SYSTEM 7000

CUSTOMER : _____

OUTPUT DATA : _____

ORDER NO : _____

PART NO : _____

SERIAL NO : _____

AC INPUT :

- ☐ **3x208VAC excl Neutral**
- ☐ **3x208VAC incl Neutral**
- ☐ **3x400VAC incl Neutral**
- ☐ **3x415VAC incl Neutral**

OUTPUT DATA : **±20A 35V or 75V**

INTERFACE : ☐**RS232** ☐**RS422** ☐**RS485**

REV.	By	Date	Description	Pages
1.0	DT	09.06.2004	Initial	All
1.1	DT	12.07.2004	Fast ADC and hardware triggering	28-29
1.2	DT	15.03.2005	Partial reset to factory settings	15
1.3	JFL	22.11.2005	Minor corrections	All
1.4	JFL	18.10.2006	Minor corrections, 415 added	All

M A N U A L
MAGNET POWER SUPPLY
SYSTEM 7000

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1 Introduction and specifications

1.1 General introduction

The SYSTEM 7000 is a DC constant current output Power Supplies designed for applications requiring very high stability and low noise combined with reliability and ease of operation.

The SYSTEM 7000 is aimed at correction magnets in ion beam applications. It is the result of an intensive development effort at Danfysik based on twenty years of experience in delivering precision DC Power supplies to industrial and research laboratory users around the world.

Up to five SYSTEM 7000 units can be connected in a parallel Master/slave configuration. All analogue signals are summed in the master unit. The master unit monitors and controls the parallel connected slave units.

- Current stability options of 100 ppm classes
- Power outputs up to 1.5 kW per unit and 7.5kW with 5 units in parallel
- Output current (maximum) up to 20 A Bipolar per unit and 100 A with 5 units in parallel
- Local controlled or Remote controlled through a RS232, RS422 or RS485 serial interface line.

1.2 Specifications

STABILITY CLASS . . . . . 100 ppm

DC OUTPUT RATINGS:

Power range 1500W
Voltage 75V
Current range . . . . . 20 A

PERFORMANCE:

All drift and regulation data are given for max. Current output.

Warm up time. (Cold start) 30 min
Warm up time. (With control power ON). 30 min

Drift:
Long term 8 hours. 100ppm

Line regulation:
+/- 10 % slow. T > 1 min. Na
+/- 1 % fast. T > 3 ms. Na

Load regulation:
+ 10 % resistance change. T > 1 min. Na

OVERALL DIMENSIONS AND WEIGHT:

CABINET:	MM
Height	132.5
Width	480.3
Depth	525

WEIGHT: (approx.)	Kg
Net weight	25
Shipping weight	27

INPUT/OUTPUT INTERFACES

Analogue 0±10VDC;
Set Current, Current- Current Error-Voltage-readback

Digital 5V TTL;
Control, Status, Interlock

Number of output channels: . . . . . 1.

Output polarity: . . . . . BIPOLAR.

TEMPERATURE RATINGS:

OPERATING. Centigrade.
Ambient temperature. 0 to 40

STORAGE temperature -20 to 50

MAIN COOLING SYSTEM.

Air cooling 0 40

AC SUPPLY POWER.

MAINS VOLTAGE:
See front page
AC voltage +/- 10 %.
48 - 62 Hz.

MAINS CURRENT:
. . 208VAC Up to 5,5 Amps pr phase
. . 400/415VAC Up to 2,75 Amps pr phase

LED INDICATIONS:

Status	ON/OFF/READY/RESET
Fault	Over-temp/Internal/AC/ Ground/External/Over Voltage/Over Current
Control mode	Remote and Local

7-segment display for indicating of:

Output Voltage
Output Current

COMPUTER INTERFACE:

RS232
RS422
RS485

LOAD:

Recommended below 500mH.
Loop might need adjustment to specific load.

1.3 Warranty and warranty repair

DANFYSIK A/S warrants that the products manufactured by us will be free from defects in material and workmanship that adversely would affect the normal functioning of the unit, for a period of 18 months from the date of shipment or 12 months from the date of installation whichever occurs first.

The exemptions to this are:

a) **Parts not manufactured by DANFYSIK A/S** which are covered by the original equipment manufacturer's warranty.

b) **Repair work**, which is warranted for six (6) months from the date of shipment from the DANFYSIK works.

DANFYSIK A/S will repair or replace either on site or at the factory, at option, any equipment which proves to be defective within its warranty period.

In the case of warranty, DANFYSIK A/S will pay or reimburse lowest freight rate (two-way) of any item returned to DANFYSIK or our designated agent/representative, provided that prior written authorisation for such return has been given by DANFYSIK A/S.

This warranty shall not apply to any equipment, which has become defective or unworkable due to mishandling, improper maintenance, incorrect use, radiation damage or any other circumstance not generally acceptable for equipment of a similar type.

On standard products, DANFYSIK A/S reserves the right to make changes in design without incurring any obligation to modify previously manufactured units.

The foregoing is the full extent of this warranty, and no other warranty is expressed or implied. In no event shall Danfysik be liable for special damages arising from the delivery, late delivery or use of the equipment.

If any fault develops, the following steps should be taken.

Notify DANFYSIK A/S, giving full details of the problems, and include Model-Type and Serial number.

On receipt of these information, DANFYSIK A/S will give you either service information or instructions for shipping.

All shipments of DANFYSIK equipment should be made according to our instructions and shipped in the original or a similar container.

For smaller parts a carton will be sufficient, if the parts are wrapped in plastic or paper and surrounded with at least 10 centimetres of shock-absorbing material.

2 Unpacking and installation

2.1 Receiving the goods

The Shipping container and the Power Supply should be thoroughly inspected for signs of obvious physical damage immediately upon receipt.
All materials in the container should be checked against the enclosed packing list.
DANFYSIK A/S will not be responsible for shortages against the packing list unless notified immediately.

2.2 Instructions for unpacking

The Power Supply is shipped in reinforced cardboard.

If the equipment is damaged in any way, a claim should be filed with the shipping agent, and a full report of the damage should be forwarded to DANFYSIK A/S or our local agent/-representative immediately.
Upon receipt of this report, you will be issued instructions for the repair, replacement or return shipment.
Please include the Model no, Type no, Serial no, and Order no for the Power Supply on any communication with DANFYSIK A/S or our representative.

2.3 Installation requirements

During installation of the Power Supply, local rules and regulations for electric power supplies should be respected and the following conditions and installations should be available.

* A normal, dust free room with humidity not above 80 % and a room temperature within 0 to 40 centigrade.

* Three-phase Mains voltage including neutral (except 208V excl. neutral) switched and fused.

* Ground connection according to the local authority regulation and the requirements for the equipment.

  Please see specification sheet chapter 1.2 in this manual for actual figures for this power supply.

2.4 Installation

Before and during installation of the Power Supply, the following points should be checked / carried out.

* Check that the main voltage and frequency matches to the specified and labelled requirements.

* Check that screw connections from the output terminals are tightened.

* Check that all screws on D-sub connectors are tightened.

* If the External Interlock 1 is unused, then short-circuit the terminals.
* If the External Interlock 2 is unused, then short-circuit the terminals.
* If the External Interlock 3 is unused, then short-circuit the terminals.
* If the External Interlock 4 is unused, then short-circuit the terminals.

2.5 Master configuration (No parallel units connected)

- The Master/ Slave slide switch, located in the back of the cabinet, must be set to Master.

- Connect Analogue or Digital interface remote control cable if applicable.

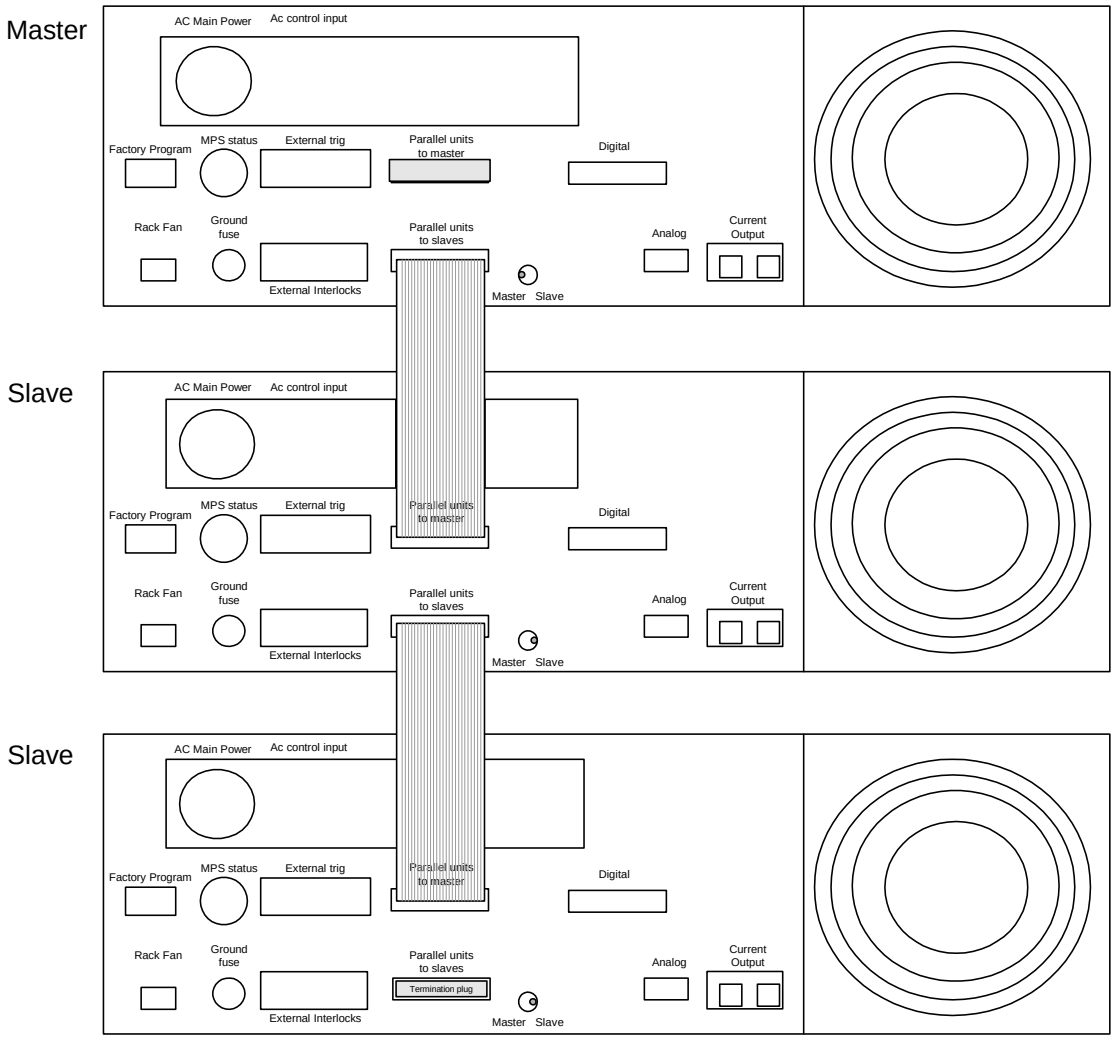
- Connect the termination plug in the "Parallel unit to slave" DB25 male connector located on the back of the cabinet. (Pin 1 & 2 shorted).

2.6 Master/ Slave configuration (two or more unit in parallel)

- The Master / Slave slide switch located on the back of the supply must be placed in Master position for the master unit and in slave position for all the other units. Only one SYSTEM 7000 must be configured as master.

