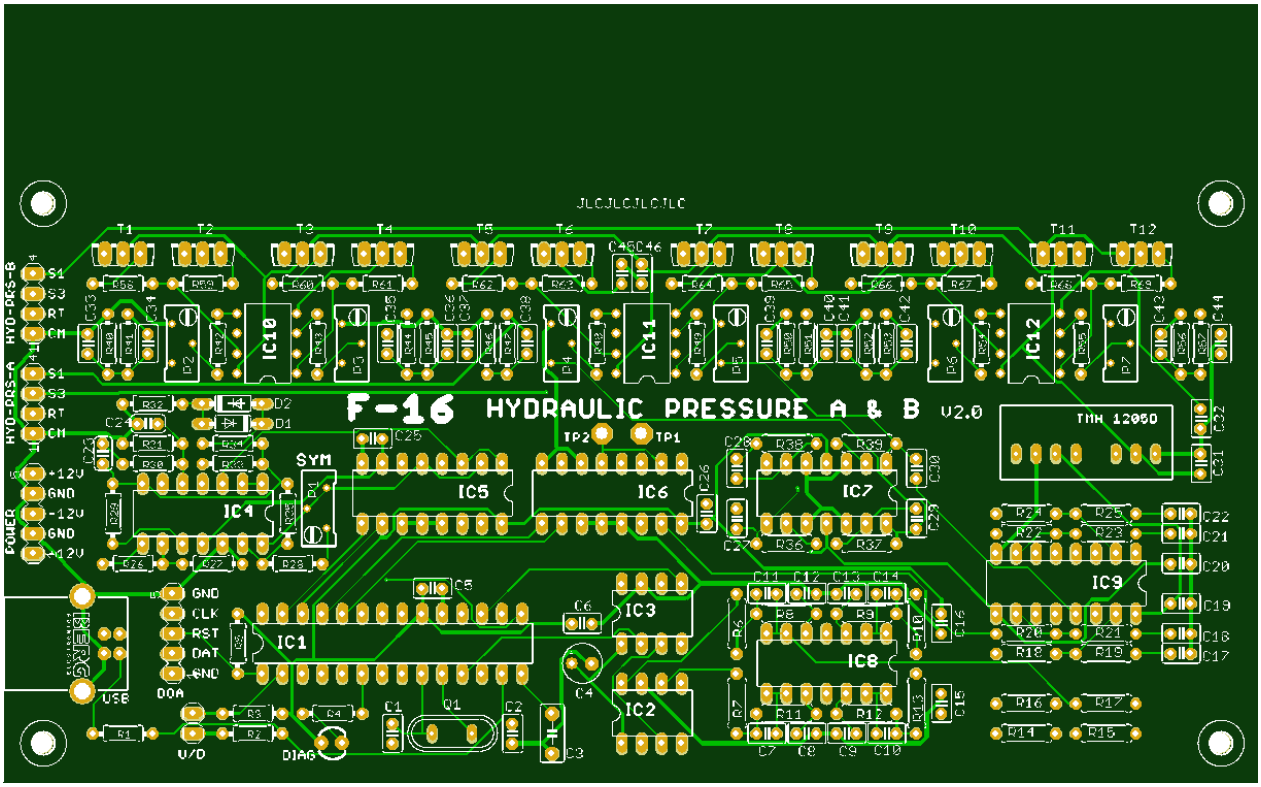
HYDRAULIC PRESSURE A/B Indicator



Controller Interface

Version: V0.1 – 27 December 2020

History

11-2020 : Draft design PCB HYDRAULIC PRESSURE A/B Indicators

Started the design based on the first version, developed some 10 years ago. Intention is to have *everything* included on one single PCB, including the output amplifiers (push-pull output stage with transistors). Only a symmetrical +12V and –12V DC power supply is required. Interface is jumper-selectable PHCC DOA or USB.

12-2020 : First version of HYD-PRESS A/B firmware written

The first firmware for the HYDRAULIC PRESSURE A/B control interface is written. The firmware is (partly) a redesign of the HSI #1 firmware.

12-2020 : Prototype PCB

The first 5 prototype PCBs of the HYDRAULIC PRESSURE A/B have arrived.

12-2019 : HYDRAULIC PRESSURE A/B board is soldered

The HYDRAULIC PRESSURE A/B board is soldered, the heat sink for the 12 output stage transistors is drilled and threaded (M3). A Python test application is written.

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1. Introduction

This design is an interface to control the *real* F-16 HYDRAULIC PRESSURE A and B indicators. The HYDRAULIC PRESSURE A/B controller interface requires 2 power supplies, +12V and –12V DC. The internal illumination of the indicators is not on this interface board.

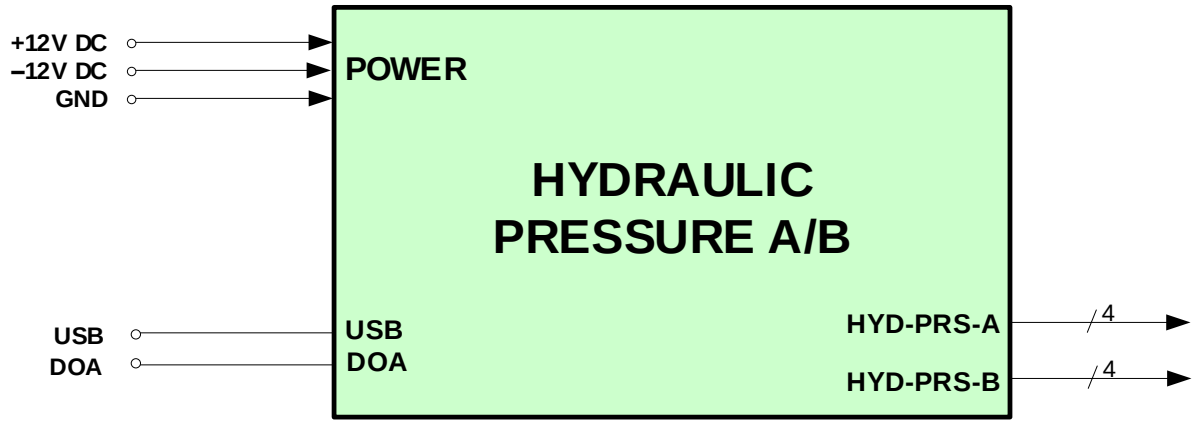
The controller interface supports USB and the PHCC DOA bus.

The HYDRAULIC PRESSURE A/B controller interface circuit board has the following features.

- PCB (3.9" x 6.3"), easy to build, all standard components (no tiny SMD components).
- Required heat sink for the output stages is mounted on the PCB.
- Generation of synchro rotor and stator signals for both indicators.
- On-board LED indicator for firmware monitoring.
- Optional, 3 spare user-definable ON/OFF digital outputs
- DOA connection or USB connection, jumper selectable.

2. Overview of the HYDRAULIC PRESSURE A/B board

2.1 Block diagram



2.2 Power supply connections

The 5-pin header "POWER" connector connects GND, +12V and –12V DC power supply to the HYDRAULIC PRESSURE A/B controller interface.

2.3 HYDRAULIC PRESSURE A/B synchro connections

The HYDRAULIC PRESSURE A/B board has two 4-pin headers to connect the A and B indicator.

2.4 Interface connections

The HYDRAULIC PRESSURE A/B board has two interface connections, mutually exclusive, either USB or DOA (PHCC). An on-board jumper ("U/D") defines which communication connection is selected at power-up.

3. Connections & jumpers on the HYDRAULIC PRESSURE A/B

The HYDRAULIC PRESSURE A/B controller interface board has 3 connectors and 1 jumper. Pin #1 is indicated on the PCB.

3.1 POWER connector

The POWER connector connects +12V and –12V DC power for the logic and analog circuits.

pin number	Signal	Usage
1	+12V	+12V (logic and analog circuits)
2	GND	Ground (0V)
3	–12V	–12V (analog circuits)
4	GND	Ground (0V)
5	+12V	+12V (logic and analog circuits)

→ *The HYDRAULIC PRESSURE A/B has no provisions against wrong power supply connections !*

3.2 HYD-PRS-A connector

The HYD-PRS-A connector connects the rotor and stators of the synchro of indicator A.

pin number	Signal	Usage
1	CM	Common connection
2	RT	Rotor connection
3	S3	Stator S3 connection
4	S1	Stator S1 connection

3.3 HYD-PRS-B connector

The HYD-PRS-B connector connects the rotor and stators of the synchro of indicator B.

pin number	Signal	Usage
1	CM	Common connection
2	RT	Rotor connection
3	S3	Stator S3 connection
4	S1	Stator S1 connection

3.4 DOA connector

pin number	Signal	Usage
1	GND	Ground (0V)
2	DOA DATA	DOA data connection
3	RESET	PIC reset (active low)
4	DOA CLOCK	DOA clock connection
5	GND	Ground (0V)

3.5 USB connector

The USB connector is a standard USB Type B connector.

3.6 USB/DOA jumper

The USB/DOA jumper selects which communication interface is used.

pin number	Signal	Usage
no jumper	USE_USB	The USB connector is used for communication
1 – 2	USE_DOA	The DOA connector is used for communication

3.7 User-definable (spare) outputs

Three pins of the PIC processor are not needed for the controller interface. For that reason, these 3 pins are defined as a digital output, and the state (logic "0" or logic "1") can be set by separate commands for each spare output. However, these outputs are not available on a connector. If you have some purpose to control some on/off switched circuit, you can connect this by soldering a wire directly to the pin of the PIC (on the circuit board of course).

- PIC pin #3 is digital output XA1
- PIC pin #7 is digital output XA5
- PIC pin #28 is digital output XB7

Keep in mind that you are making a connection directly to the output pin of the PIC. You cannot connect an indictive load (coil, solenoid, relay). If that is needed, add a buffering transistor. However, you can connect directly an LED with an appropriate series current-limiting resistor. Make sure that the maximum current is less than 15 mA.

4. Assembly of the HYDRAULIC PRESSURE A/B

Only a fine low-wattage soldering iron is required to solder the circuit board. Read through the steps below to have an idea of the work you are about to do. Take your time to solder the components on the PCB. Better spend a few more minutes working accurately now, than searching for that little solder excess that causes a short circuit or wrong component placement (especially resistors).

Soldering the components in order from smallest height to highest has the advantage that the board lays stable on your desk while soldering, and keeps the component against the PCB. Therefore, the following soldering order is proposed. All components are placed on the component side of the PCB. The component side has the white text painted on the PCB (the so-called silkscreen). See the "Appendix A – Component locator HYDRAULIC PRESSURE A/B" for reference.

Observe ESD safety measures to prevent static discharge damage.
(This applies to the LED, diodes and ICs)

1. Solder diodes D1 and D2. Observe the orientation. The "bar" is the cathode.
2. Solder all resistors. Make sure that the resistors with different values are in their correct position. Check chapter 8 and Appendix A for reference. If you are not sure that you read the color code correctly, use an Ohm meter.
3. Solder the crystal.
4. Solder the IC sockets, if you want to use sockets. I always use sockets, not to protect the ICs, but the PCB! If an IC is defective, it can easily be swapped. A soldered IC is difficult to remove and you likely damage the PCB traces or the through-hole plating. The PCB is more valuable than any of the ICs. Make sure that the notch, which indicates pin #1 location, is at the correct side. The silkscreen shows the notch.
5. Solder the LED. The cathode is the shorter lead (at the flat side) and is near C1.
6. Solder the capacitors, except the 470 pF, 560 pF, and polarized capacitor.
7. Solder the 470 pF, 560 pF, and the polarized capacitor. Observe polarity!
8. Solder all pin headers and the USB connector.
9. Solder the trim potentiometers.

Before you proceed, do a visual inspection of the board with a bright light and magnifying glass.
- ✓ Are all soldering joints clean and shiny? A dull soldering joint may be a bad soldered joint.
- ✓ No small droplets of solder near the soldering joints?
- ✓ No short circuit between pins?

TIP *You can use an old tooth brush to brush off solder residue and tiny solder droplets.*

NOTE *The 12 output stage transistors are **not** (yet) soldered!*

5. Connection wiring

5.1 Introduction

This chapter describes the interconnections per identified functionality.
The required connections are the following.

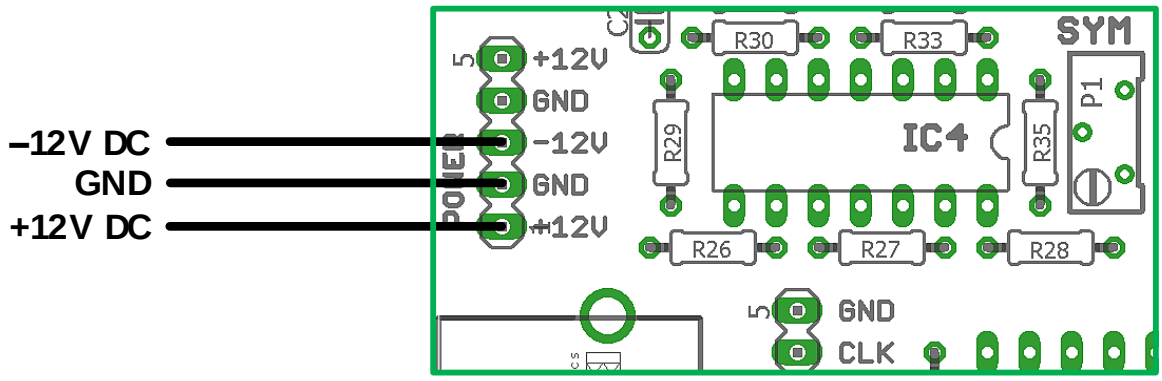
- power supply
- hydraulic pressure indicator A and B
- interface – USB (to PC) or DOA (to PHCC Motherboard)

5.2 Power supply wiring

The HYDRAULIC PRESSURE A/B controller interface board requires +12V DC and –12V DC.

