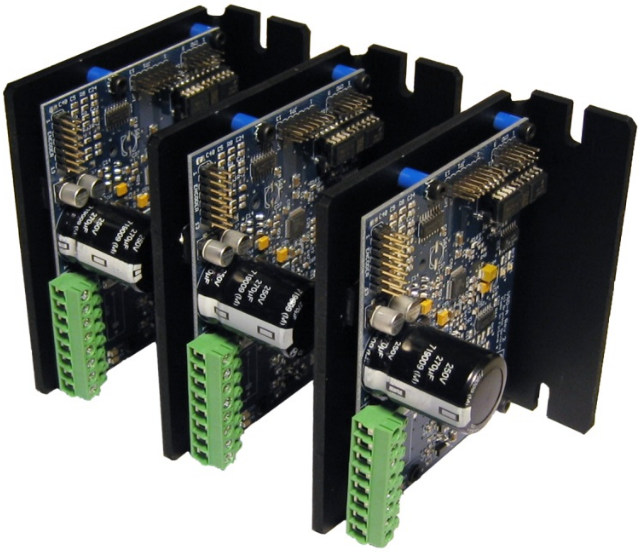
Fluxeon VSD-A documentation Ver. 0.70

VSD-A is a precision servo motor drive/controller for permanent magnet AC and DC servomotors with quadrature encoder feedback. Possible control methods include **position**, **velocity** and **torque** modes. Built-in trajectory planner enables simple point-to-point moves as well as continuous synchronous motion tracking.

VSD-A features industry standard optoisolated **pulse/direction, quadrature** and **PWM** inputs in addition to a device specific **SPI** (Serial Peripheral Interface) protocol.

Highlights



Three VSD-A Rev 2 drives

- High bandwidth field oriented flux vector control
- Position, velocity and torque modes
- AC servo motor support without hall sensor requirement
- Quadrature encoder feedback
- Fully optoisolated command I/O
- User upgradeable firmware
- PC software based tuning
- Arbitrary ratio input command scaling and gearing
- Trajectory planner with tunable velocity/acceleration limits
- Acceleration and velocity feedforwards
- Soft recovery from following error
- Configurable motor homing sequence
- Settable absolute position limits eliminates limit switches
- Separate supply terminals for logic and high voltage
- No loss of position on high voltage outage
- Typical efficiency of 95% at full power

Input voltage range	24-200 Vdc
Cont. output current	10.0 Adc
Peak output current	15.0 Adc

Applications

- CNC machine tools
- Spindle control
- Automation & robotics
- Pick and place machines
- General positioning & speed control applications

AC servomotor	Yes
Brush DC servomotor	Yes
BLDC servomotor	Yes
Linear servomotor	Yes
Stepping motor	Preliminary support

Note: specifications are subject to change without notice

Important notices

This drive has been designed to be operated on **isolated** **DC power supply** only. Optoisolator isolation distance (creepage) on circuit board is less than 4 millimeters.

A recommended way for **emergency stopping** is to cut HV bus voltage and activating motor brake if possible. Using optoisolated *disable* input may not be enough for emergency stopping.

Drive should be installed in **ventilated** enclosure. Dust filters are recommended when fans are used. The worst case operating temperature should not exceed 70 Celsius degrees (measured from aluminum plate).

Drive **should not be used** in applications where failure or malfunction could lead to danger, large financial loss, health hazard, injury, death, or other unbearable loss.

This document may contain **errors.** When operating with drive, take every precaution you can. Granite Devices do not take any responsibility of damages that may be caused by following or not following this document.

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Electrical specifications

Note: for VSD-A rev 1 specifications, download Rev 1 data sheet from www.granitedevices.fi.

	Description	Min.	Typ.	Max.	Units	Notes
Device operating conditions	Logic supply voltage	19		26	Vdc	VSD-A Rev 1 max 22V
	HV supply voltage	24		200	Vdc	Recommended max. 180V
	Logic supply current consumption	200		800	mA	Depends on encoder port load
	HV supply current consumption	0.05		13	A	Depends on motor load
	Operating temperature for currents <12A Operating temperature for currents 12-15A	10 10		70 55	°C	Plate surface temperature
	Humidity	0		95	%	Non-condensing
	Power dissipation	4		115	W	
Encoder	Encoder count rate	0		3	MHz	4X decoding, digitally filtered
	Encoder port input impedance		100		Ohms	
	Encoder supply current	0		500	mA	
	Encoder supply voltage	4.8	5	5.2	V	
I/O (CMD) characteristics	SPI bus baud rate	0		80	kbit/s	
	Output optoisolator source current (Fault & SPI out) source current	0.5			mA	Internal 2200 Ohm pull-up reisistor
	Output optoisolator (Fault & SPI out) sink current	1.0	2.0		mA	
	Output optoisolator supply voltage	3		6	Vdc	Voltage against Pin 1
	Optoisolator input current for logic 1	2	3	10	mA	All inputs
	Optoisolator input voltage for logic 1	2		5	V	All inputs
	Optoisolator minimum logic 1 time	1			µs	Step & dir inputs
	Optoisolator minimum logic 0 time	3.5			µs	Step & dir inputs
	PWM mode input frequency	3	5..10	30	kHz	

Note: socketed step/dir optoisolator (HCPL2531) can be replaced by a faster HCPL2631 if necessary. Default optoisolator provides **step rate** up to 200 kHz and HCPL2631 up to 2 MHz.