- Connect the "Parallel unit" interface cable between the "Parallel unit to slave" DB25 male plug of the first unit (normal master) to the "Parallel unit to master" DB25 female plug of the next unit and so on in a daisy chain. The first unit must have the termination plug connected to the "Parallel unit to master" and the last unit must have the termination plug connected to the "Parallel unit to slave".

- Not used external interlocks must be short-circuited.



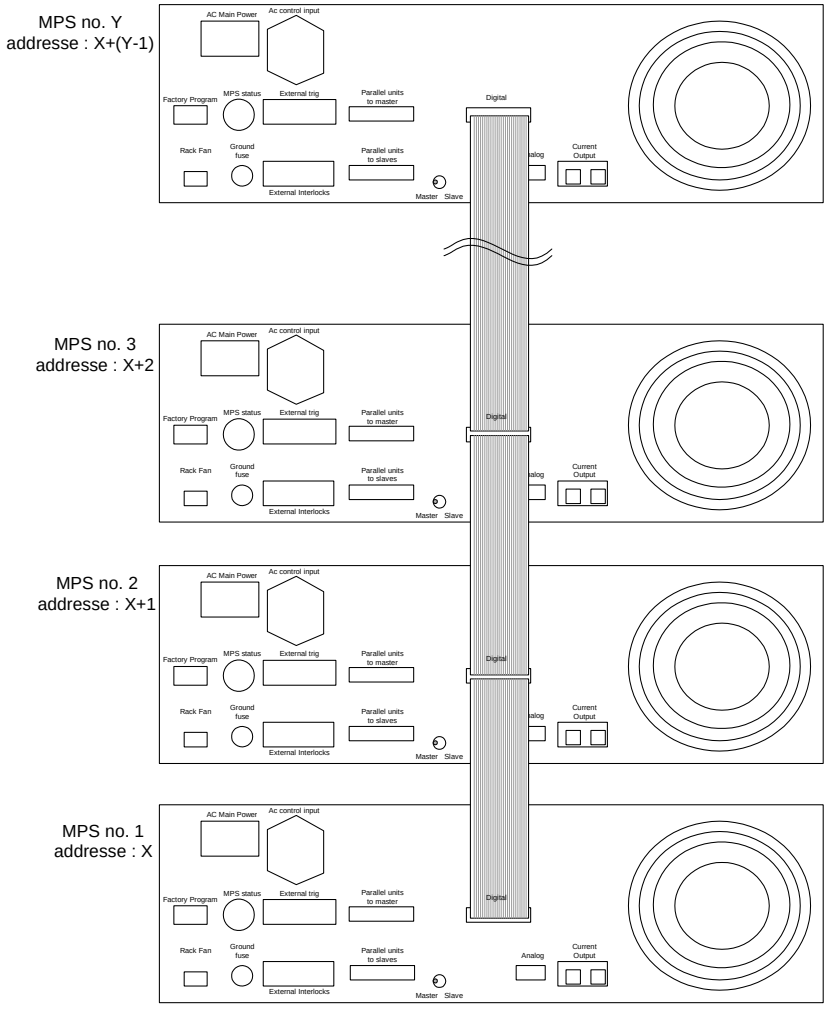
Example of a Master/Slave configuration with two slaves

2.7 RS422 or RS485 Multidrop configuration

Up to 32 SYSTEM 7000 units can be connected in a RS422 or RS485 multidrop configuration.

It is also possible to run a Master/Slave configuration within a multidrop system. All units must be connected in order to read the individual unit interlock status signals, but for controlling the system only the master connection is necessary. Trying to control one of the slaves will have no effect as the control commands are disabled on the slaves. To set up the Master/Slave configuration, see chapter 2.6.

- The Master / Slave slide switch located on the back of the supply must be placed in Master position for all masters.
- Address all units with a unique address. *See SW manual doc- ApBCPsw1c.doc on how to set up the unit address.*



X :Start address
Y : The last unit of MPS on the multdrop line

Example of multidrop configuration
About the termination of RS422 or RS45, *see chapter 3.6.1 "Termination using RS422 or RS485"*

3 Operating Instructions

This chapter describes how to operate the power supply in the local as well as in the remote mode. It also identifies the controls and the indicators on the front panel.

3.1 Switching on

After connecting the Power Supply to the mains (line) voltage in accordance with chapter 1.2, 2.3 and 2.4, it can be switched ON.

_ Switch the main power ON

_ Set control mode to LOCAL

_ If the sum Interlock indication is set (red LED illuminates in the RESET button), press this button to clear it. If it can't be cleared, interlocks are present and must first be resolved.

3.2 Main power ON, OFF, STB & Reset

The power supply can be set to three different modes for turning the power supply ON and OFF given as below.

0) Direct ON & OFF (default mode)
1) Standby mode 1
2) Standby mode 2

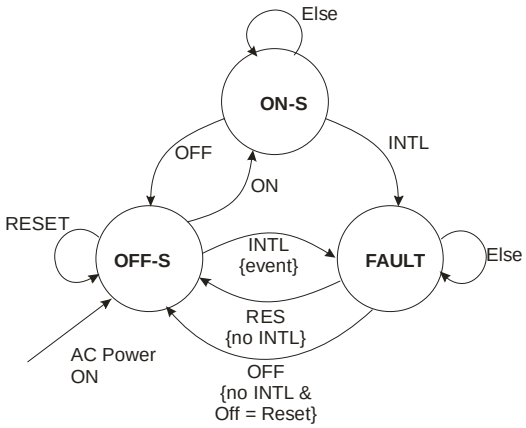
The desired working mode can be selected using the 'esc'<NFSMODE command. See the software description for setting up the power supply and for further detail of this issue.

The working principle of the different modes is described through following state diagrams. The circles are the state and the arrow lines are witch button, command or event that initiates the state shift.

Mode 0 – Direct ON & OFF

This mode is the default mode. It is characterized by the power supply is either in the ON or in the OFF state or if an interlock is present in the FAULT state.

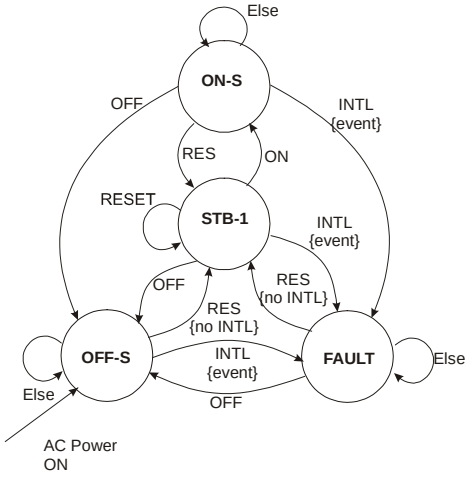
State	FAN	Output Converter
OFF	OFF	Not Powered
ON	ON	Powered
FAULT	ON	Not Powered



Mode 1 – ON & OFF through STANDBY

In this mode the power supply must first be set into the stand by state before entering the ON or OFF state. An interlock puts the power supply immediately in the FAULT state.

In the stand by mode is the output converter **without** power.

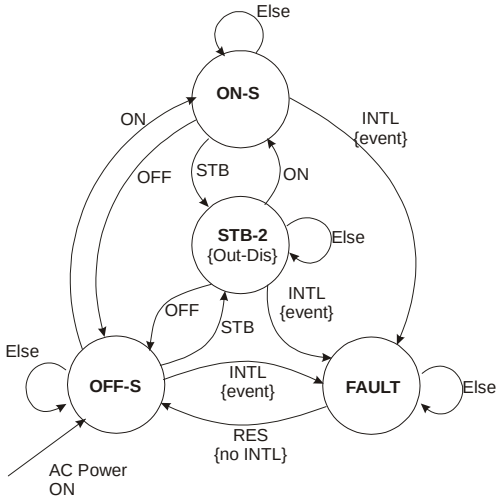


State	FAN	Output Converter
OFF	OFF	Not Powered
ON	ON	Powered
STB-1	ON	Not Powered
FAULT	ON	Not Powered

Mode 2 – ON & OFF through STANDBY

This mode can be seen as a mixture of mode 0 and 1. Here the inserted stand by mode is actually nearly the same as the ON state but with the output forced to zero (compared to mode 0). An interlock puts the power supply immediately in the FAULT state.

In the stand by mode the output converter is **with** power but forced to zero output.



State	FAN	Output Converter
OFF	OFF	Not Powered
ON	ON	Powered
STB-2	ON	Powered
FAULT	ON	Not Powered

The STB transition is locally initiated by pressing the reset button and thereafter at the same time the ON button. Remotely the STB command must be issued.

The LED inside the Reset push button indicated that the Power Supply is interlocked either due to an internal or external fault.

3.3 Local / Remote control

The LED “Remote” illuminates, when the Power Supply is in the REMOTE control mode and is off in LOCAL control mode.
The control mode (LOCAL/REMOTE) is changed by pushing the "Remote" push button if the MPS is not locked to remote line.

SYSTEM 7000 operating front panel

3.4 Current setting

In local:
The output current level can be displayed by pushing the “SET” button.
The output current display consists of six 7-segment LEDs. The left segment shows the sign. For negative set values a minus sign will be displayed and for positive set values no sign will be displayed. The other Segments display the set value. Each segment can be altered individually with the up/down button. To select which segment to alter, use the forward/back button. The chosen segment will flash.

3.5 Setting up the MPS

Two dip-switches are available for setting up of the power supply.

35V / 75V setup

The analogue ±10V output voltage read back can be scaled for either 35V or 75V
Factory settings are indicated on the back of the SYSTEM 7000 cabinet.

Output Voltage →	**35V**	**75V**
P803 SW1	Closed	Open
P901 SW1	Closed	Open
P901 SW2	Closed	Open

Bandwidth setup

For highest stability and fastest response time, the load impedance transfer function is incorporated in the total loop gain. Therefore it is necessary to adapt the internal gain and frequency response of the loop to match the actual connected load.

The current loop gain can be change between 1, 5 and 10 on switch P302. (1, 14 and 20dB)
The lowest loop pole can be shifted a decade upwards with switch P306.

Gain factor: →	**1**	**5**	**10 (factory)**
P302 SW1	Closed	Closed	Open
P302 SW2	Closed	Open	Open

Frequency Pole →	**Low (factory)**	**High**
P306 SW1	Closed	Open

Current / Voltage mode

This switch setting is for internal use and debugging only by authorized Danfysik service personnel. In general it sets the unit to a voltage supply where a 20A (full scale) setting gives a voltage output of approximately 35V.

Loop mode →	**Current mode (factory)**	**Voltage mode**
P305 SW1	Open	Closed
P305 SW2	Closed	Open

Hint:

The time constant of the magnet (transfer function of the load) can be measured, using the SYSTEM 7000 in the voltage mode together with an attached gain/phase analyser.

Machine Protection System signal

The Machine Protection System signal (Abbreviated to "M.P.S. signal") is available through an Amphenol connector located on the back of the cabinet. This signal is produced by AND'ing; the three signals; ON status, Sum Interlock and the Main contactor is on.

The M.P.S. signal is high when the SYSTEM 7000 is ON.

Sum interlock and the ON status can be excluded from the "M.P.S. signal"

Sum Interlock/ ON Status Enable / Disable

Switch ↓	**Signal name ↓**	**Enabled (factory)**	**Disabled**
P702 SW1	Sum interlock	Closed	Open
P702 SW2	ON status	Closed	Open

Interlock enable – disable - rerouting

Two interlocks (Ground Fault Interlock, Over Voltage) and one status signal (Out of regulation) can be disabled if not desired.

