Senior Design
ENG EC 464

To: Future Senior Design Team, Users

From: Power Pooches, Team 14

Date: 5/3/2015

Subject: Hardware Documentation

1.0 POWER-UP SEQUENCE

1.1 A detailed description of power-up is available in the User's Manual. Also, additional photos are available in the User's Manual and also in the "Pictures" folder of this USB drive.

1.2 Power-up sequence:

1.2.1 Plug LabJack USB drive into computer to be used for data measurement on MATLAB.

1.2.2 Plug orange power strip cord into nearby wall outlet.

1.2.3 Provide 5V and 3V (DC) to the cart's side outlets, as labeled. A typical 1A source is sufficient.

1.2.4 Make sure all loads are disconnected from the transmission lines.

1.2.5 Ensure that each transmission line has at least one path for flow (i.e., all top switches on or all bottom switches on, where the on-state is indicated by the green tab).

1.2.6 Turn on V_{REF} by flipping the switch on its top (middle shelf, red device labeled GEN REF).

1.2.7 Flip the main power switch on the top of the cart (24V)**.**

1.2.8 Energize one of the generators (A or B) by pressing the MSP430's RESET button.

1.2.9 Synchronize that generator to the rest of the grid.

1.2.10 Energize the other generator by pressing its button and synchronize it as well.

1.2.11 Now, the system is running with three generators synchronized and simultaneously feeding the power grid. Plug and play by changing loads and transmission line lengths, and observe those changes on the MATLAB interface. A user can also model an outage by disconnecting a generator during operation.

2.0 GENERATION SYSTEM

2.1 The generation system gets its input from the 120V, 60Hz power supplied by an ordinary wall socket. All supply and source plugs are gathered on the 9ft (heavy-duty orange) extension cord creating a single-outlet solution for the power supplied to the grid. There are two cutoff switches to the generation points, one is a built-in switch on the third (reference) power source and the other is the single pole ON/OFF switch on top of the cart that controls the power to the DC power supply.

2.2 The DC power supply (Siemens SITOP 6EP1336-3BA00) has two-output ports and is rated at 24V (24.4-28V capacity). The current provided by this source (rated at 20A max) is split between its outputs and is enough to drive our motors at any loading. The 24V, 2.6A, 1/18HP permanent magnet DC motors (Bodine 24A4BEPM) drive the 12V, 7 dipole wind turbine alternators (Hurricane Windpower Cat 4 Mark I Neo Core Platinum) through a belt-driven configuration that makes use of cast iron pulleys and a 4L V-belt. The pulleys create a 2:3 ratio between the motor and alternator (established through testing). This ratio requires the motor to be supplied with roughly 17.5V in order establish 60Hz at no loading, allowing enough room for the power supply to provide more voltage accordingly. The output voltages of the alternators are then stepped-down using 100.8VA/56V, 1.8A transformers (Hammond 186F56) to the desired 12Vpp, roughly 8Vrms.

