any public use, your individual Vid/Pid must be activated!** It is stored permanently when you leave the setup with command 'E' and can be reset to the default by entry of Vid = 0000 and Pid= 0000. To install the device with your own Vid/Pid, for example you could copy and rename the file "stmcdc.inf" and change the respective entries with an ASCII text editor. Install it "manually".

commands '1,2,3,4,5,6 or 7': configure which MIDI message shall be sent when the corresponding microcontoller pin is connected to Ground (pushbutton) or, if configured as analog input, when the voltage changes (potentiometer between 3.3V and Ground).
First, letter "S" is prompted. Then enter the **MIDI status byte** you want to be sent in **2 digit hex format**. If you enter only the first nibble, 8,9,A,B,C,D,E plus carriage return or with leading zero, a preconfigured constant MIDI channel is inserted (see command 'M'). This way the MIDI channel can be changed easily for all messages with a single command. If you have entered F6,F8,FA,FB,FC,FE,FF, the input is complete now. Undefined MIDI messages (F4,F5,F9,FD) and SysEx messages (F0…F7) are not supported and prompted with "?". If you have entered 8x ,9x, Ax, Bx, Ex or F2 (3 byte MIDI messages) next the letter "N" is prompted and you enter the first MIDI data byte **(note pitch, controller number) as a 2 digit hex number.** Finally the letter "V" is prompted and you enter the second MIDI data byte to be sent (or the only one for 2 byte MIDI messages) **as a 2 digit hex number.**
If the corresponding input shall be driven by a potentiometer, enter "80" as second data byte. Usually the potentiometer is evaluated in 7 bit format. For MIDI Pitch Wheel Change (status Ex), you can enter as special case "81", too. Then the potentiometer is evaluated in 12 bit format. Unfortunately the AD converter of this simple hardware is rather instable then.
If a **Note On** is configured, the corrensponding Note Off is sent when the button is released.
The **message can be deleted** (flash reset to empty state) when you enter S00.
The command numbers are assigned as follows:
1 corresponds with PA1, **2** with PA4, **3** with PA5, **4** with PA6, **5** with PA7, **6** with PB1 and **7** corresponds with PA13.The latter is the only one which has no analog capability and can exclusively be triggered by a pushbutton. When the board runs in RS-232 mode, the triggered MIDI messages are sent in ASCII hex format (if activated).

command 'M': insert the commonly used MIDI channel **1…16 in decimal format**. The MIDI channel inserted as low nibble into the MIDI **status byte - is always one less (0…F).**

command 'G': parameter "1" activates trigger of user defined MIDI messages globally, parameter "0" (zero) suppresses them temporarily, but does not delete any.

command '?': shows a list of command codes.

command '!': shows a list of actual setup (active and/or state stored in Flash)

