

Modular Concept of a DCS-BIOS-RS485-System

Intro

My intention as I designed this board-family was to create a bulletproof solution for builders of their own cockpits. The goal was a system that fits any requirements. The whole system is based on Ian's amazing DCS-BIOS.

Target audience are Flight-Sim Enthusiasts with no special knowledge or options in soldering, making PCBs or those who don't want to (or mustn't) convert their living room into an electronic workshop (As I already did – and I tell you: There is no way back!).

To those, they ignore my warning (or they went already this way) I offer the layout files for their own use.

The system is modular. It consists of one (or even more) Master-Module(s) and an arbitrary number of Slave-Modules. Each Master provides up to three chains (channels) of RS-485-Bus. Every chain can consist of up to 128 Slaves (in theory). This means also it is scalable. The maximum count of slave modules ($3 \times 128 = 384$) has still to be proven by practical experiences.

If the electrical load does not exceed 2 Amps per chain, power supply of all Slave Modules is primarily obtained by the Master.

Handicraft friendly design: All boards are designed in SMT whenever possible. Smallest parts (pitch 1,27 mm) and also trace-widths ($> 0,5$ mm) are dimensioned to allow making PCBs and soldering parts "at home" without highly specialized tools. All prototypes are made by using Toner-Transfer with a common Laser Printer.

Short explanation of Toner-Transfer:

The PCB-Design - I use DipTrace, Non-Profit Standard License - is mirror-sided printed by means of a common Laser Printer on a sheet of water soluble thin paper. I use a thin paper which is coated with thin adhesive water soluble film (like a stamp) where I print to the adhesive layer. Printed areas (the black toner) are transferred by heat and pressure - toner is melting at about $120\text{ }^{\circ}\text{C}$ - to a carefully cleaned sheet of copper coated glass-fibre reinforced plastic. This process is similar to iron on a patch to your pants. After gently and patiently wet-removing the paper (thanks to my glue coated paper it peels away by itself), toner stays on the copper (now right-reading) and acts later inside the etching bath as a shield by a hydrophobic effect while the uncovered copper will be removed from the PCB. Copper remains where Toner is because no etching agent has reached the copper. Finally Toner is washed off by means of Acetone: After check up (all traces "beep", no shorts), drilling, cleaning, coating with tin and/or flux and soldering (start always with the smallest parts!) the PCB is ready for testing.

As I have been asked for: All modules operate in the standard RS-485-manner as intended by Ian. You can add any kind of own made or third party hardware if it operates with a RS-485-Transceiver (like MAX487). You have just to make somewhat like an interface between different physical connectors.

All of this wouldn't be possible without the help of [Ian](#), [Warhog](#) and many other members of the DCS-community. I shouldn't stop to say: Thank you very much!

Dear Reader. As I can't know anything about your knowledge or intentions, this paperwork may not match your requirements. This is just a general introduction. Some special information or data you will get with your special hardware.

Please feel free to contact the author (or leave a comment here) if there is something missing, wrong or incomprehensible. :) Also, if you have a proposal how to express sth. a better way: let me know.

I recommend warmly to go back here from time to time as I continuously add new or modify features.

This document is somewhat dynamic as I add new facts always as I think about. And as I don't have the time to proofread the whole thing each time, it could happen, something's redundant (double mentioned). This is also called "old man speech". :)

Stage of Development (valid just for this document): Apr, 2019, tekkx@dresi.de

Status of Production

The whole family is still under development. All "available" boards are prototypes. This means there are seldom more than 2 boards with the same revision counter. My handicraft production line is capable of making always two (due to limited space not more than 4 PCBs at a time) ICBs at one time. And every time I made one "batch" I found something which was in need of improvement.

A small selection of the current stock you can find if you follow [this link](#). :)

Note: Not all pictured boards are still available and not all are pictured.

All in all: The status of the production is short described as "Prototyping" and "On Demand".

If I reach a stable and virtually unimprovable status, I'll give the production into third hand, maybe China.

What's my status (added on Nov 23th):

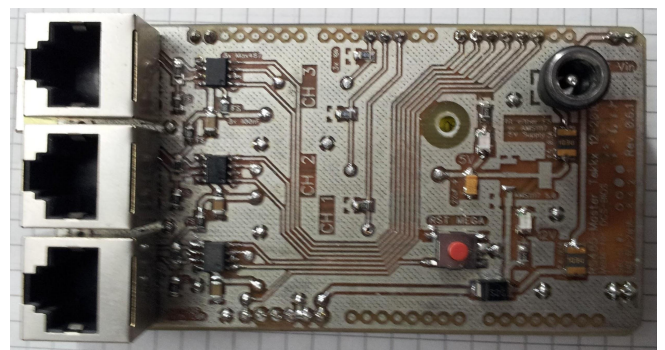
- I'm dealing right now with pcflights.com to make and roll out a real stunning CDU (and maybe other panels later). There is a first batch planned, consisting of 5 CDUs. Preorder is appreciated ;)
- As draken152 use some of my boards in [his fantastic WWII-Bird](#), I began to "re-think" my work and started to design an almost complete new family as the present design was primarily targeted on the A-10C. I plan to split the ICB (Interface- and Control-Board) into an universal (just) Interface-Board (IB) and some (very) specialized Control-Boards (CB) which are simply stacked as a sandwich. I hope this helps to prevent further confusion.

Master Board or Master Shield

The Master Board is nothing but a special shield for the Arduino MEGA 2560, similar to the more than 100 already available shields for UNO, MEGA and family. If it is stacked on the MEGA it breaks out three RS485-Transceivers (MAX487 or DS36276) and provides this way up to 3 Channels of the RS-485-Bus. There is also a connector (later there will be 3 of that) for a power supply for convenient power up these 3 Channels with 12 Volts, different fail-safe features and termination.

Fail-safe features are:

- TVS-Diode (SMBJ12A) of the common 12V supply circuit (TVS: Transient Voltage Suppressor) deflects high voltage peaks up to several 1000 Volts to the ground plain. This could happen due to flash strike during break through the clouds in stormy weather or simply by rubber soles of your slippers on synthetic (means: non conductive) flooring. I have known a 2000-Dollars-Damage to happen as my peer (at my real work at a broadcast station) walked wearing Adidas-Sports-Shoes over the felt floor inside a Broadcast-Studio while we had a device with open housing (while servicing it): Boom! (After Boom! is not imperative smoke but always silence!)
- TVS-Diodes (two are integrated in one SM712) for each line of the RS-485-Bus
- Self-Resetting PTC Fuses of 2.5 A for each Bus-Supply-Line



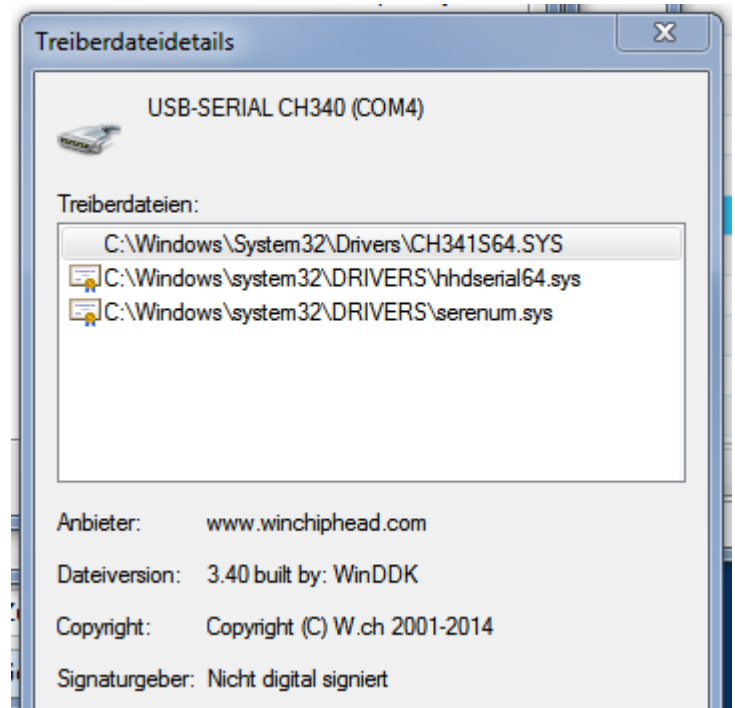
- Filter-Capacitors to decrease any noise or ripple of the Power-Lines
- Fail-safe-Bias- and Termination-Resistors on board
- protection against polarity reversal at the power feed screw terminal

TVS-Diodes are under normal condition high-resistance, so they bring no relevant extra load to the bus.

MEGA2560 (anyhow the ones from China, Original MEGA has a FTDI FT232RL on board) are usually delivered with a CH340G, so the Device has to be shown in (Windows 7) "Printers and Devices" as USB-SERIAL, CH340 (COMxx).