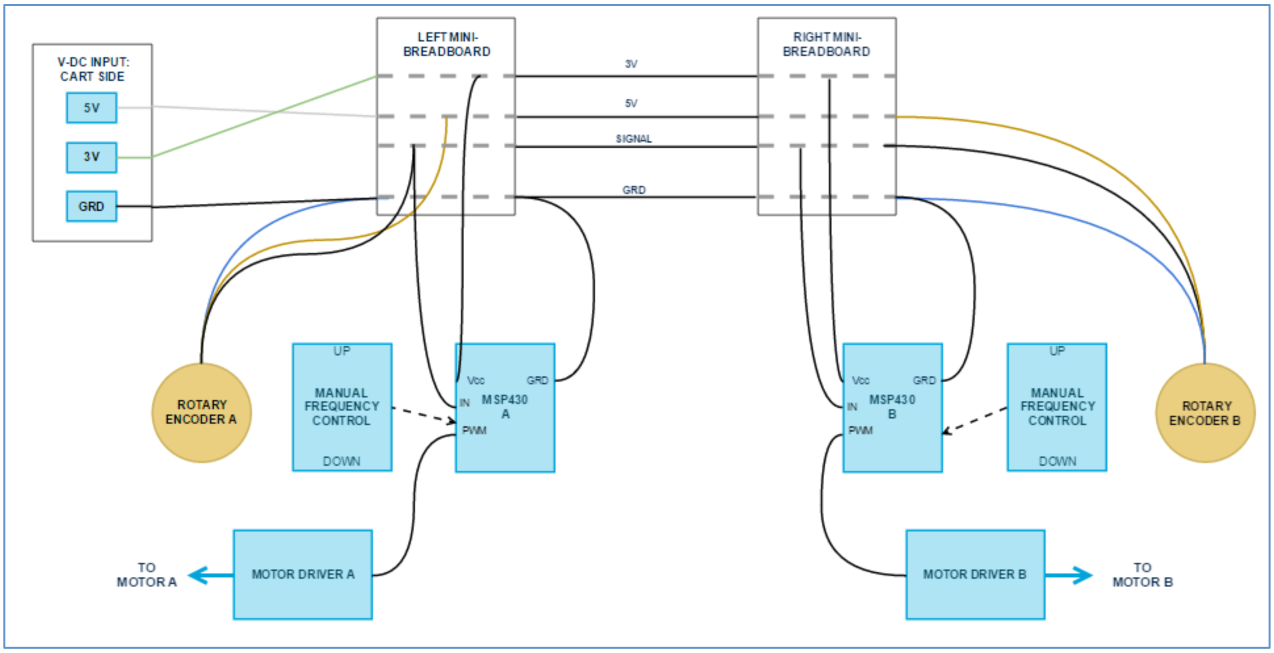
2.3 The third (reference) generation point is established using a variable voltage regulator (PHC Enterprise, Model: SC-3M) rated at 0-130VAC, 3A. This source, like the DC power supply, is powered by the wall connection (INPUT: ~117V at 60Hz) and for use in this project set to roughly 8V in order to provide the grid with 12Vpp.

3.0 FEEDBACK

3.1 The feedback loop will operate without any required action taken by the user. Refer to the User's Manual for details on the layout of the feedback loop.

3.2 You can manually change the alternator's frequency by pressing the up and down buttons on the sides of the MSP430s. If you want the alternator frequency to be slightly higher or lower, press the buttons accordingly. To reset the frequency to 60Hz, simply press the MSP430's RESET button. However, do not do this while the generators are synchronized. These buttons are intended to slightly change frequency so that synchronization is easier (it can make the LED dim and brighten slower).

3.3 Each feedback system is composed of an MSP430, a Cytron 13A, 5-25V Single DC Motor Driver, and a Yumo 200P/R rotary encoder. The rotary encoder provides a pulse signal to the MSP430, which outputs a PWM signal to the motor driver, which provides DC voltage to the motor. There are many wires that connect these parts together; the following wiring layout is implemented and should be used:



This diagram shows the proper wiring of the DC voltage input, the rotary encoders (based on wire color), and shows some information about the layout of the breadboards. This diagram is not intended to show the complete MSP430 wiring, motor driver wiring, or manual frequency control wiring. One important distinction is that the PWM signal from the MSP430 to the motor driver occurs via the breadboard.

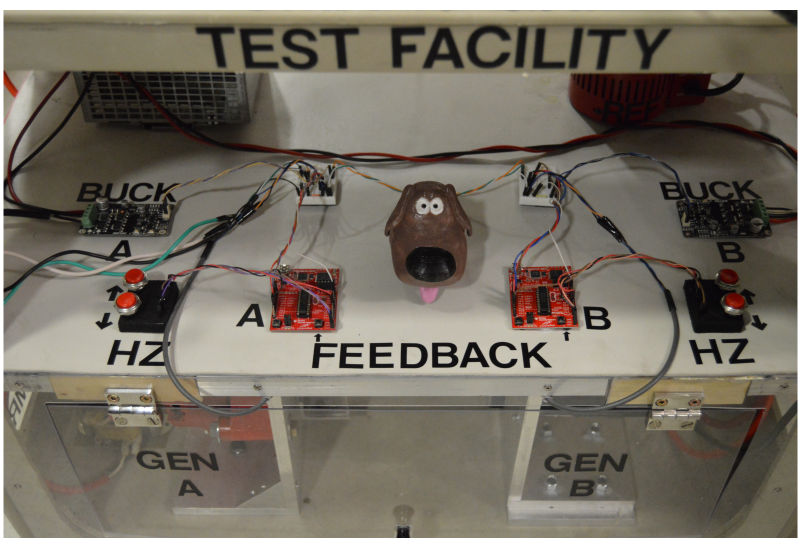


FIGURE 3.3.1 – Feedback Control Loops

The image above shows the application of the system, where the encoders are on the lower shelf, while the MSPs, motor drivers (or buck converters), breadboards, and manual frequency control are on the middle shelf.

