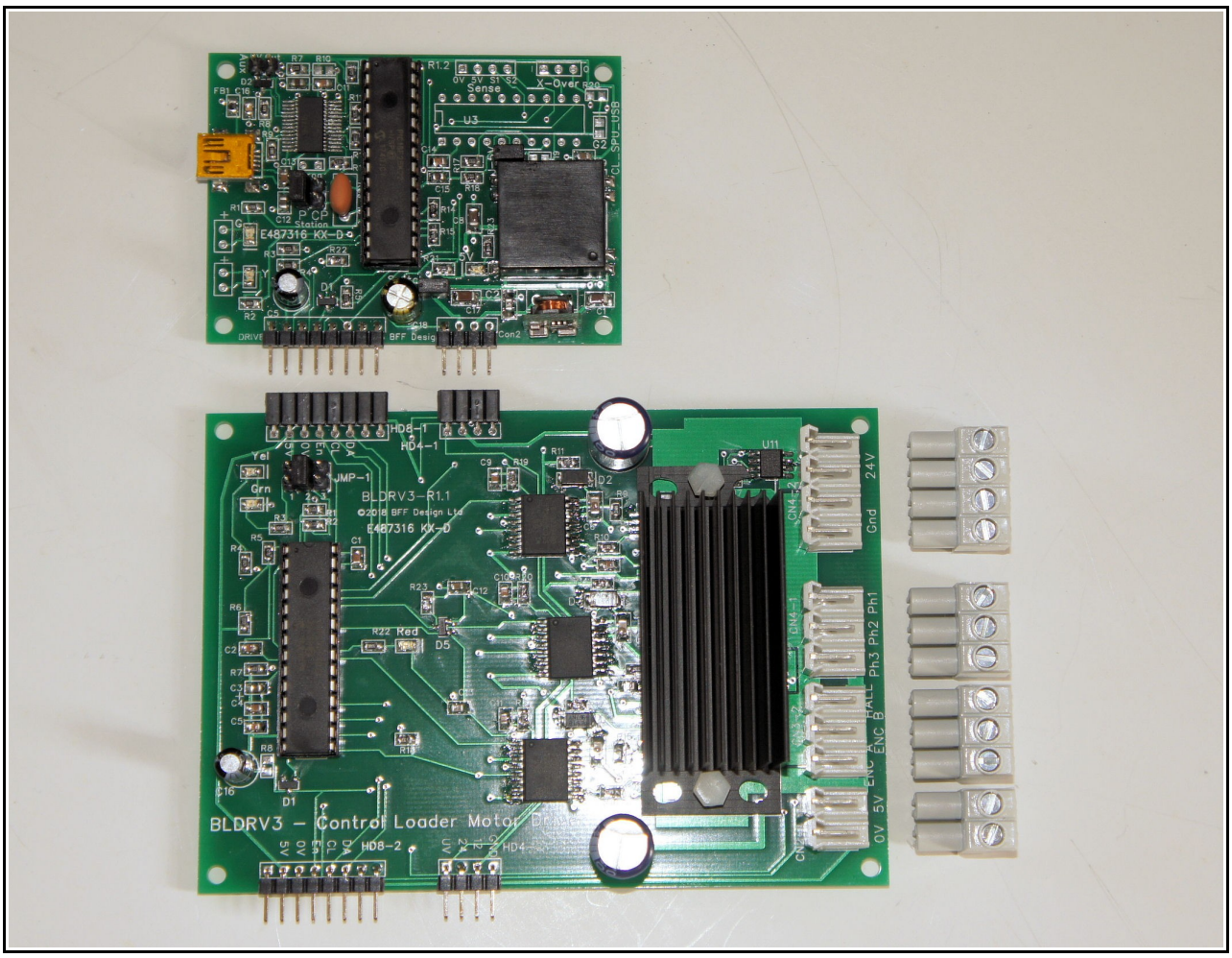
BFF Design Ltd
CL_SPU_USB + BLDRV3 Data Sheet – R0.2



WARNING – The BLDRV3 contains an exposed heat sink that may become hot to the touch when the card is in operation. Do not fully enclose the card in an unventilated enclosure and do not handle the card when it is powered and in use.

1. Introduction

The CL_SPU_USB and BLDRV3 cards provide modular (up to three channels) brushless motor drives for use in control loader systems for flight simulators. They operate with the BFF CL Software (v2.0 or later). See section 8 for a typical system arrangement.

The CL_SPU_USB card provides the communication bridge between the PC software and the BLDRV3 motor driver cards. It can operate with up to 3 BLDRV3 cards connected via the integrated inter-pcb header connectors.

The BLDRV3 card generates sinusoidal commutation voltages for a single, 3 phase brushless motor with quadrature encoder shaft position feedback. Its nominal current rating is 6.5 Amps continuous, 10 Amp intermittent peak. It operates with a 24V DC supply. In addition to quadrature encoder feedback hall-effect sensor output is required from the BLDC motor, this is required to allow the card to calibrate the encoder position.

The BLDRV3 updates motor torque output at 500Hz, the CL_SPU_USB receives controlling input from the BFF CL Software at approx 50Hz.

IMPORTANT – The CL_SPU_USB controller must be correctly programmed for the brushless motor to be used with each BLDRV3 card. The programming sets the motor pole count, encoder sensor position calibration etc. Settings are available for the 60ST-M01330 and 80ST-M02430 Servo Motors and for MB082 & MB057 Speedermotion BLDC motors.

