CAN-level shifter for MOPS (Version 4.24)
with trimming signal generator and power

Technical Information / Short User Manual

Peter Kind, University of Wuppertal, 02.08.2024
kind@uni-wuppertal.de

Features

- Interface between standard CAN-Bus (typ. 5 V or 3.3 V) and MOPS-CAN-bus (1.2 V)
- trimming signal generator for MOPS
- power supply for MOPS (typ. fix 1,90 ± 0.05 V, optional adjustable, see appendix)
- powered by micro-USB-connector (optional via CAN connector)

General

The device allows to connect a commercial CAN bus interface to the MOPS chip. The MOPS chip complies with the communication standard of the CAN bus, but the build in physical layer in 65nm technology can only handle 1.2V. This make this “level shifter” necessary in order to be able to communicate with a 5V (3.3V) CAN bus interface.

Warnings

The MOPS chip operates with an internal voltage of 1.2 V and would be damaged, if a normal CANH/CANL signal with levels higher than 1.2 V is applied.

The MOPS power supply voltage must never exceed 2.0 V, as this would damage the chip!

Fig. 1, top: The CAN-Level shifter in the case

Usage

1) Power the device with a standard micro-USB power supply (micro USB receptacle on the side of the box). There is no USB functionality available.
2) Connect a commercial CAN interface (e.g. Kvaser Leaf Light V2 CAN to USB) to the Sub-D9 female receptacle on the “5V CAN” side. The 120 Ohm termination resistor is already installed inside of the device.
3) Connect the MOPS chip(s) to the Sub-D9 male connector on the “1V2 CAN” side of the box. See below for the Pinout of these connectors. The termination resistor is installed inside of the device. Another termination resistor (100 Ohm) should be present close to the MOPS chip (e.g. on the PP0/EOS PCB). Up to 4 MOPS chips can be attached to a single CAN bus, but each chip has to have a unique node ID on the bus. This is set by means of the ADDCAN0/1 input pins of the MOPS.
4) Start software
   a) Monitoring program provided by CAN controller manufacturer. Runs often only on Windows. This allows to view the activity on the CAN bus and inject individual messages.
   b) Python scripts provided at (https://gitlab.cern.ch/mops/canmops). Check the Wiki for more information (https://gitlab.cern.ch/mops/canmops/-/wikis/home) how to install and operate the software. This software includes command line and GUI tools to communicate with the attached MOPS chips. The GUI displays the measured voltages as well.
   On Linux the CAN controller has to be supported by SocketCAN.

Once the device is powered, the red LED starts blinking. This indicates, that the internal trimming CAN node starts working and sends continuously the trimming messages to the 5V CAN bus.

The LED has to two blinking modes:

1) Ca. 1sec period with 50% duty cycle: CAN bus working normally
2) Ca. 1sec period with only short on time. CAN bus errors occur. This will be the case, if no CAN controller is connected, the CAN interface is not active, or in error state.

As soon as an active CAN bus is connected to the 5V side, the first LED mode should be present and the trimming messages (“0x555 AA AA AA AA AA AA AA AA”) will automatically be send. These should be visible, when monitoring the activity on the CAN bus with one of the software tools.
A newly connected MOPS chip should send its “sign-on message” within a few seconds. This message has an ID 0x700+nodeID. The nodeID depends on the setting of the ADDRCAN0/1 MOPS inputs and are in the range 0-3. This message indicates a successful start-up and trimming of the MOPS chip.