Connection	From	To
+12V DC	+12V DC power supply	POWER header #1 , #5 (+12V)
–12V DC	–12V DC power supply	POWER header #3 (–12V)
GND	power supplies GND	POWER header #2 , #4 (GND)

⇨ *Always double-check the connections before you switch on power!*



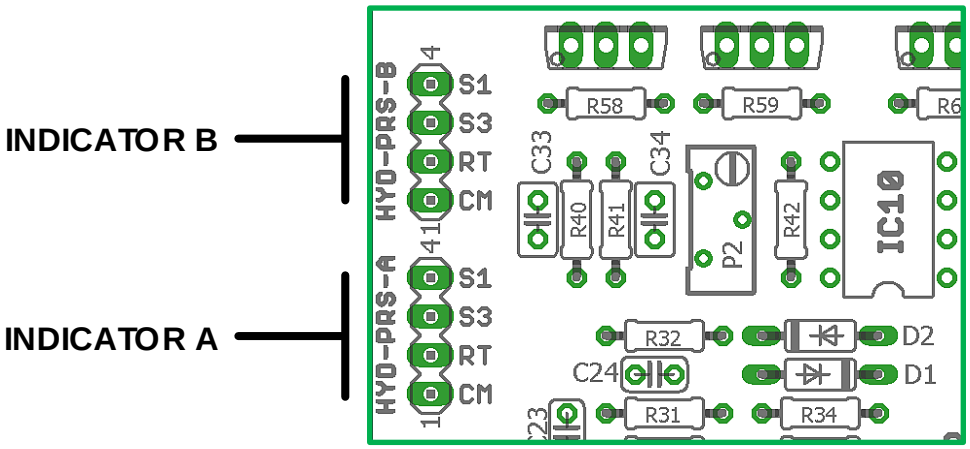
Note that you only need to connect pins #1, #2, and #3. However, in that case it is possible that you swap pins #1 and #3, which will destroy all ICs and the DC/DC converter on the board. If you wire a connector using all 5 pins, there is no risk that you connect the connector the wrong way … better safe than sorry 😊

5.3 HYDRAULIC PRESSURE A/B indicator signals wiring

The HYDRAULIC PRESSURE A and B indicators have a rotor, 2 stators and a common connection.

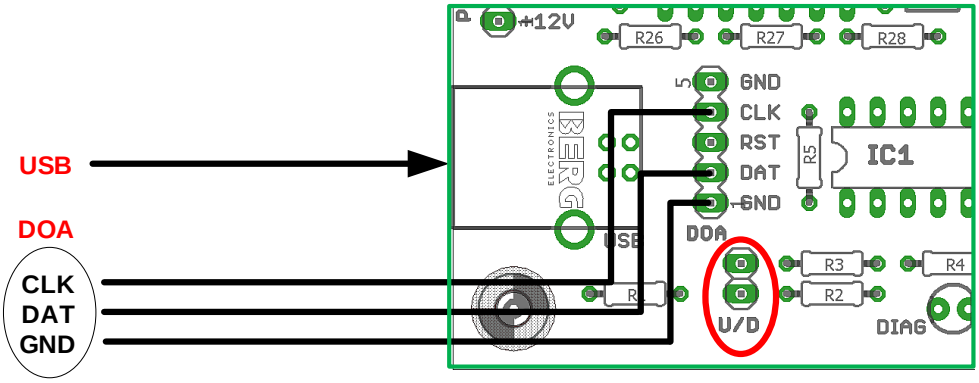
Connection	From	To
Indicator A synchro common	HYD-PRS-A header #1 (CM)	Indicator A common
Indicator A synchro rotor	HYD-PRS-A header #2 (RT)	Indicator A rotor coil
Indicator A synchro stator	HYD-PRS-A header #3 (S3)	Indicator A stator coil S3
Indicator A synchro stator	HYD-PRS-A header #4 (S1)	Indicator A stator coil S1

Connection	From	To
Indicator B synchro common	HYD-PRS-B header #1 (CM)	Indicator B common
Indicator B synchro rotor	HYD-PRS-B header #2 (RT)	Indicator B rotor coil
Indicator B synchro stator	HYD-PRS-B header #3 (S3)	Indicator B stator coil S3
Indicator B synchro stator	HYD-PRS-B header #4 (S1)	Indicator B stator coil S1



5.4 Interface wiring

The HYDRAULIC PRESSURE A/B board must be connected to the PC using the USB connection, or must be connected to the PHCC Motherboard using the DOA connection. Set the U/D jumper accordingly, see chapter 3.6.



If you use the USB connection, you need a USB Type B to USB Type A cable to connect the PC. The HYDRAULIC PRESSURE A/B board does *not* use +5V from the USB connection. The U/D jumper must *not* be installed.

If you use the PHCC connection you must connect the DOA bus (CLK, DAT and GND). The U/D jumper *must* be installed.

Optionally, you can connect a normally-open push button to pin #3 (RST) and pin #5 (GND) of the DOA header to have a possibility to reset the processor on the HYDRAULIC PRESSURE A/B board (not shown in the figure).

6. Adjustments

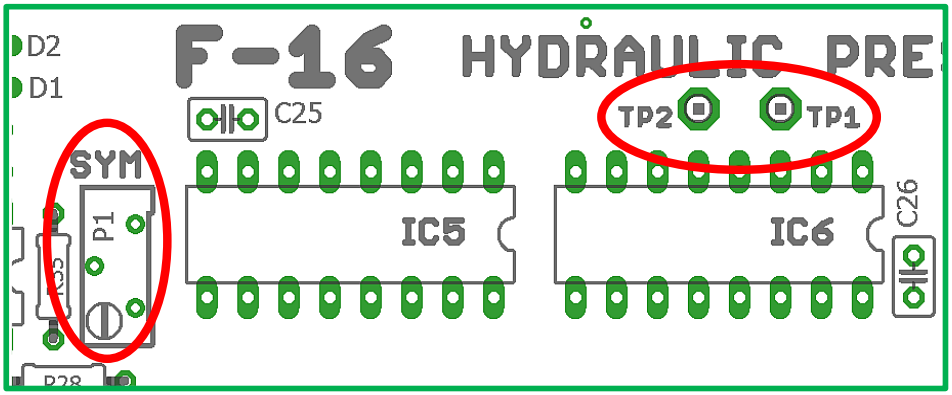
Signals to the HYDRAULIC PRESSURE indicators must have the correct amplitude for accurate and correct operation. For that reason there are several trim potentiometers on the HYDRAULIC PRESSURE A/B board. It seems like there are a lot of them, but basically you only trim one signal for identical amplitude (symmetry of the phase-shifted reference signal) and the rotor and stator amplitudes (and of those there are 6 in total, 3 per indicator).

You need a fine screwdriver and a multi-meter that has AC Volt measuring ranges. Further, for the adjustment of the output amplitudes, you need the HYDRAULIC PRESSURE Test Application.

→ Always switch all power supplies <u>off</u> before connecting/disconnecting connections.

6.1 Phase-shifted reference signal

The sine wave oscillator is on-board, taking care of the need for a 400 Hz power supply. To generate the synchro signals, a 180° phase shifted signal is also needed. The trim potentiometer "SYM" is used to set the amplitude of the phase-shifted signal to exactly the same amplitude as the output signal from the oscillator.



Do the following steps to adjust the amplitude of the 180° phase-shifted signal.

1. Connect the +/–12V DC power supply to the POWER header. Note that the power supply is still switched off.
   ➔ Note that the HYDRAULIC PRESSURE indicators are **not** connected **!**
2. Set the multi-meter range to **AC Volts**, and connect the (–) lead to POWER connector pin #2 or #4 (GND), or to the power supply GND. Connect the (+) lead to test pin TP1.
3. Switch on the +/–12V DC power supply. Measure the voltage on TP1 It will be approximately 1.97V.
4. Now connect the (+) lead to test pin TP2. Measure the voltage on TP2. Adjust trim potentiometer P1 ("SYM") so that the measured voltage level is *exactly* the voltage level measured at test pin TP1.

After this adjustment, you can adjust all HYDRAULIC PRESSURE indicator signals.

6.2 HYDRAULIC PRESSURE A output signals

You need the HYDRAULIC PRESSURE Test Application to adjust the amplitude of the signals that drive the HYDRAULIC PRESSURE A indicator.

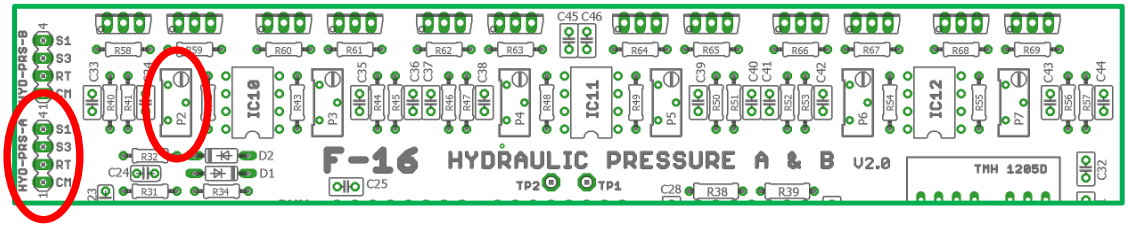
Preparation

- Set the multi-meter range to **AC Volts**, and connect the (–) lead to POWER connector pin #2 or #4 (GND), or to the power supply GND.
  ➔ Note that the HYDRAULIC PRESSURE indicators are **not** connected **!**
- Switch on the +/–12V DC power supply.
- Connect the USB cable to the HYDRAULIC PRESSURE A/B board and the PC.
- Wait until the USB connection is registered by Windows.
- Start the HYDRAULIC PRESSURE Test Application.

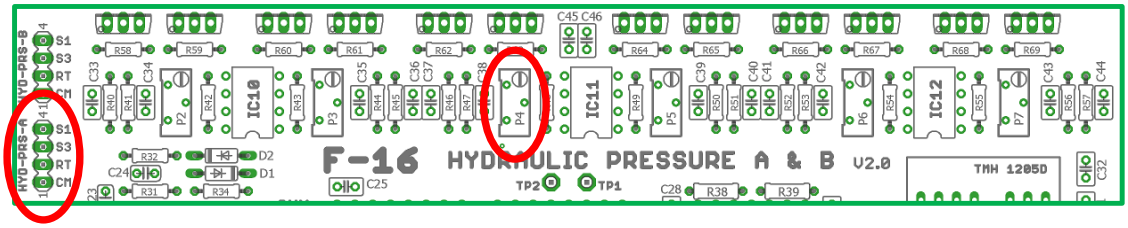
On the "Connection" tab, select the COM port in the "COM ports" section, and click the "Open COM port" button. Check that the connection is OK, by changing the selection in the "Diagnostic LED" section and clicking the "Set" button. Observe the response of the DIAG LED on the HYDRAULIC PRESSURE A/B board. Change the selection back to "heartbeat".

Do the following steps to adjust the amplitude of the HYDRAULIC PRESSURE A signals.

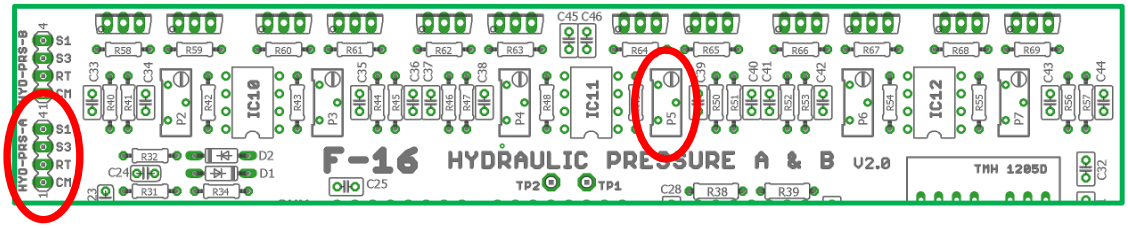
1. Select the "adjustment" tab of the HYDRAULIC PRESSURE Test Application.
2. Connect the (+) lead of the multi-meter to connector HYD-PRS-A pin #2 (RT).
3. Adjust trim potentiometer P2 so that the measured voltage level is 6.60V.



4. Connect the (+) lead of the multi-meter to connector HYD-PRS-A pin #4 (S1).
5. Adjust trim potentiometer P4 so that the measured voltage level is 2.99V.