	Description	Min.	Typ.	Max.	Units	Notes
Motor control characteristics	Motor stall output current			10.0	A	Peak of sine wave
	Motor peak output current			15.0	A	Peak of sine wave
	Peak current duration		0.5		sec	
	Motor output switching frequency		17.5		kHz	
	Effective motor output voltage swing			88	%	Percentage of HV voltage
	Torque control bandwidth		1-3		kHz	Motor dependent
	Feedback (PID) loop sampling frequency		2.5		kHz	
	Efficiency		95		%	At full power
	Motor inductance (per HV supply voltage)	0.01			mH/V	e.g. 200V supply: 0.01mH*200=2mH

Features

Position control

- Relative and absolute position commands
- Infinite motion range
- Configurable 32 bit absolute position limits after homing
- Trajectory planner with settable acceleration & velocity limits
- Soft recovery from error, configurable recovery speed

Velocity control

- Configurable velocity and acceleration limits
- Soft recovery from error
- Configurable input command sensitivity

Command inputs

- Optoisolated step/direction input (step on rising edge)
- Optoisolated quadrature input
- Optoisolated PWM input
- Optoisolated SPI (Serial Peripheral Interface) bus
- Configurable moving average input command filter, averaging time from 1 to 32 PID cycles
- Configurable scaling or gearing ratio
    - Input multiplier from 1 to 32767
    - Input divider from 1 to 32767

PID controller

- Anti-windup design
- 32 bit PID filter
- Acceleration and velocity feed-forwards
- Adjustable anti-dither region with separate PID gains
- Adjustable moving average filter for derivative gain
- 2.5 kHz update rate

Torque controller

- Field oriented sinusoidal flux vector control
- Tunable anti-windup PI torque controller
- Full PWM frequency update rate
- Precise 12 bit current sensing
- HV bus voltage variation compensation
- Power stage deadtime crossover distortion compensation algorithm

Homing controller

- Fully configurable homing sequence forming from the following parts
    - Home switch or hard stop search, settable direction [1]
    - Encoder index pulse search, settable direction
    - Adjustable 32 bit position offset move after homing
- Automatic homing after power-up or manual homing via SPI command
- Configurable torque, acceleration and velocity limits for homing sequence

Fault detection

- Configurable following error limits from 1 to 16383 units (position encoder counts, velocity error or torque error)
- Configurable motion fault detection with 0.2 second response time
    - Sensing of DC motor runaway
    - Sensing of stepping motor stall when encoder feedback is present
    - Sensing of blocked motion
- Overvoltage detection and power stage shutdown to prevent failures caused by regenerative braking current
- Undervoltage detection
- Configurable overcurrent detection and shutdown (single PWM cycle response time, not short circuit safe)
- Internal flash memory error detection
- Input command range error detection
- SPI communication error detection

Other features

- Adjustable AC motor phasing without hall-effect sensors
- Optoisolated fault-output
- Optoisolated disable-input
- User upgradeable firmware

It should be noted that some of these features are new and current release of GDtool configuration software may not support them until the next release.

1 Home switch input available in drive Rev 2 and later

Connectors

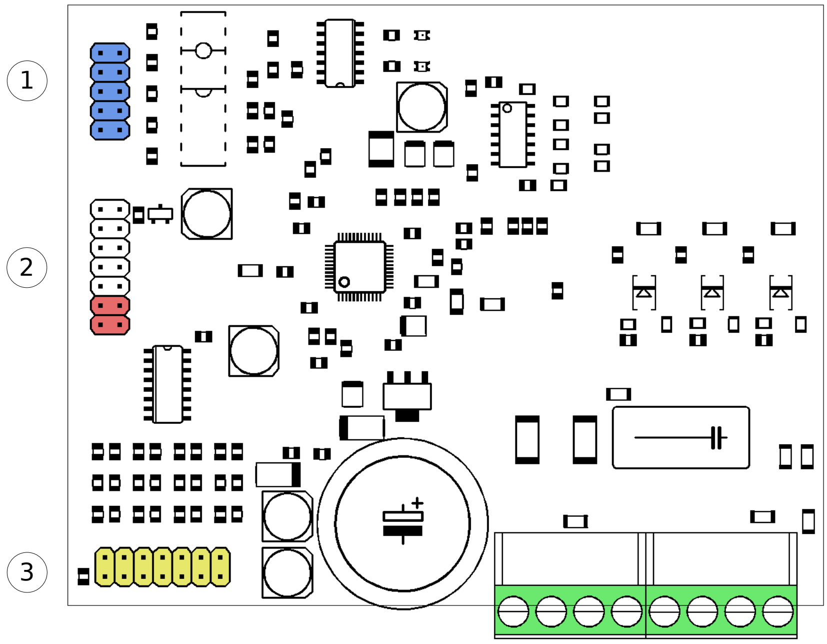


Figure 1: VSD-A connector layout

Name	Location in Figure 1	Description
CMD	**1**	Optoisolated SPI and Step/dir port
JP1	**2**	SPI and CLR jumpers
ENCODER	**3**	Quadrature encoder connector
POWER	**4**	Supply & motor terminals

Power connector

This is a modular (removable) high current connector for **logic supply**, **high voltage supply** and **motor leads**. All ground terminals are electrically connected to same ground.