If there are some issues, look for the latest drivers for CH340 (or CH341) on the [internet](#). If you're lucky you'll find a non-chinese version. As I believe, USB (and all related stuff) is charlatanism anyway, I can't give a helpful hint. But anyhow: I brought it to business every time. :)

Sometimes, after days of despondency, a simple change of an USB-cable or -port brought the solution.



General Features of this System

Connection to the RS-485-Bus is realized by shielded RJ45-connectors. I decided to use this kind of connection, because the link between Master- and Slave-Modules can easily be achieved by standard Cat5 or Cat6 Patch-Cables. These cables are available cheap and ready-made in different lengths (and colors) up from 25 cm (somewhat less than one foot).

Do not mix with PoE (Power over Ethernet)! It looks the same because of the same cable, but it has nothing else in common with Ethernet!

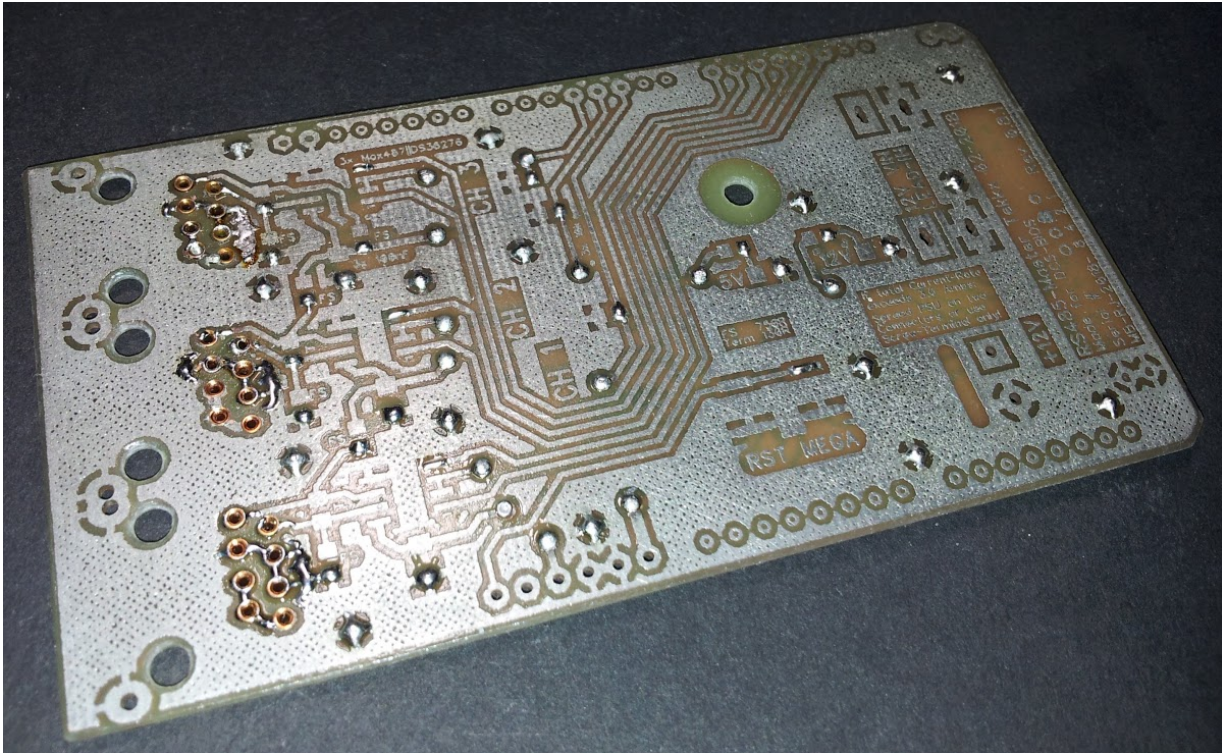
So the installation will become easy and clean. It's possible to link RS-485 and power supply for all Modules over one single cable-(Daisy-)chain with not even a small chance to do wrong. Where open wires are used to connect, inverted polarity is very common. But here it is impossible.

An early stage of the bus layout (as suggested by Ian, he also suggested the use of RJ45 in the very early days of DCS-BIOS) led 5V over the line to feed all transceivers of the bus. Because I've been afraid of too much Voltage drop over longer distances I decided to commit these 5V nearby every single RS-485-Transceiver. This kind of power supply is less than 2 Dollars, it is worth every Cent. So there will the configuration of the Cat5 wiring is as follows: Two wires (Contacts 1 and 2, according to EIA/TIA-568B twisted Pair 2 - the orange one) are for the RS-485, 3 Wires are for 12V (contacts 5, 7 and 8) and other 3 Wires are connected to Ground. Each wire (including contacts of RJ45) has a safe load capacity of 1 Amp. As we use 3 wires at each Line (or Channel), there should be plenty of headroom. There are 2.5 Amp PTCs. They will limit the current before any other components will start smoking.

If you use shielded cables (STP or S/FTP is highly recommended), Shield is also linked to the Ground-Level, so voltage drop should be minimal.

Cat5 cables provide 8 wires as 4 twisted pairs. The RS-485-bus benefits from that. The unshielded printed onboard portion of the RS-485-traces are kept as short as possible to

decrease jamming the bus by external stray radiation. The position of the MAX487 slipped closer and closer to the RJ45s with each new version or revision.



This is one of the latest Revisions of the Master Shield for two 5mm-Jacks and one Screw-Terminal. Still without components. (Hand-)Riveted Vias are already to be seen. The position of the 3 MAX487s is very close to the RJ45. Unshielded RS-485-traces are shorter than one inch.

Each ICB is equipped with two RJ45s (while the Master has just one per Channel). One is to use as the Input, while the other is accordingly Output to link the next module by a Cat5-Cable. Second RJ45 of the last Module in the Chain remains free. Here you can insert an optional special **Termination-Plug**. Relaxed interpreting of RS-485-specs, safe un-terminated operation should be possible up to 10 m (30 feet) overall bus length (before reflections will become relevant). The whole process will be some more complex, so I will break it down: Imagine those reflections as an (acoustical) echo in the mountains (it's an echo indeed): If you shout sth toward to a wall, standing close to you, you'll hear your voice virtually just in time. If the wall is far enough - in a church for instance or even in the mountains - your voice will take some travel time before it'll return to you after a while. If this echo is loud enough, it will become just as well understandable as the genuine signal. A simple machine will not know if this is an original signal or just an echo. Either the signal will be un-understandable - if original and echo interfere - or the machine will interpret it as twice the same signal.

If you put some special foam to the walls, this effect will disappear as the foam will swallow your voice - it will transform the energy of the sound waves into thermal energy. This is called damping or attenuation. Same do our termination resistors: It swallows the signal while (or even before) it is about to hit the end of the wire and will be reflected. Take note, electrical signals travel close to the speed of light!

Latest layout of Slave-Modules will add no more than 50 mm (2 inches) to the overall Bus length. Latest Revisions of Master Shield has Termination and Fail-Safe-Bias fixed on-board (soldered SMD-Resistors). So Termination becomes relevant just at longer chains and just at one side of the bus. Very handy.

Interface- and Control-Board ICB-x-RJ-yyyy-##

Nomenclature

ICB	Interface- and Control-Board
x	specific model, indicated by one or two Letters
RJ or ST	Connection of the RS-485-Bus by two RJ45 sockets. One of that is used as Input, the other one as Output or to plug a Terminator in. Later (if requested) there will be also a ST-Version (ST = Screw Terminal).
yyyy	This is the year of the design or when I got the first working prototype.
##	running number, restarted at each increment of Minor Version, indicated by 4 Checkboxes 8-4-2-1 (binary)
Rev#	I try to adopt Semantic Versioning 2.0.0 : MAJOR.MINOR.PATCH

The ICB is essentially nothing but a break-out of the Arduino NANO. Whilst the MB is a perfect matching shield to the MEGA, the ICB can rather be seen as a platform where the NANO sit on amid some other parts (in german called "Hühnerfutter" - chicken's food). During the development many accidents happened and produced the total loss of NANOs, MEGAs, AMS1117s or MAX487s. I have many devices here in the "Chest of Remembrance" without any smoke inside (I let it all out). So there are added bit by bit some safety- and failsafe features. Still unreached is bullet- and foolproof design.

Each ICB has its own stabilizer to feed just the MAX487 (or MAX487s on Duplex- and E-Boards) with constant 5,0 Volts (+/- 0,1V or less), even in the worst (even unlikely) case if the bus-power should drop down to 6.5 Volts.

Other failsafe-features are

- TVS-Diode on the 12V-supply-line
- special TVS-Diodes on both RS-485-Lines
- PTC-Fuses (self resetting) for Over-Current-Protection of the 12V-supply-line
- Pull-Down-Resistors of 10k on each TX-enable-Pin. The intended purpose of these Resistors is to prevent undefined state while starting up the system or hot-plug individual modules. These Resistors unfortunately bring potentially an additional load to the RS-485-Bus. So maybe the theoretical chain-length of 128 Nodes won't be reached without issues (still under investigation).