Interlock/ Status Enable / Disable

		Enable	Disable
P801 SW1	Interlock Ground Fault	Open (factory)	Closed
P801 SW2	Status Out of regulation	Open (factory)	Closed
P803-SW2	Interlock Over voltage	Open (factory)	Closed

3.6 Data communication

The SYSTEM 7000 uses the standard serial interface RS232 and RS422 which is compatible with many computers and terminals. The RS422 may be configured in a multidrop system. RS485 is only supported under certain conditions. See description below.

The connector labeled “digital” is the remote serial interface port.

Pin description for the “digital” port (DB25) located at the back of the power supply.

RS232 remote line DB25	
Pin No.	Signal
2	Tx
3	Rx
25	RETURN

RS422/485 remote line DB25	
Pin No.	Signal
25	RETURN
9	Tx High
10	Tx Low
11	Rx High
12	Rx Low

Rx : Signals received by the Control Module from its host.
Tx : Signals transmitted by the Control Module to its host.

NOTE! The selection between RS232, RS422 and RS485 is selected through straps on the Display Controller Module.

Serial bus	Strap ST2	Strap ST3	Strap ST4	Strap ST10
RS232	Open	Open	Close	Open
RS422	Open	Close	Open	Open
4-Wire RS485	Open	Close	Open	Close
2-Wire RS485	Close	Open	Open	Close

The default serial setting is :
8 BIT DATA, NO PARITY AND 2 STOPBIT and baud rate 9600.

The communication is done by transmitting characters in ASCII code terminated by CARRIAGE RETURN.
The termination characters from the Power Supply are LINE FEED and CARRIAGE RETURN.

An ERROR message includes a "?BELL". (Bell = ASCII 7.)
NOTE! None of the serial lines has control signals.

RS485 communication.

RS485 is only supported under certain conditions. These are:

- Disable Line turn around time: Minimum 2ms. (Time for the transmitters to tri state)
- Answer Line turn around time: Minimum 100µs t (Time after receiving the last bit of the transmission until an answer is initiated “active transmitter”.)

3.6.1 Termination using RS 422 or RS 485

As standard there is no termination resistors connected inside the display controller module. An external termination resistor of 100 Ohm must therefore be added at the end of the communication cable or the internal 100 ohm resistor must be enabled (short-circuiting strap ST9). The external resistor is preferable.

Hint. This resistor can be placed inside the last DB 25 plug for the remote line.

When using the RS 485 or the RS 422 line in the multi drop configuration, it is very important during an address transfer to leave the lines at the "SPACE" state when tri stated. That is when the line is not driven by any transmitters at all. The "SPACE" state can be utilized by adding 1K Ohm resistors to +5V (non inverting) and GND (inverting) on both the transmit and the receive lines. The display controller module can provide this by short circuiting ST5-ST8 (use a thin soldering iron). The 1K resistors increase the noise immunity eliminating noise to be treated as commands thereby flawing the first character after being addressed.

3.6.2 Partial reset to factory settings

From firmware release version *BCP V1.07*

The partial reset to factory settings resets the baudrate and address setting to factory default. This feature can be used when the baudrate or/and address is unknown and the operator no longer is able to communicate with the MPS.
To activate the partial reset to factory settings, do following on the front panel (picture of front panel, see page 12)

1. Hold the "▲" (up) and "▼" (down) buttons for min. 5 sec.
2. Release the buttons and the baudrate and address are reset to factory settings.

After partial reset, the setting for baudrate is:

8 BIT DATA, NO PARITY AND 2 STOPBIT and baud rate 9600

and the address is : 0

3.7 Programming

The power supply communication protocol is build upon plain ASCII characters where each command or reply is delimited by a "Carriage Return" <CR> character. However a reply has a “Line Feed” <LF> character added before the <CR> for a friendlier display when using a terminal. <LF> characters on commands will be ignored.

Hint. Actually the protocol allows full control of the power supply from a "dumb" terminal. In case of a service- debug- situation a terminal can be used to tap the communication transfer by a simple parallel connection.

Hint: When debugging, the "ERRT" command enables error messages to be given as a read able text.

More commands may be transmitted in a chain but each single command must be trailed individually with the delimiter character <CR>. The power supply is able to execute up to 200 commands a second depending of the complexity of each command.

Ps. Issuing short commands faster than the time to transmit the answer e.g. “S1" will overload the internal transmit buffer regardless of the selected baud rate.

All commands can be divided into three sections.

a) Directive commands. Eg. the "N" command that turns the power supply ON
b) Status commands . Eg. the "S1" that returns the power supply status

Status commands delivers always a reply whereas directive- and setup- commands only responds with an error message if the command couldn’t be understood or if the given parameters are incorrect. It is possible to set the power supply to always generate an answer. This feature is very useful when using RS485 protocol.

Hint. When using the "OK Answer" mode a retransmission of the last given command can be performed if no answer or an error message is received. The System 7000 respond time is around 5ms after receiving the last bit of the termination character.

Answer scheme if set to “Always Answer” mode.

c) Directive commands.Answer:
- No answer
- ERROR message
- OK if set to OK answer mode

d) Status commands . Answer:
- Data
- ERROR message

e) Set up commands. Answer:
- No answer
- ERROR message
- OK if set to OK answer mode

Ps. An error message is generated immediately when an error is detected although the command isn’t fully transmitted.

Below is an example written in BASIC on how to turn ON the power supply and read the status without and with acceptance answer:

Turning the power supply ON and reading/evaluating the status with always answer disabled.

```
LPRINT "N"+CHR$(13)              :REM Turns the power supply on
LPRINT "S1"                      :REM Issues the status command
LINPUT S1$                       :REM Read the MPS reply
IF LEFT$(S1$,1) = CHR$(?)        :REM Is it an error message reply?
 GOTO ERROR_HANDLING             :REM Yes then go to error module
ENDIF
J=1
DO                               :REM evaluate status reply
 IF MID$(S1$,J,1)="!"
  GOSUB STATUS(J)_ACTIVE         :REM set this status bit active
 ELSE
  GOSUB STATUS(J)_ACTIVE         :REM set this status bit inactive
 ENDIF
 J=J+1
UNTIL J=24
```

Turning the power supply ON with always answer enabled

```
J=0 :ERROR$=""
DO
 J=J+1                           :REM Counter for maximum attempts
 LPRINT "N"+CHR$(13)                   :REM Turns the power supply on
 LINPUT RE$                      :REM Read the MPS reply with 0.1 Sec. time out
 IF LEFT$(RE$,1) = CHR$(?)       :REM Is it an error reply?
  ERROR$=RE$                     :REM Mark the error code
 ELSEIF RE$="OK"                 :REM Is it a good reply
  BRAKE                          :REM then exit DO loop
 ELSEIF J=6                      :REM Try only six times
  IF LEFT$(ERROR$,1) = CHR$(?)   :REM Was it error reply?
   GOTO ERROR_HANDLING:REM Yes then go to error module
  ELSEIF
   GOTO NO_COMMUNICATION         :REM Yes then go to "No answer" error module
  ENDIF
 ENDIF
UNTIL -1                         :REM loop endless
```

Ps. An ERROR message includes a "?BELL". (Bell = ASCII 7.)

3.7.1 Software Profile Programming

SYSTEM 7000 is delivered with the software profile option.
With the ramp profile SW it is possible to down load and run a predefined ramp sequence that the output current must follow. The SYSTEM 7000 supports Equal timeslot method.

The examples below are shown for a uni-polar profile. For bipolar profiles, the output current may also be set as negative.

3.7.2 Equal time slot ramp profile method

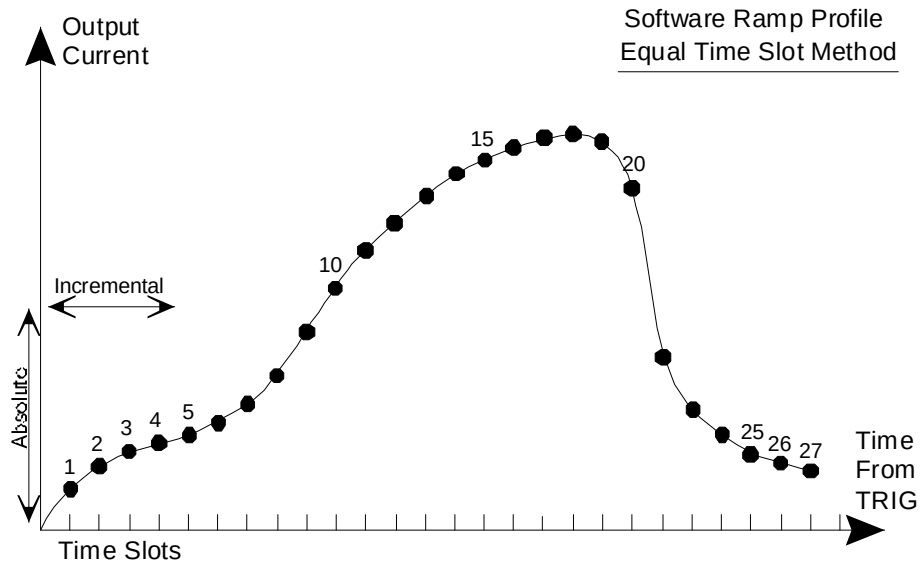
With the ”Equal time slot method” it is possible to download up to 512 current set values and a single time slot value, that will be used for all set values. Only one stack is available.
This profile method is especially useable for faster and more accurate curves fitting profiles e.g. as a function generator.

To use the Equal time slot method at least the following steps must be preformed:
- Clear and set the stack “RAMPSET [parameter]”,- Program the stack “R [parameter]”, -Start the stack “RAMP [parameter]”, -Read the status of the running stack “RAMP".

PS. All values must be given as a floating point number scaled to “1.00000". That is; 2.5ms must be entered as 0.00250 and 19.54% output current as 0.1954.

Please refer to *ApBCPsw1a.doc Software commands* for full instructions.

The figure below shows an example of one ramp profile stack. (Ps. not all 512 points need to be programmed, empty entries will be ignored.)



The time slot must be given as a multiple of 2.5ms. Between 2.5ms to 1 second. Any value in-between will automatically be rounded according to formulae:

{time slot}=frac({time}/0.00250)*0.00250

The SW will after the start command update the output current every 2.5ms. By means of interpolation regardless of the programmed time slot value:

The ramp can be initiated to run as a single shot "RAMP R", auto iteratively (auto loop) by software command "RAMP R,L" or HW triggered auto armed "RAMP T,W". For a full documentation on controlling the "Equal time slot method" please refers to *ApBCPsw1a.doc Software commands*.

If synchronization to an eternal event is required, it is possible to arm the ramp sequence first with the synchronization command "RAMP T". A hardware signal on the trigger input X7 pin 1&2 (10 to 24V) or a "RAMP R" command will start the sequence.

If more power supplies have to be synchronized, one of the supplies has to be appointed as master. Connecting the master trig output X7 pin 3&4 to the other supplies trig input will start the other supplies when the master is triggered. A maximum skew of 2.5ms between the supplies may be expected. (an external 15V auxiliary supply is needed, as the trig output is an open collector and the trig input is an opto coupler input.)