2. Features

CL_SPU_USB

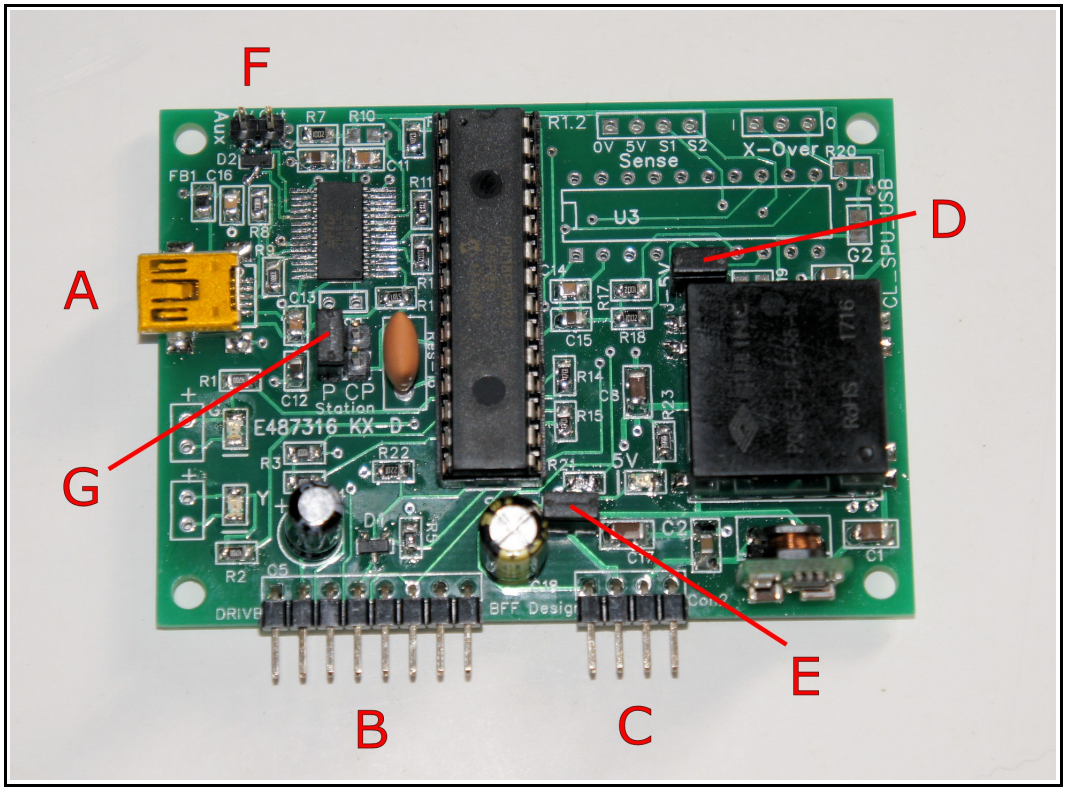
- USB connection (via FTDI FT260 bridge) to provide single point of PC connection to drive up to 3 control loader axes via connected BLDRV3's.
- Re-programmable EEPROM for encoder cpr, encoder/hall sensor position calibration, motor poles, input demand scaling and vibration effect scaling and others. Re-programming is direct from PC Driver Test App USB V1.0+.
- PC/USB side and all logic side control circuits fully electrically isolated from motor driver circuits.

BLDRV3

- Adds support for selected 60ST and 80ST Servo Motors.
- Over temperature and current limiting.
- Commutation by Space Vector Modulation generating sinusoidal commutation voltages at 10KHz PWM for smooth torque output from matched 3 phase brushless motors.
- +/- 9bit force output resolution.
- 500Hz update rate for onboard force calculations, approx 50Hz update rate for PC software data input.
- 24V DC operation (see notes and 3.C below).
- Physical chaining on common communications bus with the CL_SPU_USB to allow up to 3 axis control. Cards are connected directly via onboard inter-PCB headers.

3. Connections and Settings

CL_SPU_USB



CL_SPU_USB CONNECTIONS - Refer to photo above-

A) USB MiniB Connector for PC.

B) Right angled 0.1” 8 pin male header (DRIVER) for connection to BLDRV3. Carries 5V logic power and I2C data bus lines.

C) Right angled 0.1” 4 pin male header (DRIVER) for connection to BLDRV3. Carries 12V FET gate driver power and 24V source lines and FET driver status line.

D) J-5V: ALWAYS CLOSED 5V logic supply jumper.

E) Switch: 24V feed jumper to on-board 12V and 5V logic supplies. Must be closed to enable 12 and 5V supply to power the logic and gate driver circuits. An optional switch can fitted across the jumper to provide logic power ON/OFF switching. Otherwise when permanently closed the logic side powers-up when 24V is supplied to the BLDRV3 adjacent to the CL_SPU_USB.

F) 2 pin header (Aux) – 0V and Out to provide auxiliary programmed output from card. By Default Out is programmed as a “loading engaged” indicator – active high.

G) Pilot / Co-Pilot Station selector.

BLDRV3

IMPORTANT – POWER SUPPLY PROVISION

The BLDRV3 cards will operate on a 24V DC power supply The PSU to be used MUST be a smooth, voltage regulated supply capable of sustaining the supply voltage at the demanded current draws – variation of the supply voltage above the data sheet specifications will damage the cards, and any electrical noise on the supply will be felt as roughness in the force feedback at the controls.