The power supply of each ICB is provided by the Main Bus. Each of the three chains can be laid with 2 Amps safely. Additionally each ICB is equipped with a 5mm female Jack. There can optionally be an extra supply connected if some „heavy“ consumers (as coils, motors, screens, incandescent bulbs...) are connected to the board. This additional supply is discrete (decoupled by a Schottky) from the Main-Bus. So the external 12V in-feed supports just the consumers at this single Module. This relieves the Main-Bus and keeps the impact of heavy loads away from the Bus.

All ICBs are equipped with two RJ45 receptacles: One is as Input, the other one is as Output while order doesn't matter as both ones are equal.

Many versions are equipped with a Potentiometer for trimming intensity of PWM-controlled backlight. It works the analog way by reducing the base-voltage of the PWM. This is for matching brightness of different Panels. This pot is only to actuate by means of a small screwdriver if the related module is lifted off the Dzus-rail.

Backlight-Trim brings a little backdraw: It limits the maximum power rate of the backlight to 1 (one) Ampere. If LEDs are used, this shouldn't become a problem.

Basic design of all ICBs aims to be standardized to almost all applications. All ICBs come at the same size and same mounting holes. They are designed to easily fit into any panel designed according to Dzus-Rules.

Because the RS-485 and the PWM-Backlight at the Slave-Modules needs to be controlled, some I/O-Pins of the NANO aren't available:

- Pins D0 and D1 are occupied by the TX- and RX-Lines,
- Pin D2 is for enable the TX (TXe),
- Pin D3 is used as PWM-Out for controlling the Backlight.

Whereas all ICBs are connected by RJ-45, there are offered some different versions which are specialized for different applications. Some provide only one MAX487, others are equipped with two of these transceivers. Experimental is a board with a stackable extender to carry more than 4 MAX487s.

While each MAX487 brings just an electrical load to the bus, each connected Arduino will need an unique Bus-ID#.

ICB-S-RJ-yyyy-##

“S” for Single Arduino.

This is the board for most common applications. All digital and analog I/Os are serviceable. Except D2 and D3, these are already used for RS-485 and PWM-controlled Backlight. Both functions are hard connected on the PCB to either the MAX487 or the MOS-FET.

The digital I/Os D4 to D13 and the analog INs A0 to A7 (some versions don't use A7) are each broke out on a 10-Pin male pin header. While developing a Lightboard for the SAS-Panel it came out as a benefit to rearrange some analog Pin-Outs to easily connect a Potentiometer (5V / analog IN / GND) without to crossover the connecting cable.

Also there are two (up to) 10-pin-headers with alternating 12V-GND or 5V-GND for different purposes.

By means of temporarily removing Jumper “RX/RE” can the Transceiver be disconnected for uploading a new sketch to the AVR without the imperative removing the Arduino from the board. Meanwhile I upload all sketches by ISP. For this I converted an Arduino UNO as a Programmer. One of the benefits of this course of action is, if uploading many sketches to many different AVRs, the Programmer is always on the same serial port and I don't have to look for, where the actual AVR is :)

All ICBs (up from Rev 0.8.0) are equipped with a Test-point (TP) where RX, TX and TXenable are broke out for easy connecting a Logic Analyzer if Troubleshooting is required.

ICB-T-RJ-yyyy-##

Double Arduino, “T” for TFT. (still not for public release)

This ICB is developed to drive more sophisticated Modules. It is at the moment the most complex break out. So it features two Arduinos on board and also two FET-amplified PWM-channels to drive two different dimmable Backlights. By means of a jumper is defined if both or just one PWM Backlight is tunable by the Potentiometer. Unfortunately this Trim-Function implicates a limitation to 1 Ampere.

A typical application is the CDU (Central Display Unit). There is one AVR controlling an LCD, the other AVR could control an 8x9-Keypad-Matrix.

Additionally there is a second AMS1117-5.0 (preferably with heat sink) for providing 5.0 Volts to feed the Display. To connect the keypad, ICB features an 8pin header and a 10pin header for

columns and rows of the keypad matrix. The LCD is to link with two 8pin headers, which supply signals, power and ground.

This ICB has no extra Pin outs with 12V or 5V.

While Pilot Operation some issues with randomly wrong data shown on the 3.5"-Display. The errors are just watched while operating in RS-485-mode. A single Arduino (I tested NANO and UNO) connected by the DCSBIOS_IRQ_SERIAL method worked correctly. This issue is still under observation. Maybe DCS-BIOS 2.0 will solve this.

For Troubleshooting there are added some special Low-Current-LEDs to the TX, RX and TXenable lines and a jumper to disconnect the TX line. If the ICB-T-RJ- comes out of 0.x.x-Revision, these features will be removed or kept unoccupied even though they drag a very small current of 2 mA. These LEDs are just available in 0603 package (1,7 x 0,8 mm) and its highly enervating to set them manually. (see "handicraft friendly Design" above).

ICB-C-RJ-yyyy-##

„C“ is short for „CDU“

While developing a Switch- and Light-Board for A-10C's CDU, the ICB-T-RJ... became obsolete before it was ready to roll out.

So I modified this T-Board and it transmuted to the ICB-C-....

It is just for the CDU and it also carries two Arduino NANO. It was necessary to set a second Arduino as the first one is fully loaded with a 8x9-Keypad-Matrix. The second NANO is also linked to the RS-485 and features just 3 functions:

- CDU on/off (no longer used since it doesn't work as intended)
- Lighting of all 63 Buttons (each button has its own built-in LED)
- Lighting of the Designation-Line

Each of these AVR's needs its own unique Bus-ID.

The Board provides 4 Headers (8 Pins each) for linking to the Switch- and Light-Board. So the ICB and the SLB are easy to connect by 4 8-Wire-Ribbon-Cables.

The two Backlight Channels are each amplified by a heavy MOS-FET and they are not trimmable as you know of the other Boards of this Family. This is due to lack of space and it appears to be unessential.

Latest Revisions have optional a connector for a further RS-485-Transceiver. Maybe someday the LCD could be fed by RS-485 instead by USB.

See also the Chapter "CDU".

ICB-E-RJ-yyyy-##

“E” is for Extendable. Stackable.

This board has additional a special interface to stack several Extension-Boards (EB) on. Each EB provides an extra MAX487 with its own 5V-Supply by an AMS1117-5.0. These auxiliary Arduinos (no matter if NANO, UNO or MEGA) are connected by a 5-wire-cable: TX, RX, TXenable, +12V and GND.

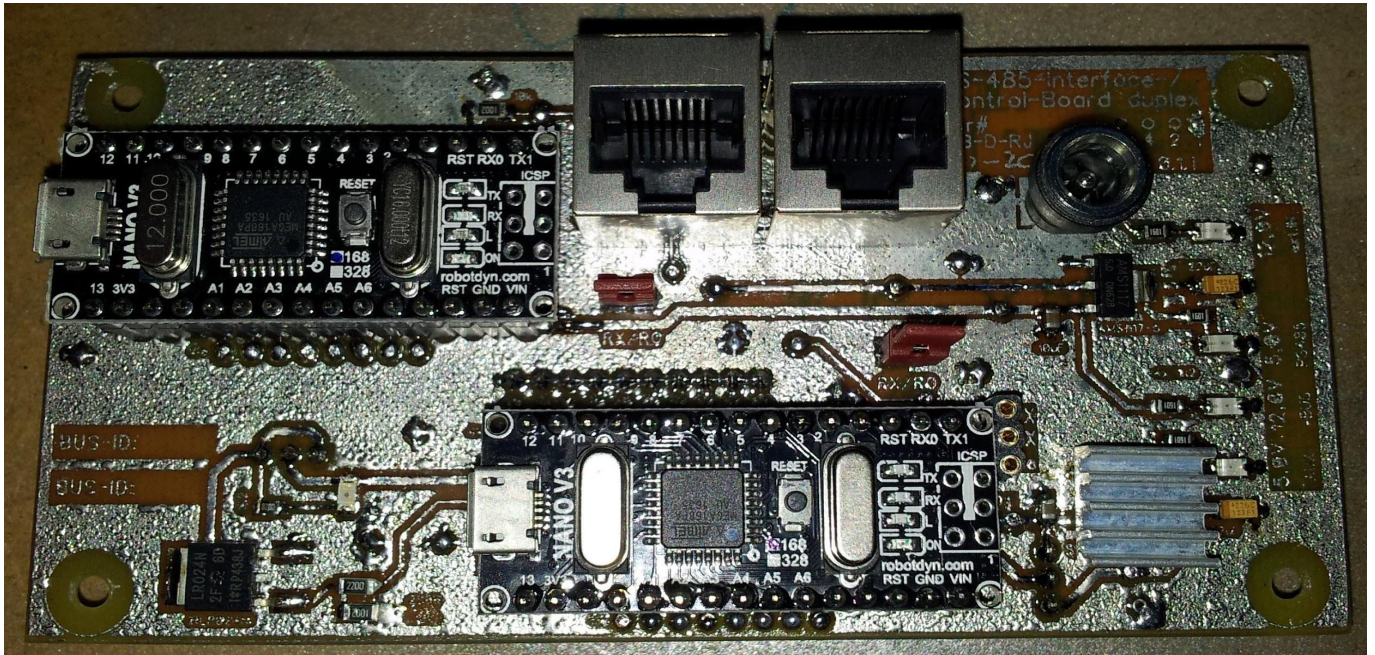
This version is still at the 0.1.x Revision and it has not been tested yet, how many EBs are stackable without too much inappropriate impact to the Data-flow of RS-485.