External input and output triggers are located on the back of the SYSTEM 7000, see overview of the back of SYSTEM 7000 in *chapter 4.1.1*

Hint: When adding values to the ramp profile, the enter point (start) and exit point (stop) shall be the same in order for running the ramp sequence in loop. Otherwise there will be an unwanted level between the exit point for the first ramp and the enter point for the next ramp as the ramp is miscalculated. Besides, the output current should set to zero before start running the ramp.

<u>In order to run ramp profile correctly, following steps must be performed</u>

- Clear the stack by typing RAMPSET C
- Enter the data points, type R 0.xxxxx and press enter. Repeat this until the last data point has been entered.
- Save the data points by typing R S
- Set the output current to zero by typing WA 0 or DA 0,0
- Turn on the MPS by typing N
- Run the ramp in loop by typing RAMP R,L

x is a number from 0 to 9

Description of how to set up and run the ramp profile, refer to the *ApBCPsw1a.doc Software command*

3.7.3 <u>SW limits</u>

The limits of the "Equal time slot method" ramp profile SW are:

- The set value must be given in a floating point representation normalized to 1.00000.
- The time slot may be between 0.0250 to 1 second given in a floating point representation normalized to 1.0000.
- Maximum numbers of stacks = 1
- Maximum number of time slots in a stack = 512

3.8 SW Commands

Following are the commands for the standard software listed in alphabetic order.
Please see the *ApBCPsw1a.doc Software command* for detail explanation on every command.

This issue is valid for software version BCP100

STANDARD COMMANDS. summary

AD X	Read value from an ADC channel.
ADR	Read the address of the MPS.
ADR XXX	Write an address to a MPS.
ADCTRIG	Read the AD channel trig setup
CMD	Read current control mode.
CMDSTATE	Read current control state.
DA 0,XXXXXX	Writes a value to an Digital to Analog converter for setting the output current. (Alternative to the WA command.)
ERRC	Coded error message.
ERRT	Text string error message.
F	Main Power OFF
LALL	Listen ALL.
LOC	Change to Local Control
LOCK	Lock the MPS in Local Control.
N	Main Power ON
NERR	No error message
PO	Polarity status
PO +/-	Change to Normal polarity
PRINT	Reads internal user information about the MPS.
RA	Read the set value.
REM	Change to remote control.
RLOCK	Remote line only
RS	Reset interlocks.
S1	Read the internal status.
S1H	Read internal status in HEX format
STB	Standby (Main Power ON with clamped output in ON/OFF/STB mode 2)
TD	Test DAC
TYPE	AD type in use
UNLOCK	Unlock the MPS
VER	Reads the software version
WA XXXXXX	Writes a value to an Digital to Analog converter for setting the output current. (preferred command DA 0,XXXXXX.)

X is a number from 0 to 9 and Commands in quotation marks are optional

Following are the commands for the standard software listed in alphabetic order.
Please see the *ApBCPsw1a.doc Software command* for detail explanation of every command

This issue is valid for software version BCP100

STANDARD COMMANDS. summary

ESC<ADR	Configures the communication address setting (in RS422 mode).
ESC<ADSET	Auto Configures the scaling "gain" and Offset for an AD converter channel.
ESC<BAUD	Configures the Baud rate for the serial lines.
ESC<COLDBOOT	Configures the power up state (Wake up position)
ESC<CPURESET	Hardware reset / CPU reset
ESC<DASET	Auto Configures the scaling (gain) and Offset for a DA converter channel.
ESC<LINE	Configures the protocol for the serial lines.
ESC<NFSMODE	Configures the ON/OFF/STB mode operation

Following are the commands for the software driven "RAMP PROFILE" listed in alphabetic order.
Please see the SW appendix for parameter format and further detail description.
These commands are optionally available.

SW RAMP PROFILE COMMANDS "Equal Time slot method". Summary

R	Write data to the stack.
RAMP	Control the stack operation
RAMPSET	Configure the ramp operation

See ApBCPsw1c.doc for detail Software commands

4 Theory of operations

4.1 Introduction

The power supply is designed to supply a magnet with direct current stabilised to 100 ppm of maximum output current.

The main AC input supply is connected through a contactor, which turns on the power in two steps to minimise the inrush current. Step one with R201 to R204 connected in parallel with the mains for a certain time. In the second step the resistors will be short circuit. The voltage is rectified in a 6-pulse rectifier and filtered with a L_C low pass filter.

The output current is controlled by means of a linear Vce controlled four-quadrant power amplifier.
One power supply is capable of transforming up to 1,5KW of power at a maximum of 20A and 75V. If more current is required up to five power supplies may be arranged in parallel.

A 70 kHz Push-Pull converter supplies the Power Amplifier. The Vce voltage of the Power Amplifier controls this converter.

Stabilisation is achieved by comparing the voltage across the burden resistor, connected to an ultra high precision D.C. current transformer (DCCT), with the ±10V set signal either supplied from the Analogue interface or the built in precision DAC.
The resultant error signal is feed into a high gain amplifier system. The output from this amplifier controls the output power amplifier, so that the output current is maintained within the specified accuracy.

Due to safety reasons it is possible to stop (interlock) the power supply. These interlocks can either be generated internally (phase_, temperature_, over voltage_, over current_ failures and others) or externally (two spare_, Magnet over temperature_ or rack fan_failure). These interlocks are latched on the power amplifier module.

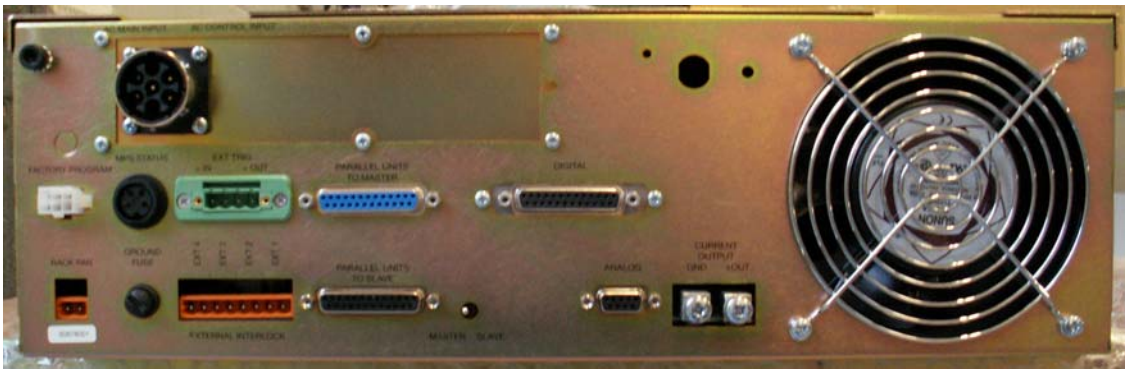
It is possible to control the power supply either from the local control panel located on the front of the supply, through the remote serial line or through the “PARALLEL UNITS TO MASTER” and “PARALLEL UNITS TO SLAVE” interface plugs, allowing a parallel control and analogue current settings. In all modes it is possible to switch the supply ON/OFF, reset interlocks, read status information as interlocks, internal voltages and output current/voltage. The slaves must also be connected to the serial line in order to read these individual interlocks.

Efforts have been taken to design the power supply to be fully protected if an error occurs. However if magnets above 500mH is connected, fast ramping beyond regulation e.g. polarity change from full positive to full negative set current, might bring the output transistors beyond SOA. The ensure best protection, it is recommended to adjust the slew rate circuit to the maximum needed ramp speed and not ramp faster than the loop can regulate.

4.1.1 SYSTEM 7000 Interface specification:

SYSTEM 7000 has following external connections:

- Analogue Interface, D-sub 9 pole female
- Digital Interface, D-sub 25 pole female
- Parallel unit Master, top position connector D-sub 25 pole female
- Parallel unit Slave, bottom position connector D-sub 25 pole female
- AC main input, 3 phase, Neutral and Earth
- AC Control input
- Earth Screw
- MPS Status, Amphenol 4 pole series C091B female
- Current output
- External trig (for use with Ramp or fast ADC) 4 pole
- External interlocks, Weidmuller 151-096, 8 pole
- Rack Fan, Weidmuller 151-096, 2 pole
- Factory program 6 pole



Connector ANALOG:
Analogue status and analogue set value interface.

Pin no:	Name	I/O	Description & Specification
1	Measured Current Error	O	Output is 5V per 1% in difference between output current and SET current.
2	Measured Voltage	O	Output is 10V if output voltage is 35V or 75V. This depends on dip switch setting.
3	Measured Current	O	Output is 10V for 100% output current 20A one unit and 40A when two units are in parallel and etc.
4	Current Setpoint readback	O	Output is equal to SET value.
5	Current Setpoint	I	Input setponit, 10V equal to 20A for one unit and 40A when two units are in parallel and etc.
6	Measured Shield	O	
7	Measured RTN	O	
8	Setpoint Shield	I	
9	Setpoint RTN	I	

Connector DIGITAL:
Remote, RS232, RS422, RS485 DB25 serial line Interface

Pin no:	Name	I/O	Description & Specification
2	Tx	O	RS232 Transmitter line
3	Rx	I	RS232 Receiver line
7	RETURN	I/O	Return line for RS232
9	Tx High	O	RS422/485 Transmitter positive line
10	Tx Low	O	RS422/485 Transmitter negative line
11	Rx High	I	RS422/485 Receiver positive line
12	Rx.Low	I	RS422/485 Receiver negative line

Connector PARALLEL UNITS TO MASTER:
Parallel hardware control P112

Pin no:	Name	I/O	Description & Specification
1	+Power is ON	O	Power ON chain. All parallel units will go OFF if one unit drops out.
2	Spare		
3	/Out of regulation	I/O	Interlock Open collector, low when output current exceeds the limit of 2,5% of the set value
4	/Summary fault	I/O	Interlock Open collector, low when SCR in Start/Stop control is activated.
5	/Over temp	I/O	Interlock Open collector, low when the heat-sink of the amplifier is above 80°C
6	Spare		
7	/Standby command	I/O	Open collector, low Standby pulse.
8	Spare		
9	Summed current error	I	Master : Converts current into error voltage signal scaled by no of units.
		O	Slave : 1 mA per 2% error per unit
10-11	Spare		
12	Setpoint	O	Master
		I	Slave
13	Spare		
14	/Over current	I/O	Interlock Open collector, low when output current reach adjusted level
15	/PS fan fault	I/O	Interlock Open collector, low when inside fan fail.
16	/Ground fault	I/O	Ground fault automatically disabled in slaves
17	/AC fault	I/O	Interlock Open collector, low when one of the voltage supply lines are low.
18	GND D		Digital GND
19	/OFF command	I/O	Open collector, low OFF pulse
20	/ON command	I/O	Open collector, low ON pulse
21	Unit parallel	I	Master : X mA = X slaves.
		O	Slave : 1 mA sink per unit
22	Spare		
23	GND A	I	Loop GND
24	GND A		Analog GND
25	Not used		