command '|': saves the actual setup incl new changes in Flash

command '@': reloads the stored setup from Flash memory and cancels new changes

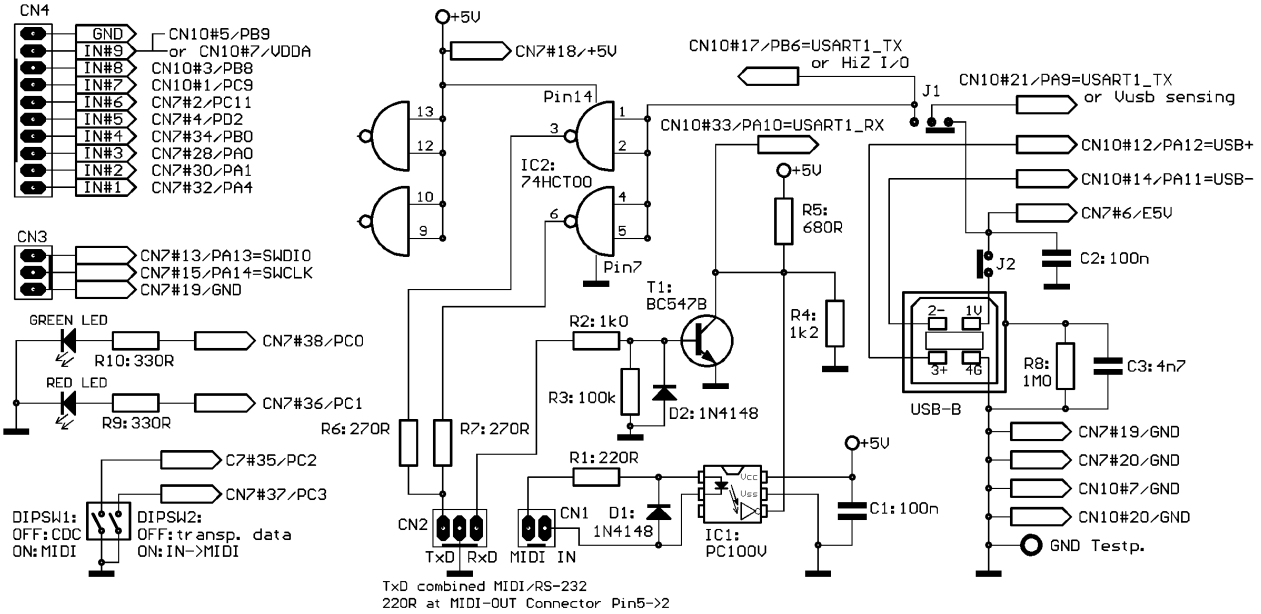
command 'E': quits the setup mode back to "transparent" mode. You are asked to save new setup changes nonvolatile in the microcontroller flash memory.

Some commands (1,2,3,4,5,6,7,S,M,G) get active immediately, other after next Power Up

Hardware for STM32L053-,STM32F411-,STM32F446,-STM32L467- Nucleo-64

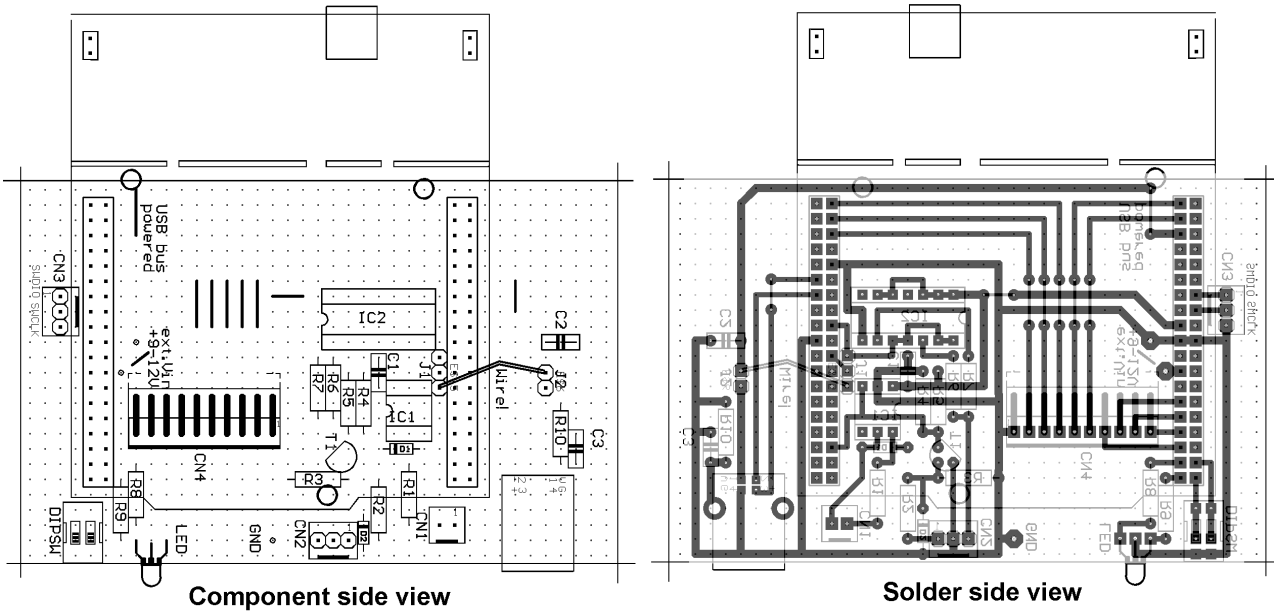
The Veroboard hardware, programming (firmware differs) and operation is the same for all Nucleo versions, but jumper J1 has to be set specifically for "HW Version1" **(STM32L053 no Vusb sensing)** or "HW Version2" (Cortex M4 models perform Vusb sensing).