4.0 TRANSMISSION LINES

4.1 Development Tool Information

4.1.1 Altium Designer is required to run the transmission line files including the schematic document and the PCB file. The preferred version of the software is Altium Designer Summer 09. Directly contact the BU IT Help Department to provide an updated license on Altium if the software does not allow you to proceed.

4.2 Vendor Information/Significant Datasheets

4.2.1 See excel spreadsheet attached, It documents vendors and contains links for transmission component datasheets.

4.3 Power Requirements

4.3.1 Just like loads, the transmission line PCBs are powered by the three generators that are provided in the project. Since a motor-alternator feeds a synchronization circuit, the transmission line immediately becomes energized when the female connector leaving a sync circuit is attached to a male header from the PCB's IN terminal. The optimal voltage for the transmission lines is $12V_{peak}$, which is also the rated system voltage. At that designated voltage, there is already a current-limiting design for the input line feeding the transmission lines, regardless of loading. In an overcurrent scenario, the user needs to ensure that I_{max} does not exceed 2A.

4.4 Power Up Sequence

4.4.1 The three transmission boards begin connected in a loop. For example, if the reference generator is turned on as the first energized source, it will power the entire delta network provided that its respective load switch is closed. Depending on the combination of six disconnect switches; the board will be powered along different RLC path lengths. If the all the switches are off, the transmission line will not conduct. In all other scenarios, see the User's Manual to determine which switch configurations will deliver power to the load.

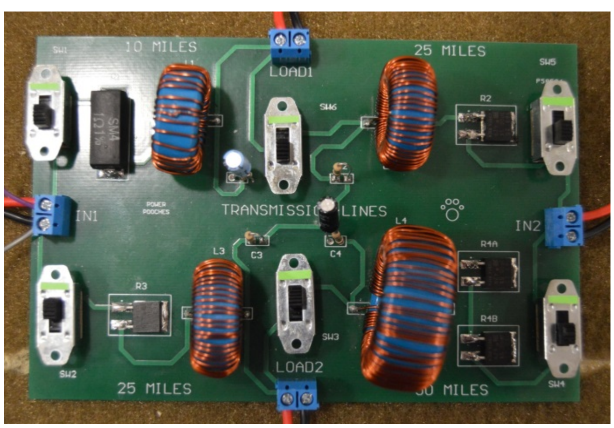


FIGURE 4.4.1 – Transmission Line PCB

5.0 LOADS

5.1 Binary Coded Load Boxes:

5.1.1 Using Altium Designer use the included PCB files to produce Gerber files to reproduce the provided circuit boards. The bill of materials for these boards includes the following.

Component	Description	Quantity
T38 Ferrite Core	36x23X15 Radial Ferrite Core	8
Assorted Resistors	Values Ranging from 1k-128kΩ	8*
Assorted Capacitors	Values Ranging from 12-1440uF	8*
SPST	Single Pole Single Throw	24
SPDT	Single Pole Double Throw	6
Magnetic Insulated Wire	#18-#22 Gauge Wire **	1 Spool

*Actual quantities dependent on part availability.

**Gauge selected at discretion of user, for design purposes.

The included excel spreadsheet aids the user in selecting parts for the intended application.

All resistive components should have a minimum power specification of 10A and capacitive components must be specified at no lower than 35V-rms.