6. Connect the (+) lead of the multi-meter to connector HYD-PRS-A pin #3 (S3).
7. Adjust trim potentiometer P5 so that the measured voltage level is 2.99V.



6.3 HYDRAULIC PRESSURE B output signals

You need the HYDRAULIC PRESSURE Test Application to adjust the amplitude of the signals that drive the HYDRAULIC PRESSURE B indicator.

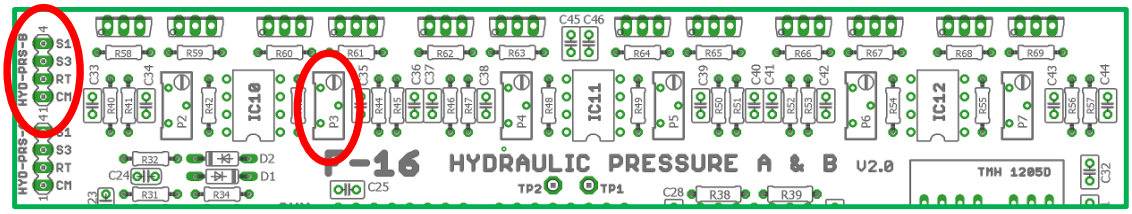
Preparation

- Set the multi-meter range to **AC Volts**, and connect the (–) lead to POWER connector pin #2 or #4 (GND), or to the power supply GND.
  ➔ Note that the HYDRAULIC PRESSURE indicators are **not** connected **!**
- Switch on the +/–12V DC power supply.
- Connect the USB cable to the HYDRAULIC PRESSURE A/B board and the PC.
- Wait until the USB connection is registered by Windows.
- Start the HYDRAULIC PRESSURE Test Application.

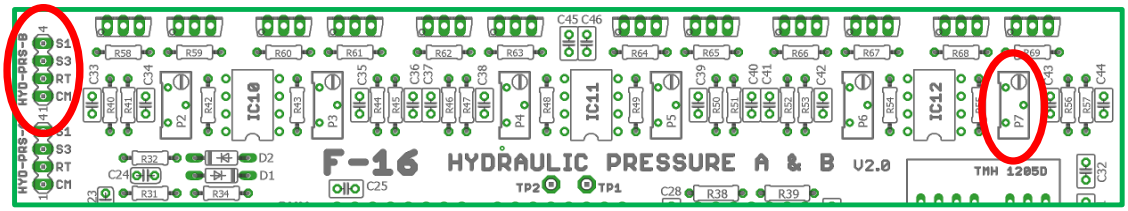
On the "Connection" tab, select the COM port in the "COM ports" section, and click the "Open COM port" button. Check that the connection is OK, by changing the selection in the "Diagnostic LED" section and clicking the "Set" button. Observe the response of the DIAG LED on the HYDRAULIC PRESSURE A/B board. Change the selection back to "heartbeat".

Do the following steps to adjust the amplitude of the HYDRAULIC PRESSURE B signals.

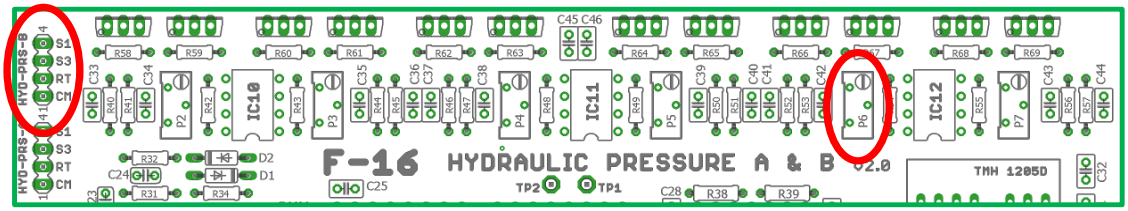
1. Select the "adjustment" tab of the HYDRAULIC PRESSURE Test Application.
2. Connect the (+) lead of the multi-meter to connector HYD-PRS-B pin #2 (RT).
3. Adjust trim potentiometer P3 so that the measured voltage level is 6.60V.



4. Connect the (+) lead of the multi-meter to connector HYD-PRS-B pin #4 (S1).
5. Adjust trim potentiometer P7 so that the measured voltage level is 2.99V.



6. Connect the (+) lead of the multi-meter to connector HYD-PRS-B pin #3 (S3).
7. Adjust trim potentiometer P6 so that the measured voltage level is 2.99V.



7. HYDRAULIC PRESSURE A/B commands

If the HYDRAULIC PRESSURE A/B control interface is used as a PHCC daughter module (DOA communication) you must send the DOA address byte, sub-address byte and data byte. The DOA address byte identifies that the data packet sent is for the HYDRAULIC PRESSURE A/B firmware. The value of the DOA address is hard-coded (hex 59) in the PIC firmware, and can be any value as long as the value is unique on the entire DOA bus. The sub-address and data byte define for which functionality the command and data is intended.

If you use the USB connection it is clear what the destination is (defined by the cable connection), and the address byte is not needed. The USB data packet consists of the sub-address, data byte, checksum byte, and a delimiter byte (in that order). Implementation of the checksum and delimiter byte improves the data transmission robustness. Any message in which the sub-address value is outside its valid range, checksum not equal to the 8-bit sum of sub-address and data byte, or delimiter byte not equal to 0xFF is discarded. The checksum and delimiter data bytes cannot be added in the DOA message as the PHCC protocol is (pre)defined.

This chapter describes the implemented commands with their possible data (byte) values. Remember that the HYDRAULIC PRESSURE A/B is a "listen-only" device, thus if you want to know what data was sent, the sending program must keep a local copy.

HYDRAULIC PRESSURE A indicator indication

sub-address	data byte	function / description
0	0x00 … 0xFF	HYD PRS A indicator range 0000 – 0255
1	0x00 … 0xFF	HYD PRS A indicator range 0256 – 0511
2	0x00 … 0xFF	HYD PRS A indicator range 0512 – 0767
3	0x00 … 0xFF	HYD PRS A indicator range 0768 – 1023

HYDRAULIC PRESSURE B indicator indication

sub-address	data byte	function / description
4	0x00 … 0xFF	HYD PRS B indicator range 0000 – 0255
5	0x00 … 0xFF	HYD PRS B indicator range 0256 – 0511
6	0x00 … 0xFF	HYD PRS B indicator range 0512 – 0767
7	0x00 … 0xFF	HYD PRS B indicator range 0768 – 1023

HYDRAULIC PRESSURE A & B indicator synchro stator offsets

sub-address	data byte	function / description
8	0x00 … 0xFF	Stator coil offset value (lower 8 bits)
9	0x00 … 0x03	Stator coil offset value (upper 2 bits)
10	0x00 … 0x0F	Load offset value stator coil mask 0x01 :: [A]S1 – 0x02 :: [A]S3 – 0x04 :: [B]S1 – 0x08 :: [B]S3

HYDRAULIC PRESSURE A indicator stator setpoint (direct access, coarse setting)

sub-address	data byte	function / description
11	0x00 … 0xFF	S1 coarse setpoint value
12	0x00 … 0xFF	S3 coarse setpoint value
13	0x00 … 0x03	S3, S1 polarity and LOAD coarse setpoint (lsb ≡ S1 polarity)

HYDRAULIC PRESSURE B indicator setpoint (direct access, coarse setting)

sub-address	data byte	function / description
14	0x00 … 0xFF	S1 coarse setpoint value
15	0x00 … 0xFF	S2 coarse setpoint value
16	0x00 … 0x03	S3, S1 polarity and LOAD coarse setpoint (lsb ≡ S1 polarity)

User-defined (spare) outputs

sub-address	data byte	function / description
17	0x00 … 0xFF	Output XA1 – 0x00 ≡ off (0V) , any other value ≡ on (5V)
18	0x00 … 0xFF	Output XA5 – 0x00 ≡ off (0V) , any other value ≡ on (5V)
19	0x00 … 0xFF	Output XB7 – 0x00 ≡ off (0V) , any other value ≡ on (5V)

WATCHDOG functionality

sub-address	data byte	function / description
20	(*)	Disable watchdog functionality -- See text for description.
21	0x00 … 0xFF	**Watchdog control** -- See text for description.

MISCELLEANOUS

sub-address	data byte	function / description
22	0 – 1 – 2 – 3 – 4	**DIAG** LED operation mode 0 – LED always OFF 1 – LED always ON 2 – LED flashes at heart beat rate (power-up default) 3 – LED toggles ON/OFF state per *accepted* command 4 – LED is ON during DOA packet reception
23	don't care	**IDENTIFY** USB only: send identification "`HYD vX.Y $59`"
24	'N' or 'Y'	**USB** debug command (USB only ☺)

7.1 How to control the HYDRAULIC PRESSURE A/B functionality

7.1.1 HYDRAULIC PRESSURE A indicator

Commands 0, 1, 2, and 3 control the setting of the HYDRAULIC PRESSURE A indicator. The set value has 10 bit accuracy, thus a value between 0 and 1023. The value 0 sets the indication to 0 (depending on the offset values). As the data byte can only be in the range 0 – 255, the commands are 0, 1, 2, and 3 defining the "quarter" in which the indication must be set.

7.1.2 HYDRAULIC PRESSURE B indicator

Commands 4, 5, 6, and 7 control the setting of the HYDRAULIC PRESSURE B indicator. The set value has 10 bit accuracy, thus a value between 0 and 1023. The value 0 sets the indication to 0 (depending on the offset values). As the data byte can only be in the range 0 – 255, the commands are 4, 5, 6, and 7 defining the "quarter" in which the indication must be set.

7.1.3 Synchro offset values

A synchro consists of a rotor and 3 stator coils. The rotor is excited with an AC voltage which generates a magnetic field. When a stator coil is excited with an AC voltage of certain amplitude, that stator coil will also generate a magnetic field. The strength of the magnetic field depends on the amplitude of the excitation voltages. The stator coils in a synchro are spatially separated by 120°. By controlling the amplitude of the excitation signals for the coils a resultant magnetic field is generated. As the rotor can move freely, the magnetic field of the rotor and the magnetic field of the stator coils force the rotor to rotate to a "magnetic equilibrium". This is the positioning principle of a synchro. By adjusting the amplitude of the stator coils you can rotate the axis of the synchro. When you send a setpoint value (for example Command 0), the data value + offset values define the stator amplitudes. Thus, when the data value is 0, you can set the offsets to a value such that the indicator has a "defined" position, for example "0".

The generated voltage amplitudes have a resolution of 10 bits, that is, the value range is between 0 and 1023. The value 1024 equals 0. This value range coincides with one full rotation of the axis of the synchro, thus 1023 coincides with 360°. As the stator coils are spatially arranged at 120°, the control voltages must also have this amplitude "angle". For that reason, the offset values of the 3 stator coils must have a delta of 1024 * 120 / 360 = 341 between them. This applies for a synchro with 3 stator coils that can be connected. In the HYDRAULIC PRESSURE indicators the coil S2 is connected internally to GND. That configuration is called "S2-grounded". Mathematically it can be shown that the resulting phase shift is no longer 120°, but 60°. Due to the different electrical wiring, the offset values for the controllable 2 stator coils must have a delta of 1024 * 60 / 360 = 171 between them.

You can select any offset value, as long as the offset value for the other coil(s) have the correct delta value between them. The firmware has predefined offset values to set the HYDRAULIC PRESSURE indicators to "0" when the sent data value is 0.

To load an offset value for a specific synchro stator coil, you always have to send 3 commands. The first command is 8 to send to lower 8 bits of the offset value. The second command is 9 to send to upper 2 bits of the offset value. The third command 10 is a bitmask in which one bit defines for which stator coil the sent offset value applies. Note that you should set only one bit at a time. Offset bit 0 loads the specified offset value for S1 of indicator A, bit 1 loads the specified offset value for S3 of indicator A, bit 2 loads the specified offset value for S1 of indicator B, and bit 2 loads the specified offset value for S3 of indicator B.

7.2 IDENTIFY command

The IDENTIFY command (23) is only available when the USB communication connection is used. When the IDENTIFY command with an "any value" data byte is sent, the HYDRAULIC PRESSURE A/B controller interface returns a message in the form of "`HYD vX.Y $59`" followed by a CR (0x13) and LF (0x0A). The "`X`" and "`Y`" represent the major and minor version number of the firmware. "`$59`" is the hexadecimal device code of the HYDRAULIC PRESSURE A/B firmware, and used for recognition of DOA PHCC commands. Although the DOA device code is irrelevant for the USB communication, it can still be useful. Suppose you have more than one USB-connected PHCC device (for example the SDI boards of the ADI, altimeter, or FFI). Using the IDENTIFY command you can find out which specific instrument is connected to a virtual COM port, because the device code (should be) unique.