A suggested PSU is **Mean Well NES-350-24** or similar. This is a 24V 14.6 Amp power supply suitable for 2/3 axis systems (depending on motor),

See - https://www.meanwell.com/webapp/product/search.aspx?prod=NES-350

The **Mean Well SE-450-24** 18.8 Amp is suitable for most 3 axis systems. However if all three axes are to be used routinely at full output simultaneously then a larger PSU may be required for MB082GA210 motors.

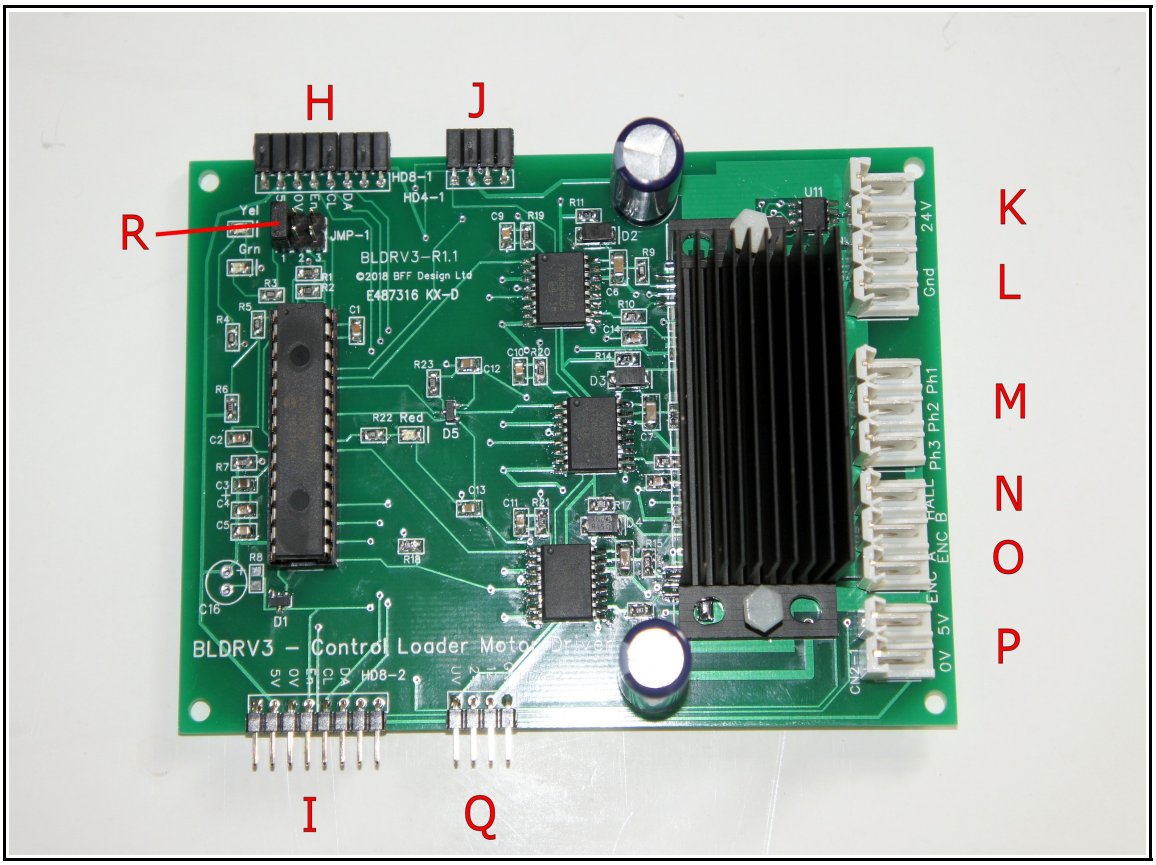
For reference allow the following current capacity per motor (for simultaneous full output on each axis):

60ST-M01330 – 4 Amps per motor

80ST-M02430 – 5 Amps per motor

MB082GA210 – 6.5 Amps per motor

DO NOT IGNORE THESE REQUIREMENTS.



BLDRV2-24 CONNECTIONS - Refer to photo above-

H) Right angled 0.1” 8 pin female header (HD8-1) for connection to CL-SPU_USB.

I) Right angled 0.1” 8 pin male header (HD8-2) for connection to adjacent BLDRV3.

J) Right angled 0.1” 4 pin female header (HD4-1) for connection to CL-SPU_USB.

K) 24V DC input.

The supply voltage should be between 22V and 27V **at all times**. Exceeding 27V may damage the CL-SPU_USB. The recommended supply voltage is 24V.

NOTE the card is NOT reverse polarity protected – ENSURE CORRECT SUPPLY POLARITY.

The supply current requirement is approximately 6.5 Amps per card. However this depends on the details of the motors, gearing and settings used for the system. MB082 motors with 24V supply and default card programming will draw approximately 6.5 Amps each at stall. Continuous load at this current draw will cause the heat sinks on the BLDRV2 card to become hot to the touch.

The supply will need to be capable of delivering this current for each card simultaneously held on load. Under normal flying conditions sustained control loading is not present (the controls are trimmed and in balance) so simultaneous peak loading on each card would be unusual. The system builder should assess actual current draw and ensure the power supply is adequate.