This board does not have a power up sequence. It simply must be connected to the transmission network using the matching connectors that are soldered onto the board. *(Connectors appear in general BOM).*

Below can be found the URL linking to the Ferrite Core manufacturer for this application:
http://en.tdk.eu/inf/80/db/fer_13/R3600x2300x1500.pdf

6.0 DATA ACQUISITION

6.1 Setup:

6.1.1 To setup the sensor PCB, start by attaching the 15V/-15V power supply using the provided 3 conductor wiring and the header to the left of the pcb, and match the values printed on the PCB to the supply voltages. However you orient the wiring is personal preference, however recommended convention is 15 volts/ **15V** (red wire), -15 volts/**-15V** (black wire), and ground/**GND** (green wire). For the supplied power supply 15 volts is **V1**, -15 volts is **V2**, and ground is one of the **COM** pins.

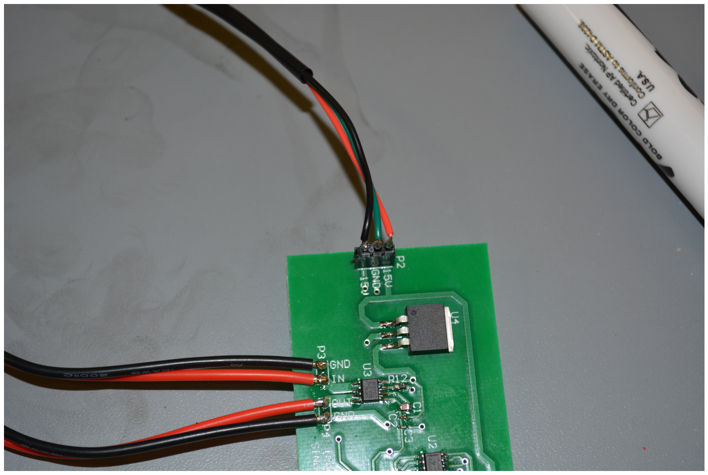


FIGURE 6.1.1 – Correct Attachment of Power Supply Wiring to PCB

6.1.2 Next, connect the PCB to the grid using the Tamiya connectors located on the bottom of the board. The **IN** reference should be attached closest to the source and **OUT** reference closest to the load. If incorrectly attached, readings will be altered due to the reference direction of power flow from source to load. (if reversed, negative power factors will be a main symptom in the output.)

6.1.3 Lastly, attach the PCB to the LABJACK utilizing the header to the right of the board, the provided 4 conductor wiring, and the screw terminals on the LABJACK. In order for the code to provide correct readings, **V_SIG** must be attached to even numbered inputs and **I_SIG** attached to odd numbered outputs. (i.e. V_SIG attached to FIO0,FIO2,…. ; I_SIG FIO1, FIO3,FIO5,…..). Take care to ensure both signal wires use the same terminal block on the LABJACK as they come from the same sensor. Recommended wiring convention is green for **GND,** red for **V_SIG**, and black for **I_SIG**. This leaves the white as an extra **GND** reference.