7.3 USB debug command

The USB debug command (24) enables or disables debug output sent to the USB connection. Obviously, this command only operates when you use a USB connection. Default USB debug output is disabled. To enable USB debugging output you must send the command with the data byte ASCII character 'Y'. Likewise, to disable the USB debugging output send the command with the data byte ASCII 'N'. When USB debug is enabled a specific character is returned every time a byte is received via the USB connection, followed by the data byte itself (in hexadecimal format). Depending on the interpretation (by the firmware) of the data byte one of the following specific characters is returned leading the echoed (hexadecimal) data byte.

returned character	SDI interpretation
–	following 2 characters are hexadecimal command (first byte)
=	following 2 characters are hexadecimal data (second byte)
.	correct delimiter data byte (0xFF) received
x	"disable watchdog" command received
#	invalid sub-address in command
*****	invalid delimiter data byte received
!	USB receive data state machine in illegal state (firmware error ☹)

7.4 Watchdog functionality

The watchdog functionality makes sure that the data communication stays "synchronized". Commands sent via the PHCC DOA channel are 3 "bytes" (device address, sub-address and data byte, where the sub-address is 6 bits!). Commands sent via the USB channel are 4 bytes. The firmware uses a state machine to keep track of the received data bits and bytes. If, due to some external disturbance, one byte is not correctly received the receive routine may treat the next byte as the first, because the state machine is in the wrong state. If the firmware gets in this state, all subsequent commands received will be wrong. This condition is not recognized by the sender (PHCC Motherboard or the PC), but you will notice that all functionality of the HYDRAULIC

PRESSURE A/B controller interface no longer seems to work (because the "commands" are wrong). You could say that the firmware has become "deaf".

To solve this problem a so-called watchdog timer is implemented in the firmware. In a normal condition the bytes sent via USB that belong together (they form the command) are sent one after the other without much delay. Every time a byte is received the watchdog timer is reloaded to some value. Every millisecond the value is decreased by one. When the watchdog timer reaches 0, the firmware state variables that control the data reception are reset to the initial state. Thus, as long as a command transmission is active the watchdog will not expire. If there is some (predefined) time no communication activity the watchdog will expire and by resetting the state variables that control the data reception, the communication channel is forced to be "in sync".
For DOA the story is similar, but here the data *bits* are sent one after the other, and the watchdog timer is reloaded at every received *bit*. If some disturbance causes the communication to go out of sync, it is corrected as soon as a short pause between commands occurs. That the mechanism works is proved by "deaf" PHCC daughter boards after power-up. Without the watchdog functionality, they remain "deaf", but with the watchdog functionality they work OK. (Power-up can cause spurious pulses which can mistakenly be detected as data bits).

However, experiments have shown that this watchdog solution is not perfect either ☹ To solve the most common DOA communication problem at power-up start, a one second delay is implemented if DOA communication is selected. After the one second delay it is assumed that all noise spikes on the DOA communication lines (specifically clock) are gone, and the state machine is initialized. During the one second delay the diagnostic LED flashes at a high rate.

The watchdog functionality is by default disabled. The watchdog command itself consists of 2 data bytes. As long as the watchdog is active, a manually sent command to disable the watchdog will fail, because of the possible elapsed time between the data bytes. Therefore, the "disable watchdog" command is "special command", because it does not require the data byte. This solution only works for USB as it will make the command a single byte. Sending commands via the USB connection with a PC terminal communication program will work fine. For DOA the solution will not work.

A separate command (21) is available to define the watchdog timer count-down value, and optionally, enable/disable the watchdog. The data format is as follows.

7	6	5	4	3	2	1	0
ENA	**0**	6 data bits representing the watchdog count-down value					

Bit 7 ("ENA") controls whether the watchdog is enabled or disabled. When bit 7 is '1' the watchdog is enabled. When bit 7 is '0' the watchdog is disabled. So, you can disable the watchdog with this command and you can disable the watchdog with the special "disable watchdog" command (20). The 6 bits count-down value allows a less strict setting than default set by the firmware (8). If the 6 bits are all zero ('000000'), the firmware default value is set. Note, you can set the count-down value also when the watchdog is disabled ("ENA" bit is '0').

8. Parts list HYDRAULIC PRESSURE A/B circuit board

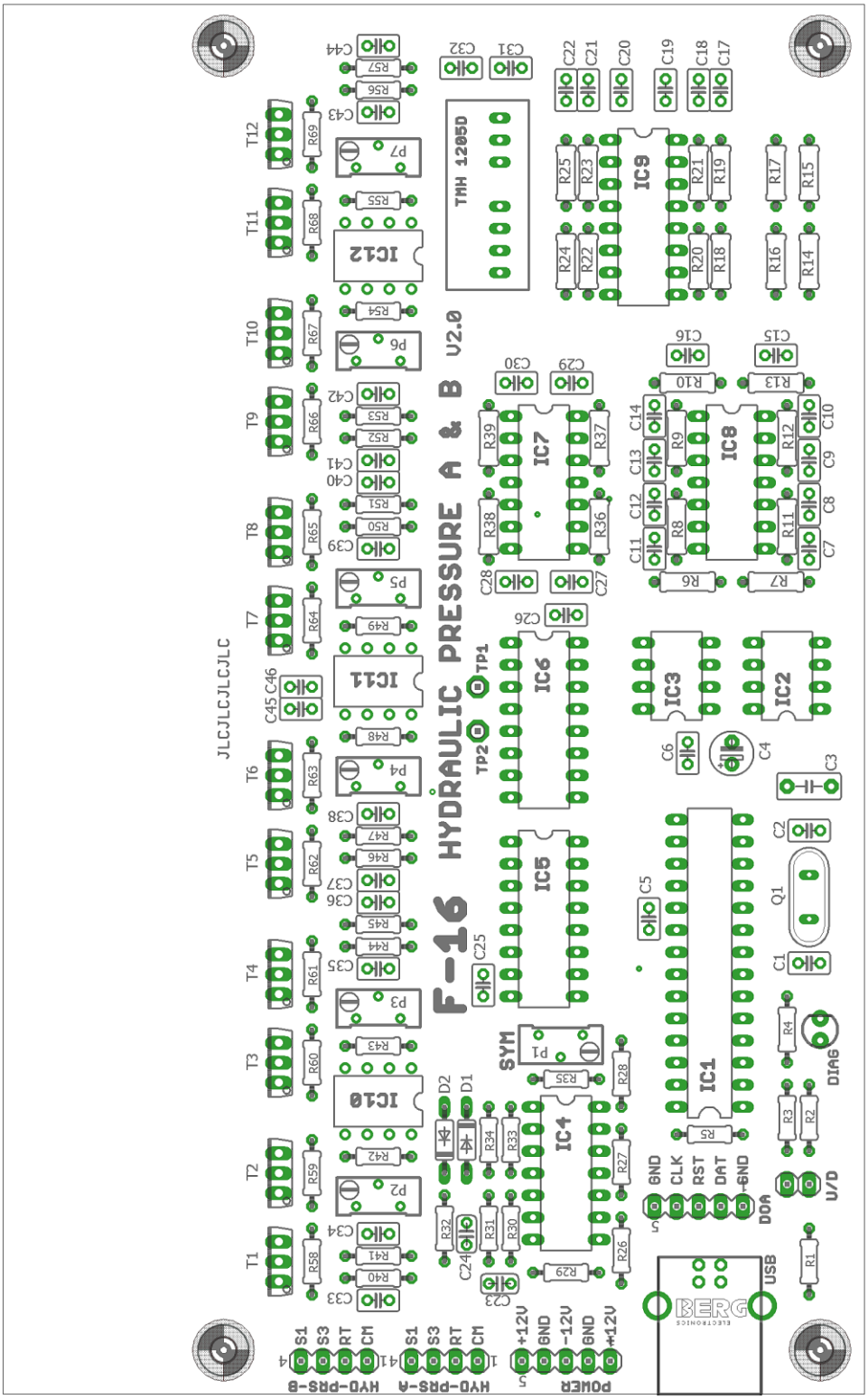
Quantity	Component	Description
1	IC1	PIC 18F2550
2	IC2, IC3	MCP4812
3	IC4, IC7, IC8	TL084
2	IC5, IC6	CD4053
1	IC9	CoolAudio V2164P
3	IC10, IC11, IC12	TL082
1	IC socket DIL, 28-pin	high-quality machined pin socket
3	IC socket DIL, 16-pin	high-quality machined pin socket
3	IC socket DIL, 14-pin	high-quality machined pin socket
5	IC socket DIL, 8-pin	high-quality machined pin socket
1	LED	3 mm, any color (diagnostic)
2	D1, D2	1N4148
1	Q1	20Mhz crystal
1	TMR 3-1221	TRACO DC/DC converter
2	C1, C2	22 pF
1	C3	220 nF
1	C4	4.7 µF (polarized) 25V
12	C5, C6, C15, C16, C19, C20, C25, C26, C31, C32, C45, C46	100 nF
8	C7, C8, C9, C10, C11, C12, C13, C14	470 nF
4	C17, C18, C21, C22	560 pF
2	C23, C24	33 nF
4	C27, C28, C29, C30	470 pF
6	C33, C36, C37, C40, C41, C44	10 nF
6	C34, C35, C38, C39, C42, C43	100 pF
5	R1, R27, R29, R32, R35	1k
1	R2	100k
14	R3, R5, R40, R42, R43, R45, R46, R48, R49, R51, R52, R54, R55, R57	10k
1	R4	470Ω
8	R6, R7, R8, R9, R10, R11, R12, R13	150k
4	R14, R15, R16, R17	2k7
14	R18, R20, R22, R24, R36, R37, R38, R39, R41, R44, R47, R50, R53, R56	47k
5	R19, R21, R23, R25, R28	560Ω

1	R26	1k5
2	R30, R31	33k
1	R33	2k2
1	R34	6k8
12	R58, R59, R60, R61, R62, R63, R64, R65, R66, R67, R68, R69	68Ω
1	P1	5k RTRIM64Y trim potentiometer
6	P2, P3, P4, P5, P6, P7	20k RTRIM64Y trim potentiometer
6	T1, T3, T5, T7, T9, T11	BD235
6	T2, T4, T6, T8, T10, T12	BD236
2	TP1, TP2	1-pin male header (optional)
1	U/D	2-pin male header
2	HYD-PRS-A, HYD-PRS-B	4-pin male header
2	POWER, DOA	5-pin male header
1	USB	USB Type B
1	Heat sink 50 x 160 x 40 mm	Reichelt – V 6506E
1	PCB	HYDRAULIC PRESSURE A/B v2.0

Component values may change without notice.

Appendix A. Component locator HYDRAULIC PRESSURE A/B

This image is retrieved from the actual Eagle .BRD file. For clarity all PCB traces are hidden.

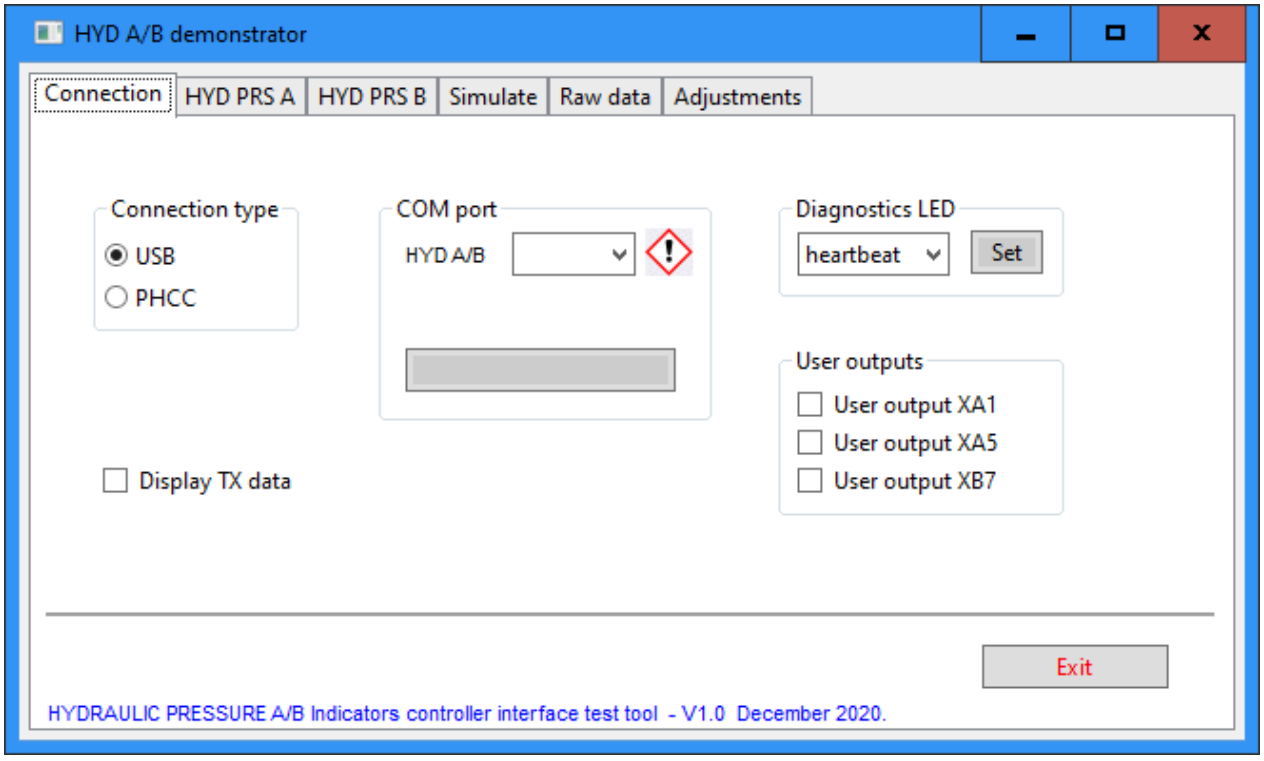


Appendix B – HYDRAULIC PRESSURE A/B demonstrator program

A test application is written in Python. The language allows for fast program development and with available libraries you can create programs with a user-friendly graphical interface. I do not pretend the Python program is well-written – it gets the job done ☺

The "Package" is a zip file that contains the Python application "hyd-press-testappl.exe" and 3 GIF files that are used by the application. Extract and put the program and GIF files together in a folder. Double-click the hydpress-testappl.exe file to start the application.

