Technokrat

Manual – High Current Power Supply for MRI Magnet Charging & Discharging

Customer: Digit Systems International (DSI)

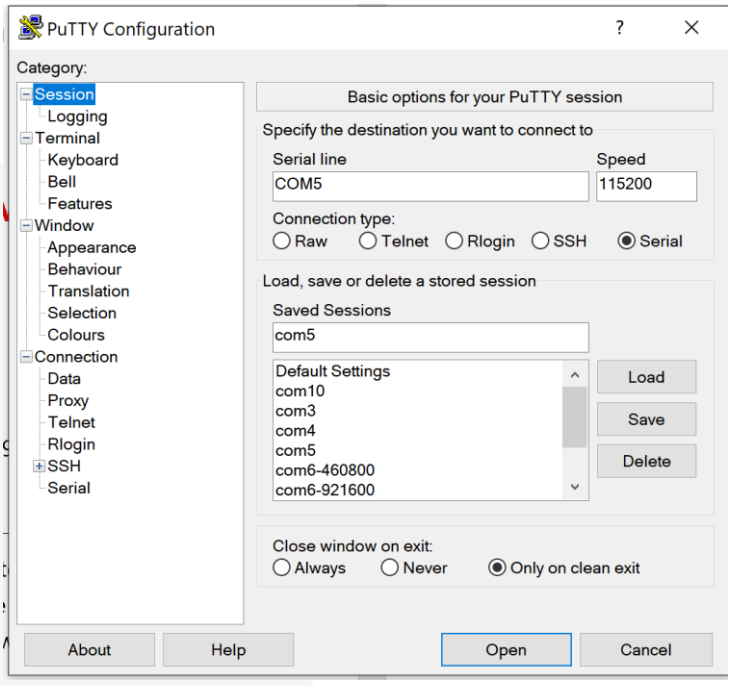
Document Revision: A2

Date: May 3rd, 2022

Applies To: Prototype Unit of second revision shipped to DSI in April 2022

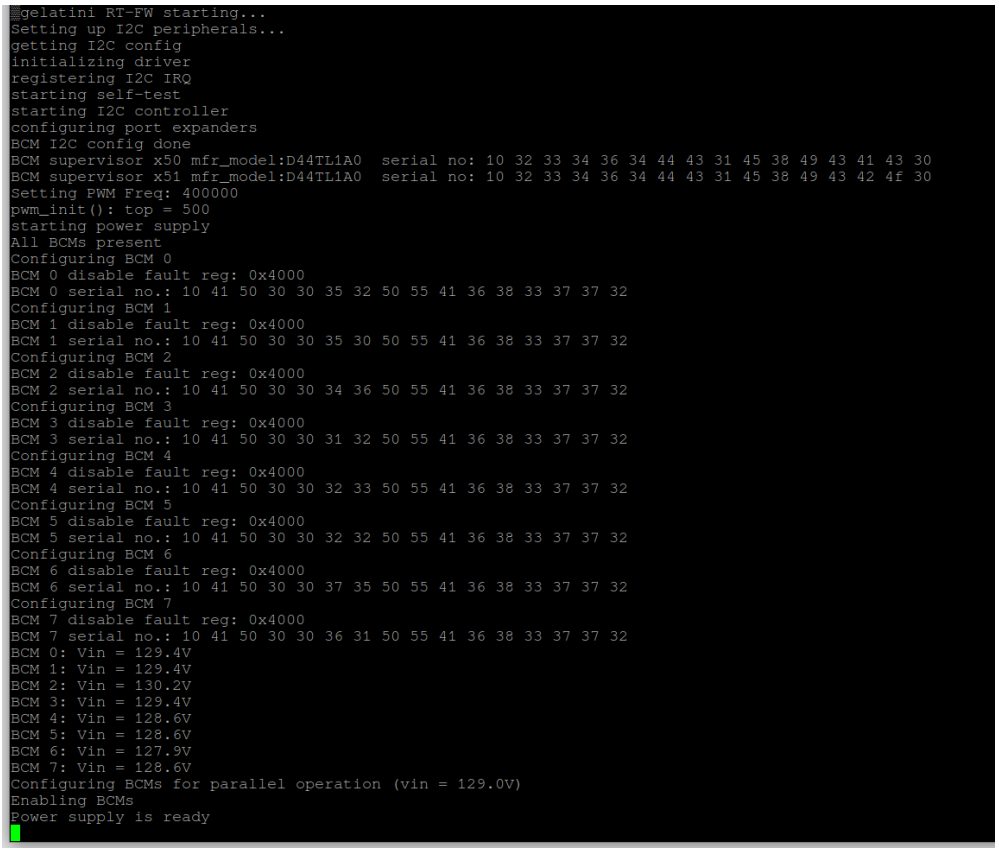
1. Preparation

- Data Connection: Connect a USB-RS232 adapter to a computer or laptop and use a Null modem cable to connect the RS232 adapter to power supply. Use the RS232 port X4.
- Install the terminal emulation software PuTTY on the computer: https://www.chiark.greenend.org.uk/~sgtatham/putty/latest.html
- Identify the COM port number (on Windows) or the /dev/ttyUSBx path (on Linux) used by the USB-RS232 adapter. (E.g. by checking the Windows device manager while disconnecting and connecting the adapter.)
- Open PuTTY and configure it for the correct *serial port*, enter *115200* as speed (baud rate):



Click Open to open a new black terminal window.

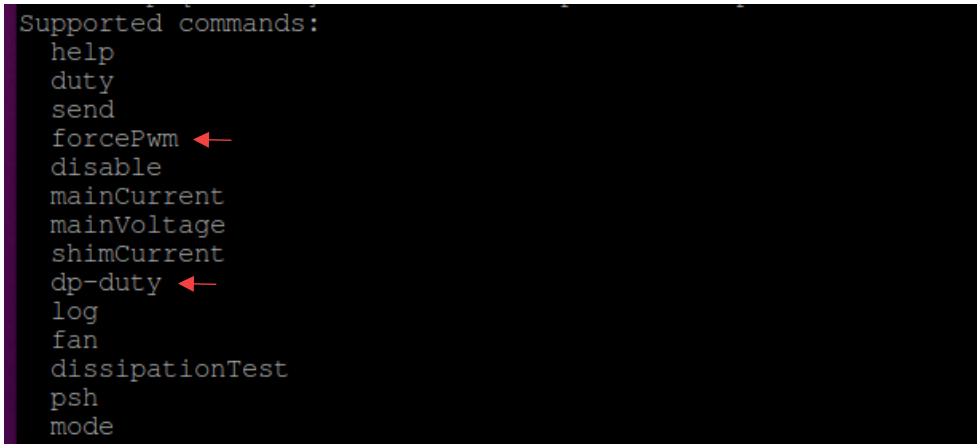
- Make sure the breaker in the front is off and connect the unit to the three-phase mains. Either 120 V ac (line-neutral, i.e. 208 V ac line-line) or 230 V ac (line-neurtal, i.e. 400 V ac line-line) are possible. A neutral wire is not required. The unit detects the voltage at power-on and configures itself accordingly. Once the power cord is connected, turn the unit on using its breaker. The FPGA starts and prints the following log messages in the serial console (PuTTY). Check that the last line says *Power Supply is ready.*



2. Using the Serial Terminal

The unit is controlled by entering text-based commands, similar to a computer's command line (e.g. cmd, bash, etc.). Each command consists of a command name and may have one or more arguments, separated by blanks. Commands are executed immediately when pressing enter. A list of all available commands can be printed by pressing enter one or more times.

Here is a list of the available commands.



The commands marked with red arrows are intended for development purposes only and may cause immediate damage. Do not use those!

Short explanations of the commands are available using the help command:

help <command name>

For example, enter *help fan* and press enter.

To correct typos, you can use the arrow keys and the back-space key. The terminal also has a (limited) history which is accessed by the up and down arrow keys.

Auto-completion of command names and some parameters is possible using the tab key. For example, enter *he* and then press tab. This autocompletes the command name *help*.

3. Performing a Ramp-Down

- Connect the main coil's power wires and the according switch heater wires to the unit.
- Execute the command
  mode main-coil
  to prepare the unit. The unit configures all internal modules, ADCs, etc. and then closes the high current contactor (aka quench relay). Check for error messages. At any time you can check the current operating mode by calling the mode command without parameters. For example:

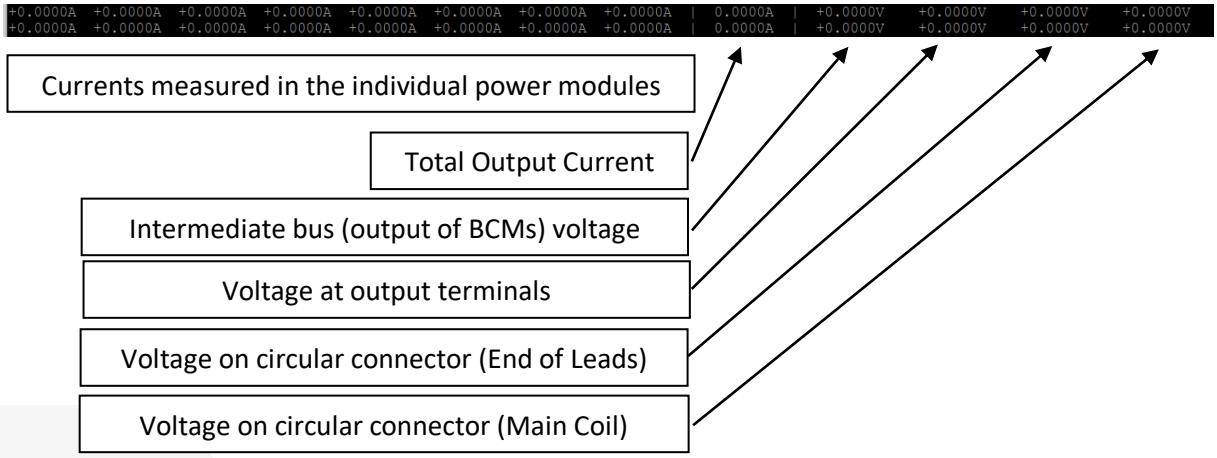
```
mode
Current operating mode is: disabled (0)
```

- The fan is automatically turned on at minimum speed (20%) when main-coil mode is reached. You can increase the fan speed with:
  fan 0.5
  The parameter is the fan duty cycle and can vary from 0.2 to 1.
  Executing the command *fan* without a parameter prints the measured fan

speed in rpm. Note that measurement errors due to noise exist.

```
fan 0.2
fan
Tacho reg: 830323
measured speed: 3613.051758
```

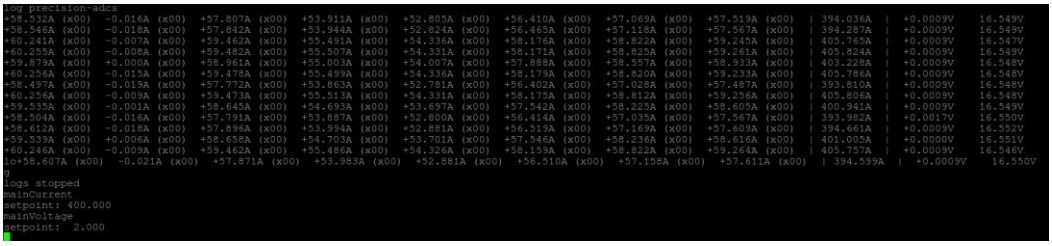
- Set a first target current in Ampere with the following command
  mainCurrent <current in ampere>
  Start with a low current value, e.g., 10.0A.
- Set the maximum allowed voltage using
  mainVoltage <voltage in Volts>
  Start with a low value, e.g., 0.1
- Note that the voltage is measured at the output terminals of the unit, not at the MRI coil. Negative voltages are not yet possible (see below).
- Check the measured currents & voltages using the log command by running
  log filtered-adcs
  or
  log raw-adcs
  The following example shows the result of these commands:



- The log output can be stopped at any time by executing the *log* command without any parameters.
- Increase the current & voltage set-point values until the desired current is achieved in the lead wires. When the desired current is achieved the voltage set-point should be lowered until it begins to limit the output current. (This is the value required to compensate the voltage drop of the wires.)
  Lowering the voltage set-point prevents the supply from applying voltage to the inductor once the persistence switch has opened.
- To open the persistence switch, set the required heater current by running the following command:

psh 0 <current in ampere>
The maximum current value is 1.0 Ampere. The measured heater currents can be printed by running the *psh* command without any parameters. This prints two values, the one on the left is the PSH current of the main coil.

- Once the persistence switch has opened, the output current is impressed by the magnet. However, the supply still tries to control this current. If the actual current in the magnet is higher than the set-point value, the supply reduces its output voltage to zero. If the actual current is lower than the set-point value, the supply increases its output voltage up to the limit defined by *mainVoltage*. It is therefore important to set this limit as tightly as possible.
- To bring down the current in the coil, lower the setpoint using the *mainCurrent* command. The actual current value can be monitored using the *log filtered-adcs* command.