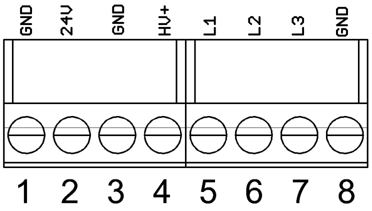


Figure 2: Power connector pin out

<table>
<tr><th>Pin (text on board)</th><th colspan="3">Function (split for different motor types)</th></tr>
<tr><td>1 (GND)</td><td colspan="3">GND (logic)</td></tr>
<tr><td>2 (24V)</td><td colspan="3">Positive logic supply voltage (recommended 20 VDC)</td></tr>
<tr><td>3 (GND)</td><td colspan="3">GND (High voltage)</td></tr>
<tr><td>4 (HV+)</td><td colspan="3">Positive high voltage supply</td></tr>
<tr><td>5 (L1)</td><td>AC motor winding W</td><td>DC motor winding 1 or -</td><td>Stepper A+ & B+ windings common</td></tr>
<tr><td>6 (L2)</td><td>AC motor winding V</td><td>DC motor winding 2 or +</td><td>Stepper winding A-</td></tr>
<tr><td>7 (L3)</td><td>AC motor winding U</td><td></td><td>Stepper winding B-</td></tr>
<tr><td>8 (GND)</td><td colspan="3">GND (motor)</td></tr>
</table>

Note: motor rotation direction can be reversed by flipping any of two wires in motor windings. For example by connecting V to pin 5 and W to pin 6. Correct rotation direction **must** be set for stable servo operation. If unsure about correct setting, it can be found experimentally by using a freely running motor.

Encoder connector

This is a connector for quadrature encoder with differential line driver (26LS31 or equivalent). Single-ended encoders without inverted (-) outputs are not supported directly. 26LS31 conversion chip can be used to interface to single-ended encoders.

Optional *home switch* should be connected directly between pins 9 and 10. Contact to other conductors and machine ground must be avoided.

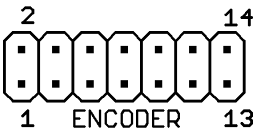


Figure 3: Encoder connector (2x7 0.1" pin header)

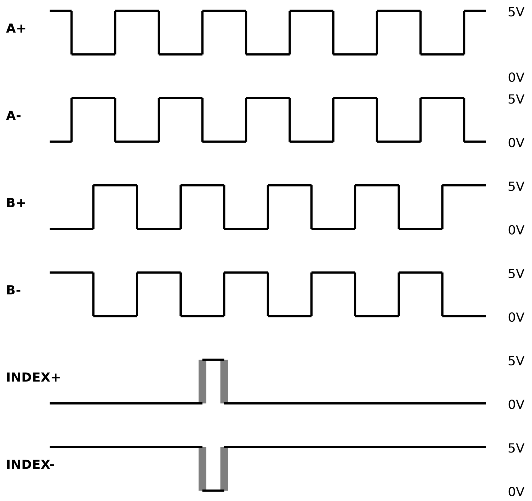


Figure 4: Differential encoder signals

Pin number	***Function***
1	**+5V**
2	**GND**
3	Channel **A-**
4	Channel **A+**
5	Channel **B-**
6	Channel **B+**
7	**GND**
8	**GND**
9	Home switch input
10	Home switch ground (connected to GND)
11	**Index+** or **C+** or **Z+**
12	**Index-** or **C-** or **Z-**
13	**GND**
14	*No connection*

CMD connector

This is a connector for optoisolated **SPI**, **step/dir**, **quadrature** or **PWM** interface.

Positive and negative terminals of optoisolators are brought to connector. In most cases negative (**-**) pins are connected to control source ground.

In step/dir mode, step is being taken at rising edge of step signal. Fault output pin FLT+ is logically inverted, logic 0 in FLT+ indicates fault state and logic 1 normal operation. Disable/clear faults input is active on logic 1. For more information, see chapter **Operation in pulse input mode**.

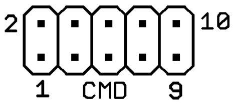


Figure 5: CMD connector (2x5 0.1" pin header)

Pin number (signal name)	***Function in SPI mode***	***Function in Step/Dir and Quadrature mode***	***Function in PWM mode***
1 (OUT-)	Data out -	Fault indicator output - (FLT-)	Fault indicator output - (FLT-)
2 (OUT+)	Data out +	Fault indicator output + (FLT+)	Fault indicator output + (FLT+)
3 (DISABLE-)	Disable/clear faults input -	Disable/clear faults input -	Disable/clear faults input -
4 (DISABLE+)	Disable/clear faults input +	Disable/clear faults input +	Disable/clear faults input +
5 (CMD_VCC)	Output **VCC** supply	Output **VCC** supply	Output **VCC** supply
6 (STEP+)	Clock in +	**Step+** or quadrature **A+**	**PWM+**
7 (STEP-)	Clock in-	**Step–** or quadrature **A-**	**PWM-**
8	*No connection*	*No connection*	*No connection*
9 (DIR+)	Data in +	**Dir+** or quadrature **B+**	No function
10 (DIR-)	Data in -	**Dir–** or quadrature **B-**	No function