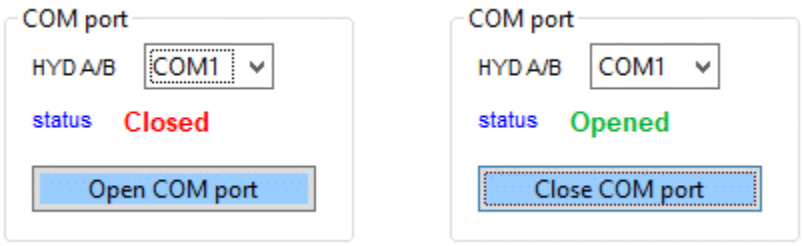
Two windows appear when the program starts. The CMD window, that shows diagnostic output, and the application window with 6 tabs.



Connection tab

The program always starts on the "Connection" tab. The first action you must do is configure how the program (and PC) connects to the HYDRAULIC PRESSURE controller interface. This can be a USB connection cable or using the PHCC Motherboard (and a DOA cable). You can select the connection with the radio buttons in the section "Connection type". Next to that section you can select the COM port which is used to connect (either DOA or USB). You can see in the diagnostic window which COM ports the program detected, but you can also check the Windows

Device Manager under “Ports (COM & LPT)”. As long as you do not select a COM port the error sign will stay up blinking as a warning that you must select a COM port. When a COM port is selected, the error sign disappears, and below the selection drop-down box appears a port status indication, and below the status indication appears a button with which you can open and close the selected COM port. The button legend changes accordingly.



If you selected the wrong COM port, you can simply select another COM port from the drop-down list. If the previous COM port was opened, it is automatically closed.

In the section “Diagnostics LED” you can set the functionality of the DIAG LED on the HYDRAULIC PRESSURE A/B board. You can select the options “heartbeat”, “off”, “on”, “ACK”, and “DOA”. “off” means that the DIAG LED is not used and it is turned off. Likewise, “on” means that the DIAG LED is not used and it is turned on. “heartbeat” means that the DIAG LED blinks at a certain rate to indicate that the firmware is running. If you selected “heartbeat” mode (which is the power-up default setting), and the LED stopped blinking, you know the firmware crashed ☹. “ACK” toggles the state (on or off) of the DIAG LED per received command. “DOA” is a check that DOA packets are correctly received; if you use the USB connection, the “DOA” selection makes no sense.

The “Set” button sends the selected functionality of the DIAG LED to the HYDRAULIC PRESSURE A/B board. When the button is grey, nothing is sent, because the selected setting is already the current setting.

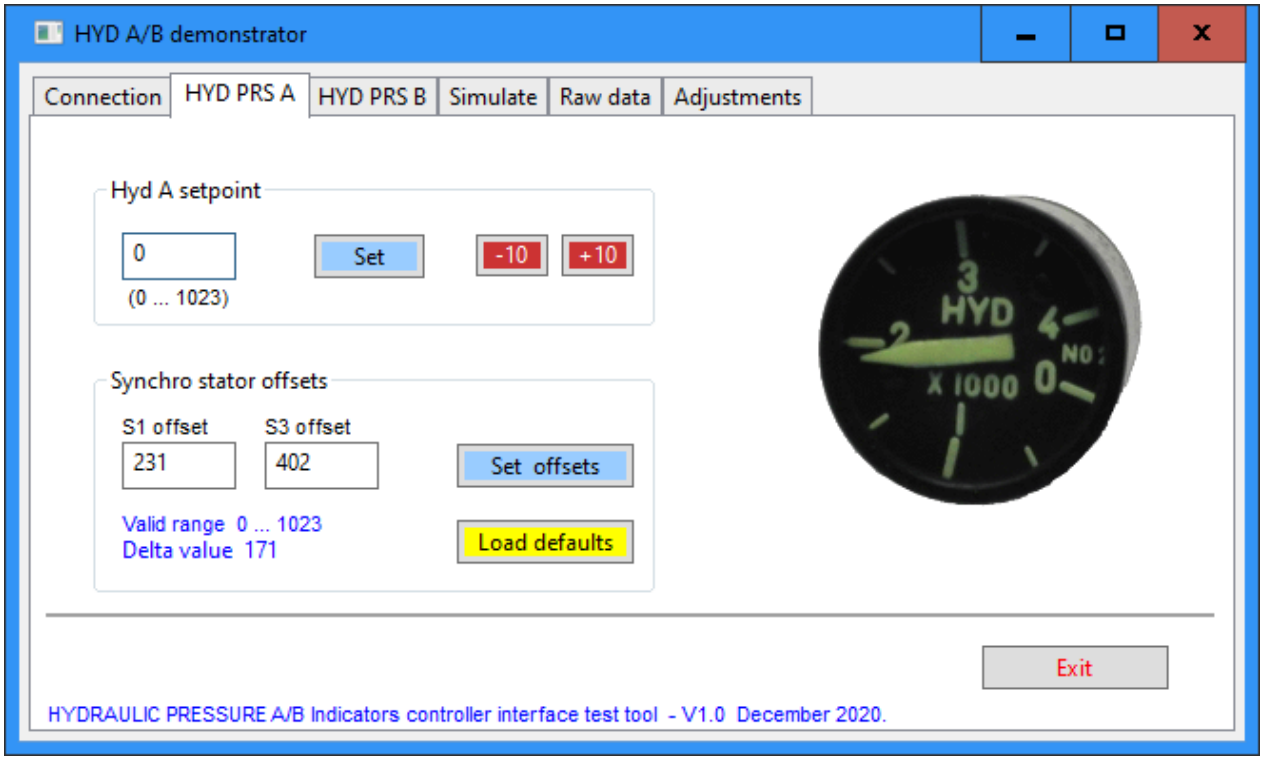
When the button is blue, clicking the button will send the command to the HYDRAULIC PRESSURE A/B board to change the DIAG LED indication functionality, and will change the color of the button to grey.

In the section “User outputs” you can activate/de-activate each user-definable output.

In the section “display TX data” you can enable and disable the printing in the CMD window of the transmitted data to the HYDRAULIC PRESSURE controller interface.

HYD PRS A tab

On the “HYD PRS A” tab you can control the setpoint indication of indicator A. The “Hyd A setpoint” section sets the indicated value, either specified as a value between 0 and 1023, or in 10 increment or decrement steps from the current setpoint. The “Synchro stator offsets” section allows you to change the stator offsets. It will change the actual indicated setpoint when a specific setpoint is set. Note that the 2 stator offsets have a relation, thus if you change one offset, you must change the other offset accordingly.



“Hyd A setpoint”

In the “Hyd A setpoint” section you can enter any integer number between 0 and 1023 (inclusive). When you subsequently click the “Set” button, the indicator will rotate to the requested setpoint. Indicated value “0” coincides with setpoint value 0, but that depends on the setting of the offsets. If the entry value is not correct and you click the “Set” button, no command is sent to the HYDRAULIC PRESSURE A/B board, but an error sign appears next to the entry field. Simply enter a correct number (0..1023) and click the “Set” button to send a new setpoint to the HYDRAULIC PRESSURE A/B board. This will remove the error sign.

With the small “–10” and “+10” buttons you can change the setpoint value with a decrement or increment of 10 from the current setpoint. Note that the setpoint is changed immediately, so you do not need to click the “Set” button.

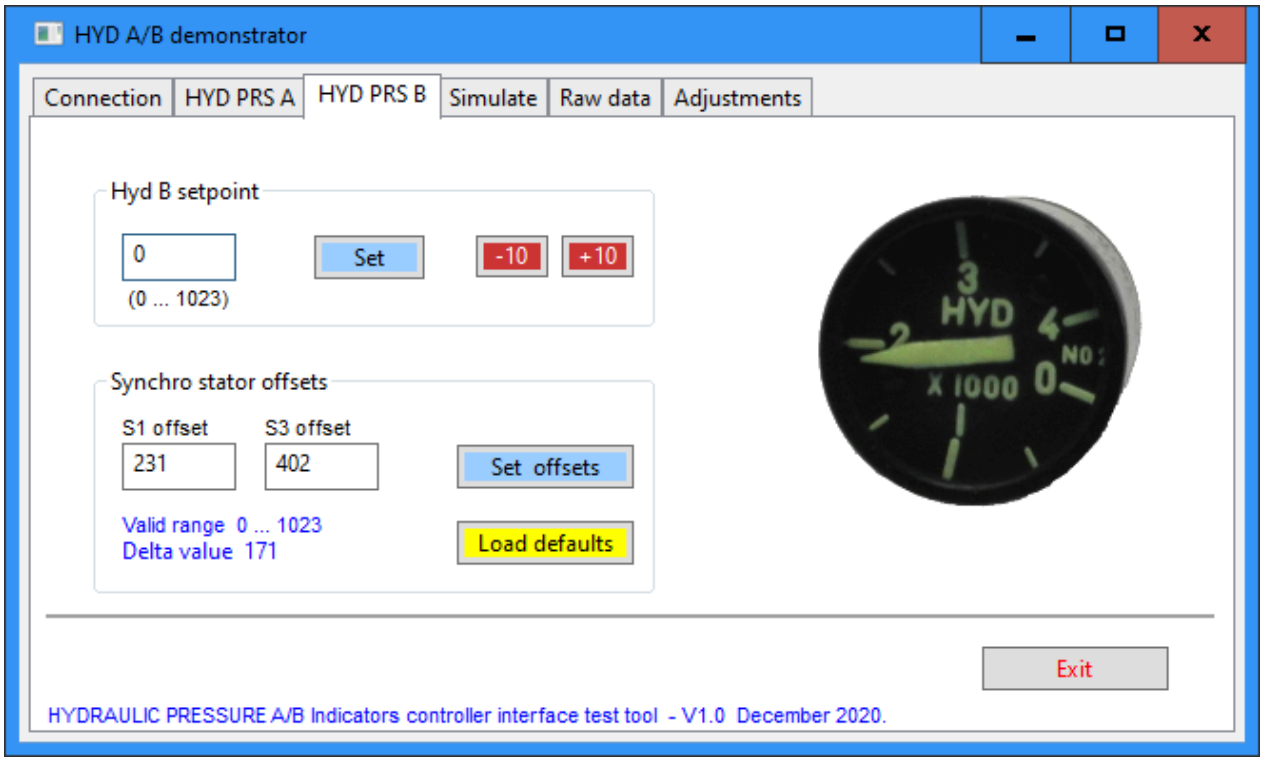
"Synchro stator offsets"

In the "Synchro stator offsets" section you can define the "offset" values for each of the stator coils of the indicator synchro. These offsets define the position (indication) when the setpoint "0" is commanded. A value change of 1 of the offsets represents approximately 0.35° rotation. However, the stator coils must maintain a 120° phase shift relation. Thus, if you change one coil setting, you must change the other coil with the same amount. The resolution is 10 bits, thus 1024 values, representing 360° rotation.

Click the "Set offsets" button after you entered the new offset values. If in any of the entry fields is an error, the color of the "Set offsets" button changes. Either enter correct numbers (valid data is 0 .. 1023), or click the "Load defaults" button. Then subsequently click the "Set offsets" button to send the new offset values to the HYDRAULIC PRESSURE A/B board. The color of the "Set offsets" button changes back to blue.