To prevent the need to disconnect and lead back the Bus-Traces on-board – this would lead to other unwanted fallouts – the Extension-Interface is designed as a branch or like a fork. As RS-485-Specification says, the maximum length of such nodes (or stubs) is up to 6 inches (15 cm) without extra Termination. Because the traces on the ICB (20mm) and the EB (15mm) are very short, up to 3 stacked EBs should work fine. In other words, you can drive up to 4 (tested) Arduino NANO in one Module, linked to the Bus with just one Cat5-cable. A conceivable application could be the Engine Instruments Panel of the A-10C with 12 stepper-driven gauges.

It is still to investigate, what's the behavior of the Bus, if many Slaves are connected.

ICB-D-RJ-yyyy-##

“D” is for Duplex, as two Arduino NANO are onboard



The picture shows an early Prototype. Tin-Coating of the 35um Copper has failed because of too much heat for too much time (it works anyway even if it looks ugly). You have a clear view to (top-left to down-right):

- Arduino #2
- 2x RJ45 connectors. Both are equally usable as Input, Output or for the Terminator-Plug.
- 5 mm Jack for feeding 12 Volts external Power. External Power is just demanded, if the related Module drives some heavy loads whereby overall Bus Load would exceed 2.0 Amps.
Close to it sits the AMS1117-5.0 which provides 5.0 Volts to drive the two MAX487s
- two empty Fields for marking BUS-IDs
- MOSFET for amplifying PWM signal of D3.1 (Dot 1 means: first Arduino NANO). There is also a green LED which monitors PWM-Output of the MOSFET. Max Load is limited by Power Supply and PCB-Traces. There is a self resetting Fuse which blows at 2.5 Amps.
- Arduino #1
- AMS1117-5.0 with Heatsink
- at the right you see 4 LEDs. These monitors (from Top):
 - 12.0 V of external Power-Supply
 - 5.0 V provided by AMS1117 just as supply for the MAX487s
 - 12.0 V if the Bus provides that
 - 5.0 V provided by second AMS1117 (supported by Heatsink) for Auxiliary Purposes

The layout of INs and OUTs of both NANOs are similar. As a second Backlight is an exception, the ICB-D- carries just one MOSFET. This is driven by D3 of the first NANO. Anyway D3 of the second NANO is broke out at a 2pin-Header, called D3.2

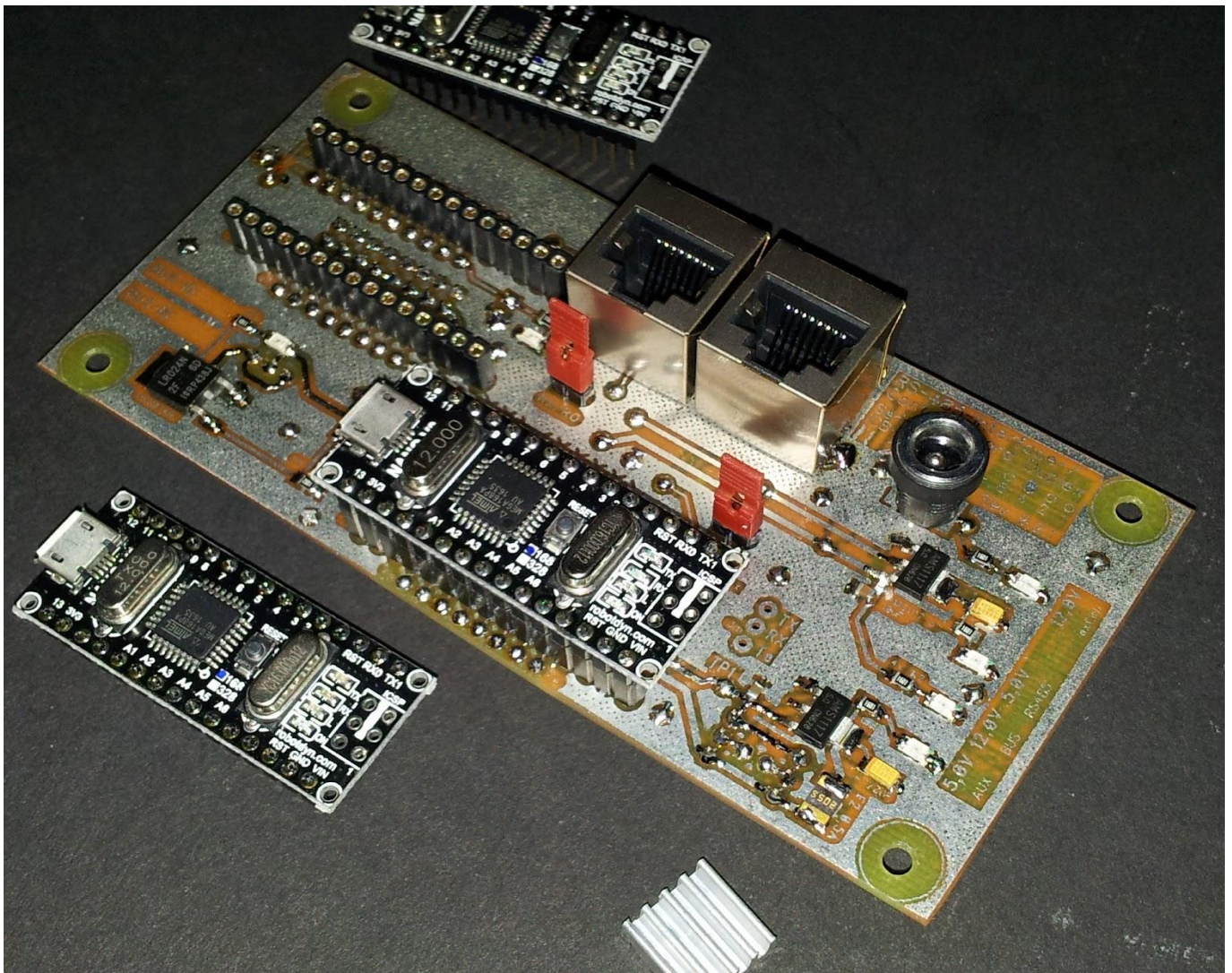
This ICB carries two Arduino NANO (that's why Duplex) and provides in addition to the usual safety features

- all digital and analog I/Os are broke out by a male Pin Header
- 2x 10 digital I/Os. Each has its own GND-connector

- 2x 8 analog Inputs. Each of them has its own GND and 5V connector. So connecting Potentiometers becomes very easy over the 3pole female Dupont connector. One trap has been kept: Due to Layout reasons Pin-Sequence is Input-5V-GND. A Pot asks for sequence 5V-Input-GND.
- 10pin-male Connector (J6 at this Revision) with selectively 5.0 or 12.0 Volts. This is achieved by two Jumpers (AUX1 and AUX2) that are set either at 5.0 or at 12.0 Volts-Position.
5.0 Volts are generated onboard by an AMS1117-5.0, hidden under the Heatsink.

Caution!

Even though all Duplex-Boards can operate with just one Arduino NANO set, **NEITHER set** an Arduino up **NOR remove** an Arduino while the ICB is powered. The potential consequence is that MAX487 and AMS1117 could overheat and burn because of (not researched yet) swinging-effect.



The second Prototype, which is very close to the final Layout. Heatsink of the auxiliary AMS1117-5,0 is not set yet.

Pin-Out Reference ICB-D-2017-...