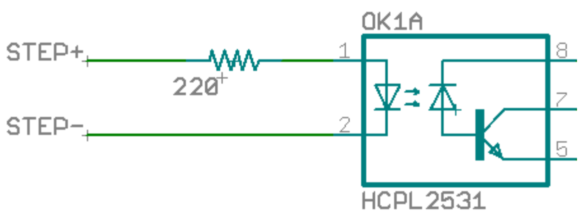


Figure 6: Step & Dir input equivalent circuit

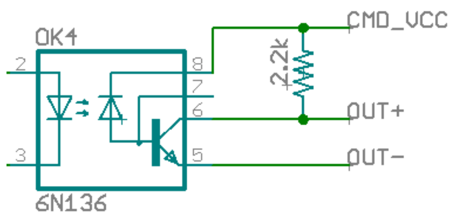


Figure 7: Output optoisolator equivalent circuit

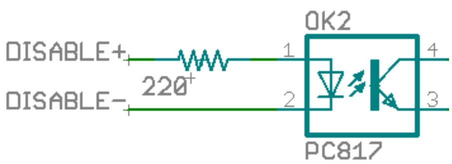


Figure 8: Disable/clear faults input equivalent circuit

Jumpers

This is a combined jumper connector and factory programming connector.

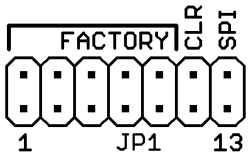


Figure 9: JP1 connector

Jumper settings take effect on power-up.

Jumper	***Function***
SPI	• Jumper **on**: **step/dir**, **quadrature** or **PWM** mode is selected • Jumper **off**: **SPI** mode is selected
CLR	• Jumper **on**: **Bootloader** (firmware upgrade) mode is selected • Jumper **off**: **Normal** motor control mode is selected
Factory	Factory programming connector, do not use

Installation notes

Wiring

Typical wiring of driving is presented in figure 10. For detailed information about encoder connector pin out, see the chapter of **Connectors** and compare pin order with the specifications of motor or encoder. If you experience runaway or motor jamming, try reversing any of two phase wires to reverse motor rotation. *Microstepping* feature of tuning software can be used to test proper motor configuration.

Grounding

Encoder, motor and power supply should be grounded to their respectable connector ground pins on drive. *Avoid* grounding these on other ground points like enclosure. For HV bus and logic voltage use separate grounding leads from power supply to each drive.

In typical cases control source ground should be connected to all of the negative terminals (-) of the optoisolated **CMD** connector. See figure 10.

Shielding

Shielded cables are strongly recommended to minimize high frequency electrical interference that can cause errors in operation. Connect cable shields to **machine earth** only from one end.

A shielded metal enclosure is recommended for complete drive electronics system.

If a compliance for CE or UL is required, the system should be characterized as whole in appropriate test arrangements.

Protection

Separate **fuses** should be used for HV bus for every drive. Fuse sizing should be done by estimating peak load power of the motor axis. Using larger fuse than configured peak current is not recommended.

For additional motor protection, fuses can be added in series to motor phase wires. In three phase motor fusing two leads should be enough in most cases and for DC motor one lead will be sufficient protection.

It is recommended to do initial testings with reduced HV bus voltage and with lower current fuse rating.

Cooling

Additional cooling should be used if aluminum plate temperature rises over 70^{0} Celsius during hard use. Improved cooling can be achieved generally by two ways:

- Adding forced air flow by using a dust filtered fan
- Mounting a heat sink on back side of drive's aluminum plate

The most efficient cooling can be achieved by combining the both methods.

See mechanical drawings for heat sink mounting hole pattern.

Warning: when mounting heat sink, take care screws are not too long to reach circuit board through aluminum plate. Leave at least 3 mm isolation distance between the circuit board and screw ends.