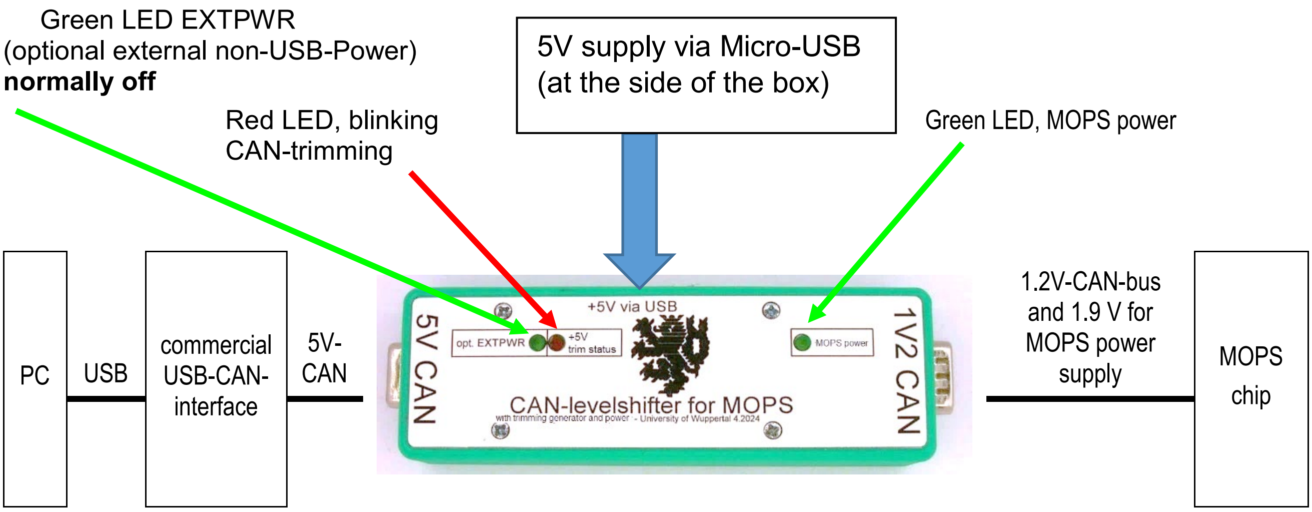


Fig. 2: Connections of the CAN-levelshifter

Example Commands and responses

The sign-on message of the MOPS chip should appear on the 5V CAN-bus a few seconds after power up. The message should look like (assuming an ID of 3):

0x703 05 00 00 00 00 00 00 00

To access channel 3 of the ADC, send the following message: 0x603 00 24 01 00 00 00 00 00

Here 00 24 is the index in the CANOpen dictionary in little endian notation. So, the index is actually 0x2400 (see MOPS manual for the implemented indices). 01 is the ADC channel number 3.

The response should look like: 0x583 43 00 24 01 13 00 00 00 00

Here the ADC count is 0x0013, again in little endian format

In case of an erroneous formatted request message, the MOPS responds with

0x583 80 XX XX XX 00 00 02 06

The last four bytes 0x00000602 contain the abort code (little endian format). In this case the requested index could not be found in the object dictionary. See the manual for details.

Technical details

The circuit consist of a 5-V-CAN-transceiver (CANH/L to RX/TX) and a 1.2-V-CAN-transceiver (CANH/L to RX/TX). Between both transceivers is a so called loop breaker logic, for details see Appendix, circuit description item d).

The frequency trimming of the MOPS chip requires to send within 5 seconds after power-up a sufficient number of bit changes. The transition edges are utilized by the chip to adjust the internal oscillator to the correct frequency. For this purpose the device contains a CAN node, which permanently sends the same message (0x555 AA AA AA AA AA AA AA AA). This message is visible on the 5V CAN bus side as well.

An internal voltage regulator provides 1.9V on Pin 1 of the Sub-D9 connector, on the 1.2V CAN bus side, to power the MOPS chip. This should cover most applications with short cables. For longer cables a higher voltage might be needed and should be supplied externally (e.g. patch cable). The internal CAN node allows to power cycle the MOPS voltage (see Appendix f) for details) by sending a CAN message 0x3F0 02 A5. This will power cycle the power for 2 seconds (first data byte defines the time.

Pinout of the connectors

"CAN 5-Volt-side" a SUBD9-female connector.		
Pin	**Signal** (name in schematic)	**comment**
2	CANL_1	5V-CAN-Bus L
3	GND	(CAN-Bus GND)
7	CANH_1	5V-CAN-Bus H
1,4,5,6,8,9	NC	No connection (can be connected to optional signals by internal pad option)

"CAN 1.2-Volt-side" a SUBD9-male connector.		
Pin	**Signal** (name in schematic)	**comment**
1 *)	VCAN+ see also “internal options”	Approx.. +1,9 V Power (plus) for MOPS (1,85 .. 1,95 V)
2	CANL_2	1.2-V-CAN-Bus L

3	GND (VCAN-)	CAN-Bus GND
6 *)	GND (VCAN-)	Power (GND) for MOPS
7	CANH_2	1.2-V-CAN-Bus H
4,5,8,9 *)	NC	No connection
*) connection can be changed by different wiring at SV2, see picture “internal options” and schematic		

USB-micro-socket.		
Pin	**Signal** (name in schematic)	**comment**
1	+5V_USB	5 V (power supply plus)
2, 3, 4	NC	No connection
5	GND	GND (and power supply GND)