ENSURE you use power cabling of adequate gauge for the card maximum operating currents. AWG 12 is suggested.

See section 4 below on Cooling necessary if sustained current loading is expected to occur.

L) Power supply ground.

Suitable grounding of the cards is very important. The main return line to the power supply -V terminal MUST be of suitable gauge and must not offer significant resistance to the return flow of current from the cards to the power supply.

See power wiring and grounding diagram in Section 10.

The main return cable to the power supply should at least be 12AWG (4mm^2) or or ideally 10AWG (6mm^2). The L connectors will accept 12AWG (4mm^2) directly – so use short length12AWG connecting lengths between each card and the main 10 AWG return cable to the power supply.

Daisy chaining of the return lines across the K/L connectors may be satisfactory in most applications but is not recommended for all installations.

M) BLDC Motor 1, 2 & 3 phase connections. For MB082 & MB057 Speedermotion BLDC motors Phase 1 is Black (T), 2 is Red (R) and 3 is White (S).

For 60ST and 80ST family servo motors Phase 1 is Brown (U), Phase 2 is Blue (V) and Phase 3 is Black (W)

For other BLDC motor makes the correct phase connections must be determined experimentally.

N) Single Hall-effect position sensor input. For MB082 Speedermotion BLDC motor this should be Yellow (Hall A), for the MB057 motor use Yellow (Hall C).

For 60ST and 80ST motors this is core Grey (U+) on the small signal extension cable.

For other BLDC motor makes the correct hall sensor connection must be determined.

The single hall sensor channel is used for absolute position calibration of the motor quadrature encoder at start-up. The absolute electrical angle for calibration is defined in the CL_SPU_USB and programming and can be altered by re-programming the microcontroller EEPROM via the USB cable.

Note: For automatic power-up modes the hall sensor input is not used.

O) Quadrature encoder A and B channel connections. The encoder used must be capable of operation with a 5V supply. PLEASE refer to your encoder technical documentation to identify the A & B channels. Note that it may be necessary on testing to reverse the A & B connections if motor cogging is observed on first loading.

For 60ST and 80ST family motors Encoder A connects to core Orange (B+) of the small signal extension cable. Encoder B connects to core Yellow (A+).

P) 0 & 5V logic supply output for the hall sensors and quadrature encoder.

For 60ST and 80ST family motors 0V connects to core Black (0V) of the small signal extension cable. 5V connects to core Red (5V).

Q) Right angled 0.1” 4 pin female header (HD4-2) for connection to CL-SPU_USB.

R) Jumper JMP-3, Address setting for the driver. The jumper should be set to position 1 for Elevator drive, 2 for Aileron drive and 3 for Rudder drive.

4. Cooling

MB082 motors with 24V supply and default card programming will draw approximately 6.5 Amps each at stall. This current level will cause the heat sinks on the BLDRV3 card to become hot to the touch if this loading is held for a period of minutes.

Under normal flying conditions sustained control loading is not present (the controls are trimmed and in balance) so such loading tends to be sustained only for the duration of the flight manoeuvre before being released. Under these normal-use conditions of intermittent loading it is likely that the cards will not require additional cooling.

If non-standard flight conditions are expected, for example sustained flight under simulated systems failure modes, then loading on the controls and cards may be seen at high levels for sustained periods – long enough to cause heating problems for the mosfets. If such use is anticipated it is **recommended** that additional forced air cooling is provided for the cards. PC case type fans mounted directly above the card heatsinks can be effective in cooling the heat sinks.

NOTE: Over temperature and over current limiting is provided in the BLDRV3 cards. These use smoothed average temperature and current readings and provide some protection. The temperature and current levels at which limiting

becomes active are set in the CL_SPU_USB EEPROM and can be viewed/changed using the EEPROM Update facilities of the Driver Test App.

Temperature limiting is based on temperature sensing at the base of the heatsink and will by default activate at 60 Centrigade. The red LED will light when either temperature or current limiting becomes active.

Current limiting is based on the average input current to the BLDRV3 and is intended to catch excessive bulk current flow leading to MOSFET heating. It does not provide instantaneous protection from, for example, load short circuiting.

5. Setup

PLEASE READ CAREFULLY THE PROJECT OVERVIEW DOCUMENTATION PROVIDED ON THE WEB SITE – THIS PROVIDES MORE COMPLETE AND DETAILED INFORMATION ON THE SETUP AND COMMISSIONING OF THE OVERALL SYSTEM.

The default programming of the CL_SPU is for use with 60ST-M01330 servo motors (with 2500cpr quadrature encoders).

These are 8-pole 3 phase servo motors requiring four electrical commutation cycles per shaft revolution. With the 2500 cpr encoders fitted there are 6.94 encoder edge transitions per one degree of electrical rotation giving 0.036 degree resolution for shaft physical position reporting.

If different motors are to be used then the CL_SPU_USB EEPROM settings will require to be modified to suit their pole count, encoder resolution and hall sensor position calibration etc.

EEPROM settings files are available for selected 60ST and 80ST family motors and for MB082GA210 and MB057 Speeder Motion motors. These can be used with the Driver Test App USB V1+ to change the EEPROM settings directly.

The CL_SPU_USB and BLDRV3 cards also have a “Discover” power-up calibration mode in which appropriate EEPROM settings can be automatically detected for other 3 phase brushless motors. Please read the separate documentation for this feature.

