

3D Magnet field meter type 981201.

This product is a special, designed for the D-zero project.
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Specifications.

The B-field meter consist of a conditioner and 1...3 measurement heads which 3 Hall sensor and 1 temperature sensor.

B-field

Sensor type : Hall
Range : ≥ 2 Tesla
Resolution : $\approx 60 \mu\text{Tesla}$

Temperature

Sensor type : NTC
Range : $0^\circ \dots 70^\circ\text{C}$ or $32^\circ \dots 158^\circ\text{F}$
Deviation : $15^\circ \dots 45^\circ\text{C} < 0.5^\circ\text{C}$ or $59^\circ \dots 113^\circ\text{F} < 0.25^\circ\text{F}$

Scan frequency : With default setting max. 10 times/sec.

Control

Type : Micro-Wire^{TM1} (Di, Do, Clk en Cs)
Di, Cs : 3...5 V
Clk : 4.5...5 V

Conditioner

Ambient Temp. Range: $0^\circ \dots 60^\circ\text{C}$ or $32^\circ \dots 140^\circ\text{F}$
+12 supply range : 5.2 ...20V
+5 supply range : 4.75 ...5.25V
+5 or +12 supply current : $< 5\text{mA}$
-5 supply range : -3 ...-10V
-5 supply current : $< 1\text{mA}$

Dimensions

Conditioner : $100 \times 54 \times 27\text{mm}^3$ (mounting plate is 135mm long) or
 $3.93 \times 2.13 \times 1.07\text{inch}^3$ (mounting plate is 5.31 inch long)
Measuring head : $15 \times 10 \times 4 \text{mm}^3$ or
 $0.59 \times 0.39 \times 0.16 \text{inch}^3$

¹ is a trademark of National Semiconductor Corporation.

Abstract.

The B-field meter is an instrument to measure magnetic field strength and direction. The information about the direction is obtained from three Hall sensors, oriented in X, Y and Z direction. Field strength to • 2 Tesla can be measured with a resolution of 60 μ Tesla. The meter consists of a conditioner and 1...3 heads containing the three Hall sensors and a temperature sensor. Both the head and calibration software are inventions of CERN². CERN also performs the calibration. The conditioner is an invention of NIKHEF. A CAN node provides the communication (Micro-Wire™) and power. The development is done for the D-zero project.

How it works.

Hall effect sensors are elements yielding a voltage depending on the current through them and the strength of the magnetic field. The open circuit sensitivity $K_{b0} = 150...230 \text{ V/AT}^3$ (Volts per Ampere Tesla). With a current of about 200 μ A this results in a sensitivity of about 50mV/T.

The Hall sensors are connected in series to make sure they carry the same current. The current through the Hall sensors is supplied by a current source. The drawing labeled “**power circuit.**” on page 9 shows the current source. Also in series with that chain is a resistor giving 100mV for this current. The purpose of that voltage is to calibrate the full-scale value of the ADC. Doing so makes the measurements insensitive to the tolerance of all other components. The reason that the circuit contains high accurate resistors is to obtain a high accuracy for the temperature measurements.

The voltage across the chain exceeds the common mode range of the ADC. To overcome this problem an opamp is added to manipulate the lower end of the chain to shift the voltage to be measured into the range of the ADC. Fig. 1 and “**b-sensor circuit.**” on page 8 shows the principles of operation.

NTC resistors are used to measure the temperature of the heads. These temperature values are intended to make corrections for temperature effects from the Hall sensors. As the power dissipation in the heads is only 100 μ Watt, the measured temperatures are close to the ambient temperature. The resistors have a value of 5k Ω (at 25°C or 77°F). A Wheatstone bridge is used to measure their value.

“**T-sensor circuit.**” on page 8 shows the circuit. The first three branches are used to measure the NTC's of the Hall heads. The fourth branch contains a reference resistor of 5k Ω , which gives a way to adjust resistor R21 from the reference branch, during production test.

The time it takes to settle after selecting another channel is < 20mSec. The used ADC contains software programmable registers for configuration, gain and offset and filters to suppress 50Hz and 60Hz noise and interference. Here the ADC (CRYSTAL CS5525) is used in its default state. This means a 100mV full-scale range, bipolar and 15Hz Conversion-Word-Rate. The complete data sheet, 26 pages, from this ADC can be downloaded from <http://www.crystal.com>.

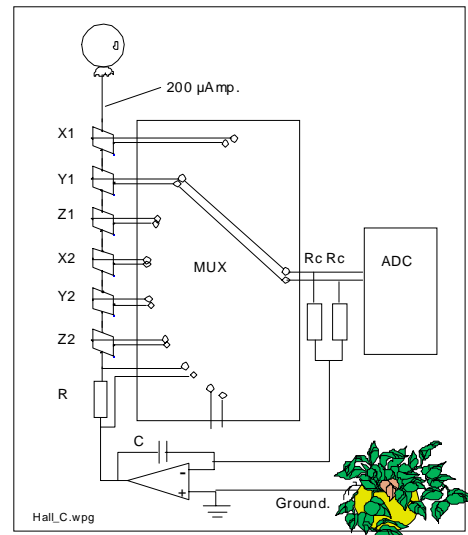


Fig. A: How the voltage to be measured is shifted into the ADC measurement range.