Pin#	I/O-Type	recommended use	alternative use
D2.1	I/O	occupied by TX enable	none
D3.1	I/O	Backlight, determined by ICB	none

D4.1	I/O	Button/Switch	LED on/off
D5.1	I/O PWM	Button/Switch	LED dimmable, Servo
D6.1	I/O PWM	Button/Switch	LED dimmable, Servo
D7.1	I/O	Button/Switch	LED
D8.1	I/O	Button/Switch	LED
D9.1	I/O PWM	Button/Switch	LED dimmable, Servo
D10.1	I/O PWM	Button/Switch	LED dimmable, Servo
D11.1	I/O PWM	Button/Switch	LED dimmable, Servo
D12.1	I/O	Button/Switch	LED, Matrix Col/Row
D13.1	I/O	Button/Switch	LED, Matrix Col/Row
A0.1	analog IN	Potentiometer	Button/Switch, Matrix Row
A1.1	analog IN	Potentiometer	Button/Switch, Matrix Row
A2.1	analog IN	Potentiometer	Button/Switch, Matrix Row
A3.1	analog IN	Potentiometer	Button/Switch
A4.1	analog IN	Potentiometer	Button/Switch
A5.1	analog IN	Potentiometer	Button/Switch
A6.1	analog IN	Potentiometer	-
A7.1	analog IN	Potentiometer	-
D3.2	I/O PWM	Button/Switch	LED dimmable, Servo
D4.2	I/O	Button/Switch	LED, Matrix Col/Row
D5.2	I/O PWM	Button/Switch	LED dimmable, Servo
D6.2	I/O PWM	Button/Switch	LED dimmable, Servo
D7.2	I/O	Button/Switch	LED, Matrix Col/Row
D8.2	I/O	Button/Switch	LED, Matrix Col/Row
D9.2	I/O PWM	Button/Switch	LED dimmable, Servo
D10.2	I/O PWM	Button/Switch	LED dimmable, Servo
D11.2	I/O PWM	Button/Switch	LED dimmable, Servo

D12.2	I/O	Button/Switch	LED, Matrix Col/Row
D13.2	I/O	Button/Switch	LED, Matrix Col/Row
A0.2	analog IN	Potentiometer	Button/Switch, Matrix Row
A1.2	analog IN	Potentiometer	Button/Switch, Matrix Row
A2.2	analog IN	Potentiometer	Button/Switch, Matrix Row
A3.2	analog IN	Potentiometer	Button/Switch, Matrix Row
A4.2	analog IN	Potentiometer	Button/Switch, Matrix Row
A5.2	analog IN	Potentiometer	Button/Switch, Matrix Row
A6.2	analog IN	Potentiometer	-
A7.2	analog IN	Potentiometer	-
all IN (I or Inputs) (except A6 and A7) are useable as Matrix Rows all Out (O or Outputs) are useable as Matrix Columns if LEDs are plugged to outputs, take always care for the maximum load.			

ICB-SD-RJ-yyyy-##

“SD” is for Stepper Driver.

It started with thinking about a special WWII-Version as a new member of the ICB-Family. Ancient Warbirds do not carry as much electronics as modern Jets (most famous example is A-10C). So my thoughts. The focus should be at Switches, Pots, incandescent Bulbs and analog Gauges.

This Board, which came out, is somewhat like the twin of ICB-D-... (“D” like Duplex) cause development based on it. There was a request for driving 2 Steppers in a WWII-Cockpit. ICB-D-series was just at the Threshold from Prototype to the first Roll-Out, so it was just a small step to bring some extra Gimmicks to the Boards where Steppers could benefit from.

Near to the Digital Outputs you’ll find a Pin with extra Power-Supply and also a Ground-Connector. So you can link your Stepper-Driver-Board with just one Plug.

Drawback is, like at the Duplex-ICB: It consumes two (2) places at the RS-485 Bus-Chain and you have to write two different sketches.

Pin-Out Reference ICB-SD-2017-...

Pin#	I/O-Type	recommended use	alternative use
D3.1	I/O	Backlight, determined by ICB	-
D4.1	I/O	Button/Switch	LED
D5.1	I/O PWM	Button/Switch	LED dimmable, Servo
D6.1	I/O PWM	Button/Switch	LED dimmable, Servo

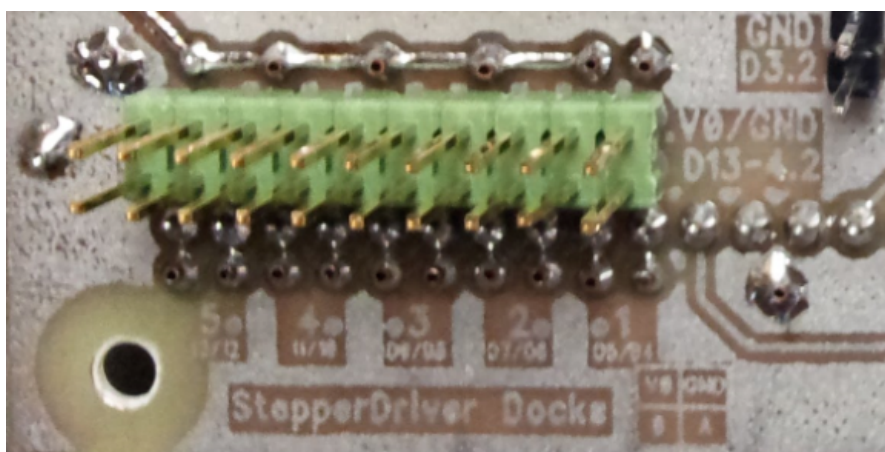
D7.1	I/O	Button/Switch	LED
D8.1	I/O	Button/Switch	LED
D9.1	I/O PWM	Button/Switch	LED dimmable, Servo
D10.1	I/O PWM	Button/Switch	LED dimmable, Servo
D11.1	I/O PWM	Button/Switch	LED dimmable, Servo
D12.1	I/O	Button/Switch	LED
D13.1	I/O	Button/Switch	LED
A0.1	analog IN	Potentiometer	Button/Switch
A1.1	analog IN	Potentiometer	Button/Switch
A2.1	analog IN	Potentiometer	Button/Switch
A3.1	analog IN	Potentiometer	Button/Switch
A4.1	analog IN	Potentiometer	Button/Switch
A5.1	analog IN	Potentiometer	Button/Switch
A6.1	analog IN	Potentiometer	* Button/Switch
A7.1	analog IN	Potentiometer	* Button/Switch
D3.2	I/O PWM	Button/Switch	LED dimmable, Servo
D4.2	I/O	Stepper 1 Dir	LED
D5.2	I/O PWM	Stepper 1 Step	LED dimmable, Servo
D6.2	I/O PWM	Stepper 2 Dir	LED dimmable, Servo
D7.2	I/O	Stepper 2 Step	LED
D8.2	I/O	Stepper 3 Dir	LED
D9.2	I/O PWM	Stepper 3 Step	LED dimmable, Servo
D10.2	I/O PWM	Stepper 4 Dir	LED dimmable, Servo
D11.2	I/O PWM	Stepper 4 Step	LED dimmable, Servo
D12.2	I/O	Stepper 5 Dir	LED (V0 -> GND)
D13.2	I/O	Stepper 5 Step	LED (V0 -> GND)
A0.2	analog IN	Potentiometer	Button/Switch

A1.2	analog IN	Potentiometer	Button/Switch
A2.2	analog IN	Potentiometer	Button/Switch
A3.2	analog IN	Potentiometer	Button/Switch
A4.2	analog IN	Potentiometer	Button/Switch
A5.2	analog IN	Potentiometer	Button/Switch
A6.2	analog IN	Potentiometer	*
A7.2	analog IN	Potentiometer	*

all I (Inputs) (except A6 and A7) are useable as Matrix Rows

all O (Outputs) are useable as Matrix Columns

* Even if a Button or Switch is connected, you have to read and interpret the input values like a Pot as these Pins can just work as analog INs. I suggest the use of a 10k pull up resistor between 5V and the Pin and the Button/Switch to link between the Pin and GND.



This Picture shows the StepperDriver Docks Section of the ICB-SD-2017-... The green Pin Header (color may vary on later Revisions) provides on its 20 Pins 5 Groups of 4 Pins, arranged as Quads. The sketch to the right shows the Voltage Selector.

The intents of the 4 Pins are	
top left: V0	top right: GND
down left: digital Out B	down right: digital Out A

V0 is determined by setting a Jumper at the Voltage Selector (see other picture):

connected Pins	Symbol	value of V0
1 and 2		5 V
2 and 3		GND
2 and 5		12 V

If you set V0 to GND you can conveniently use each pin in the lower row as a common digital IN or OUT instead of connecting a stepper driver. Some pins are **marked by a Dot**. These pins are PWM-capable (e.g. Pin A of Dock 2, Pin B of Dock 3...).

All other combinations are forbidden! The PowerSelector is represented by a 2x3 male Pin Header, where Pins 4 and 6 are cut off.

As a matter of available space, all Docks are to be set at one time, means, all Pins “V0” will have the same value, depending on which value is selected.

Special Features of some Boards

Auxiliary Power Connector (APC) and Auxiliary Voltage Selector (AVS)

As my boards up from the early days had an extra Power-Connector as a supply for heavy consumers, later versions will have this too, but in a different way: As you see at the picture, there is a 10pin male Pin-Header (some of later Revisions provide up to 16 Pins) with 2 green jumpers beside (colors may vary at later roll-outs). The 10 Pins of the Header are (virtually) numbered top down from 1 to 10 (16).