Wire the driver cards in accordance with the wiring diagram shown in Section 8.

BEFORE power-up set JMP-1 to the correct channel address - position 1 for Elevator drive, 2 for Aileron drive and 3 for Rudder drive. Set JMP-2 for Mode 1- Normal Operation.

Note: depending on power-up calibration mode the cards may not initialise fully unless the system wiring is complete and the BFF CL Software (v3.00 or later) or Driver Test App is setup and running.

6. Operation

PLEASE READ CAREFULLY THE PROJECT OVERVIEW DOCUMENTATION PROVIDED ON THE WEB SITE – THIS PROVIDES MORE COMPLETE AND DETAILED INFORMATION ON THE SETUP AND COMMISSIONING OF THE OVERALL SYSTEM.

The BFF CL Software (v2+ or later) will need to be operational and running.

In order to control the brushless motors the BLDRV3 must first calibrate the absolute position of the shaft quadrature encoder against the motor's internal electrical position. This is done either manually by the pilot, or automatically by the drive system. The automatic power-up calibration feature is available in all BLDRV3 cards.

Manual power-up calibration (MPUC):

On power-up the LED's will flash an initialisation sequence. During this period the cards will suspend motor commutation until the quadrature encoder shaft position feedback has been calibrated. To do the calibration wait until the LED startup sequence has started and you see a STEADY FAST blinking of the YELLOW LED on the cards. Then move the flight control at a steady pace backwards and forwards from end stop to end stop until you see the LED fast blinking on the appropriate BLDRV3 card stop.

Once all active axes are calibrated the fast amber LED blinking on the CL-SPU-USB will also stop.

(The calibration movement will first induce an edge transition from the motor's internal hall-sensor to allow the shaft encoder position to be calibrated to the exact electrical rotation position of the motor shaft, and secondly allow the encoder position full working range to be established. Motor commutation will not become active until this calibration is complete. This should be done with the CL or Driver Test App software setup and running and with the software set to

RELEASE.)

Automatic power-up calibration (APUC):

In this mode the cards will drive the required movements automatically. APUC can be initiated immediately on card power-up, or after go-ahead is provided by the pilot via the CL software.

For more details of the APUC options see the APUC Options document.

After initilisation and calibration the yellow LED continuous flashing will stop and the green LED on the CL_SPU-USB will blink once per 30 received data updates. Intermittent blinks of the yellow LED's on the BLDRV3 cards indicate that the respective card is active on the shared I2C data bus. Intermittent Yellow LED flashes on the CL-SPU-USB indicate time-outs on the serial data comms – if these are too frequent the force feel will be affected, if USB comms are lost the CL-SPU Yellow LED will stay on and the force response will be held at the last good input.

Flashing of both CL-SPU LEDs at 1 Hz indicates an error condition. To determine the error click “Ping” on the CL software to write the card status data to the BFF_PRY.log log file which can then be opened and inspected for error messages. For some error conditions blinking of the BLDRV3 card affected may also be seen.

Cutting power to the driver cards will stop the motor drive commutation.

WARNING – the heat sinks on the BLDRV3 cards may become hot to touch. The mosfet heat sinks will heat with increased current flow to the motors – they will become hot if currents around the rated current (6.5 Amps) are sustained for several minutes. Normal FFB loading does not involve sustained high levels of force on the controls, so under normal operation the mosfets will warm slightly and not become hot. If excessive heatsink temperature is experienced without significant force output then there may be a fault with the wiring, motors or driver card – power down at once and inspect.

See also section 4 Cooling.

7. CL-SPU-USB EEPROM Re-programming

The motor drive configuration settings such as motor pole count, encoder resolution, hall sensor position calibration and input force scaling etc are set in the CL-SPU-USB control chip EEPROM. The EEPROM settings can be re-programmed directly by the BFF Driver Test App USB via the USB cable.