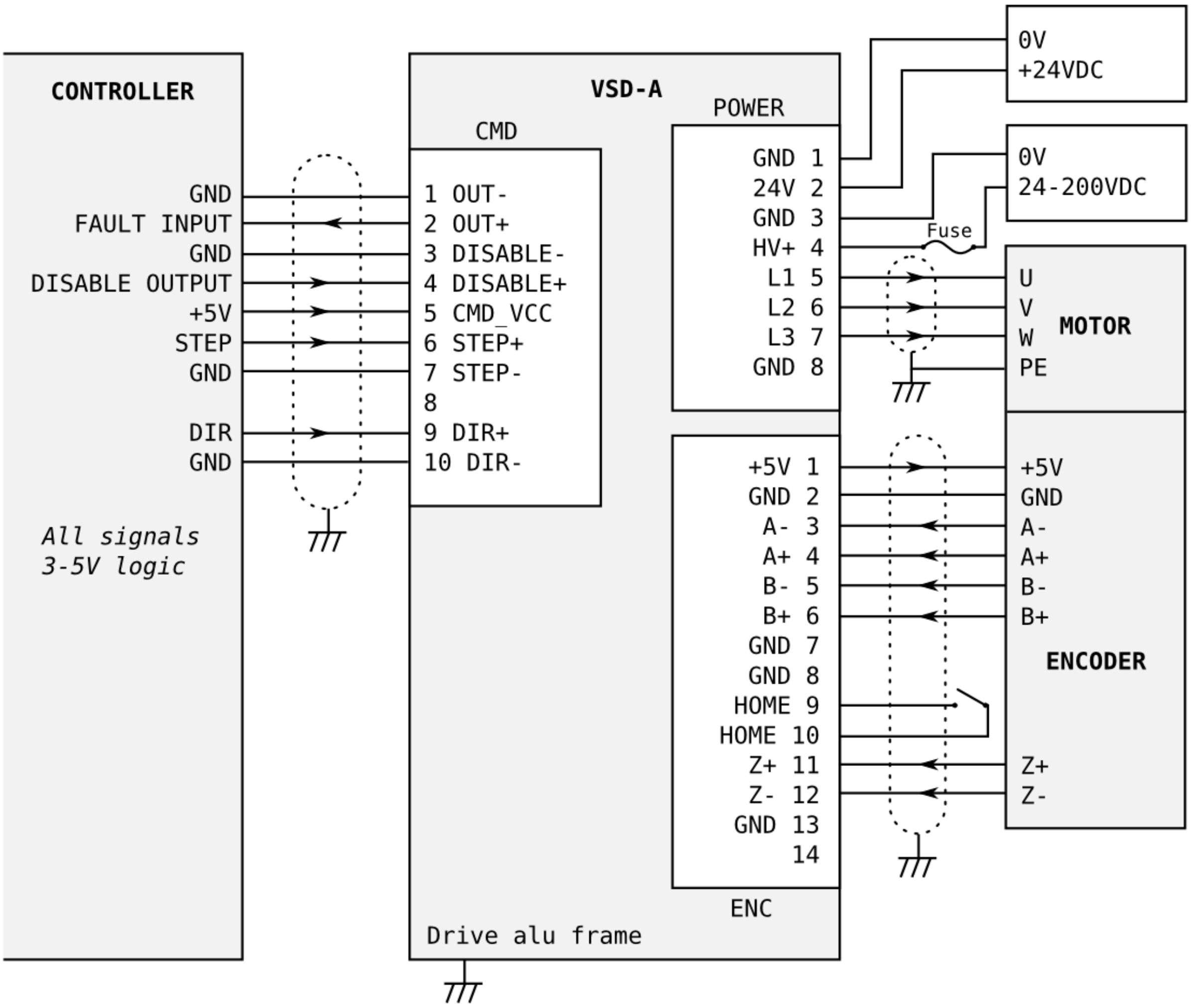


Figure 10: Typical wiring of 3 phase servo motor

Notes: Z- and Z+ are index channel inputs (optional), HOME switch is optional

Power supply

VSD-A runs on unregulated **isolated** power supply which means that there is no galvanic or conductive connection between the AC line and DC bus. A linear transformer based PSU is preferred over switching mode power supplies (SMPS) for servo systems since transformers are capable of delivering high peak output power just like motors are.

For logic power, a separate regulated power supply is required.

Warning: This is only a very brief guide of powering the system in basic cases. An experienced electrician should always be consulted when designing or building power system.

Pay attention to *RMS* and *peak* terms in this text. Mixing these can lead to unpredictable results.

Basic guide for sizing linear PSU components

In short, PSU should be sizes so that it does not overload or overheat during any condition in machine use. Since servo systems typically have greatly varying load, it might be necessary to find effective power consumption by measuring *RMS power* consumption of the system during at least 10 second period of heavy use.

If measurements can't be done, then maximum RMS power load can be estimated roughly by summing rated power values of motors in the system. However, in typical setups power consumption is significantly less than summed motor power since required power is directly proportional to actual produced Speed ◊ Torque.

Transformer

Transformer can be selected after RMS power need is determined. One should choose transformer with some safety margin since VA rating of transformers do not equal to RMS watts in linear PSU. For example, if RMS power consumption is 200 Watts, then using of at least 300 VA transformer is recommended.

Transformer primary voltage should match with the voltage of AC mains network of your area. Secondary voltage should be about 1.41 times *smaller* than desired DC bus voltage. To convert DC bus voltage to transformer secondary voltage, use equation

$$U_{secondary}=\frac{U_{DC}}{1.41}$$

Bridge rectifier

Bridge rectifier should be able to handle *peak current* of rectification. Typically a very high peak currents can be present during power-up and during motor peak loads. Use at least safety factor of 4 when choosing rectifier current rating compared to RMS current. Rectifier may need cooling to prevent overheating damage.

Capacitors

VSD-A HV bus accepts unregulated power up to 20% ripple voltage. To solve required power supply capacitance need, use equation

$$C=\frac{I_{load}*T}{U_{ripple}}$$

where C is required capacitance in Farads, I_{load} is the *peak load current*, T cycle time of rectified voltage and U_{ripple} is the desired maximum ripple voltage.