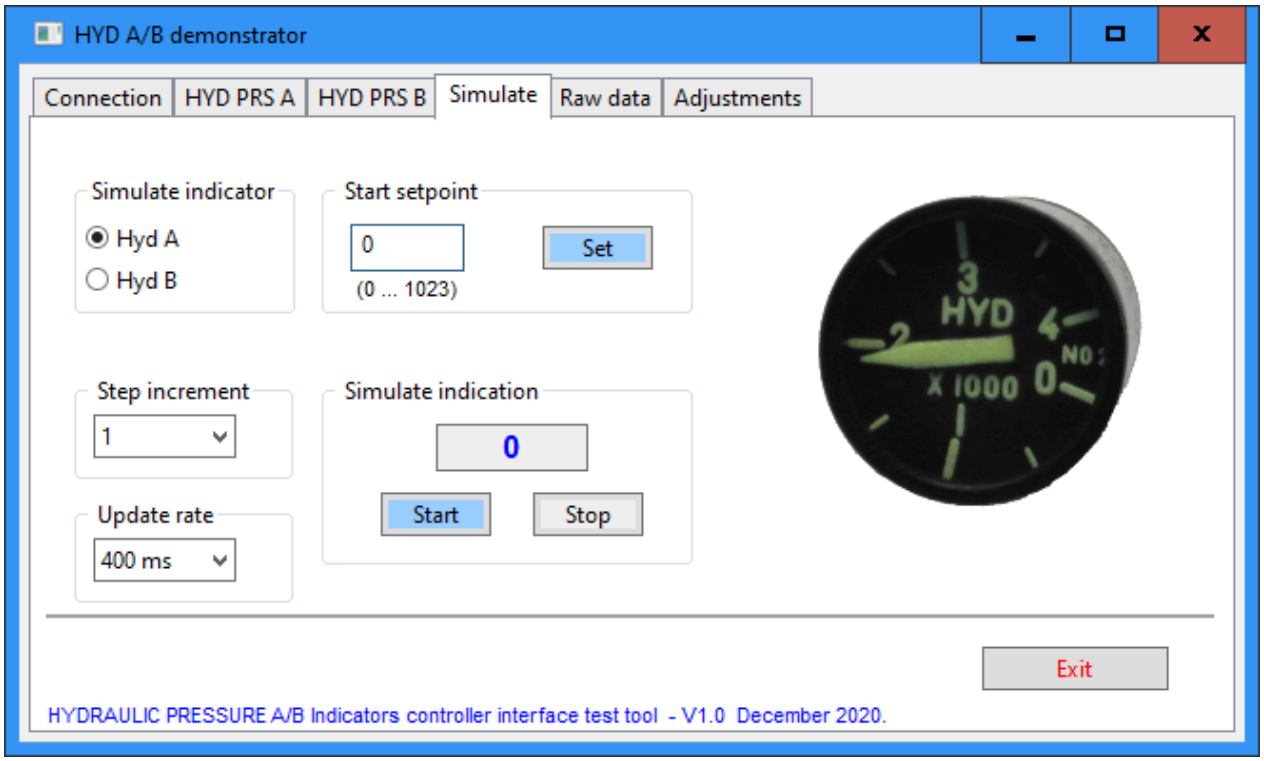
HYD PRS B tab

On the "HYD PRS B" tab you can control the setpoint indication of indicator A.
See "HYD PRS A" for a detailed description of the fields and buttons.



Simulate tab

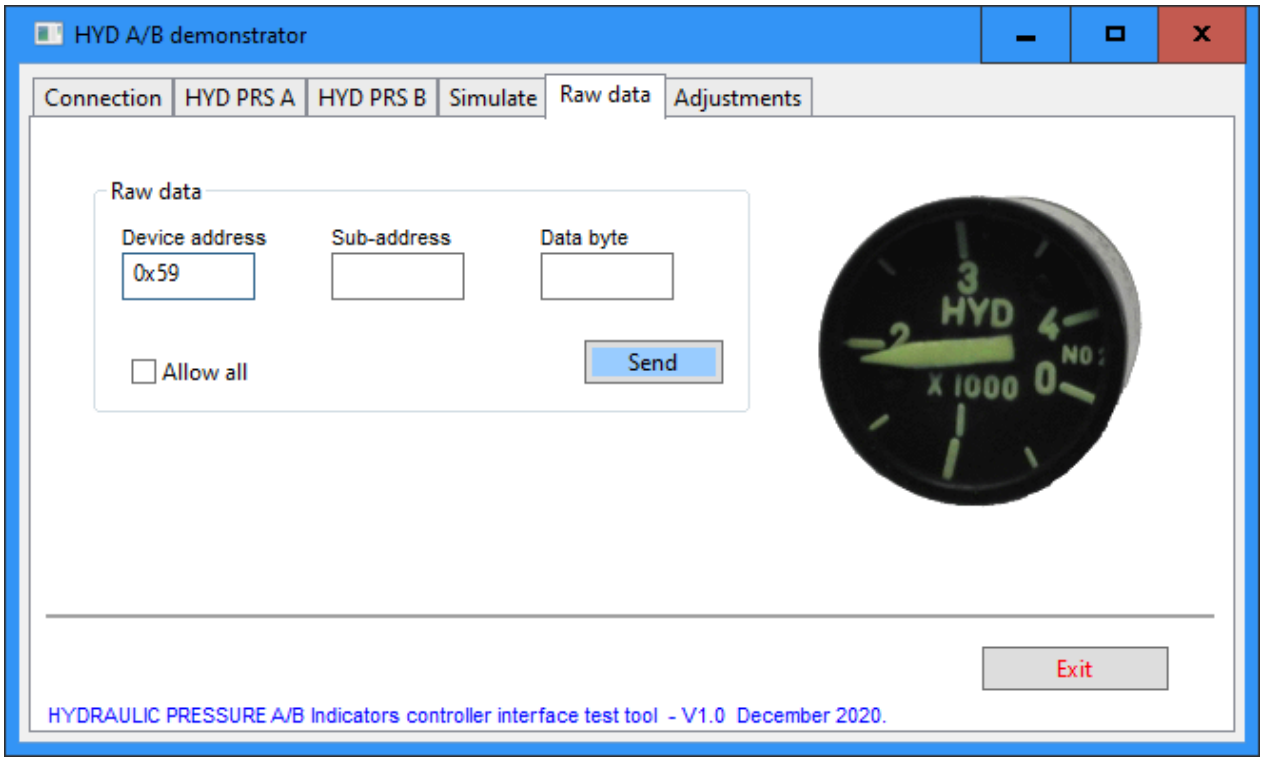
On the “Simulate” tab you can start and stop the simulation of an indicator of which the setpoint is continuously updated. With the radio buttons in the “Simulate indicator” section you select which indicator is controlled. You can select the Hyd A indicator or the Hyd B indicator. With a selection from the drop-down list of the “Update rate” section you can set how fast (or slow) the update is performed. Per update the setpoint value is increased by the value set in “Step increment”, and wraps around at 1023 back to 0 (1024 ≡ 0). The update rate is defined by timing in Windows, so definitely not milli-second accurate …



In the “Start setpoint” section you can set the selected indicator to an initial position before the simulated update is actually started. If the entry is not correct and you click the “Set” button, no command is sent to the HYDRAULIC PRESSURE A/B board, but an error sign appears next to the entry field. Simply enter a correct number (0..1023) and click the “Set” button to send a new setpoint to the HYDRAULIC PRESSURE A/B board. This will remove the error sign.

When the start entry setpoint is accepted, that position is also shown in the “Simulate indication” section. In this section are two buttons, “Start” and “Stop”. When you click the “Start” button, the color of the button changes to grey, the color of the “Set” also changes to grey, and the color of the “Stop” button changes to blue. The colors give a cue which buttons are “active”. After you stopped the update, you have a choice how to continue. When you click “Start” the update resumes from the current setpoint. When you click “Set” the indicator is moved to the setpoint specified in the “Start setpoint” section. When you click another radio button in the “Simulate indicator” section, the current selected indicator update (if active) is stopped.

Raw data tab



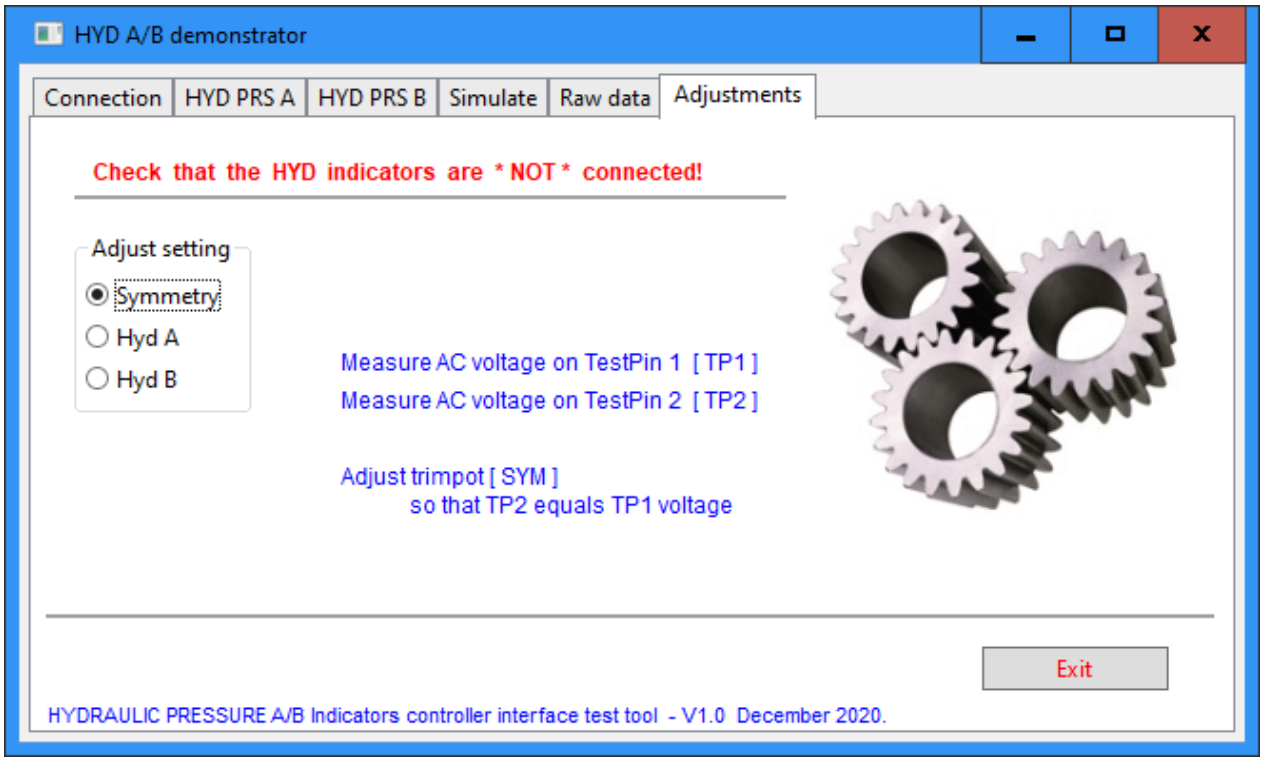
On the "Raw data" tab you can specify any command in the "Raw data" box. The edit field "Device address" defines the device address for which the command is intended. If you use a USB connection, this byte is not sent; it is only relevant if you use PHCC. The device address is the first byte of a DOA command, and effectively defines which PHCC daughterboard must react on the received message. The "Sub-address" and "Date byte" edit fields are used for USB and for DOA. These two bytes define the command and, if applicable, the data required by the command. As this is the test application for the HYDRAULIC PRESSURE A/B board, the "Device address" edit field is preloaded with the device address of the HYDRAULIC PRESSURE A/B controller interface (ASCII uppercase letter "Y", 59 hexadecimal). When you click the "Send" button the data is validated. If all data is valid, the message is sent to the HYDRAULIC PRESSURE A/B board, and the color of the "Send" button remains blue. If one or more data fields are wrong, the message is not sent, and the color of the button changes. Which data field is in error is indicated by an error sign.

Simply specify a correct value and click the "Send" button. If the data is correct, the error sign disappears, the command is sent, and the color of the button changes to blue.

If you want to send a command to another device you must change the “Device address” value. Default, the test program only accepts the address of the HYDRAULIC PRESSURE A/B board, and if you change that value an error sign appears. To allow a different device address you must put a checkmark in the “Allow all” checkbox. Of course, this only applies for PHCC connected devices.

Adjustments tab

This tab is only needed to do the adjustment of the output signals of the HYDRAULIC PRESSURE A/B controller interface.



With the radio button of the “Adjust setting” section you can select the adjustment of the phase-shifted amplitude (see chapter 6.1) and for which indicator you want to do the adjustment of the output amplitudes (see chapters 6.2 and 6.3). Note the red warning text: make sure that you have no real HYDRAULIC PRESSURE indicator connected when doing the adjustment procedure(s). I am not sure, but possibly you could overdrive the synchro coils, which might cause an irreparable damage. Better be safe than sorry!