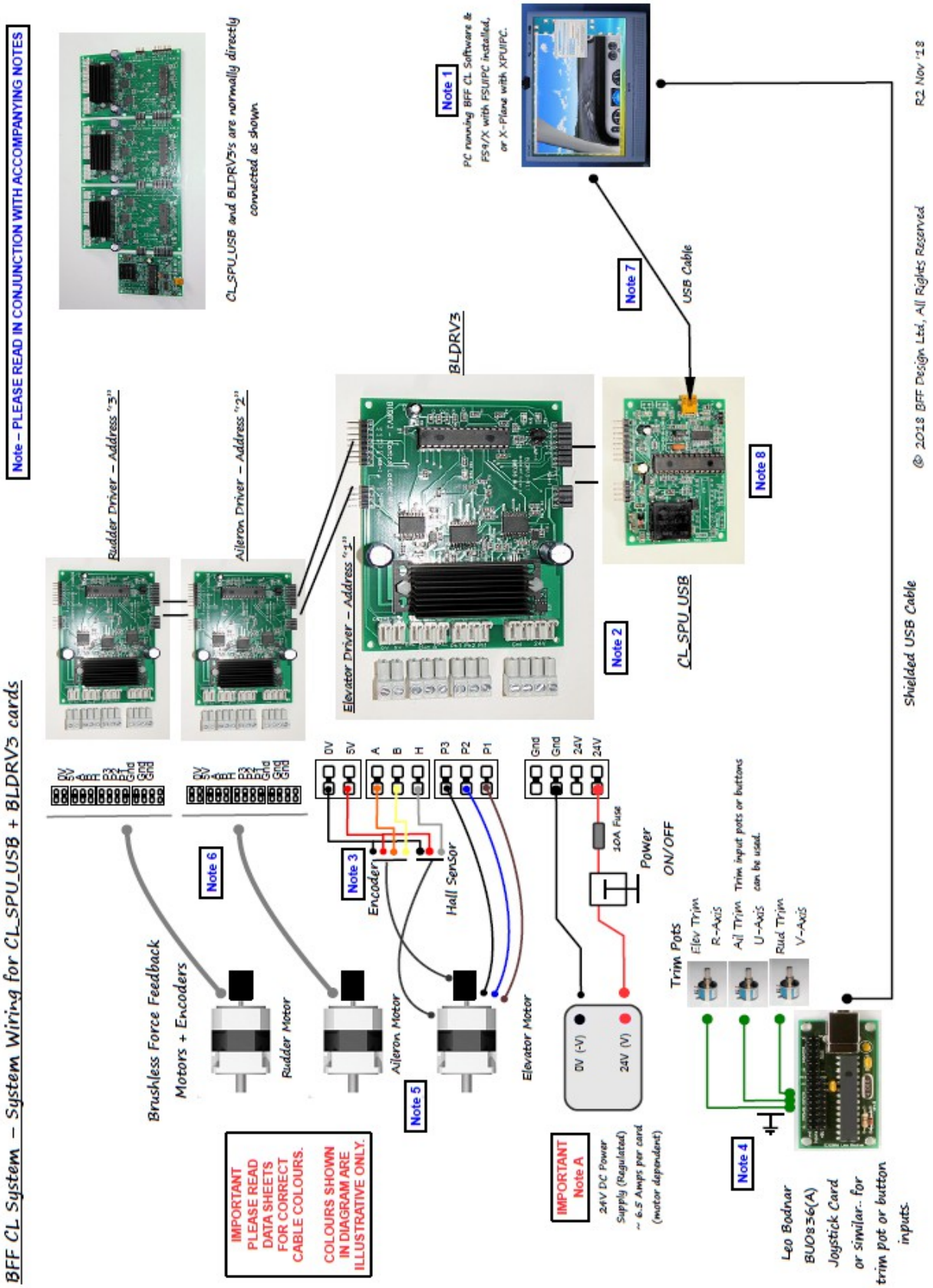
This facility allows the BLDRV3's to be used with different brushless motor makes and encoder resolutions. Use of different motor makes may however require that the correct phase ordering, choice of hall sensor output and hall sensor to encoder calibration values be determined experimentally.

Input force scaling can be used to concentrate the force demand at the lower end of the available range provided by the card power supply voltage. This allows the full force demand resolution to be used over, for example, half of the output voltage range.

The magnitude of vibration effects is limited by the programming in order to protect the drives. This amplitude scaling can be can be altered by adjusting the appropriate parameter in the 28X2 EEPROM programming.

Other settings that can be changed in EEPROM include temperature and current limits, A/P following force limits, force inversion etc. See the Update_EEPROM button in the Driver Test App USB GUI.

8. Typical System Wiring



NOTES – BFF CL System Wiring.

A) **IMPORTANT – POWER SUPPLY PROVISION**

The BLDRV3 cards operate on a 24V DC power supply The PSU to be used MUST be a smooth, voltage regulated supply capable of sustaining the supply voltage at the demanded current draws – variation of the supply voltage above the data sheet specifications will damage the cards, and any electrical noise on the supply will be felt as roughness in the force feedback at the controls.

A suggested PSU is **Mean Well NES-350-24** or similar. This is a 24V 14.6 Amp power supply suitable for 2/3 axis systems depending on motor choice,

See - https://www.meanwell.com/webapp/product/search.aspx?prod=NES-350

The Mean Well SE-450-24 18.8 Amp is suitable for most 3 axis systems using MB082GA210 motors. However if all three axes are to be used routinely at full output simultaneously then a larger PSU may be required.

Most Mean Well PSUs provide protections such as fast short-circuit cutoff and, if these features are present in the PSU, can avoid the need for fuses in the 24V supply lines.

NOTES:

1. BFF Control Loader software V2+ and FS9/X with FSUIPC or with X-Plane V9.6+ and XPUIPC. For X-Plane a custom XPUIPC offsets file must be installed – see CL Software user guide.

   The CL software can be run on a networked PC via WideFS.

2. Three BLDRV3 brushless motor drivers are shown – one for each control axis. Elevator, aileron or rudder allocation is set using jumper settings on the cards.

   The driver cards are normally connected together and to the CL_SPU_USB card using the on-board inter-pcb header connectors. They are shown separated in the diagram for sake of clarity.

   PC comms is to the CL_SPU_USB card via a standar USB-MiniB cable.

3. Wiring details are shown for the Elevator drive only – the Aileron and Rudder wiring is the same to their respective drivers. All the drivers can be supplied from the same 24V DC power source so long as it has adequate current capacity.

   PLEASE NOTE the grounding requirements for the cards described in the driver card data sheet section 3.L.