Calculation example

1. If you have 70 Vdc DC bus voltage, then 70*20% = 14 V ripple (U_{ripple}) voltage is allowed.
2. If you are using full-wave rectifier for 50 Hz mains voltage, then cycle time T is 0.01 seconds
3. If your peak power load is 500 Watts, then I_{load} becomes 500W/70V = 7.2 A
4. By substituting these values in equation above, the minimum required capacitor value becomes

$$C=\frac{I_{load}*T}{U_{ripple}}=\frac{7.2\mathrm{A}*0.01\mathrm{s}}{14\mathrm{V}}=0.00514\,Farads\approx 5000\,\mu F$$

Notice that capacitor voltage rating should be at least 20% more than rectified DC bus voltage.

Warning: capacitor voltage can reach drive's maximum DC bus voltage (200 Vdc) during motor braking because of regenerative current flowing back to PSU. A braking resistor circuit in PSU is recommended when significant loads are driven by motor.

Fuses

Use slow-blowing fuses that can withstand the peak currents required by the circuity after fuse.

Example circuits

Following figures show simplified PSU cases. Line filters may be required before AC input to comply with local EMI regulations.

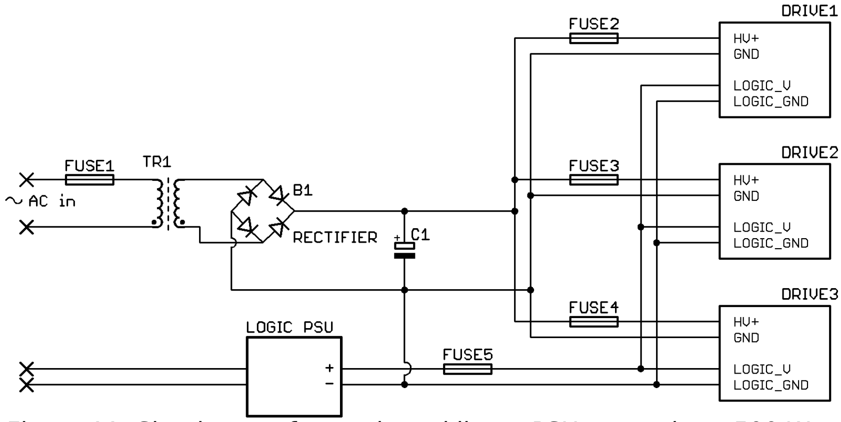


Figure 11: Simple transformer based linear PSU up to about 500 Watts

Drive can be powered also by a switching mode power supply (SMPS). A diode (D1) and capacitor (C1) are required to prevent regenerative current from flowing back to SMPS.

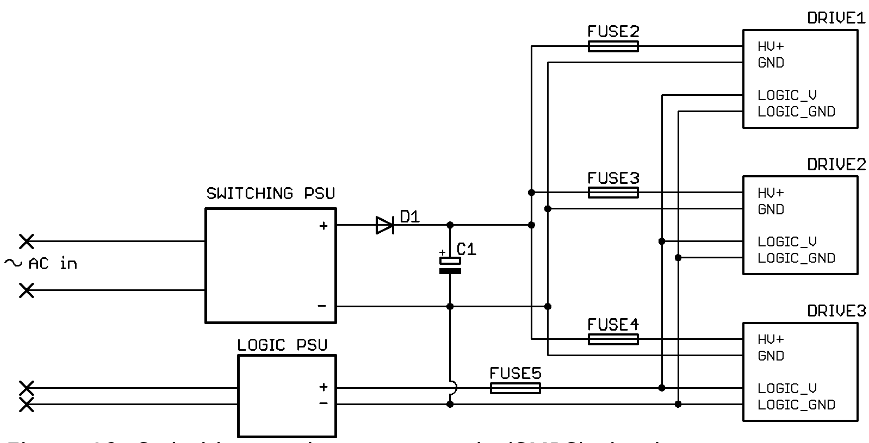
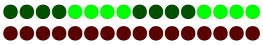
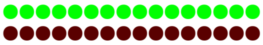
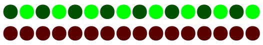
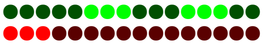
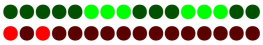
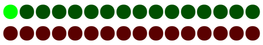
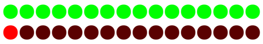
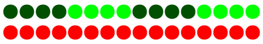
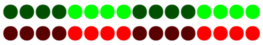
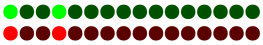
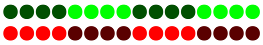
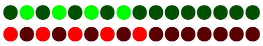
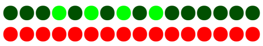
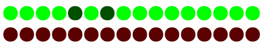
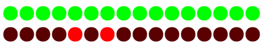
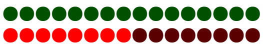


Figure 12: Switching mode power supply (SMPS) circuit

Status indicators

The VSD-A has two LEDs (**green** and **red**) which have various sequences described in table below. Read sequences from left to right and note that all patterns are repeating.