Schematic diagram:



Assembly:

Because etching of PCBs is critical without experience and some tools, a Veroboard design is proposed here. **It has to be mounted below the Nucleo board** instead of in "shield" position.



Component side view **Solder side view**

Please note that the assembly diagram is drawn mirrored (solder side view) for easier wiring.

J1 sets the wiring for Vusb sensing (sensing OFF = HW version 1-> towards IC2, sensing ON = HW version 2 -> towards IC1)
J2 is only used for measurement of supply current. For longterm practical use it should be shorted with solder.

If you only need a USB to MIDI or RS-232 converter, it is not necessary to assemble the MIDI trigger wiring

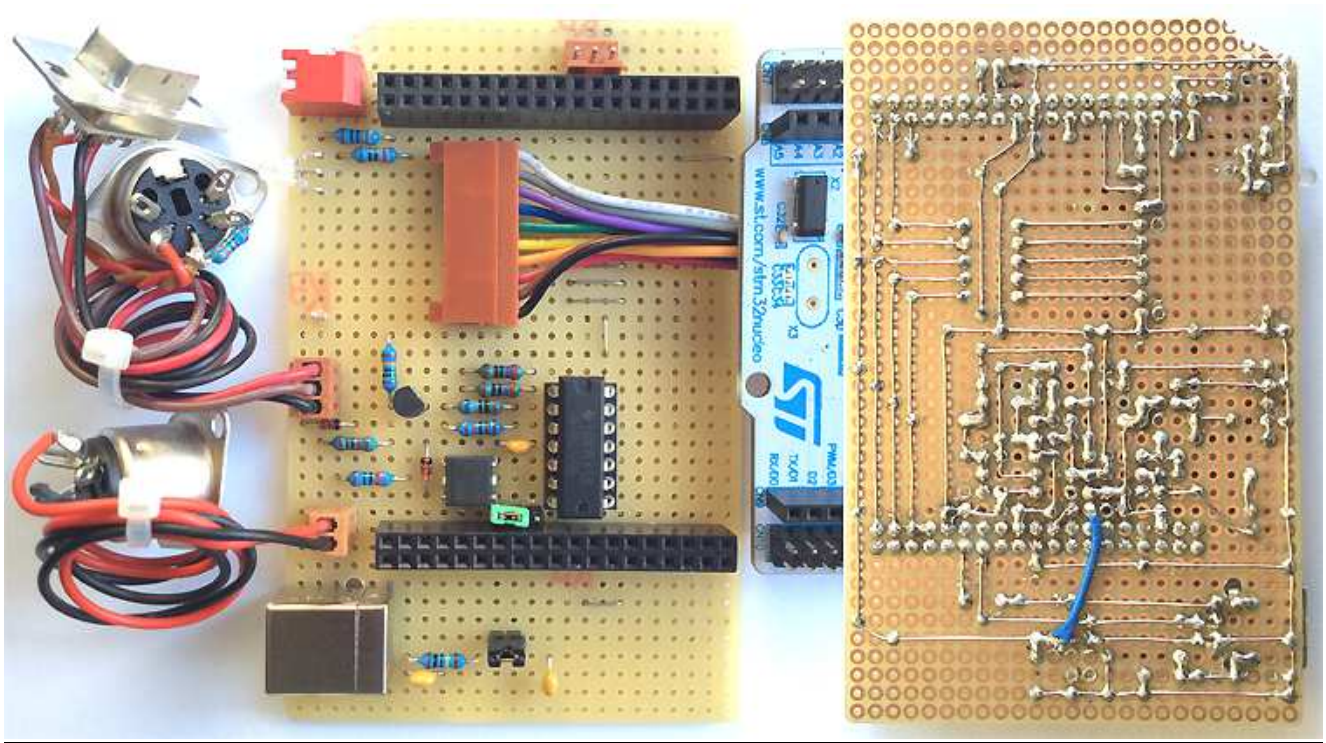
For IC2 it is essential to use a 74HCT00 instead of a 74HC00, because the HCT has a lower input threshold voltage and such works better as voltage level converter.