   The driver to motor wiring connects the 3 power phases, the quadrature encoder and one hall-effect position sensor to the driver. The hall sensor input is used to calibrate the absolute position for the quadrature encoder during manual power-up calibration. The quadrature encoder provides the continuous motor shaft position feedback required for the motor commutation.

4. Position feedback to FSX via a joystick card is NOT normally required for the main control axes. The control positions are instead instead derived from the motor encoders and sent to the flight sim via FSUIPC. This can be overridden in the CL software settings to allow potentiometer position feedback to FSX if required.

   However a joystick card WILL be required for trim inputs – either via pots or buttons.

   Joystick card axes or buttons can be assigned to the CL system trim inputs using the Configuration Manager Tab 7.

   Do not enable these trim axis assignments in FS9/X and do not use the FS9/X internal trim adjustments otherwise the sim and CL flight controls zero positions will not match.

5. Low cogging force feedback motors. Brushless Servo or BLDC motors with sinusoidal back EMF characteristics of the type specified. Not all low cost BLDC motors will operate satisfactorily in a CL system – even with the BLDRV3 drivers. Many have trapezoidal back-emf characteristics or excessive cogging behaviour and can not

generate smooth enough torque output.

60ST-M01330 Servo Motors are suggested (fitted with 2500 cpr encoders). For greater torque output 80ST-M02430 motors are suggested (about 2x torque output).

MB082GA210 motors will provide similar torque output to the 60ST-M01330 and should have 360cpr quadrature encoders fitted.

The mechanical design of the motor to control drive is another critical area for the overall system performance, as is the mechanical connection of the position pots to the controls. Transmissions must be rigid (not flexible) and precise with low levels of friction and as little backlash as is possible.

6. The Aileron and Rudder axis wiring is the same as is shown for the Aileron. All three drivers can share the same power supply if it has adequate current capacity.

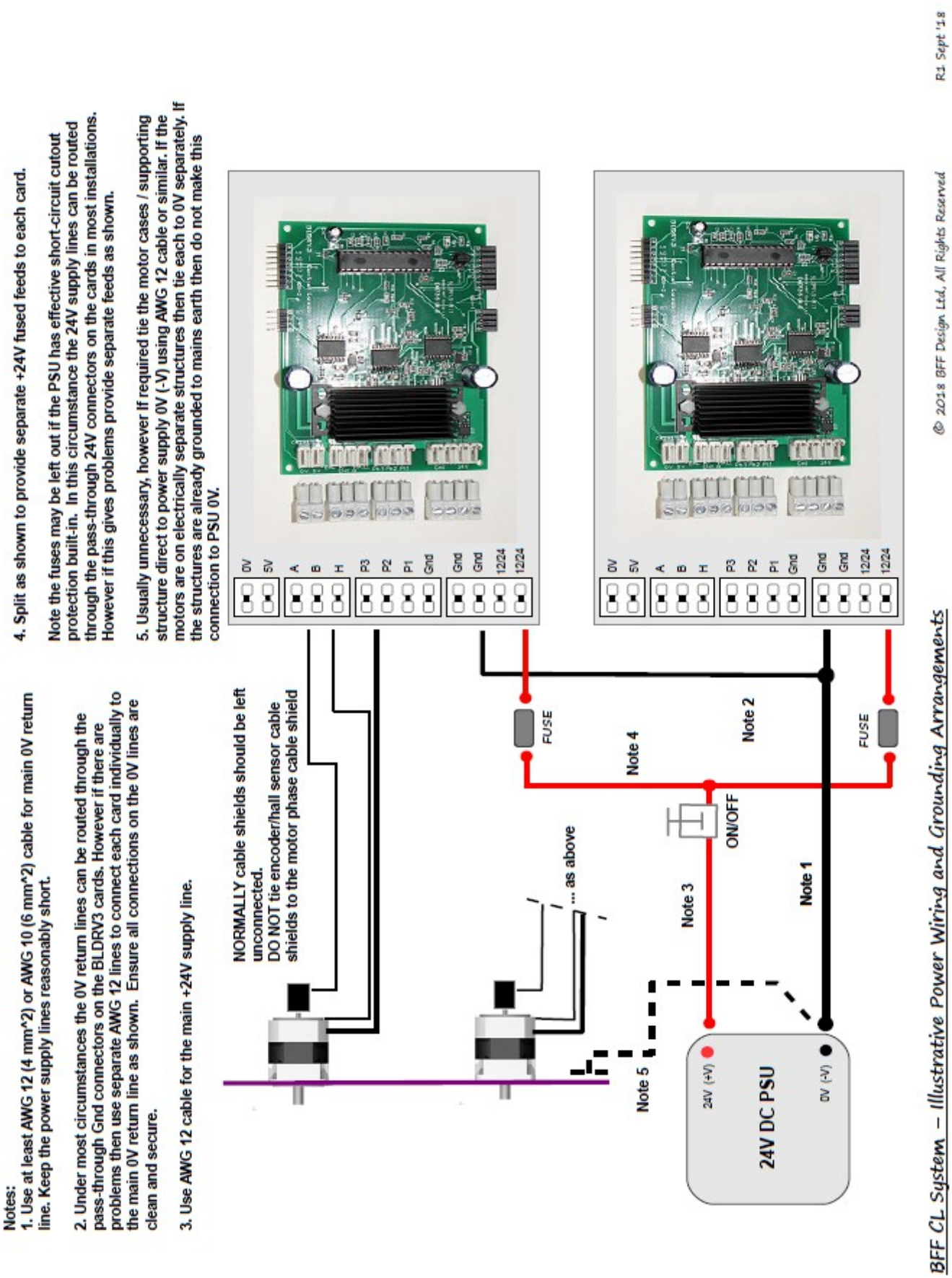
7. A standard USB to USB Mini B cable is required to connect the PC to the CL_SPU_USB.