No	***LED sequence (time →). Repeating approx. once a second.***	***Sequence description***	***Status***	***Motor output on***
1		Green blinking	AC motor phase search or drive init	**Yes**
2		Green on	Enabled and running	**Yes**
3		Green flashing fast	Recovering from follow error	**Yes**
4		Red, green, green repeating sequence.	Following error	No
5		Two short red and two green flashing sequence	Motion error. Motion stalled or encoder (wiring) failure	No
6		Short green flashes	Disabled by user	No
7		Green on and short red flashes	Input motion command range error	**Yes**
8		Green blinking and red on	Init or AC motor phase search failed. Possibly too low voltage.	No
9		Green and red blinking simultaneously	Other fault, get details via SPI bus. Possibly over current fault.	No
10		Two red and green flashes simultaneously	Over voltage or under voltage fault	No
11		Red and green alternating constantly	Communication error, invalid command or invalid command parameter. Check cabling & jumper settings.	No
12		Red and green alternating very fast and pausing	Internal error, contact us for support. See also #11.	No
13		Red on and green blinking in short bursts	Drive stopped until next power cycle. Occurs after motor type changed in configuration or motor not configured.	No
14		Green flashing off	Drive ready for firmware update	No
15		Green on and red flashing twice per second	Firmware upgrade failed, cycle power and try again	No
16		Red blinking slowly (0.5 Hz)	Memory checksum error, install upgrade firmware again or contact us if problem stays	No

Controller diagram

VSD-A implements a position mode controller by utilizing PID error amplifier with encoder feedback. A greater performance has been achieved by utilizing separate high-bandwidth vector torque controller and feedforward paths.

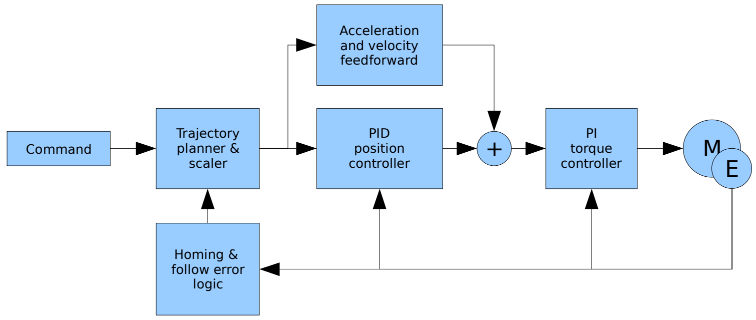


Figure 13: Simplified controller diagram

Operation in pulse input mode (Step/Dir, Quadrature, PWM)

In many cases various pulse input modes are preferred methods of control because of their wide availability and simplicity. In this chapter operation of pulse mode is discussed in detail. Please refer to chapter **Connectors** about pin-out of optoisolated pulse interface.

Setup

After drive configuration & tuning, a jumper **SPI** must be placed before logic supply power-up to enter in pulse input mode. After successful power-up and initialization drive starts following pulsed input from the optoisolated interface.

Powering up

Powering up logic and HV bus can be done in any order or simultaneously. If logic power is being connected first, drive will wait for HV bus rise before initiating motor control.

Delaying power-up

Drive start-up can be delayed by driving logic 1 value to **disable input** while power supplies are switched on. Drive begins initialization after input value is released to logic 0. Logic 0 should be active during whole initialization process (i.e. while green led *not* constantly on). If drive gets interrupted by disable signal during initialization process, an **init fault** condition will occur. Init fault can be cleared only by power cycling.

Faults

In fault condition, optoisolated **fault out** gets activated (CMD connector **FLT+** pin is logic 0). This signal can be used to inform control source about fault condition or, for example, to activate an external alarm. Fault output will return to its non-active state after faults have been cleared.

Clearing faults can be done by cycling logic value 1 in **disable input.** In no-fault condition OUT+ pin is in logic high state.

Notes about PWM mode

In the PWM mode, drive's target value is controlled by input signal duty cycle (percentage of logic 1 time against whole cycle time period). PWM range **0%...100% equals absolute command value range of -16384...16384** in all operation modes (position, velocity or torque). 50% duty cycle equals command 0.

User may adjust PWM **sensitivity** by adjusting input scaling (multiplier/divider) just like in other modes. User may also adjust PWM **offset** to match control source PWM to drive PWM.

0% and 100% duty cycles are theoretical references only and in practice cannot be used. Drive sets output command value to zero if PWM input is not detected (i.e. no logic transitions pass through optoisolator). To stay in **valid duty cycle range**, limiting input to 10%...90% range is recommended.

PWM mode is a digital equivalent of standard **analog input** but has benefit of optical isolation and lower sensitivity to noise. It is possible to convert standard +/- 10V analog signal to PWM with the help of a simple external circuit.

Differences between drive revisions

Determining drive revision

In Rev 2 and later the revision number is marked on circuit board edge with clear white text. In Rev 2 the identifier text reads “**VSD-A Rev 2**”. Rev 2 and later also has a black anodized back plate while Rev 1 has bright aluminum plate.

Changes from Rev 1 to Rev 2

New features in Rev 2

- Faster output optoisolator, CMD_VCC input added in CMD connector
- Electrically isolated back plate
- Added home switch input
- 24V logic supply compatibility
- Black anodized back plate instead of uncoated aluminum

Known limitations

VSD-A does not include mechanical *brake control* so it may be unsuitable for applications where axis may fall by gravity if not held at position by a brake or by the motor. However, in brushed DC servo mode this application may be possible since motor position control starts almost instantly after power-up.