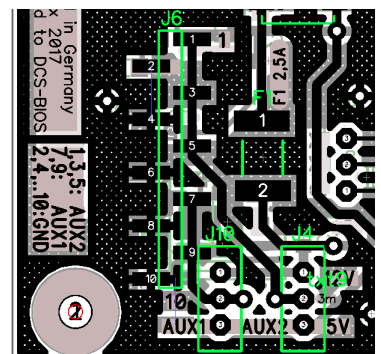
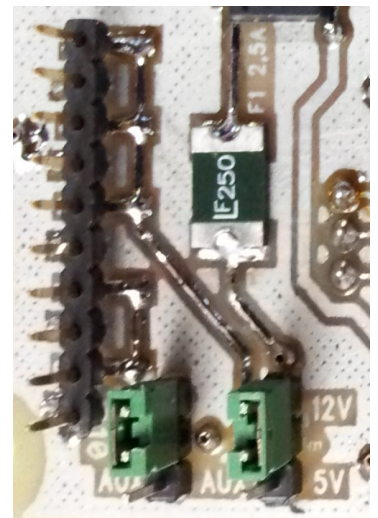
All Pins with odd numbers (2, 4,...) are connected to common Ground (GND), Pins 1, 3 and 5 are called AUX1, Pins 7 and 9 are AUX2.

Jumpers are to be set in two optional positions: Center Pin to Top means 12V, Center to lower Pin sets 5V to the respective Pins (other positions are forbidden). At the pic both parts of the APC are set to 12V.

12V are provided by the Main-Bus or by the extra Power Infeed over 5mm Jack and can be loaded with up to 2.5 Amps. The 12V circuit is protected against short by a self-resetting 2.5 Amps Fuse F1.

5V are raised by the second AMS1117-5,0. It's that one, where the heatsink is set optional (near Monitor-LED “5,0V AUX”). So the AMS1117-5.0 onboard the NANO is not burdened.

Anyway 5V shouldn't be loaded at more than 800 mA for a long time. PTC F2 blows at 0.75 Amps.



Medium-term Strategy

Here follows a list of items I think about at the moment.

Adapter-Board AB-RJST-yyyy-##

As not everyone has the whole system at RJ-45, there came the exigence for developing something like a Bridge (or Change Over) between the two worlds: Screw-Terminal vs. RJ-45.

This board (while just at “Think-about-Status”) consists of an in-feed of our 12V and 6 (six) RJ-45-Connectors and 6 Screw-Terminals. Maybe also a 2-Port-Version.

There should also be some jumpers to set up different operating-modes.

Master and Power Supply Module

This is a module to mount into Dzus-Rails. It provides the 3 channels of RS-485 and an adequate power supply. The panel shows voltage and current (load) of each channel.

ICB-DSD-RJ-

PWM- or LED-Amplifier-Board

Special Light- and Button-Boards

Following listed and (someday) described boards are just for testing and not yet for sale. Light- and Button-Boards are always very special and just to use with a special Backplate and/or Lightplate.

The plan is to bring my laser cutter in operation but I have no time for that these days.

AAP

I have one operating prototype here. Back- and Light-Plate are made by Third Person and both have been very expensive.

So it is not for sale (see remark).

SAS

Here I used instead of very expensive Magnetic Hold Switches just LEDs to show the status of each channel of the SAS. As these LEDs are continuously operated, I joined a FET (small ones in SOT-225) to each one to protect Arduino's outputs.

I have just one (1) working prototype. Although it works excellent it is still without a Light-Plate until I manage to bring my LaserCutter into business.

So it is not for sale (see remark).

CDU

This CDU consists of a ICB-C-RJ- and a SLB-CDU (SLB: Switch- and LightBoard). The ICB carries two Arduino NANOs. One of them provides the button matrix for 8x9 buttons, the other one controls the two independent backlights. Both are linked to the system by RS-485.

The SLB carries (you will already know) the 65 buttons and the LED-fired backlight of these buttons and the separating line. There is also an Arduino UNO set which drives a 3.5" TFT-display.

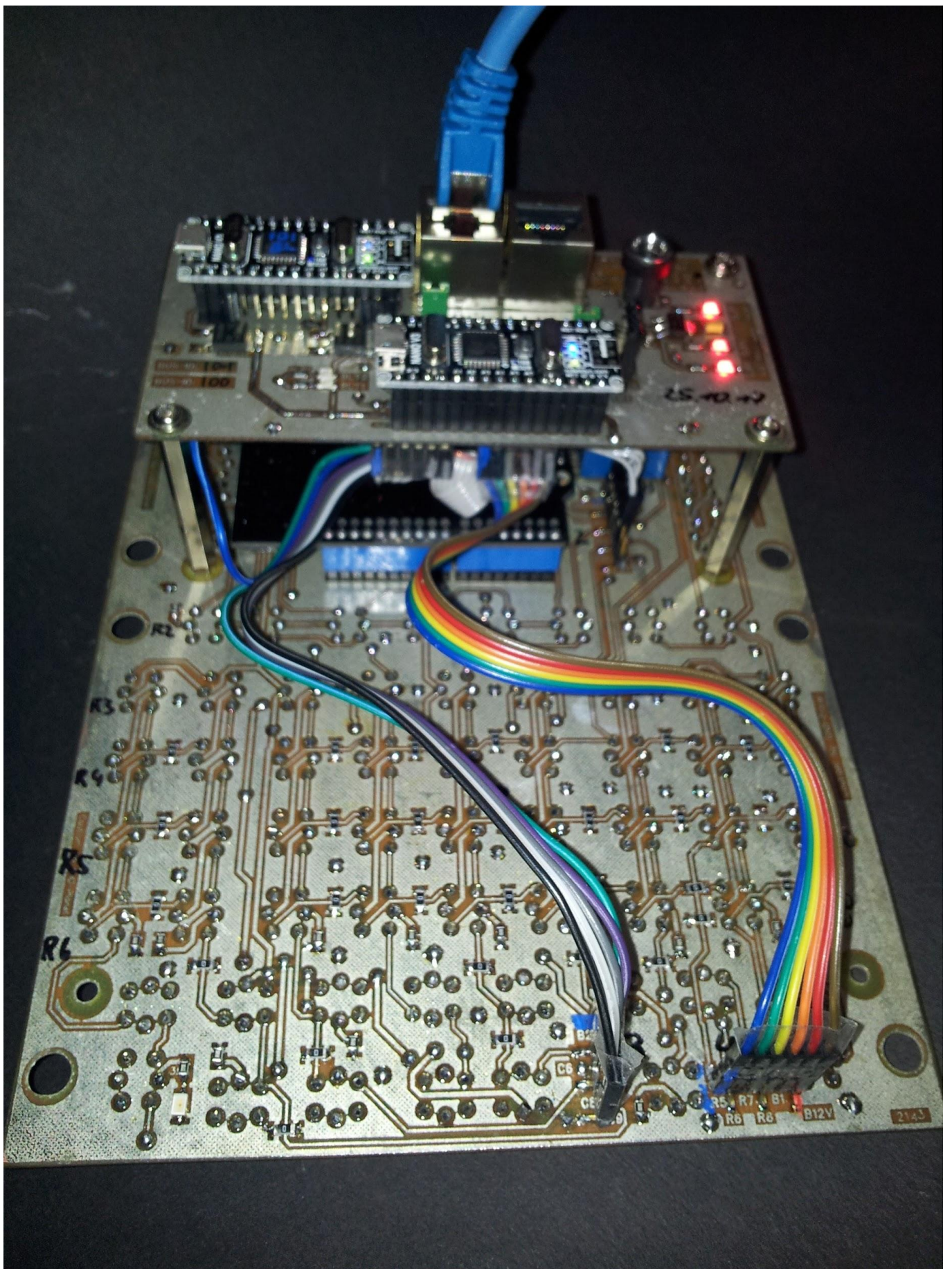
At the moment RS-485 produces errors while this UNO is also connected by RS-485, so at this stage of development the UNO is connected to a separate USB-port. Regardless I know, it's a big drawback, I have no other solution on hand at the moment.

I have atm a few working prototypes here, just ONE with a Light-Board. The Light-Board is 3rd-party-made in the USA (look for pcflights.com - they sent me generously their layout files). The offer is still valid!) and it has (even they did a tremendous job at even a good price) to be adopted (modified) some. At the moment I do not find the time for that as I'd have to make exact sketches.