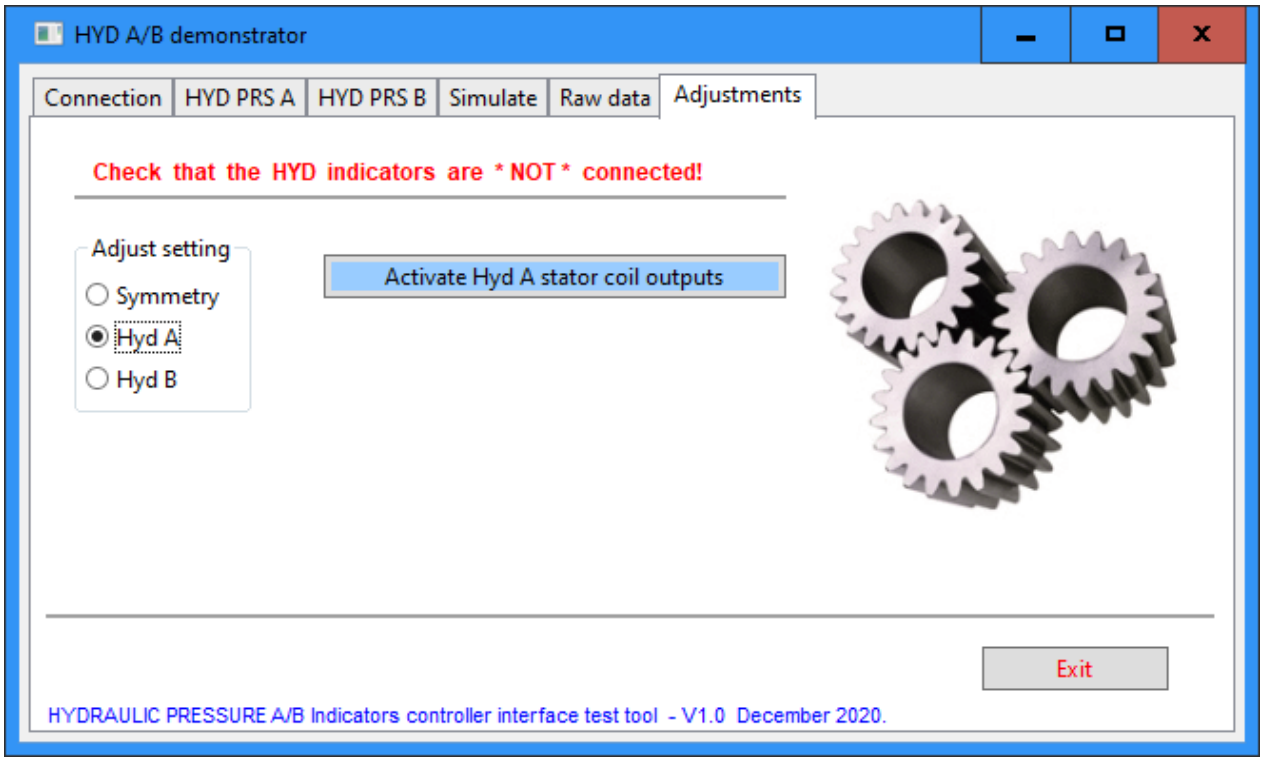
“Symmetry”

When the radio button “Symmetry” is selected, the blue text described what you have to do. See chapter 6.1 for a detailed description of the adjustment procedure.

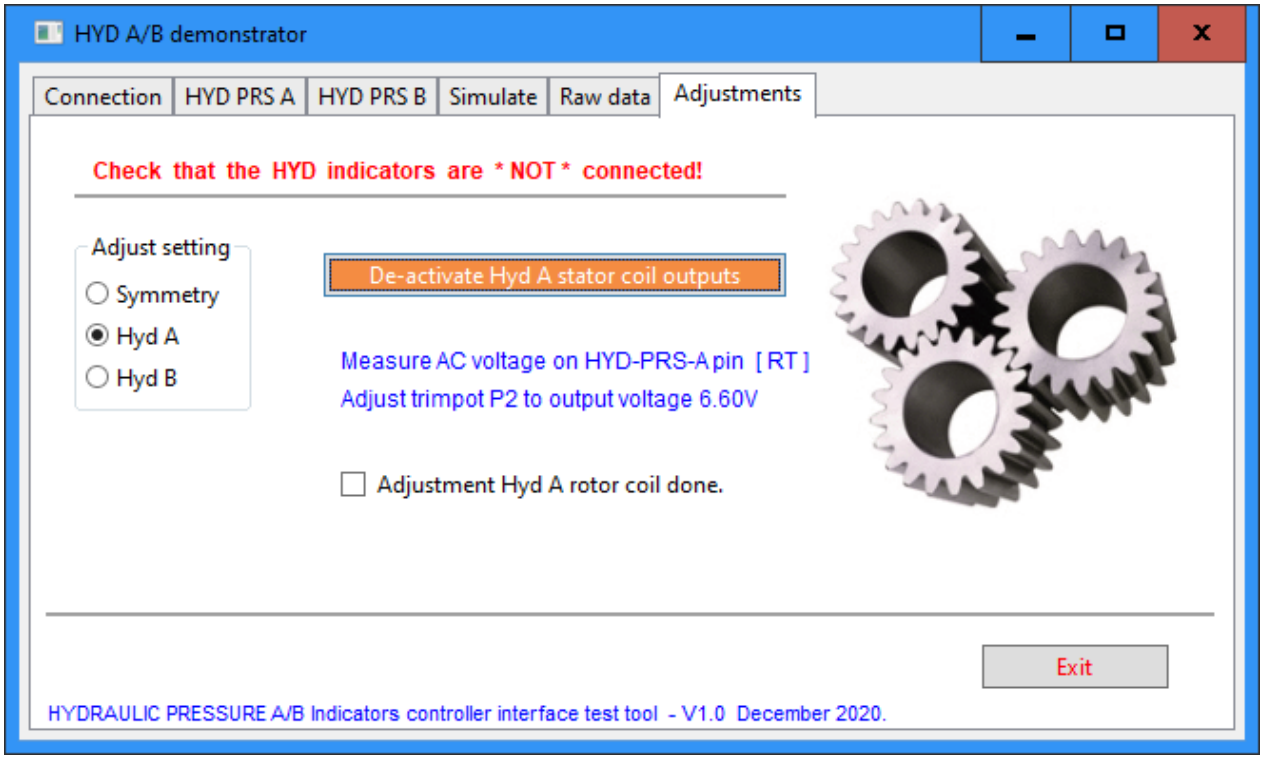
"Hyd A" and "Hyd B"

The adjustment procedure is identical for both indicators. See chapters 6.2 and 6.3 for a detailed description of the adjustment procedure.

The procedure starts when you click the "Activate …" button. When the button is blue, the stator output voltages are zero. When the button is orange the stator outputs are active, the button text changes to "De-activate …", and the output voltage level can be adjusted. Note that the **rotor** output voltage is always active.



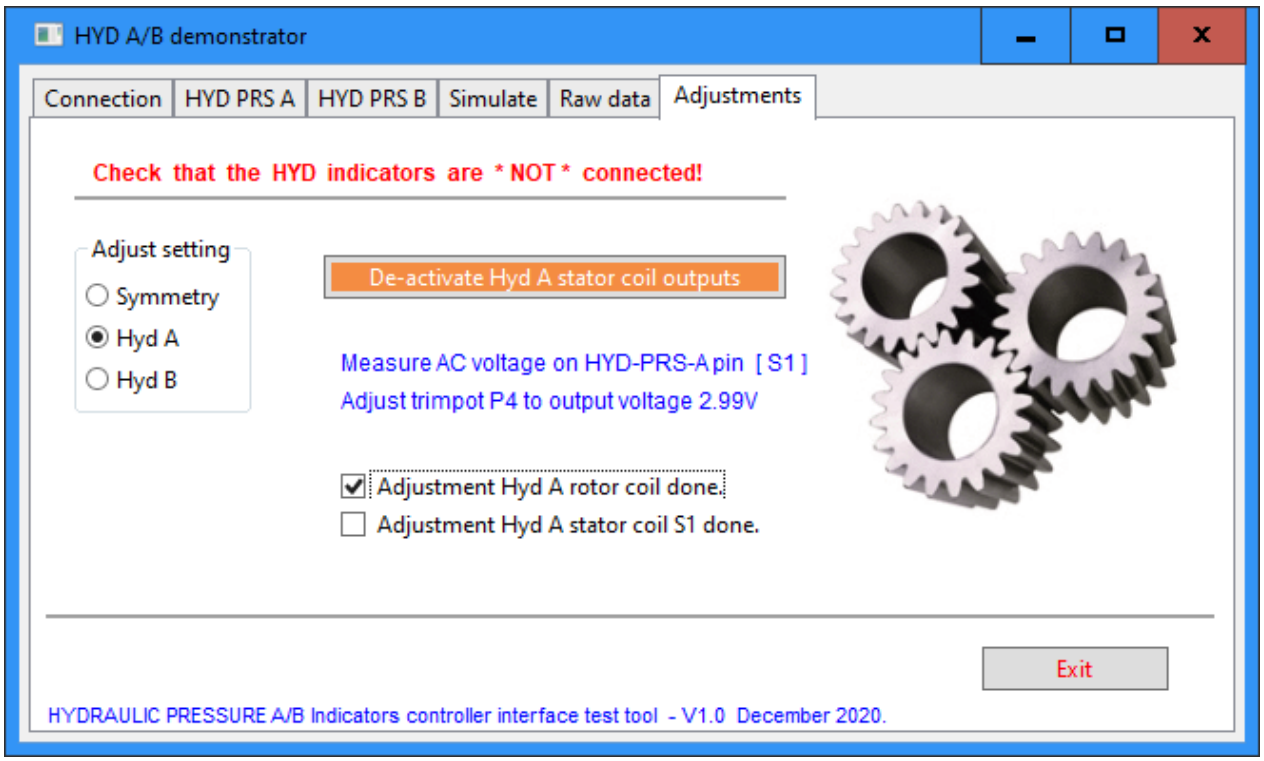
After the "Activate …" button is clicked, you see the actions printed in blue text that you must do for the adjustment.



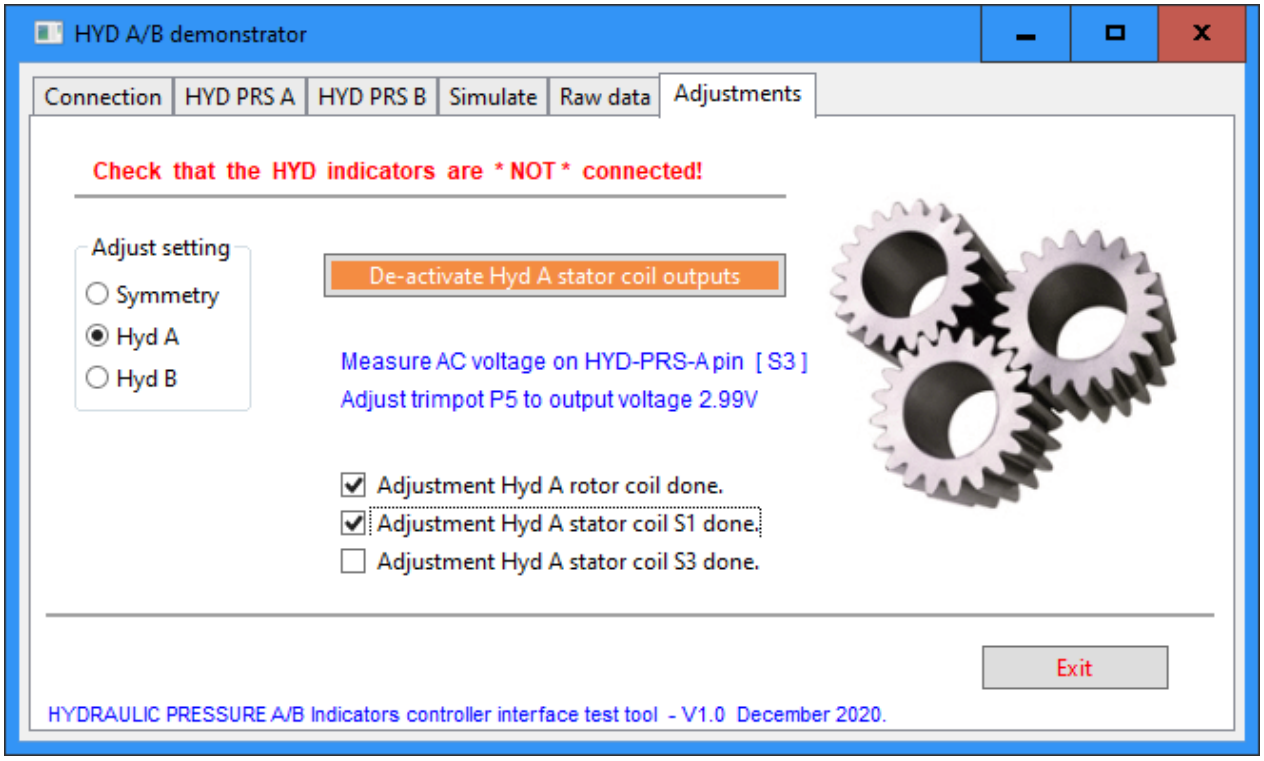
The actions are written in blue color, and always consists of two steps:

1. Measure the voltage on the indicated pin.
   Set the meter range to **AC Volts**, connect the (–) lead to GND, measure with the (+) lead.
2. Adjust the specified trim potentiometer to the specified output voltage.