Connector PARALLEL UNITS TO SLAVES:
Parallel hardware control P111

Pin no:	Name	I/O	Description & Specification
1	-Power is ON	I	
2	-15VD	O	
3	/Out of regulation	I/O	Interlock Open collector, low when output current exceeds the limit of 2,5% of the set value
4	/Summary fault	I/O	Interlock Open collector, low when SCR in Start/Stop control is activated.
5	/Over temp	I/O	Interlock Open collector, low when the heat-sink of the amplifier is above 80°C
6	Spare		
7	/Standby command	I/O	Open collector, low Standby pulse.
8	Spare		
9	Summed current error	I	Master : Converts current into error voltage signal scaled by no of units.
		O	Slave : 1 mA per 2% error per unit
10-11	Spare		
12	Setpoint	O	Master
		I	Slave
13	Spare		
14	/Over current	I/O	Interlock Open collector, low when output current reach adjusted level
15	/PS fan fault	I/O	Interlock Open collector, low when inside fan fail.
16	/Ground fault	I/O	Ground fault automatically disabled in slaves
17	/AC fault	I/O	Interlock Open collector, low when one of the voltage supply lines are low.
18	GND D		Digital GND
19	/OFF command	I/O	Open collector, low OFF pulse
20	/ON command	I/O	Open collector, low ON pulse
21	Unit parallel	I	Master : X mA = X slaves.
		O	Slave : 1 mA sink per unit
22	Spare		
23	GND A	I	Loop GND
24	GND A		Analog GND
25	Not used		

Connector MPS STATUS:
P103

Pin no:	Name	Description & Specification
1	MPS	This pin is conncted to pin 3 when the SYSTEM 7000 is ON.
2	PIN2&4	Pin 2 and 4 is connected
3	MPS	This pin is conncted to pin 1 when the SYSTEM 7000 is ON.
4	PIN2&4	Pin 2 and 4 is connected

Connector EXTERNAL INTERLOCKS:

Pin no:	Name	I/O	Description & Specification
1	EXT 1	I	+15V connected to RTN GND if no interlock.
2	RTN GND		
3	EXT 2	I	+15V connected to RTN GND if no interlock.
4	RTN GND		
5	EXT 3	I	+15V connected to RTN GND if no interlock.
6	RTN GND		
7	EXT 4	I	+15V connected to RTN GND if no interlock.
8	RTN GND		

Connector EXT TRIG:
Ramp profile synchronization / ADC trig

Pin no:	Name	I/O	Description & Specification
1	SYNC+I	I	Applying a 15 to 25 V signal between pin 1 and 2 will start the SW ramp profile if armed or trig signal for ADC 0
2	SYNC-I	I	Return wire for pin 1
3	SYNC-O	O	Return line for SYNC +O
4	SYNC+O	O	Open collector output up to 24V/100mA. Active in minimum 2.5ms when a ramp profile has been triggered.

Connector FACTORY PROGRAM :
Software upgrade plug X2. Only to use by authorized Danfysik service personnel.

Pin no:	Name	I/O	Description & Specification
1	ISOGND		Ground
2	RESET	I	Reset
3	Rx	I	Receiver line
4	Tx	O	Transmitting line
5			
6	ISO5V		5V

Connector RACK FAN:
Auxiliary fan

Pin no:	Name	I/O	Description & Specification
1	Fan 1	O	NO contact for auxiliary fan close in standby and on mode. Contact may be loaded with maximum 220VAC/0.5A
2	Fan 2	O	See above

Connector AC MAIN INPUT:

Pin no::	Name	I/O	Description & Specification
⏚	Earth	I	Green/Yellow
1	L1	I	Line 1
2	L2	I	Line 2
3	L3	I	Line 3

Earth screw

Pin no:	Name	I/O	Description & Specification
1	6mm		Safety Ground

4.2 Display controller module.

Schematic: 85089-1 & 2
Assy.: 85088

The display controller module contains the display, local buttons, DAC for the set value, ADC for the read back, serial interface and the controlling micro-processor.

4.2.1 Micro-Processor

The micro-processor circuit is the intelligent part of the system and build around a Zilog micro-processor U8,

The CPU runs at 20MHz, controlled from the crystal Y1.
The micro-processor has built-in "Watchdog" circuit and will reset the CPU, if it for some reason stops to refreshing the watchdog.

As memory it uses its internal FLASH EEPROM for the PGM storage and U20 as the data storage “FRAM type FM25CL64-S with 64Kbit capacity” as well as its internal RAM.

4.2.2 Display

The display consists of 12 single LEDs for status and 2x6 common anode 7-segments LEDs for displaying set/output currents and voltage respectively. The display refreshment is done through multiplexing controlled by the CPU.
For driving the segments, buffer U9 and U18 with transistor Q1 and Q2 are used.

Connecting the power supply as slave in a master slave configuration (in parallel with another supply) the 7 segment display of the slaves will be turned off. The master will automatically display the total current of all paralleled units.

4.2.3 DAC circuit

The DAC circuit converts the serial digital set value to a voltage reference.

The circuit is built around U1 for the I-reference set value and U10 for the V-reference set value.

The DAC circuit delivers a bipolar output voltage proportional with the digital input value.

4.2.4 Slow ADC circuit

Different voltages are monitored by means of the Analog to Digital converter U19. The measured values and their resolution are shown in the table below.
The 2.5V reference voltage for the ADC converter comes from U25.

The following analogue signals are monitored:

VALUE	BIT RESOLUTION
Output current	17 + sign
Current Limit	17 + sign
Output Voltage	17 + sign
Voltage Limit	17 + sign
Voltage reference	17 + sign

4.2.5 Voltage reference

The voltage reference circuit is constructed around U25 “MAX6350” which delivers a 5V high precision voltage to the ADC “U19” and the DAC “U1 & U10”.

4.2.6 Fast ADC for reading/displaying of output current

From PCB revision B

The ADC U19 has a sample rate of 1 second. If a faster sample rate is required, the fast ADC circuit can be selected by inserting strap ST11. The fast ADC is capable of converting the output current up to 30 times a second with a resolution of 12 bit + sign. The sampling may be synchronized from an external trig signals SYNC+I and SYNC-I on connector X6. For enabling the external ADC trig, pin 16 on connector X7 need to be set low (high-to-low transition) otherwise the fast ADC will run continuously at highest speed.

The fast ADC circuit is built around A4A and A4B together with two of the CPU internal ADC channels in an average over sampling technique.
The sampling frequency of these two channels is 10 kHz each, but due to the running average calculation, to achieve the 12 bit accuracy from the 10 bit internal ADC, is the practice sampling rate reduced to 30Hz.

The sign for the fast ADC reading is built around a comparator LM311.

For enabling fast ADC mode, strap ST11 must be short-circuited (close) otherwise it is normal mode.

Mode	Strap ST11
Fast ADC	Close
Normal	Open (default)

The maximum frequency for the ADC external trigger pulse is 30 Hz.

Trig mode	Pin16 (connector X7)
ADC External trig	Low [1)]
Running	High[2)] (default)

1) Short-circuit pin 8 and pin 16 at the connector X7
2) Pin 16 is high at default

Ps. The fast ADC external trig input and the external trig for the ramp profile share the same physical port line. Due to this, the external trig for ramp profile option will automatically be disabled if the fast ADC external trig is enabled.

4.2.7 DC/DC Converter:

A small 100 kHz 5W galvanic isolated push pull converter is provided. It supplies circuits with two isolated +5V suppliers. Galvanic isolation is used to avoid ground loops.

A voltage mode pulse width modulator, U30 is controlling the push pull converter.

±5V for the ADC is generated from two linear regulators, U23 and U24
+3.3V for the µ-processor is generated from Low-Noise Ultra Low-Dropout Regulator U26.

4.2.8 Serial Interface:

The SYSTEM 7000 supports serial communication RS232, RS422 and RS485. The default setting is RS422.

The serial communication circuit consists of U39, U35, U36, U37A, ISO5, ISO6 and ISO9 and the serial link is optically isolated.

The connector “REMOTE CONTROL” is the serial interface port. For information about pin description for this connector at the back of the power supply, please refer to chapter 3.6.

The selection between the RS232, RS422 and RS485 mode is done through straps located on the Display Controller Module. Please refer to chapter 3.6 about strap settings.

4.2.9 Front Panel Interface specification:

The Front Panel has following connection:

Connector X1: (Analog signals To/From the Front Panel)

Pin no:	Name	I/O	Description & Specification
1	Local Reference	O	0 - ±10VDC from DAC circuit in Front Panel
2	Current Limit	O	0 - +10VDC from current limit potentiometer.
3	Voltage Measured	I	0 - ±10VDC to BNC connector in Front Panel
4	Current Measured	I	0 - ±10VDC to BNC connector in Front Panel
5	Current Setpoint	I	0 - ±10VDC to BNC connector in Front Panel
6	Number of units in parallel	I	1-7VDC to ADC in Front Panel
7-10	Spare		
11-12	+15V	I	
13-14	-15V	I	
15-16	GNDA		

Connector X4: (Digital signals To/From the Front Panel)

Pin no:	Name	I/O	Description & Specification
1	Local, /Remote	O	Signal from µ-Processor 0V=Remote, 5V=Local
2	/OFF Local	O	Active low signal from push button in Front Panel
3	OFF status	I	5V to OFF status LED
4	/Standby,/Reset	O	Active low signal from push button in Front Panel
5	Standby status	I	5V to Standby status LED
6	/ON Local	O	Active low signal from push button in Front Panel
7	ON status	I	5V to ON status LED
8	Over Current Interlock	I	5V to Over Current Interlock LED
9	Over Voltage Interlock	I	5V to Over Voltage Interlock LED
10	Over Temperature Interlock	I	5V toOver Temperature Interlock LED
11	PS Fan Fault Interlock	I	5V to PS Fan Fault Interlock LED
12	Out of Regulation Interlock	I	5V to Out of Regulation Interlock LED
13	Ground Fault Interlock	I	5V to Ground Fault Interlock LED
14	AC Fault Interlock	I	5V to AC Fault Interlock LED
15	Summary Interlock	I	5V to Summary Interlock LED
16	Magnet Over Temperature Interlock	I	5V to External Magnet Over Temperature Interlock LED
17	Rack Airflow Interlock	I	5V to External Rack Airflow Interlock LED
18	Spare 1	I	5V to External Spare 1 Interlock LED
19	Spare 2	I	5V to External Spare 2 Interlock LED
20	In Current Limit	I	5V to In Current Limit LED
21	Converter Over Voltage Interlock	I	5V to Converter Over Voltage Interlock LED
22	Master, /Slave	I	Display in Front panel is off in Slave mode. 5V=Master, 0V=Slave
23	75V, /35V	I	µ-Processor is scaling Voltage Display to 35V or 75V. 5V=75V, 0V=35V
24	Unit0	O	Unit 0-2 is 3 bit showing no of units in parallel.
25	Unit1	O	The 3 bit scales the summed regulation error to 2%=10V.
26	Unit2	O	The 3 bit scales the measured current to 100%=10V.
27-28	B+5V	I	
29-30	GNDD		
31-34	+15VUREG	I	Supply For DC/DC Converter
35-40	GNDUREG	I	

4.3 Power Amplifier module:

Schematic: 84571 (9 sheets)
Assy.: 84570

The Power Amplifier module has the following functions on board;
Power amplifier interface specification.
ON/OFF/STANDBY control.
Protection circuits and Interlock.
Analog Local/ Remote current SET point controls.
Analog measurements.
Current regulation
Power Amplifier.
Load dump circuit.
DC Current Transducer.
Interface to Display & AC/DC Converter.
+5V linear regulator.

Two modules are connected to the Power Amplifier module;

1) The Power Converter module. See description in Converter section
2) The Display panel. See description in Display section.