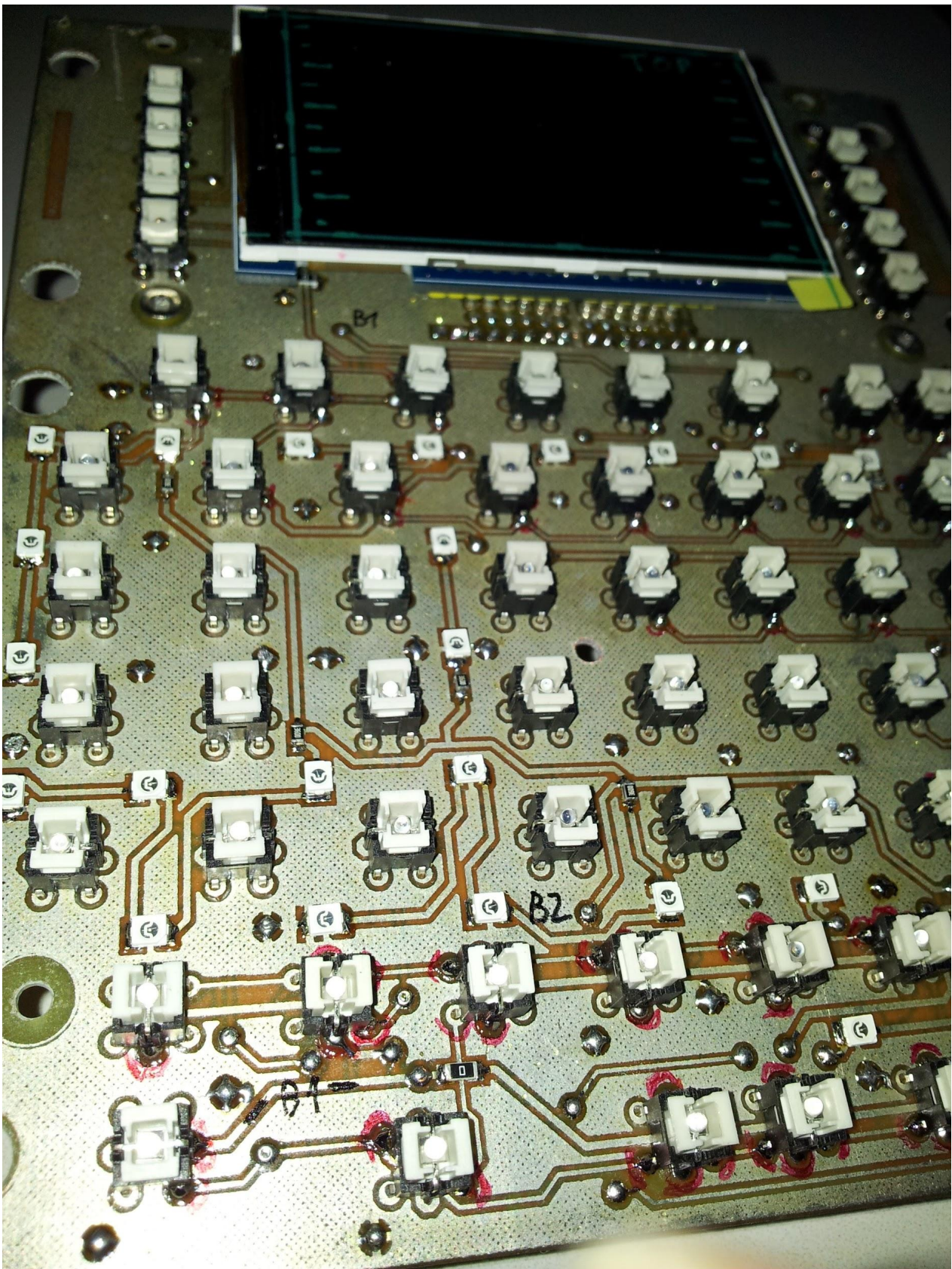
In the meantime I show you a few photographs. You see the Panel (mentioned above) and front- and rear-view of the first prototype (Indicated by hand written markings. Red marker means here is still a linking problem between the two layers of the PCB.):



unmodded CDU panel, original made by www.pcflights.com



Back View of ICB and the first prototype (to recognize by handwritten markings) of SLB



Front View of CDU's SLB with 3.5" TFT (still with green positioning markings on protective film; red circles mark failed Vias).

Connecting Devices

For more detailed Information read more sophisticated literature. Even the manual to DCS-BIOS gives some hints to beginners.

Pay attention to the different Pin-Out of the different versions of the Interface-Boards. To leave no doubt, refer to the relevant paperwork.

Switches

To connect a switch is the most simple action: A switch or button is realized by the system as „actuated“ if the corresponding pin is connected to GND.

If you have a simple SPST-switch (Single Pole, Single Throw), you should just connect one pole to the pin, the other pole to Ground.

At a SPDT-switch (Single Pole, Double Throw) you have to find out, which (of 3) pole is common (in most cases center pin is common, to play safe see the relevant manual). This is to link to GND, the other two poles you have to connect to the relevant two pins at the input-headers at the ICB. It is also possible to use just one of these two poles and to let the other one unused (don't expect any action from that pole now).

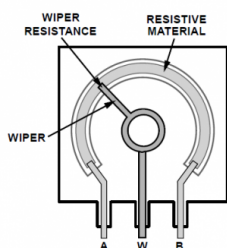
Buttons

Buttons are (in an electrical sense) equal to switches: Connect one pin to GND, the other one to the referring pin at the board. If the button is pressed, (voltage at) the pin is pulled down to GND - DCS-BIOS sends sth like “pressed”.

Potentiometers

A potentiometer is a variable resistor, which value is depending on the actuator's position. The most common form is with a turnable spindle. We read this position (equal to turning angle or rotational property) and translate this to a digital value from 0 to 255 (H0x00 to H0xFF). The best suiting value to the Arduino is 5 to 10 kOhms. It must not be too low, as the current depends on that. If the Pot is 5 kOhms the current is (between 5V and GND) 1 mA, at 10k the value will be half of that.

There are pots with different characteristics: Linear or logarithmic, other ones even have a center point with a logarithmic curve to each side (logarithmic pots are used to get a feel like linear behavior of the volume knobs at your transistor radio). In my SAS I used a pot with a center detention for the TRIM knob. So you will get physical feedback if center position is reached. Problem was, the mechanical center wasn't the same as the electrical center. TAKEOFF-TRIM works just if TRIM is centered. So I had to shift the electrical center by adding a Trim-Pot to the TRIM-Pot. Funny. (Note upper and lower case.)



Potentiometers are usually equipped with 3 pins. Two (generic the outer ones) span over the nominal value of the pot (remember: we use 5 or 10k here). The third pin (usually the center one) is linked to a pickup shoe (or sliding contact or wiper) which moves depending on turning angle over the whole span of the resistor. This pick up

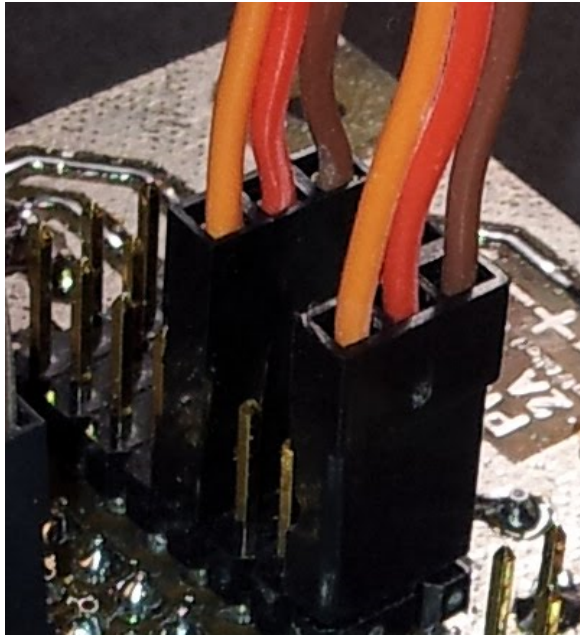


we connect to one of the analog inputs of our Arduino, while the other two pins are to connect to 5V and GND. So at this wiper “occurs” a pickoff-voltage from 0 to 5 V (against ground level), representing the turning angle. The Arduino applies its magic to convert this voltage into a digital value between 0 and 255 (8bit resolution). For comparison only: At 16bit (as in most commercial joy-sticks) this would be 65536 steps. As DCS-BIOS works with this value, we have to scale or translate arduino-given values to this.

For accuracy the reference voltage of 5 Volt has to be very stable. So it is important not to add other (particularly variable) loads to these 5 Volts. Some ICBs provide their own 5 Volts for auxiliary purposes to seize that.

- one AMS1117-5,0 just for MAX487 (RS-485)

- some ICBs have one extra AMS1117 for auxiliary purposes
- Pots are fed strictly by the onboard regulator of the related Arduino



This is a typical example. You see connectors of two pots plugged to one of two 8port analog rows of the ICB-SD-2017-02. Orange wires are connected to an analog port, red wires lead 5.0 V to the pot, brown here is GND (back from pot).

LEDs or Incandescent Bulbs

Due to the limited endurable load to the outputs of the AVR, it isn't a good idea to connect any kind of load directly to these outputs.

Most versions of my ICBs provide one amplified output for connecting PWM-controlled backlight. If you have to control one or more other notification lights, it is highly recommended to protect these Outputs by an amplifier.