8. An optional logic power switch can be fitted across jumper “Switch” on the CL_SPU_USB. This can be used to switch the logic power to the card separately from the main 24V power to the BLDRV3's.

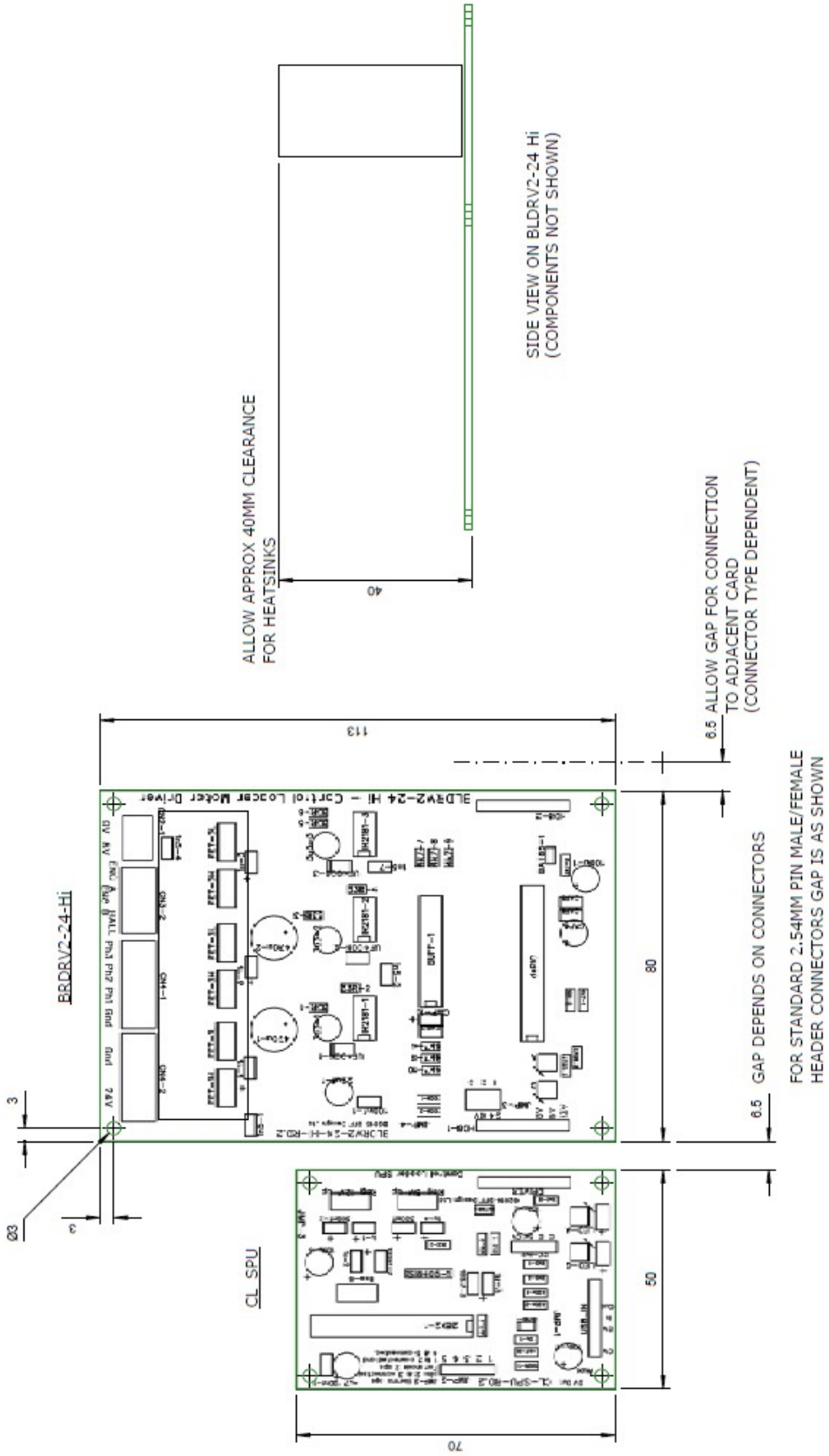
   If jumper “Switch” is permanently closed (by default jumper link) then the logic circuits will activate when the 24V power is connected to the BLDRV3 adjacent to the CL_SPU_USB.

   Note the Pilot/Co-Pilot station assignment for the CL_SPU_USB is set via jumper “Station” on the CL_SPU_USB. Co-Pilot assignment should only be used in dual electrically linked set-ups.

9. Typical System Power Wiring and Grounding Arrangements for 2 card system.



10. Dimensions (CL_SPU_USB & BLDRV3 dimensions are the same as the older BLDRV2 cards shown here)



9/18 – V0.2 – Small change to note references on wiring diagram

9/18 - V0.1 – First draft

Ian Hopper (BFF Design Ltd), CL_SPU_USB + BLDRV3 Data Sheet Rev 0.1 (Sept 18)