4.3.1 Power Amplifier Interface specification:

The Regulation module has following connection:

- P108: Analog signals to Front Panel, Header 16 pole for ribbon cable
- P110: Digital signals to Front Panel, Header 40 pole for ribbon cable
- P115: Internal Fan 24VDC, Molex serie 231, 2 pole
- P116: Amplifier supply voltage +V, Faston Receptacles 6,3x0,8mm
- P117: Amplifier supply voltage GND, Faston Receptacles 6,3x0,8mm
- P118: Amplifier supply voltage –V, Faston Receptacles 6,3x0,8mm
- P119: Converter control, Header 26 pole for ribbon cable

Connector P108: (Analog signals To/From the Front Panel)

Pin no:	Name	I/O	Description & Specification
1	Local Reference	I	0 - ±10VDC from DAC circuit in Front Panel
2	Current Limit	I	0 - +10VDC from current limit potentiometer.
3	Voltage Measured	O	0 - ±10VDC to BNC connector in Front Panel
4	Current Measured	O	0 - ±10VDC to BNC connector in Front Panel
5	Current Setpoint	O	0 - ±10VDC to BNC connector in Front Panel
6	Number of units in parallel	O	1-7VDC to ADC in Front Panel
7-10	Spare		
11-12	+15V	O	
13-14	-15V	O	
15-16	GNDA		

Connector P110: (Digital signals To/From the Front Panel)

Pin no:	Name	I/O	Description & Specification
1	Local, /Remote	I	Signal to analog switch controlling local and remote SET value.
2	/OFF Local	I	Active low signal to Start/Stop control circuit
3	OFF status	O	5V from buffer
4	/Standby,/Reset	I	Active low signal to Start/Stop control circuit
5	Standby status	O	5V from buffer
6	/ON Local	I	Active low signal to Start/Stop control circuit
7	ON status	O	5V from buffer
8	Over Current Interlock	O	5V from buffer
9	Over Voltage Interlock	O	5V from buffer
10	Over Temperature Interlock	O	5V from buffer
11	PS Fan Fault Interlock	O	5V from buffer
12	Out of Regulation Interlock	O	5V from buffer
13	Ground Fault Interlock	O	5V from buffer
14	AC Fault Interlock	O	5V from buffer
15	Summary Interlock	O	5V from buffer
16	Magnet Over Temperature Interlock	O	5V from buffer
17	Rack Airflow Interlock	O	5V from buffer
18	Spare 1	O	5V from buffer
19	Spare 2	O	5V from buffer
20	In Current Limit	O	5V from buffer
21	Converter Over Voltage Interlock	O	5V from buffer
22	Master, /Slave	O	Signal from Master/Slave switch placed in back of SYSTEM 7000. 5V=Master, 0V=Slave
23	75V, /35V	O	Signal from dip-switch setting 35V or 75V. 5V=75V, 0V=35V
24	Unit0	I	Unit 0-2 is a 3 bit signal to analog switches. The switches are controlling the voltage scaling.
25	Unit1	I	The 3 bit scales the summed regulation error to 2%=10V.
26	Unit2	I	The 3 bit scales the measured current to 100%=10V.
27-28	B+5V	O	
29-30	GNDD		
31-34	+15VUREG	O	Unregulated auxiliary supply voltage from AC/DC Converter
35-40	GNDUREG	O	

Connector P115: (To/From the Fan)

Pin no:	Name	I/O	Description & Specification
1-2	Fan contactor	O	ON/ OFF contactor for the internal FAN

Connector P119: (To/From the Converter)

Pin no:	Name	I/O	Description & Specification
1	Output Voltage of Power Amplifier	O	SYSTEM 7000 output voltage feedback to AC/DC Converter for Vce regulation.
2	ON	O	Converter pulse width modulator ON/OFF. 5V=ON.
3	PWR ON+	I	Cathode of opto coupler. Opto coupler keeps SYSTEM 7000 ON
4	PWR ON-	I	ON chain signal to parallel cable.
5	AC Fault	I	Input of AC Fault camparator. OK=15V.
6	PWR Contact	I	Part of Machine Protection System signal. ON=0V.
7	ON Relay	O	Open collector. Main contactor ON/OFF. 0V=ON,
8	Inrush Relay	O	Open collector. Inruch relay. 0V=End of inruch time.
9-14	Spare		
15-16	+15VUREG	I	
17-18	GNDUREG		
19-20	B+5V	I	
21-22	+15V	I	
23-26	GNDS		

4.3.2 ON/OFF/STANDBY control

SYSTEM 7000 has three ON/OFF/STANDBY modes. See chapter 3.2 for more information about these modes.

Remote ON, Standby and OFF pulse is pulse shaped by U201.

A delay-line ensures that sum interlock signal (named SET on sheet 2) is only accepted, if it stays high for a longer time than app. 50 mSec.The delay circuit consists of R251, C207, R252 and C208. The purpose is to eliminate false noise generated interlocks. The output of the delay-line will trigger Q209, Q212 that acts like a thyristor and thereby turning the transistor Q210 and Q214 off that controls the main contactor. The sum interlock signal is also connected to Q212 for a latched interlock indication.

Turning the power supply ON is initiated by turning Q211 on with a pulse. /ON_PULSE will if allowable (no interlock) conduct thereby turning the main contactor on. This will in turn activate the PWR_ON line that will direct Q210 on, and thereby permit the power supply to stay on. If though for some reason the main contactor doesn't goes on within the ON pulse time of Q211 will the ON sequence be terminated.

Turning the power supply OFF (as a response to a command from the local control panel or the remote line) will activate Q207 that forces Q210 and Q211 OFF.

For safety reasons the main interlock chain is hard wired.

4.3.3 Interlock and ON/OFF/STANDBY status

This block processes the interlock and ON/OFF/STANDBY status signals.

Internal and external interlock and status signals are connected directly without galvanic isolation.

The latched interlock information can be seen from the LED's, on the local control panel and from the remote serial line (Digital interface plug).

Each interlock is individually connected to a SR latch. Every time an edge transition is detected it will be latched in a SR latch. The first one though will be latched on arrival of the delayed sum interlock.

This circuit consists of the integrated circuits U701, U705, U707 and U712.

4.3.4 Over Current Interlock

The task of the overload protection is to turn the power supply OFF if the output current rises above adjusted level that is adjustable by means of P807.

This circuit is build upon U807.

When the power supply delivers 100% output current, the DCCT delivers exact 0,1A. This 0,1A current is fed through a 10Ω resistor in the Regulation Circuit, sheet 2, and giving 1V and then amplified by 10 gives10V. If this rises above adjusted threshold at the comparator U807, transistor Q804 will open and an overload interlock is activated.

4.3.5 Out of Regulation Status

The output voltage from the "ERROR" amplifier located in the compensation loop circuit is proportional to the accuracy of the output current. Since the gain in the ERROR amplifier is known, the window discriminator U802 is able to test, if the output current lies within the desired level. The window span (R807, R814, R822 and R824) is calculated to 2.5%.

4.3.6 Power Output Over Voltage Interlock

If the output voltage of the Power Amplifier exceeds the adjusted threshold level, interlock is activated.

Threshold level is adjusted at P802.

4.3.7 Converter Over Voltage Interlock

If Converter voltage rises above app. 100V, interlock is activated.
The window span (R828, R829, R833, R834, R837 and R839) is calculated to 100V.

Due to limit in Interface Interlock lines, the Converter OV Interlock is not represented separate. Summery is activated, but optional Converter OV is OR'ed to the Output OV Interlock.

4.3.8 Over Temperature Interlock

K801 is an 85 degrees C thermal sensor used on the Power Amplifier heat sink.

4.3.9 PS Fan Fault Interlock

If the PS Fan is short or open circuit, interlock is activated.

The fuse F801 will blow, if the Fan makes a short circuit. When the current is zero, interlock is activated.
PS Fan interlock is bypassed when the Fan is powered up, to avoid interlock.

4.3.10 Ground Fault Interlock

Output ground is connected to chassis through a 1A fuse. Only the Master is connected to chassis. This is controlled by the relay, K802.

The detector circuit is built upon U808. If the Ground-Fuse blows, the detector circuit will detect a voltage between Output ground and chassis and interlock is activated.

4.3.11 Soft start

The soft start circuit enables the Power Amplifier to smoothly ramp up the output current. This circuit has nothing to do with the normal ramp time controller in the regulation circuit, but ensures only a proper start of the Power Amplifier.

The circuit is build around U911

When the "main power signal" switches on the integrator output ramps slowly up until D903 is reversed. It takes about 3 seconds to ramp to max output.

Soft Start pulls down the current limit signal via D903. Slowly this voltage increase and finally the D903 are reversed.

4.3.12 Analog local/remote current set point controls

Shifting between Local and Remote SET value is done in the analog switch U906A.

4.3.13 Slew Rate limit

The slew rate limit is build around U905. The slew rate is adjustable from 5A/sec to 400A/sec at P902.
Always adjust to minimum slew rate needed for best protection of the system.

4.3.14 Current limit

SET value from U906A is limited via the voltage from the Current Limit trimmer on the back side of the Front Panel PCB. U908 and U909 are controlling this limitation.

4.3.15 Summed Measured Current

The measured current signal from U301B is converted into a proportional current, U914A and U920A.
Each Slave unit feeds this current to the parallel interface cable.
The Master unit converts the total current in the parallel cable into a voltage. The number of units in parallel, U914B, U915B and U919 then scales this voltage. Hereby 100% current out is equal to ±10V. The scaling is controlled by a 3-bit code coming from the Front Panel.

4.3.16 Summed Current Error

The measured Error signal from U303A is converted into a proportional current, U913A and U920B.
Each Slave unit feeds this current to the parallel interface cable.
The Master unit converts the total current in the parallel cable into a voltage. The number of units in parallel, U913B, U916 and U918 then scales this voltage. Hereby 2% current error is equal to ±10V. The scaling is controlled by a 3-bit code coming from the Front Panel.

4.3.17 Analog measurements

This block processes the Analog measurements.
A high input impedance low drift differential amplifier U301B gives excellent stable measurement of the voltage across the burden resistor (1V).

4.3.18 Current Regulation

The ERROR amplifier U301A amplifies the ERROR signal from the summing point.

The output current is converted to 0.1 ampere in the DCCT and it is measured as a voltage across the high precision, very low drift 10 Ω burden resistor. This voltage is converted to a current using the resistors R304. This negative current is then compared with the positive current in a sum point, and the difference is fed to the amplifier U301 an LT1112. The amplification factor of U301 and its frequency response can vary with the specification for each power supply.

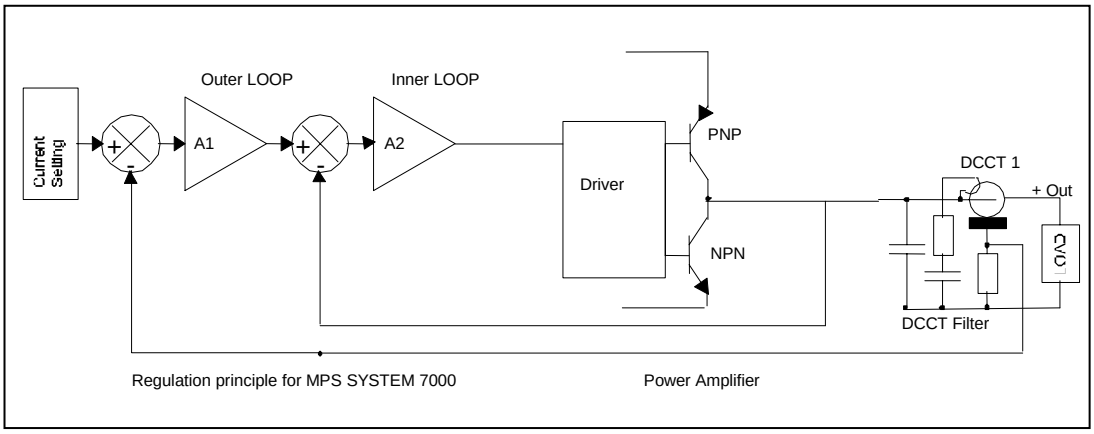
The main task of the Regulation circuitry is to produce a regulated signal to the power output stage from the "ERROR" amplifier.