If you want to drive a LED with your Arduino you have basically to take care for three things:

- maximum load of your output
- rated current of your LED (This is related to Point 1: Load!)
- polarity of your LED

	LED	incandescent Lamp
Load	Low, even too high if several or High-Power-LEDs are used.	High current, just to use with adequate control gear.
Intensity	by Current	by Voltage and Current
Polarity	Important, LEDs work just if current flows in direction from A to K.	not relevant
Scale Appearance	Poor, as most LEDs have mismatching colors, filtering works bad as a LED has just a very narrow spectral range.	Good, as a bulb emits almost the full range of white light we gain almost all colors by applying a filter film.

Button-Matrices

As the number of available Inputs at a NANO (even at a MEGA2560) is limited, you'll easily find applications where you run out of pins. This is the moment where a Button Matrix becomes interesting.

Imagine a Button Matrix as a table (or a chessboard) with Rows and Columns. These rows and cols can be represented by straight wires, each wire is connected to a pin of our MC. Each cell of this table is the same as a junction (or crossing) of one Row(-wire) and one Column(-wire).

At each crossing we can set a normally-open button with each of its contacts to one of these wires.

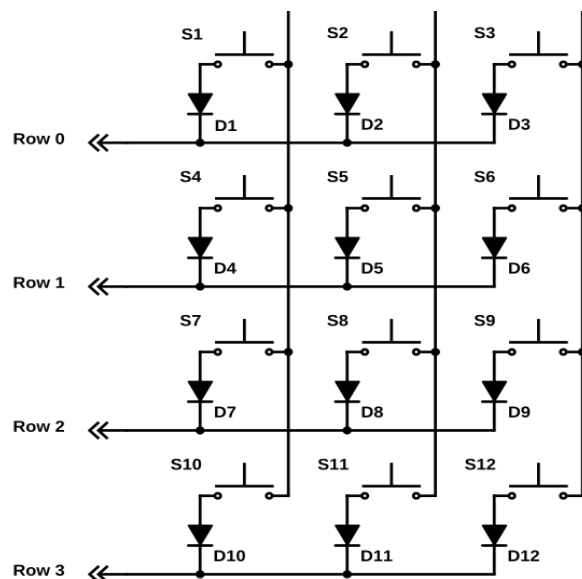
Everytime you press a button you connect one specific row with one specific column. So the label of the row and the label of the column are represented as a pair of the two-dimensional coordinates of our button.

That simple!

Note: To prevent your device from strange behavior it isn't recommended to set pots or encoders here. I also do not recommend using other switches than momentary working ones.

The code, based on the [keypad library](#), will interpret this as a button-press (resp button-hold or button-release) and returns a (context sensitive determined) value.

Multiple button presses are possible if you decouple each (it looks like it's OK if you just decouple buttons you plan to push at same time with others) button by means of a diode. The other way round, if you intend to press just one button at a time, you're not forced to add these diodes. This can even simplify your PCB's layout. I used these diodes also as bridges to cross over traces. The PCBs of my MFCDs are somewhat narrow so I have had to do so. Instead of setting resistors with 0 Ohms I used Mini MELF Diodes. So I killed two birds with one stone.



To be continued.

Glossar of DCS-BIOS' typical Abbreviations:

Acronym	full Name	Description	Application
APC	Auxiliary Power Connector	male 2,54mm Pin Header. It provides (determined by AVS) Voltage for module intern use.	
AVR	Atmel AVR	AVR is a family of microcontrollers developed by Atmel beginning in 1996.	
AVS	Auxiliary Voltage Selector		

BP	Backplate	The second layer of a panel or module. Here are the pots, switches and other heavy elements mounted on. It also made direct contact with the Dzus-Rails.	
BIAS		Pre Definition of a certain Voltage level at the Lines of our RS-485-Bus, established by Pull-Up- or Pull-Down-Resistors. This prevents undefined status of the Bus while startup. Bias is overwritten by real level if the bus is working.	Line A is pulled up to 5V by 750 Ohm, Line B is pulled down to GND-Level by 750 Ohm. It is set just at the Master Shield!
CDU	Control Display Unit, on some places untruly called Central Display Unit	interface device unit used to access the flight management computers (FMC)	
FS	Fail Safe	Prevention of undefined conditions on Bus Lines by biasing these lines to a predefined Voltage Level.	see BIAS
GND	Ground Potential	Against this potential all relevant voltages are defined or measured. Voltage between GND and chassis is 0 (null) Volt.	
ICB	Interface- and Control-Board	these boards provide connectors to link it to the RS-487 chain, 12V input and one or more MCs	
LCD	Liquid-crystal Display	a flat-panel display or other electronically modulated optical device that uses the light-modulating properties of liquid crystals	
LP	Lightplate	Top layer of a panel or module. It is made of translucent materials, covered by an opaque coating where lettering	

		or markings are engraved. See also Day-Night-Design.	
MC or MCU	Microcontroller Unit	like a small computer, containing interface, processor and memory (RAM and/or ROM)	Arduino is (or is based on) one very handy form of MCU.
MELF	Metal Electrode Leadless Face	One of the first types of SMT components. It evolved from cutting off the wires of a diode or resistor and replacing that with metal caps. That's why MELFs are of cylindric shape.	
MOSFET	Metal-Oxide-Semiconductor Field-Effect Transistor	It has an insulated gate, whose voltage determines the conductivity of the device. This ability to change conductivity with the amount of applied voltage can be used for amplifying or switching electronic signals.	As the gate is somewhat like a capacitor, you have to place a resistor to unload this C. Otherwise the device stays conductiv.
MS	Master Shield	or sometimes also Master Board: is part of the interface between PC, Arduino MEGA and RS-485	
PCB	Printed Circuit Board	a carrier, made of glass- or carbon-fibre reinforced plastics where thin layers of conducting metal, mostly copper, present. Look here :)	
PSU	Power Supply Unit		
PTC	PTC thermistor	If high current occurs, the device heats up, causing its resistance to increase. This creates a self-reinforcing effect that drives the resistance further upwards, therefore limiting the current.	

PWM	Pulse-width Modulation	is a modulation technique used to encode a message into a pulsing signal. Although this modulation technique can be used to encode information for transmission, its main use is to allow the control of the power supplied to electrical devices.	here used for dimming Backlight and for positioning Servos
Resolution	here: Analog to digital Resolution	Accuracy of translation of an analog value to a digital value. 8-Bit-Res. means, 8 digits in Binary are used to depict this value. As 11111111 binary is (FF in hex and) 255 in decimal, you can have, including 0 (zero), 256 different values, means also 256 steps.	
RJ-45	Registered Jack #45	also called Modular Connector or 8P8C (eight positions, eight contacts). Note: Same connectors are used for Ethernet.	PinOut: 1 - RS-485 A 2 - RS-485 B 5 7 8 - 12V + 3 4 6 - GND
RVP or RCP or RPP	Reverse Voltage (or Current or Polarity) Protection (or Prevention)	prevents device's damage due to Power Source accidentally connected the wrong way around	
SLB	Switch- and Light-Board	PCB, where buttons, switches and LEDs for backlighting are located. It is arranged directly under the Backplate of a module, so it's the third logical layer of a module.	
SMD	Surface mounted Device or Surface-mount technology (SMT)	Method for producing electronic circuits in which the components are mounted or placed directly onto the surface of printed circuit boards (PCBs). An electronic device so made is called a surface-mount device (SMD). In industry, it has largely replaced the through-hole technology construction method of fitting	SMDs are often smaller than THT parts. So I used this as often as possible. Also it's easy to set as there is no need to drill holes. The smallest package I use is 0805 (2.0 mm × 1.25 mm). See handicraft friendly

		components with wire leads into holes in the circuit board.	design.
Term	Terminator	Resistor, set at each end of the RS-485-Bus. It is somewhat like a Trap for Signal Reflections at the end of the wire. See also BIAS and FS.	At Master Shield is Termination fixed set (soldered SMD resistors, nominal 130 Ohms), at ICBs you can set it by a special plug at the last device in your chain.
TFT	short for Thin-Film-Transist or Liquid-Crystal Display (TFT LCD)	variant of a liquid-crystal display (LCD) that uses thin-film-transistor (TFT) technology to improve image qualities such as addressability and contrast.	at the moment I just use a 3.5" variant for CDU
THT	Through hole technology	components with wire leads into holes in the circuit board. These components can be bigger and heavier than SMD components; so its more ruggedised against mechanical loads.	Pots, sockets for MCs, receptacles for power and RJ45 here are in THT.
TP1	Test Point 1	3pin male or female Pin Header. It provides easy access to the lines for troubleshooting purposes, it is designed on each Board but not always set.	lead out of TX, RX and TXenable
TP2	Test Point 2	2pin male Pin Header, not designed or set on each Board	lead out of RS-485 A and RS-485 B. TP2 can also be used as Termination-Point.
TVS	Transient Voltage Suppressor	A TVS diode, also <i>transil</i> or <i>thyrector</i> , is an electronic component used to protect electronics from voltage spikes induced on connected wires, while flash strike or rubber soles on textile floors.	A SM712 protects the RS-485 Pair, SMBJ12A protect the 12V Power Line. There is one device at each Power-IN connector.