Hardware options

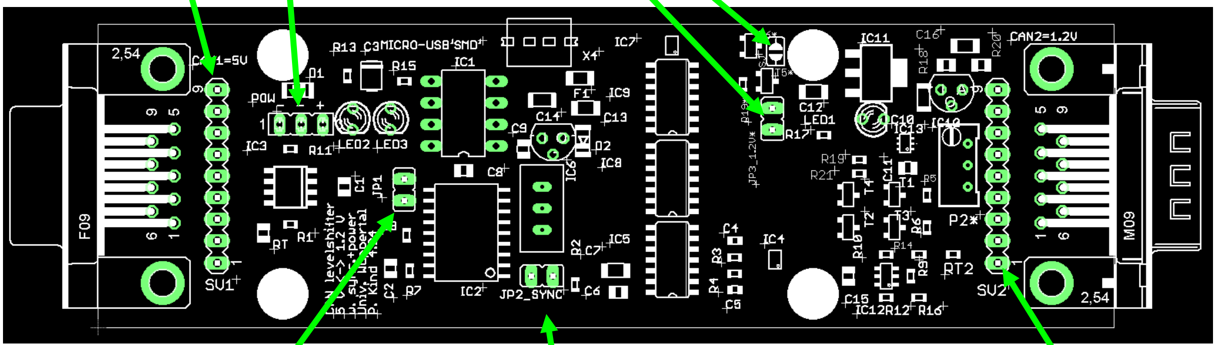
Some optional settings are available on the PCB of the device.

SV1 *gives access to all 9 pins of the 5V-CAN-SUBD9 connector.*
(pin 1 of SV1 is connected to pin 1 of SUBD9, pin 2 to 2, etc., 9 to 9)

POW: *optional external Power (if not by USB), e.g. via 5V-CAN-SUBD9 pin 1=2= minus, pin 3 = plus. needs U > 8 V*

JP3_1.2V:
closed: 1.2-V-side permanently powered
Open: 1.2-V-side power on/off optional controlled by CAN commands, see appendix
(SJ is closed)

SV2 for MOPS power
Pin 1 of SV2 = GND,
Pin 9 of SV2 = 1.9 V
Pins 2..8 gives access to all pins (except pin 2, 3, 7) of the 1.2V-CAN-SUBD9 connector.
default wiring: ***1.9 V*** *(Pin 9 of SV2) to Pin 3 of SV2 = Pin 1 of CAN-SUBD9,*
GND *(Pin 1 of SV2) to Pin 2 and 8 of SV2 = Pin 3 and 6 of CAN-SUBD9,*
because this is compatible to CIC card of MOPS-Hub.



JP1: normally unused,
optional Pins to MCP2510 CAN controller Pin 11 (/RX0BF) and Pin10 (/RX1BF)

JP2_SYNC = trimming
open/remove to DISable CAN-trimming-signals
(but the red LED3 is blinking anytime!)

optional Potentiometer for adjustable MOPS voltage (see appendix)

Appendix: circuit description, layouts and schematics

Circuit description (see schematic on following page)

Note: Text in small italic font is relevant for special options only.

The circuit consists of the following functionality groups:

a) At the upper left on the schematic the device IC3 is a commercial CAN driver (MCP2551) to transform the 5-Volt-CANH/CANL into the unidirectional RX1 and TX1 signals.

b) In the middle part of the schematic is the 1.2-Volt-CAN-interface, designed by Wuppertal. The signal "TX2_1.2V" is driven by the MOSFETs T1..T4 into CANH_2/CANL_2 which is the 1.2-V-CAN-bus. The bus signals are received and transformed into "RX2_5V" by a fast comparator IC12 (TLV3501).

c) The logic level downscaling of TX is done by IC13 (SN74LVC1T45). The output voltage level is defined by VB, which is just the forward voltage (approx. 2,0 V) of the green LED1.
In case its supply voltage VB needs to be reduced to have a "cleaner" CAN signal by the MOSFET-driver, the resistors R19 and R21 can be modified to build a voltage divider.