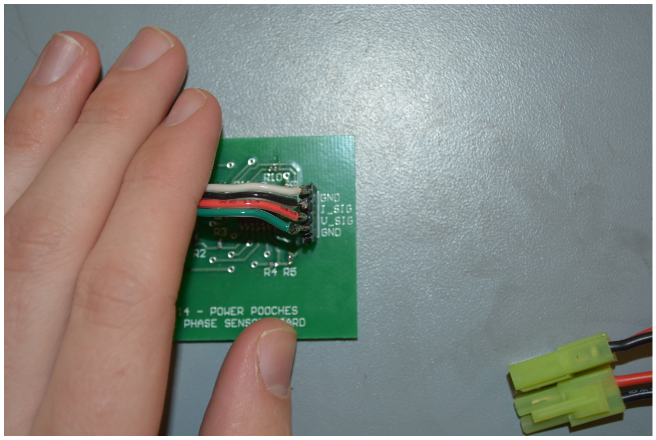


FIGURE 6.1.2 – Correct Attachment of Signal Wires to PCB

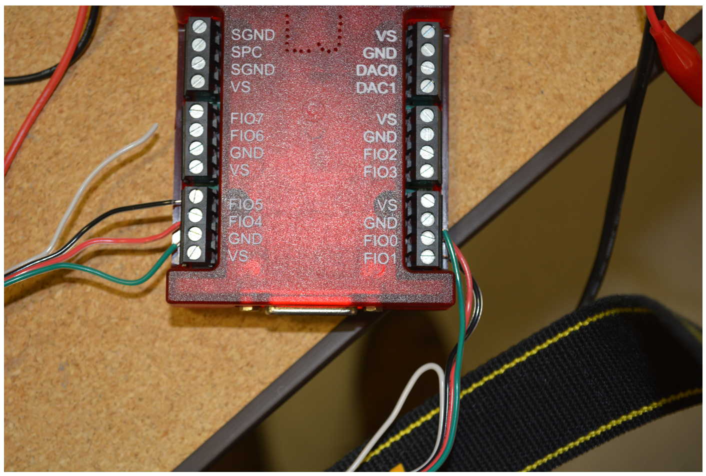


FIGURE 6.1.3 – Correct Attachment of Signal Wires to LABJACK – note that each group of wires utilizes the same terminal block.

6.2 THE PCB: The sensor board is composed of two separate parts, a voltage interface and a current interface.

6.3 Voltage Interface: The voltage module performs analog manipulation of the voltage reference to fit it in the 0V to 2.4V input range of the LABJACK U3-LV. Thus, -12V corresponds to 0V and 12V corresponds to 2.4V. Ideally, this would mean the transfer function of the circuit is Vout = Vin/10 + 1.2. However, 12.5 KΩ SMD resistors are expensive so a 12.4 KΩ resistor was used instead. From left to right on the schematic: U2A is a simple buffer, U1C performs the analog operation, and U1D is an inverting amplifier to achieve the correct sign.

6.4 Current Interface: The current interface performs analog manipulation of the ACS712 output to fit the LABJACK input parameters as well. For our project, we found 2 amps would be the maximum current flow and thus the circuit is designed around that parameter. However unlike the voltage interface, there is an additional low-pass filter and a 5V reference/source provided by a Texas Instruments LM2937-5.0. From left to right on the schematic: U2B is a low pass buffer, then U1A and U1B perform the analog operation.

6.5 Board Construction: The PCB is composed of primarily SMD components and utilizes the footprints provided in the Sensor PCB folder of the resource USB. Refer to the altium files if you wish for a more detailed look into how the board is constructed. The PCB was manufactured by 4PCB.com for the $33 student rate. All components were bought on Digikey.com.

7.0 DATA SHEETS

Part Number Dual Primary 115/230VAC	Fig.	Secondary (RMS) VAC	Secondary (RMS) Current (Amps)	VA Rating
NOT AVAILABLE	-	56V C.T.	0.04	2.5
186B56	6B	56V C.T.	0.11	6.16
186C56	6B	56V C.T.	0.21	12.3
186D56	6D	56V C.T.	0.53	30.0
186E56	6D	56V C.T.	1.00	56.0
186F56	6D	56V C.T.	1.80	100.8

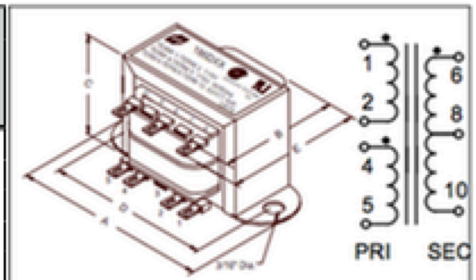


Figure 6D

Permanent Magnet DC Motors

1/50 - 1/7 HP

Standard Features

- Totally Enclosed, Non-Ventilated (IP-40)
- Class "F" insulation, Class "B" rating
- External brush access for easy inspection and replacement
- Oversized brushes for long life
- Skewed armature for smooth low speed operation
- Oversized magnets resist demagnetization, stabilized to common strength for consistent performance
- High starting torque and self-braking
- Noise-tested ball bearings permanently lubricated
- Locked bearing minimizes endplay

Application Information

- For connection diagram 074 10101 see page 66
- Performance ratings of 130 V models based on use with filtered controls
- Flange mount or base mount

Optional Accessories

- Encoder model 0940, see page 101
- "L" bracket mount kit model 0990 available, see page 100

Matching Controls

- Bodine stocks a full line of speed controls for Bodine PMDC motors. See pages 86-99