For AC motors, VSD-A does phase alignment by driving user specified amount of DC current into windings for several seconds. DC injection is safe when current has been configured to be less or equal than motor rated current. Alignment process may cause a short position jump at power up (typically less than 90 mechanical degrees). The AC servo start-up process takes typically few seconds before final control mode (position etc.) is being activated.

Motor compatibility

This is a short guide for determining whether or not a motor is suitable for VSD-A.

Motor type must be one of the following:

- Permanent magnet brushed DC
- Permanent magnet brushless DC (BLDC)
- Permanent magnet AC

Motor must be equipped with an quadrature/incremental **encoder** with **differential line outputs** (see chapter *Encoder*). However, a *single ended* or *open collector* encoder can be fitted to VSD-A by using a conversion circuit (26LS31 chip) between the drive and encoder.

Encoder notes:

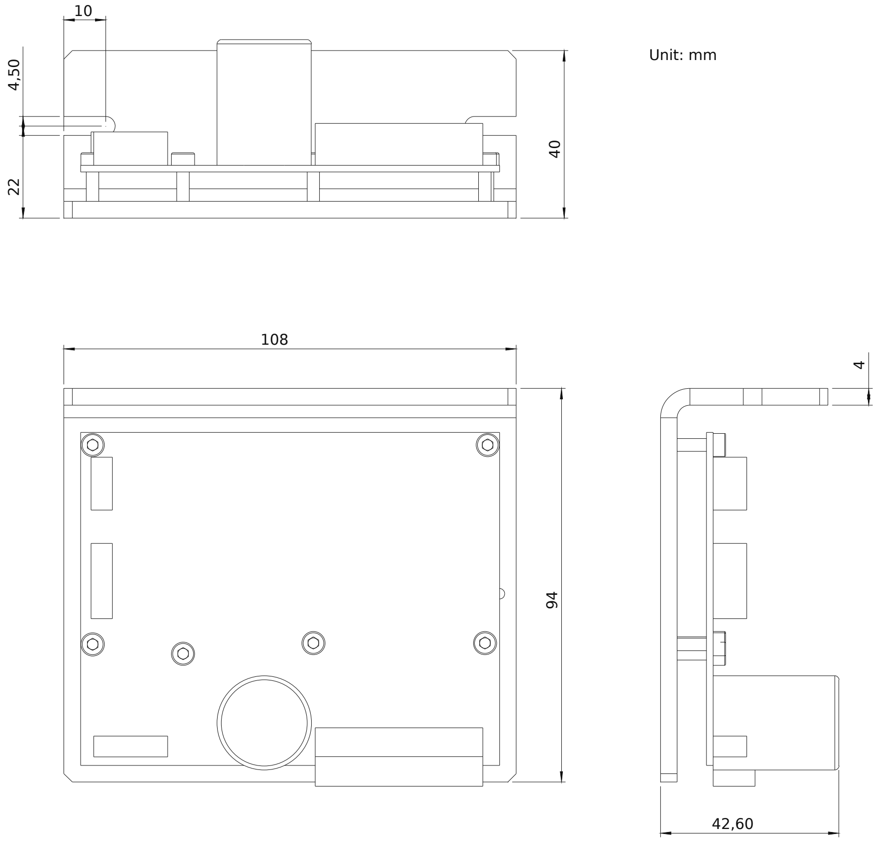
- 2 channel encoder is enough for all motor types
- *Index* channel is not required but is supported for homing
- *Hall* or *commutation* sensors are not needed or used
- Suitable encoder resolutions are from about 100 PPR to 20000 PPR (pulses or lines per revolution)

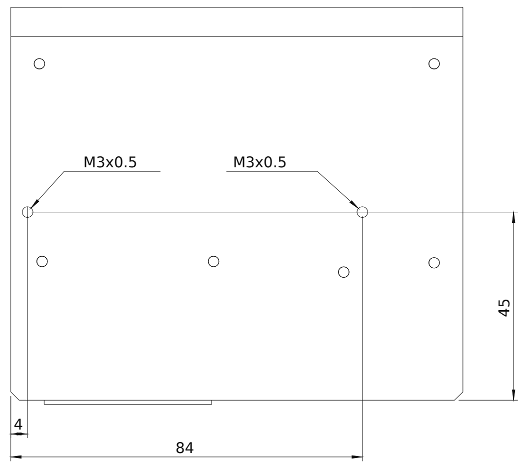
Motor **voltages** and **currents** can introduce some limitations to motor output speed and torque but *does not cause unsuitability*.

- **Motor voltage** is the limiting factor for maximum **speed**. For example, if you have a 300 VDC brushed DC servo motor and run it at 170 VDC using VSD-A, then you can expect to get a speed of 88%*170/300 = 50% of motor's rated speed. 88% comes from VSD-A effective voltage swing at power outputs (see *Electrical specifications*).
- **Motor current** is the limiting factor for maximum **torque**. For example, if you have motor rated for 20A DC and drive's maximum output is 10A DC, then you get 50% of the rated torque.

VSD-A may be unoptimal or even unsuitable for very small motors that have rated current below 1 Amp.

Mechanical drawings





Heatsink mounting hole pattern (bottom view)

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