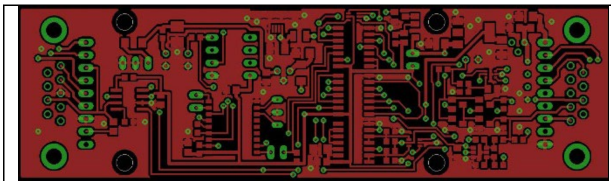
d) The most tricky part is the so called loop breaker at the upper side of the schematic between signals TX1/RX2 and TX2_5V/RX2_5V. One can NOT feed the RX1 (from IC3) directly as TX2_5V into the 1.2-Volt-driver, because this creates a loop: A dominant bit would cause a dominant state on the 1.2-V-CANH/L, this will cause a dominant bit RX2_5V and this - if also feed directly back to IC6 as TX1 - causes a dominant state on the 5-Volt-CANH/L, which causes a dominant state on RX1 and so on ... One needs an arbitration logic to prevent this loop. The circuit between IC41 and IC42 is based on a design of Texas instruments (TIDA-01487: Isolated CAN FD Repeater Reference Design).

e) To power the device, a Micro-USB-connector (X4, right side of schematic) is foreseen.
By option, this powering can be done via the 5V-SUBD9-connector. For this, the 5V-SUBD9-connector pins are available via the pins of SV1. The external power has to be connected then to the pins "POW". See descriptions above in "Internal options".
The 1.2-V-side power on/off can optional controlled by CAN commands, see f). For this, SJ near T5/T6 must be closed.

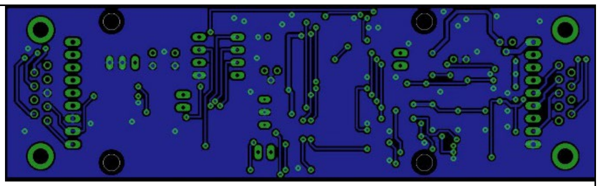
f) The IC1 and IC2 generate "trimming-signals for MOPS", i.e. periodically a simple CAN message (id = 0x555, data = 8 bytes 0xAA) is sent to the CAN-Bus to give the MOPS within the first seconds after power up signals to adjust its internal oscillator to 10 MHz.
If JP3_1.2V is open (see above "internal options"), the 1.9 V MOPS-power (and the 1.2-V-CAN-interface) can be power cycled by the following CAN message: node-ID = 0x3F2, DLC = 2,
1st data byte = length of power-off-time in seconds (1..127 = 0x01 ..0x7f), 0x00 = permanently off, 0x80 = permanently on. (don't use 0x81..0xff),
2nd data byte = 0xa5 (magic byte! Must be 0xa5, otherwise the command is ignored).
Be aware that the device remembers the power state at the next start. This means: If the power is switched permanently off by 0x00, it will still be off after a power cycle of the device and has to be enabled again by sending 0x80.
Some parameters for the trimming generator can be adjusted by special CAN commands. For details: Christian Zeitnitz (zeitnitz@uni-wuppertal.de).

g) A voltage regulator IC10 (LM317) produces from the 5-V supply the MOPS supply voltage VCAN, which is typ. 1,9 V. Via SV2, this voltage is connected to the 1.2-V-CAN-SUBD9-connector, see table above "Pin assignment".
If one needs an adjustable MOPS supply voltage VCAN, remove R18 (62 Ohm, the SMD above IC10=LM317) and insert potentiometer P2 with 100 Ohm or 250 Ohm (3/8" Square (10 mm) Multi-Turn Cermet Trimmer, size package 64W).
Take care not to exceed 2.0 V for the MOPS power supply voltage, as this would damage the chip!