90 COMPATIBLE WITH 90 V CONTROLS
SEE PAGES 98 & 99

Speed (rpm)	Rated Torque (oz-in.)	Rated Amp	HP	K_T (oz-in/A)	K_E (V/krpm)	Winding Resistance (ohms)	Winding Inductance (mH)	Rotor Inertia (oz-in-sec.^{2})	Radial Load (lbs.)	Length XH (inch)	Wt. (lbs.) Shaft	Product Type Shaft	Model Number[1] 24 V. Winding Acc'y. Shaft	Model Number[1] 24 V. Winding No Acc'y. Shaft	Model Number[1] 130 V. Winding Base No Acc'y. Shaft	Model Number[1] 130 V. Winding Flange Acc'y.	Model Number[1] 130 V. Winding Flange No Acc'y.
2500	8	1.2	1/50	8.3	6.1	5.7	6.7	.003	25	3.31	2.0	24AOBEPM	N4440	N0040	–	–	–
2500	8	.22	1/50	42	31	176	220	.003	25	3.31	2.0	24AOBEPM	–	–	–	N4439	N0039
2500	16	1.8	1/29	10	7.5	2.5	3.6	.005	25	3.93	2.5	24A2BEPM	N4445	**0045**	–	–	–
2500	14	.30	1/29	55	41	84	133	.005	25	3.93	2.5	24A2BEPM	–	–	**0042**	N4441	**0041**
2500	22	2.6	1/18	9.2	6.8	2	6.7	.007	25	4.68	3.0	24A4BEPM	N4444	**0044**	–	–	–
2500	24	.45	1/17	55	40	5	184	.007	25	4.68	3.0	24A4BEPM	–	–	–	**0047**	**0043**
11,500	12	1.1	1/7	14	10	3.15	4.5	.007	25	4.68	3.0	24A4BEPM	–	–	**0049**[2]	–	–

[1] NOTE: Model numbers shown in bold type are in stock. "N" model numbers require lead time and minimum quantities.

[2] NOTE: Ratings for model 0049 are based on 115 V, not 130 V.

Overview

SITOP modular

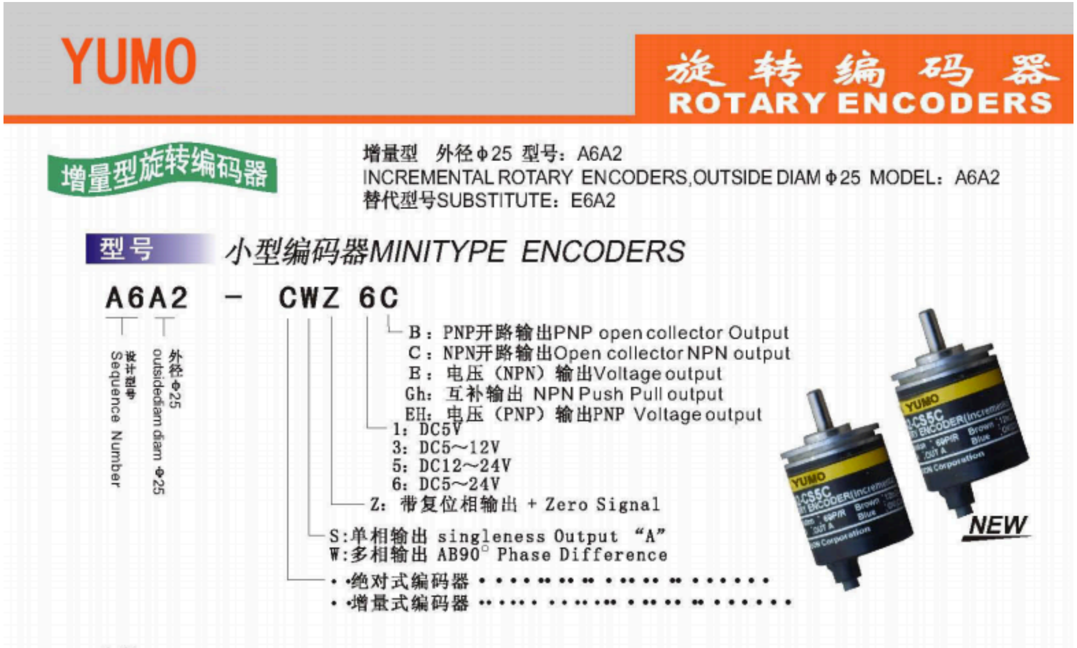
SITOP modular

Application

The modular power supply units with single-phase and two-phase inputs for global use in many different fields of application; expansion of functions possible using add-on modules.