The Regulation circuit contains the following main functions:
- Current loop Amplifiers/compensation
- Current Error Amplifier

Due to the output load DCCT compensation, is it possible to connect many different loads to the output terminals of the power supply still keeping the regulation loop stable. On special requirement and loads, fine tune some loop components are necessary. Please see the change notes in chapter 8 for possible change in component values.

The regulation principle can easiest be illustrated by looking at the two major criteria for the loop.

1- Inner loop for Power Amplifier
2- Outer loop for ppm stabilisation.



The figure shows the Principia of the two-loop regulation.

Inner loop
One of the advantages of the inner loop is cancellation of supply ripple and hum.

The inner loop is fast, without too much gain, just adequate to cancel any phase shift and gain variations from the load and output stage. In other words, the next loop sees a linear load without any phase shift and gain deviations, and is therefore simpler to make.

Outer loop
The outer loop ensures the over all stability of the power supply.

This loop amplifies the “ERROR" signal coming from the summing resistor R304 and it is built upon operational amplifiers U301 and U302.
A local clamp loop around U301 and U302 is provided. Saturation of U302 is avoided, by this clamp loop.

The impedance of the output load affects the actual frequency response of the loop.

The gain of the current loop bandwidth can be changed up to 20 dB on switch P304.

4.3.19 Current Error Amplifier

A second summing resistor R361 is added.
The signal from this is amplified to a magnitude of 2% Current error equal to ±10V signal.

4.3.20 Power Amplifier

The Linear Power Amplifier class A/B is souring the output current of the MPS SYSTEM 7000.

The AC/DC Converter supplies the Power Amplifier. The supply voltage level is Vce controlled. Meaning that collector-emitter voltage is 10V when the transistor is souring current.

The amplifier is designed with operational amplifier and discrete bipolar signal and power transistors.

The differential amplifier U501 located in input separates signal and power ground.
U502 controls the voltage loop and compensation of the Power Amplifier.
Output of U502 is level shifted in Q513. The current from Q513 is amplified in current mirror Q507, Q509, Q508 and Q510.

Quiescent current of the power stage is adjusted by potentiometer P503 to app. 100 mA.
Quiescent current is temperature linearised by NTC R544.

Each power transistor Q501 to Q506 is equipped with an emitter resistor to guarantee current sharing.

Q516 protect the power stage against high peak current.

4.3.21 Load Dump

The Load Dump circuit will dissipate the power stored in magnet connected to the MPS SYSTEM 7000, if the main AC power suddenly drops.

The Load Dump circuit is designed only with discrete components, because auxiliary power will disappear when the AC input supply drops.
The Load Dump circuit is capable of dissipating up to 500J in two large power resistors mounted on the chassis.
The current stored in the magnet will be returned to the Power Amplifier positive or negative supply line by the two reverse diodes in the Power Amplifier D502 and D518. When the positive supply line reaches app. 125V, the discrete thyrister Q511 and Q512 will turn Q515 ON. When The FET is ON, the Power resistor is connected across the supply line to dissipate the magnet energy. The "thyrister" will turn the FET OFF, when supply lines gets below 100V.

Circuit equal to positive line, but transistor of complimentary types protects the negative line.

4.3.22 Auxiliary Voltage and Ground planes

The Amplifier Board is supplied by a ±15V-regulated supply.

The Amplifier Board carries its own +5V supply for the digital interface, interlock and LED's. This +5V is regulated from the +15V by U603.

The Ground in the Amplifier Board is divided in five ground planes;

GNDD:	Are ground for ON/OFF/STANDBY circuit, Interlock and digital interface.
GNDA	Are ground for Analog measurements.
GNDP	Are ground for the Output Power Stage.
LGND	Are ground for the Regulation Loop.
GNDDCCT	Are ground for the DCCT circuit.

GNDD, GNDA, and GNDP are connected in one star-point.

LGND and GNDDCCT are connected to GNDA in a star point.

4.3.23 Current Transducer

The Current Transducer delivers a current proportional to the output MPS current measured by the DCCT head. This module is calibrated with the DCCT head to give exact 0,1A with a 100% output current.

This circuit contains the following four main functions:

- A power output amplifier.
- A zero flux detector.
- An interlock circuit.
- A low voltage supply.

The Power Output Amplifier

This circuit consists of U3 and U7. The Power Output Amplifier receives a signal from the feedback winding on the transducer head and a signal from the zero flux detectors. With these two signals the output of U7 is driven in such a way that the secondary ampere turns of the transducer head balances the primary ampere turns. At the same time the voltage across the secondary winding is kept to a minimum, and by this it approaches an ideal current transformer. The primary ampere-turns of the transducer head are the same as the output current.

The Zero Flux Detector

The Zero Flux Detector is a circuit patented by DANFYSIK. In principle it consists of U4. Those IC's monitor if the flux inside the DCCT head is zero, and if not and error signal is produced to the power output amplifier.
The error flux signal is monitored in two ways: a) Frequencies from Dc to 5 kHz and b) frequencies above 5 kHz. a) ensures a excellent stabilisation in the DC area, and b) ensures a high frequency bandwidth. The bandwidth is typically like:

- 20A DCCT: 100 KHz

The Interlock Circuit

If the compensating winding is unable to cancel the ampere turns of the primary current (typically by overload or faulty circuit), the zero detector cores will saturate and the magnetising currents will rise to a high value only limited by the R15, R19, R26, and R27 resistors. The average of the two driver outputs will go low. This is then detected by U6, which drives the LED “Normal ON”, and the opto coupler ISO1 "Normal OFF".
The transistor of the opto coupler is available for an external interlock system. At the same time U6B switches the connection to the output amplifier from the zero detector to the bi-stable circuit IC 7B.

The output amplifier now starts sweeping the compensating current to find the actual DCCT current again. When the DCCT current again is below its maximum rated value, then the compensating current will, after some time, cancel the primary ampere-turns. The cores will now be de-saturated and the circuit will "lock in".
The interlock circuit receive an AC signal from the zero detector driver via a short circuit in the transducer head. This signal is rectified and drives Q 4 that is part of the interlock chain.
In this way both a missing driving signal and a missing cable connection is detected.

It is made from the local +/-12V power supply interlock together with the interlocks mentioned above.

4.4 AC/DC Converter Module

Schematic:	84655 (3 sheets)
Assy.:	84654

PWM module

Schematic:	84663 (1 sheet)
Assy:	84662

A small PCB with SMD components containing the PWM control is placed in the Converter.

The AC/DC Converter is supplied from 3-phase line including neutral. Inside of the main contactor controls converter start/stop. A 6-pulse rectifier and a LC- filter ensure a high power factor.
The rectified filtered DC voltage supplies a 70 kHz H-bridge Push-Pull Converter. The ferrite power transformer is wound on an ETD 59-coil form designed with minimum creepage of 6mm from primary to secondary windings.

The UNITRODE UC3846 PWM controller controls the Push-Pull converter. The UC3846 auxiliary power is produced from 50/ 60 Hz transformers placed in the primary side. An 18V linear regulator regulates this auxiliary voltage.

A 50/ 60 Hz transformer provides the secondary with ±15V regulated auxiliary power.

The Vce voltage of the Power Amplifier module controls the voltage loop of the Push-Pull Converter.
The collector-emitter voltage of the Power transistors inside the amplifier is supplied with minimum 10V in order to avoid saturation of the amplifier.

Each phase line is provided with a phase detector build on the safety approved OPTO coupler CNY17.

An interface cable from the Power Amplifier module contains the Auxiliary power, phase detector, start/ stop signals, MPS SYSTEM 7000 output voltage and “Power is ON” detection.

4.4.1 AC/DC Converter Interface specification

The Regulation module has following connection:

- P100 AC Main Power Supply voltage, 1. Phase, Faston Receptacles 6,3x0,8mm
- P101 AC Main Power Supply voltage, 2. Phase, Faston Receptacles 6,3x0,8mm
- P102 AC Main Power Supply voltage, 3. Phase, Faston Receptacles 6,3x0,8mm
- P103 AC Main Power Supply voltage, Neutral, Faston Receptacles 6,3x0,8mm
- P104 Earth connection, Faston Receptacles 6,3x0,8mm
- P105 Amplifier supply voltage +V, Faston Receptacles 6,3x0,8mm
- P106 Amplifier supply voltage GND, Faston Receptacles 6,3x0,8mm
- P107 Amplifier supply voltage –V, Faston Receptacles 6,3x0,8mm
- P108 Converter control, Header 26 pole for ribbon cable

Connector P108: (To/From the AC/DC Converter Board)

Pin no:	Name	I/O	Description & Specification
1	Output Voltage of Power Amplifier	I	Feedback to Vce regulation.
2	ON	I	Converter pulse width modulator ON/OFF. 5V=ON.
3	PWR ON+	O	Collector from opto coupler. Signal from Main contactor . Used in ON chain.
4	PWR ON-	O	Emitter from opto coupler. Signal from Main contactor . Used in ON chain.
5	AC Fault	O	AC-line voltage detector . OK=15V, Fault=open.
6	PWR Contact	O	Signal from Main contactor. Part of Machine Protection System signal. ON=0V, OFF=open.
7	ON Relay	I	Opto coupler. Main contactor ON/OFF. 0V=ON,
8	Inrush Relay	I	Opto coupler. Inruch relay. 0V=End of inruch time
9-14	Spare		
15-16	+15VUREG	O	
17-18	GNDUREG		
19-20	B+5V	O	
21-22	+15V	O	
23-26	GNDS		

4.4.2 Auxiliary Power

The Auxiliary Power delivers the supply voltages for the Converter control, the Power Amplifier board and the Front Panel. See sheet 2 of the diagram 84655.

A ±15V regulated auxiliary voltage is generated on the secondary side of the converter. This voltage supplies the secondary side regulation feedback in the converter. The ±15V supply voltage is also used on the Amplifier Board.

The Front Panel uses the unregulated +15V supply.

A +18V regulated auxiliary voltage is generated on the primary side of the converter. This voltage supplies the primary side regulation and the pulse width modulation circuitry in the converter.

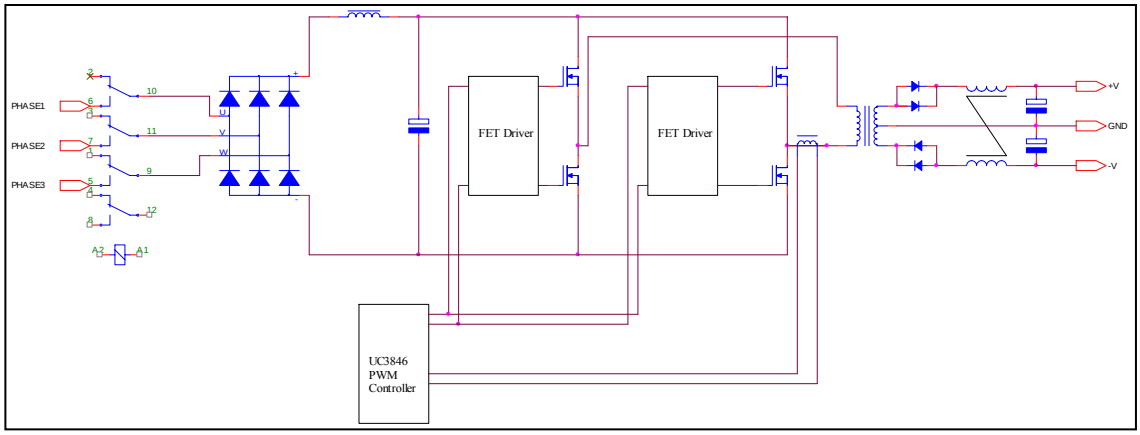
Be aware of the galvanic isolation between most of the voltages; please do not connect these voltages during measurements and servicing.
The voltage levels indicated in the connector specification are not the exact voltages, but

indicate the voltage levels they are intended to be after regulation. Please see also the schematic for the right levels.