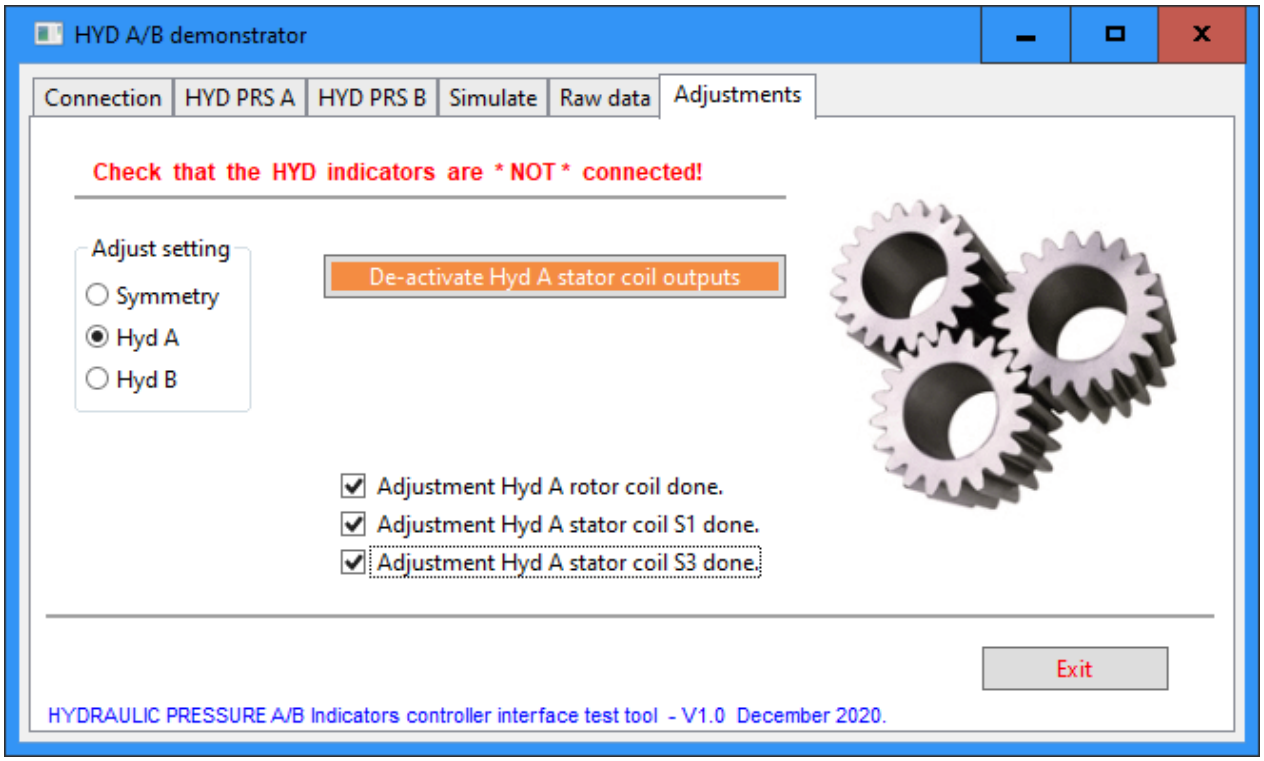
After you have done the adjustment, put a checkmark in the check box below the adjustment instruction. If there is another adjustment step it will appear where the previous adjustment step was displayed. If there are no more adjustment steps, you only see the checkmarks. See the following 2 screenshots.



In the above screenshot, the first adjustment has a checkmark, the next adjustment is displayed.



In this screenshot, all adjustments have a checkmark; no more adjustments left to do.

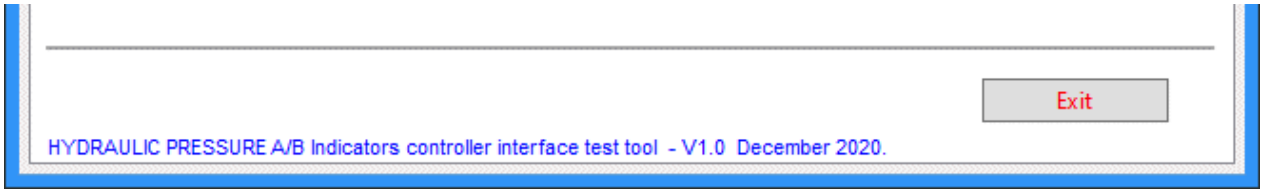


When all adjustments are finished you can click the "De-activate …" button to set the stator output level of the indicator synchro to zero. You can also select another radio button of the "Adjust setting" section to proceed to that adjustment procedure.

If you want to go back to a previous adjustment step, just click its checkbox again. The checkmark is removed, and you are back to that adjustment step.

When you select another radio button of the "Adjust setting" section, the current adjustment procedure is aborted and the stator output signals for the synchro are set to zero.

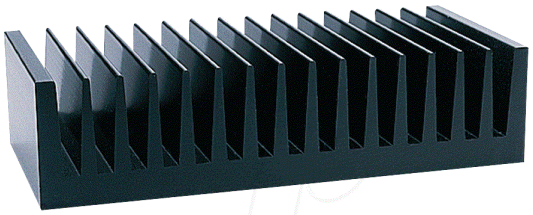
Exit button

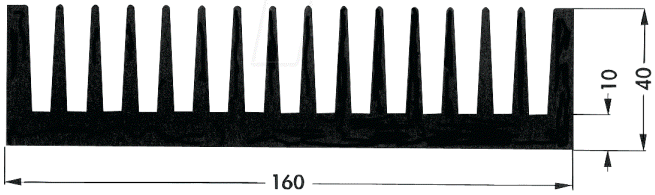


With the "Exit" button you terminate the application. If the COM port is still open, it will be closed. Note that activated outputs of the HYDRAULIC PRESSURE A/B board are not affected by terminating the test program.

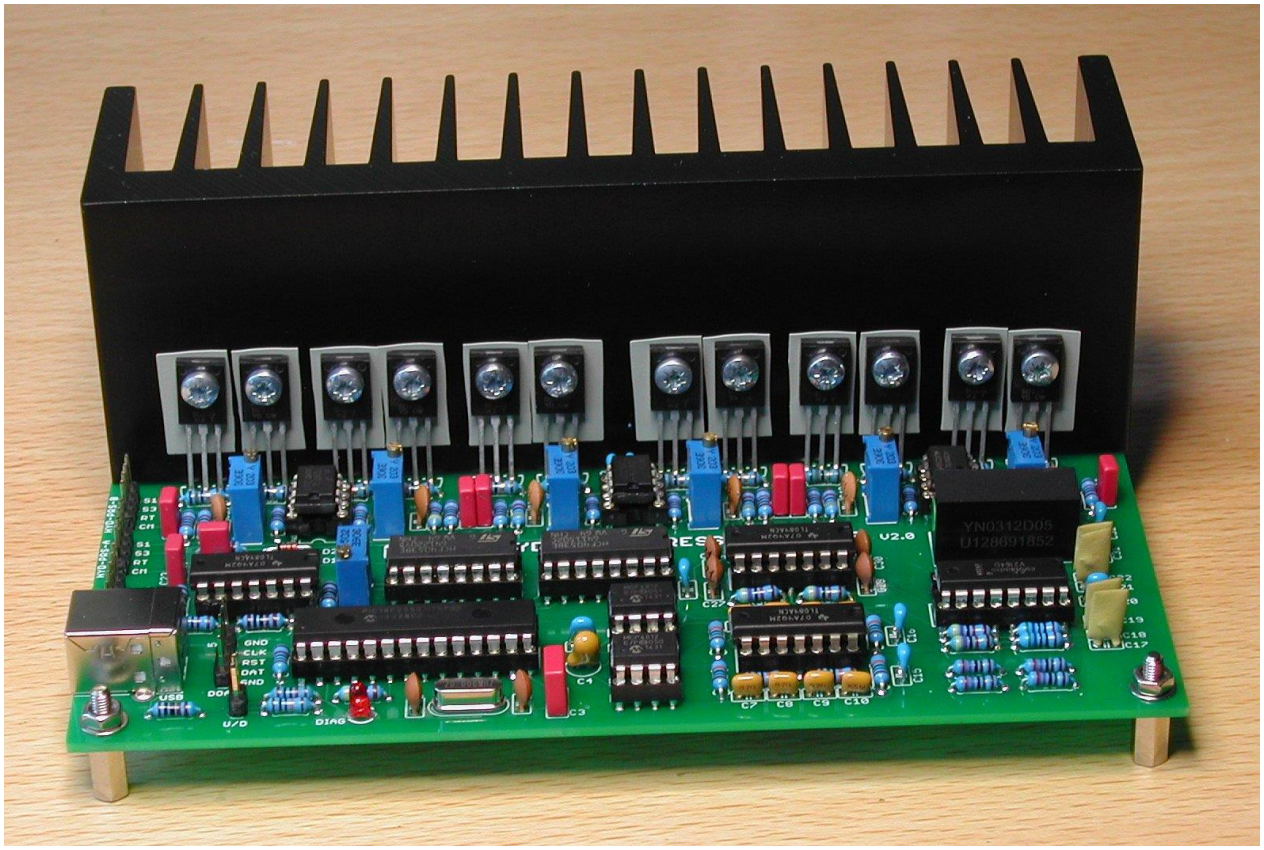
Appendix C – Heat sink for output stages

The HYDRAULIC PRESSURE A/B board has 6 push-pull output stages to drive the rotor and two stator coils of the two synchros. Each output stage consists of an NPN and PNP transistor. These transistors need a heat sink to get rid of the dissipated energy. A suitable heat sink is the ***V 6506E*** from https://www.reichelt.de/. Its dimensions are 50 x 160 x 40 mm.





1. Drill the 2 mounting holes (diameter 2.5 mm) to mount the heat sink onto the PCB; then tap an M3 thread in these holes.
2. Mark the position of the 12 holes for mounting the power transistors onto the heat sink. The distance from the edge of the heat sink to the mounting holes of the transistors is 17 mm.
3. Drill the 12 marked holes with 2.5 mm drill; then tap an M3 thread in these holes.
4. Mount the (assembled) PCB onto the heat sink with a screw at both ends of the heat sink.
5. Put the 12 transistors on the PCB, do not solder them.
   Check that you put the correct type in the correct location!
   a. Slide the 12 silicone insulation pads underneath the transistors, over the M3 holes.
      Do **not** forget these insulation pads !!
      You may need to cut off a small piece from both sides of each pad (symmetrical), so that all pads fit next to each other without overlapping. See the picture of the final assembly. Tip: check fitting of all 12 pads next to each other before you proceed.
   b. Put the transistors (still not soldered!) on the pads.
   c. Mount the transistors with the M3 screw. Do not yet tighten the screws.
6. Before you tighten each screw, align the pad to be symmetrically covered by the transistor.
   a. Tighten the screw.
   b. Proceed with the next transistor.
7. Finally, solder the 3 leads of each transistor.



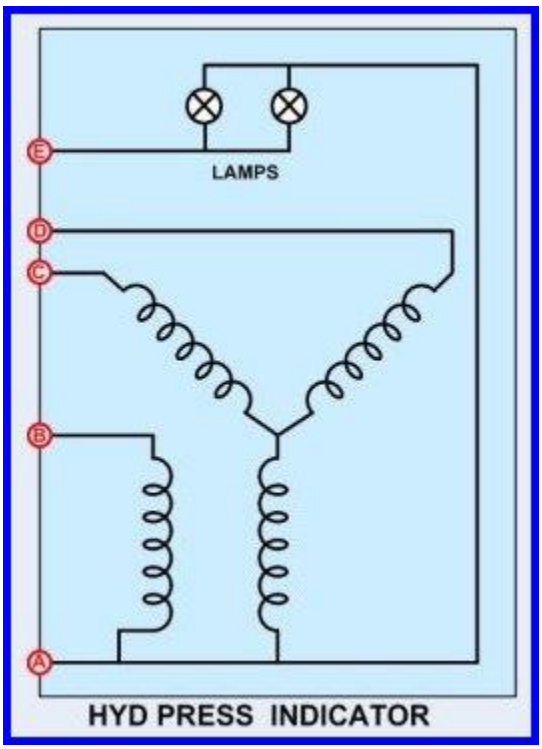
This is how the final assembly looks.

All connections are at the left side.

- USB connector (and behind the USB connector, the DOA header).
- +12V / –12V power supply header
- HYD-PRS-A header
- HYD-PRS-B header

Appendix D – HYDRAULIC PRESSURE indicator connections

The HYDRAULIC PRESSURE indicators have 6 pins, named A, B, C, D, E, F.
As you can see in the diagram, the stator coil S2 is internally connected to GND, pin A. That is why this configuration is called "S2-grounded".



The following table lists how the connections are made to the HYDRAULIC PRESSURE controller interface.

Indicator connector	HYD-PRS-x connector
pin A (common)	CM pin #1
pin B (rotor)	RT pin #2
pin C (stator 3)	S3 pin #3
pin D (stator 1)	S1 pin #4

If you swap pin #4 and pin #3 (S1 and S3) no damage will occur. The only effect is that the indicator "needle" will move in the opposite direction. So, if the movement is in the "wrong" direction, you can solve this in hardware by swapping the S1 and S3 connections, or solve this in software by swapping the S1 and S3 stator offset values in the application.