Take care to assemble CN3 (SWD programming connector) a little bit tilt. Else it would be difficult to connect the programmer there.

The ST-LINK programmer is already provided on the Nucleo board. For practical use and to save supply current, it may be desirable to cut off the ST-LINK part (see programmer picture above). For details see the Nucleo manual. Then the programmer module can be used standalone for external programming as described above together with the 3 pin connector provided on the Veroboard.

Special parts:

STM32xxxx Nucleo-64 board, source: Reichelt, www.tme.eu, Mouser, Farnell, RS-Components
LED: V-L-115-WEGW, source Conrad 187496. Flattened side directed to PCB for correct colors.
Other dual red/green LED types may be used, but then values of R9 and R10 have to be adjusted
Optocoupler: PC900V, source: Conrad 184098
socket arrays for Nucleo: source: Reichelt MPE 094-2-50, 2 pcs, have to be shortened manually
connectors for MIDI/RS-232/pushbuttons: source Reichelt PS 25/2G BR, PS 25/3G BR, PS25/10W BR



The USB +5 V is connected with a (blue) wire to jumper J1, because it is impossible to cross it "veroboard style" like over the Nucleo socket. The green jumper is in Vusb sensing position. After a lot of testing and some modifications, the board already looks a little bit damaged.

Installation and operation: (some commands and features are changed with respect to earlier versions)

Is quite similar as described above for the small PCB. **The DIP switch at the outer left board edge selects between RS-232 (open) and MIDI(closed).**
Trigger of MIDI messages is switched ON and OFF with the other DIP switch. The MIDI messages are laid over the "transparent" data traffic. When the RS-232 mode is active, the MIDI messages are sent as ASCII text.
The setup mode is entered the same way with three +++ and the commands codes are the same as described above. The **setup is terminated and saved** (exclusively then) when the "E" command is given.

The command characters are assigned as follows:
1 corresponds with PA4,
2 with PA0,
3 with PA1,
4 with PB0. Only these 4 have analog capability.
5 corresponds with PD2,
6 with PC11,
7 with PC9,
8 with PB8,
9 with PB9.These have no analog capability and can exclusively be triggered by a pushbutton. A 10 pin connector is provided on the Veroboard to connect these pins with a user designed control panel.

> **Attention: when potentiometers shall be used for analog input, PB9 (or the wire leading to PB9) must be connected with the AVDD pin next to it. The connection itself does no harm to PB9, but NO PUSHBUTTON IS ALLOWED TO BE CONNECTED THERE !**

Finally with **Comand 'U'** a MIDI message may be assigned to the blue "User Button" on the Nucleo board. This is connected with PC13 and externally acessible at CN7,Pin23.

The supply current of all Cortex M4 versions including the ST-LINK part and inclusive some potentiometers varies between about 65 and 80 mA. Particularly each LED of the ST-LINK part uses about 10mA! When the ST-LINK part is cut off, the supply current is in the order of 32-35 mA. The STM32L053 takes about 5 mA less current.

The firmware is programmed straightforward on register level, no "libraries" are used. Especially the USB implementation is totally different for the Cortex M4 microcontrollers (USB_OTG vs. USB_FS for STM32F0xx,L0xx).

The STM32L476 is driven by a free running oscillator (MSI clock) which is locked with the 32kHz quartz crystal mounted on the Nucleo board (LSE clock) and provides very good stability.

The STM32L053, STM32F411 and the STM32F446 use a quartz clock oscillator (HSE clock). The **STM32L053 needs different hex codes** for unmodified Nucleo board and ST-LINK part cut off (distinguish external HSE clock from CPU internal quartz oscillator).

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