4.4.3 Current mode Push-Pull regulator

The Push-Pull circuit can be divided in following blocks:

- Pulse Width Modulator module.
- Gate driver for the FET's
- Power output stage with FET's .
- Power transformer
- Output Filter.



The figure shows the Current mode Push-Pull regulator.

4.4.4 Pulse Width Modulator module

Schematic: 84663
Assy. 84662

The current mode control system generates the pulse width modulated signal according to the output voltage of the converter.

The circuit is build upon U404 Current mode controller chip

From the controller chip internal oscillator signal the current mode controller chip U404 generates two alternating pulse width controlled signals "A" and "B". The saw tooth current signal from the current transformer controls the maximum output current.
The saw tooth signal of the U404 oscillator is mixed with the current signal from the cycle by cycle current transformer signal is used by the U404 to switch off the FET's, when the level of the output voltage feedback opto-coupler is reached.
This saw-tooth mixing, also called slope compensation is about 20%.
The compensation amplifier of U404 is an integrator with zero at app. 100 Hz and a pole at app. 1 kHz. Gain between 100 Hz and 1 kHz is app. 25 dB.
The current mode controller has a built in "low supply voltage" detector, which prevents

inadequate trigger signals in case of power failure.
C430, R455, R445 and R496 perform a 50 mS soft start of the current mode controller.
The two outputs are programmed to have a deed time of app. 1 µS.

4.4.5 FET Gate driver

The FET's gates are driven from two dual gate driver chips. This chip has the following feature.

- High speed
- Capable to drive up 2A gate current.
- Rated for 1200V
- Built in "low supply voltage" detector.

The IR 2213 is an ideal driver when MOS FET's is driven in an H-bridge configuration.
The 2A-gate drive current is sufficient to drive two or three TO247 housed power MOS FET's.
The bootjumper capacitor C306 and C307 is charged by D312 and D313, every time the LO output of the IR2213 is low.

4.4.6 Power output stage

FET's (Field Effect Transistors) are chopped for driving the Power transformer.

Using the new FET's from International Rectifier with low gate charge, increases the switching speed and hereby decreases the power switch loss.
The power loss in the FET's is low due to the very low ON resistance.

Cycle by cycle switch current is measured with a current transformer T302. The output current of the current transformer is reduced 100 times due to the 1/100 transformer ratio.
The PWM Module for current mode control and overload protection uses the current transformer signal.

4.4.7 Power Transformer

The ferrite power transformer T301 is wound on an ETD 59 coil form and is designed with minimum creepage of 6 mm from primary to secondary windings.
Three layer of high temperature isolation material is applied between primary and secondary windings.
Resistive loses and loses from high frequency skin depth effects are reduced to a minimum by use of 0.1 mm isolated copper foil in the primary and the secondary windings.

4.4.8 Output filter

The power transformer current is rectified and filtered by L301, C304 and C314.
High-speed diodes from International Rectifier decreases the switching loses in the diodes and the reflected reverse recovery current in the switch FET's in the primary.
The storage choke L301 is wound on an ETD 49-coil form. Thin parallel enamelled copper wires make the windings in the choke. Thin wires reduce the power loss to a minimum due to the high frequency skin depth effect.
The rectifier diodes are also the free wheeling diodes when FET's are OFF.

5 Maintenance

5.1 Introduction

Servicing DANFYSIK Magnet Power Supply should be attempted only by trained and qualified personal.

Dangerous voltages capable of causing loss of life are present inside this power supply. Use extreme caution when accessing, handling, testing and adjusting.

5.2 Preventive maintenance

In normal operating environment, perform the following tasks at one year intervals.:

- Clean all fan protection grill.
- Vacuum the openings in the cabinet and all heat sinks mounted on printed circuit boards to ensure a normal flow of cooling air.
- Check that screw connections from the output terminals are tightened.

In dusty or dirty environments the above-mentioned points should be performed more often.

- Inspect visually the power supply for components that have been overheated or other suspicious sign.

In high radiation environment, performances of following tasks are recommended at one year intervals:

- Replace all ICs mounted in sockets on the printed circuit boards.
- Printed circuit boards with ICs mounted without sockets should be replaced.

5.3 Adjustment and calibration

This power supply does not need any regular adjustment or calibration.

6 Trouble shooting

The syntax for trouble shooting hints:

WILL NOT GIVE MAIN POWER ON:

- Check for interlocks.
- Check connections to main contactor:

PHASE FAIL INTERLOCK:

- Check all phases.
- Check AC main power voltage.

MPS OVER TEMPERATURE INTERLOCK:

- Check ambient temperature: Shall be below 40°C
- Check for dust
- Make sure that heatsink is proper tightened

MAGNET TEMPERATURE INTERLOCK:

- Check connections to magnet.

RACK FAN FAULT INTERLOCK:

- Check airflow switch in Rack:
  - > Failure in thermal breaker.

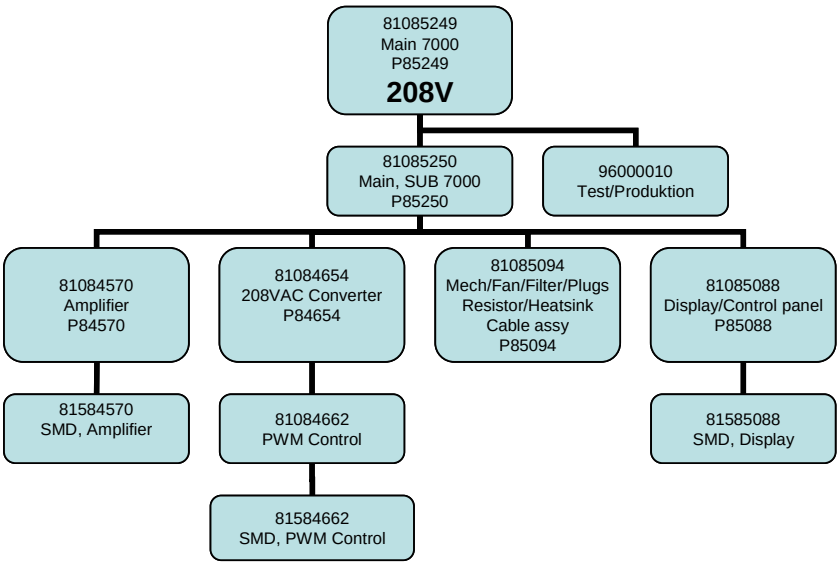
7 Drawings

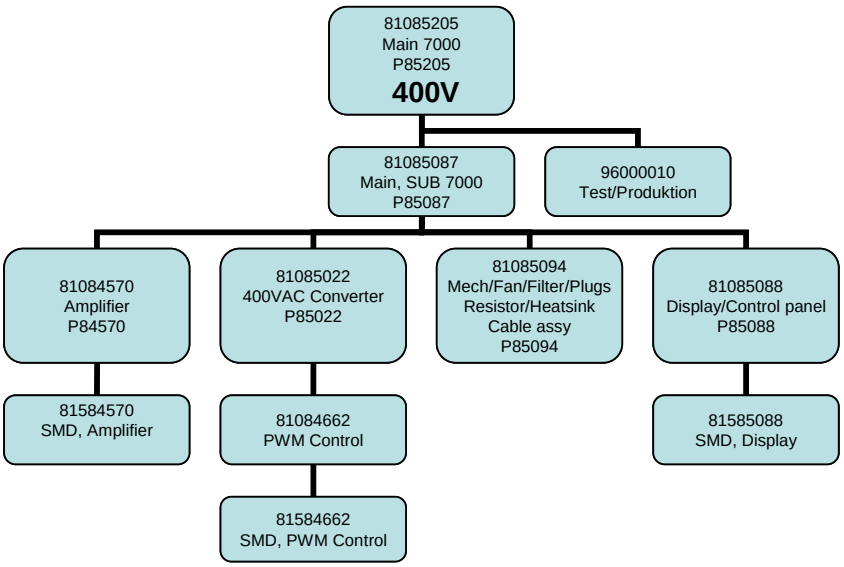
	SCHEMATIC Dwg. No.	ASSEMBLY Dwg.No.
Amplifier PCB	84571	84570
Converter Schematic	84655	84654
PWM for Converter	84663	84662
Display/Control Panel	85089	85088
Parallel Cable	DF: 65800001	

8 Parts Lists

See parts list structure

9 Parts Lists structure

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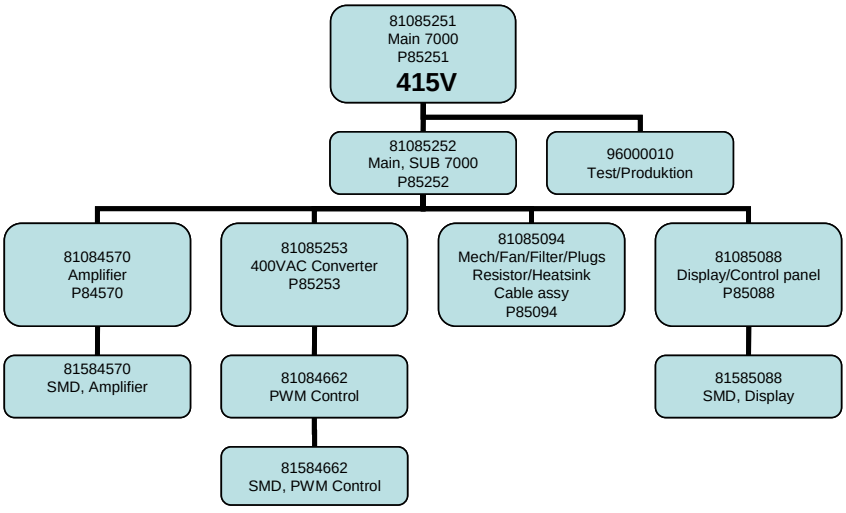
P85205
400V
81085087
Main, SUB 7000
P85087
96000010
Test/Produktion
81084570
Amplifier
P84570
81085022
400VAC Converter
P85022
81085094
Mech/Fan/Filter/Plugs
Resistor/Heatsink
Cable assy
P85094
81085088
Display/Control panel
P85088
81584570
SMD, Amplifier
81084662
PWM Control
81584662
SMD, PWM Control
81585088
SMD, Display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P85251
415V
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96000010
Test/Produktion
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Amplifier
P84570
81085253
400VAC Converter
P85253
81085094
Mech/Fan/Filter/Plugs
Resistor/Heatsink
Cable assy
P85094
81085088
Display/Control panel
P85088
81584570
SMD, Amplifier
81084662
PWM Control
81584662
SMD, PWM Control
81585088
SMD, Display

EOD