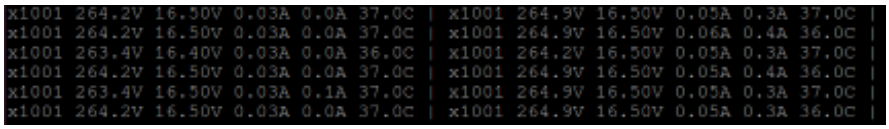
- To increase ramp-down speed by negative voltages, two power modules can be connected to dissipation resistors. Execute the following command to switch the modules. (Note that the modules cannot be switched back)
dissipationTest <channel>
Where channel can be either 0 or 1 for the two modules. When the module is successfully switched, a relay inside the unit clicks and the current of this module reads approx. zero in the log. (As in module 1 in the log above.)
- Increase the fan speed to 60% to provide sufficient cooling of the dissipation resistors:
fan 0.6
Note: The current firmware has no thermal protection; temperature monitoring must be performed by the operator. The temperature of the power semiconductors (SIC651) can be monitored using:
log power-modules

- When at least one module is configured in dissipation mode the supply can output negative voltage. Use the mainVoltage command with a negative value, for example:
mainVoltage -0.1
Start with a value close to zero and reduce the negative voltage slowly.

- Remember to slowly decrease the current set-point value such that it stays below the inductors actual current, otherwise the supply will not create negative voltages.
- Once the inductor current has ramped down to zero, set the voltage and current setpoints to zero and disable the persistence switch heater current by running the following command:
  psh 0 0
- Execute this command
  disable
  to stop the supply. Note that this command immediately opens the main contactor (quench relay).
- The supply can be turned off now using the circuit breaker on the front.

4. HV Power Supply Log Outputs

Status information of the Vicor BCMs can be printed with:
log bcms
The log shows one group per BCM, so 8 groups in total per line. Groups are separated with a vertical bar (|). This example shows two groups:



Printed are a binary status word, the input voltage, the output voltage, two current measurements (not working) and the measured temperature.

5. Performing a Ramp-Up

- Connect all wires, turn on the unit and check the startup sequence.
- Execute the command
  mode main-coil
  to prepare the unit. The unit configures all internal modules, ADCs, etc. and then closes the high current contactor (aka quench relay).
- Set at duty cycle (speed) of 0.5 (50%):
  fan 0.5
- To open the persistence switch, set the required current by running the following command:
  psh 0 <current in ampere>

- Set a first target current in Ampere with the following command
  mainCurrent <current in ampere>
  Start with a low current value, e.g. 10.0A.
- Set the maximum allowed voltage using
  mainVoltage <voltage in Volts>
  Start with a low value, e.g. 0.1V and slowly increase by calling the the command again.
- Slowly increase target current and voltage to reach the desired values.
- Once the inductor current has reached the desired value, disable the persistence switch heater current by running the following command:
  psh 0 0
- When the persistence switch has closed, set the current and voltage set-points to zero to ramp down the current in the wires.
- Execute this command
  disable
  to stop the supply. Note that this command immediately opens the main contactor (quench relay).
- The supply can be turned off using the circuit breaker on the front.

6. Pin Assignment of Circular Connector

Pin J1 (Circular)	*Pin J2*	*Description*
2	B6	Main Coil (psh 0) Persistence Switch Heater Negative
1	B4	Main Coil Persistence Switch Heater Positive
5	B3	Shim Group 1 Persistence Switch Heater Positive
6	B2	Shim Group 2 Persistence Switch Heater Positive
3	B1	Shim Group 3 Persistence Switch Heater Positive
4	B5	Shim Groups 1…3 Persistence Switch Heater Negative
7	A8	Coil Voltage Sensing Positive Input
8	A9	Coil Voltage Sensing Negative Input
14	A7	Analog Ground. **For shielding only, do not connect!**
13	A1	Digital Ground
17	A3	Communication Positive (CAN or RS485)
18	A2	Communication Negative (CAN or RS485)
15	A4	End of Leads Voltage Sensing Positive Input
16	A5	End of Leads Voltage Sensing Negative Input
12	A6	Digital Ground (Return for Resistor Sensing)
9	B9	Resistor Sensing Power Out
10	B7	Resistor Sensing Input Positive
11	B8	Resistor Sensing Input Negative