Technical specifications

Power supply, type	**20 A**	**40 A**
Order No.	**6EP1 336-3BA00**	**6EP1 337-3BA00**
Input	Single/two-phase AC	Single/two-phase AC
Rated voltage $V_{in\ rated}$	**120/230 V AC** Settable using wire jumper on device	**120/230 V AC** Settable using wire jumper on device
Voltage range	85 to 132/176 to 264 V	85 to 132/176 to 264 V
Overvoltage strength	2.3 x $V_{in\ rated}$, 1.3 ms	2.3 x $V_{in\ rated}$, 1.3 ms
Mains buffering at $I_{out\ rated}$	> 20 ms at V_{in} = 230 V	> 20 ms at V_{in} = 230 V
Rated line frequency; range	50/60 Hz; 47 to 63 Hz	50/60 Hz; 47 to 63 Hz
Rated current $I_{in\ rated}$	7.7/3.5 A	15/8 A
Inrush current limitation (+25 °C)	< 60 A	< 125 A
I^2t	< 9.9 A^2s	< 26 A^2s
Integrated line-side fuse	Yes	Yes
Recommended circuit-breaker (IEC 898) in mains supply line	10 A Char. C (2-pole coupled with 2-phase operation) or motor circuit-breaker 3RV1421-...	20 A Char. C (2-pole coupled with 2-phase operation) or motor circuit-breaker 3RV1421-...
Output	Stabilized, floating direct voltage	Stabilized, floating direct voltage
Rated voltage $V_{out\ rated}$	**24 V DC**	**24 V DC**
Total tolerance	± 3 %	± 3 %
• Stat. mains compensation	Approx. 0.1 %	Approx. 0.1 %
• Stat. load compensation	Approx. 0.1 %	Approx. 0.1 %
Residual ripple (clock frequency: approx. 50 kHz)	< 100 mV_{pp} (typ. 30 mV_{pp})	< 100 mV_{pp} (typ. 60 mV_{pp})
Spikes (bandwidth: 20 MHz)	< 200 mV_{pp} (typ. 60 mV_{pp})	< 200 mV_{pp} (typ. 120 mV_{pp})
Setting range	24 to 28.8 V (max. 480 W)	24 to 28.8 V (max. 960 W)
Status display	Green LED for 24 V O.K.	Green LED for 24 V O.K.
Power ON/OFF behavior	Overshoot of V_{out} approx. 3 %	Overshoot of V_{out} approx. 3 %
Starting delay/voltage rise	< 0.1 s/< 50 ms	< 0.1 s/< 50 ms
Rated current $I_{out\ rated}$	**20 A**	**40 A**
Current range		
• Up to +45 °C	0 to 20 A	0 to 40 A [1)]
• Up to +60 °C	0 to 20 A	0 to 40 A [1)]
Dyn. V/I with		
• Starting on short circuit	Approx. 23 A constant current	Approx. 46 A constant current
• Short-circuit in operation	typ. 60 A for 25 ms	typ. 120 A for 25 ms
Parallel connection for increased output	Yes, 2 (selectable current characteristic)	Yes, 2 (selectable current characteristic)



3. PRODUCT SPECIFICATION AND LIMITATIONS

Absolute Maximum Rating

No	Parameters	Min	Typical	Max	Unit
1	Power Input Voltage	5	-	25	V
2	I_{MAX} (Maximum Continuous Motor Current)	-	-	13	A
3	I_{PEAK} – (Peak Motor Current) *	-	-	30	A
4	V_{IOH} (Logic Input – High Level)	3	-	5.5	V
5	V_{IOL} (Logic Input – Low Level)	0	0	0.5	V
6	Maximum PWM Frequency	-	-	20	KHz

**** Must not exceed 10 seconds.***