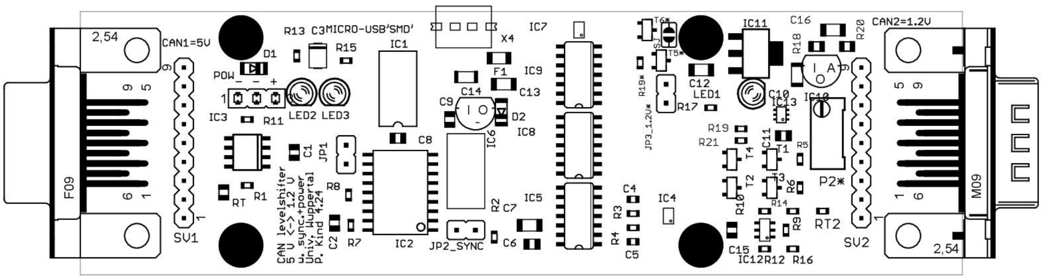
Layouts



Top layout

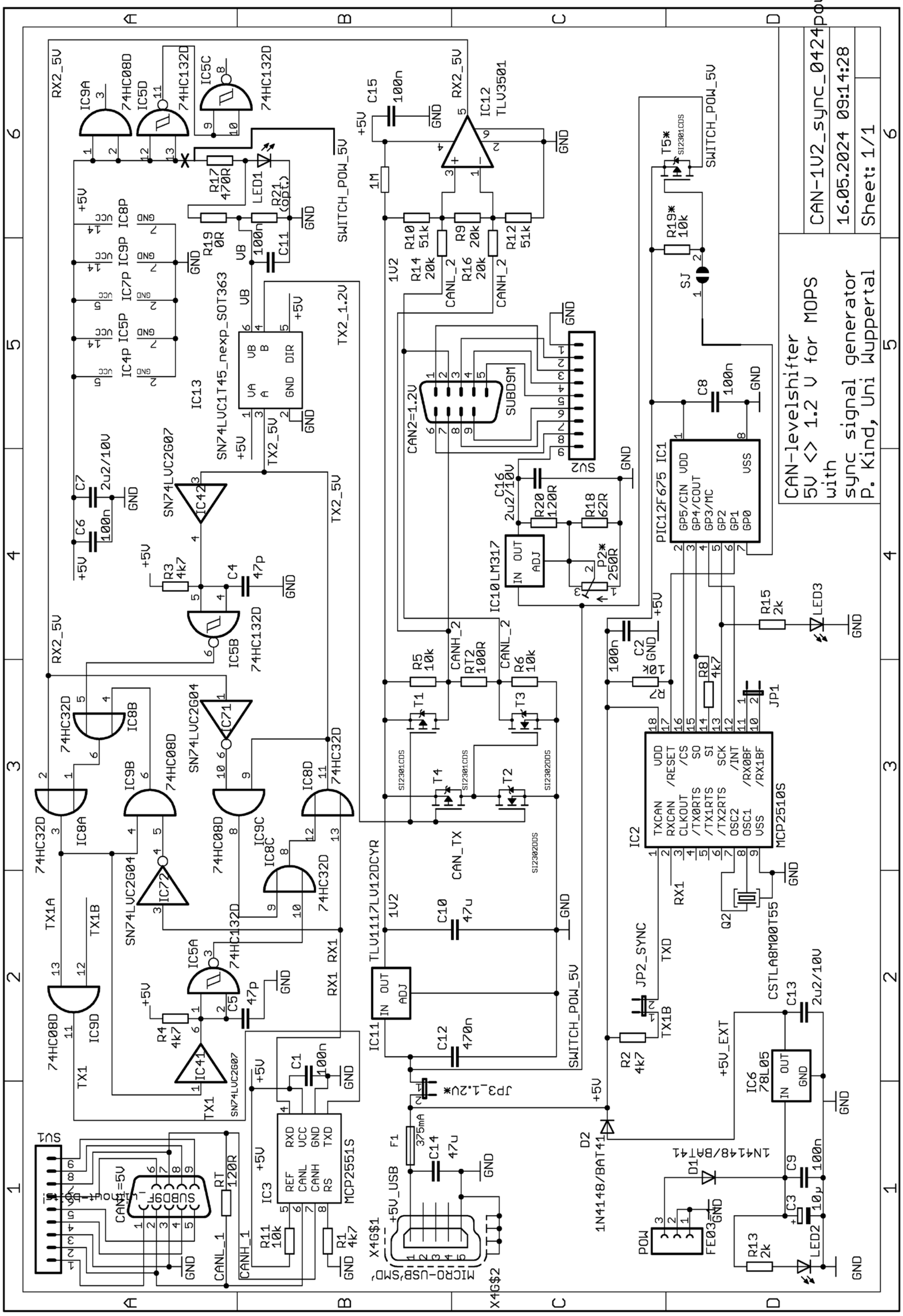


Bottom layout (mirrored)



Top placement (no parts on bottom side) see below for list of modifications

Schematic (see below, list of modifications)



Errata (modifications on version 4.24):	
- T6 (SI2302 NMOS) removed and pads bypassed, because logic of IC1 (pin 7 GP0) is inverted: GP0 is 0 for 1.2-V-CAN-power ON. GP0 is 1 for 1.2-V-CAN-power OFF - R17: +5V side disconnected, connected to switched 5 V. The LED1 is now off if 1.2-V-CAN-power is OFF. - 1 MOhm inserted between +5V and R10/R14/pin 3 of IC12 (TLV3501). This prevents a dominant bit if 1.2-V-CAN-power is switched off