² Dept. PPE-EC magnetic measurement group. Tel: 0041 22 767 8499 Fax: 0041 22 767 8760

³ Siemens KSY44

Control and reading.

Communication with the ADC is provided by a Micro-Wire™ link. Such a link consist of four signal wires. Out of which there is one for data input, one for data output, one for clock signal and one for chip select. There are also a couple of wires for power. Across the link goes a simple protocol.

The ADC contains the following registers:

- Configuration register.
- Gain register.
- Offset register.
- Data register.

The first three registers are read/write registers. The fourth register is read only. The complete instruction set can be found in the data sheet of the CS5525 from CRYSTAL (<http://www.crystal.com>). This article gives only a description of the relevant ones.

Read and write instructions should be issued through a command byte. Read instructions to the ADC will cause the ADC to delivery three data bytes. Write instruction must by followed by three data bytes. Special instructions are Calibrate and Convert.

Register	Read Command Byte	Write Command Byte
Offset Register	0x90(H)	0x80(H)
Gain Register	0x92(H)	0x82(H)
Configuration Register	0x94(H)	0x84(H)
Data register	0x96(H)	

After a reset or after switching the ADC on, the registers will have the following contest:

	Hb	Mb	Lb
Configuration register	00	00	40 (H)
Offset register	00	00	00 (H)
Gain register	80	00	00 (H)
Data register	00	00	00 (H)

The Hb and Mb from the data register contain data. The Lb contains two flag bits. D0 is the overrange flag. D1 is the oscillation detect flag, which goes up when the ADC is radically overloaded. The other bits from the Lb have no meaning.

The settings of the ADC register for the B-field meter are the default settings, which means 100mVolt FS¹, bipolar and 15Hz Conversion-Word-Rate.

Channels 0...3, 4...7 and 8...11 belongs to the heads A, B, C. The first three channels of a group are the Hall sensors X, Y and Z. The fourth channel gives temperature information.

Channels 12 and/or 13 are to perform "0" (offset) calibration.

Channel 14 is to perform FS (gain) calibration.

Channel 15 is for adjustment of R21 during production. (25°C or 77°F point.)

¹ FS = Full Scale

Configuration Register			
BIT	NAME	VALUE	FUNCTION
D23-D20	Logic Outputs, D3-D0	0000 R*	Bits for sensor select
D19-D16	Not Used	0000 R	Must always be logic 0.
D15-D13	Word Rate		Conversion Word Rate
D12	Uni-/Bipolair	000 R 0 R	15.02 Hz Bipolair Measurement mode
D11-D9	Gain Bits	000 R	100 mVolt
D7	Reset System, RS	0 R	Normal Operation
D6	Reset Valid, RV	1 0	Activate a Reset cycle No reset has occurred or bit has been cleared (read only)
D5	Port Flag, PF	1 R 0 R	Valid Reset has occurred. (Cleared when read.) Port Flag mode inactive
D4	Not Used	1 0 R	Port Flag mode active Not used. Must be a logic 0.
D3	Done Flag, DF	0 R 1	Done Flag bit is cleared (read only) Calibration or Conversion cycle completed (read only)
D2-D0	Calibration Control	000 R 101 110	Normal operation (no calibration) Offset -- System Calibration Gain -- System Calibration
* R indicates the bit value after the part is reset			

Calibration.

To perform an **Offset-calibration**, which must be done before the FS-calibration, select the channel for that purpose (12) by setting bit D22 en D23 from the Configuration-Register. Inclusive command byte the message to be send will be **84 C0 00 00** (H). After sending, wait 20mSec to let the input circuit settle.

After this time set the following bits:

- D0 and D3 to initiate an Offset - System Calibration action.
- D5 to activate the Port Flag mode.
- D22 and D23 to select (maintain) the "0" calibrate channel.

The message to be send to the ADC, inclusive command byte, will be **84 C0 00 25** (H). When the ADC has received this message, it set the Do-line (Port-Flag) high and, when the calibration is finest, it reset it to low.

Toggleing the Clk pin 8 times will clear the Do Port-Flag signal.

When the Offset-calibration is done **FS-calibration** can be performed. To do this, select channel 14 by setting bit D21, D22 and D23 from the Configuration-Register by sending the message **84 E0 00 00** (H) to the ADC. Wait 20mSec to let the input circuit settle.

After this time set the following bits:

- D1 and D2 to initiate a Gain - System Calibration.
- D5 to activate the Port Flag mode.
- D21, D22 and D23 to select (maintain) the FS calibration channel.

The message to be send to the Configuration register, inclusive command byte, will be **84 E0 00 26** (H). When the ADC has received this message, it sets the Do-line (Port-Flag) high and when the calibration is finest it reset it to low. Toggleing the Clk pin 8 times will clear the Do Port-Flag signal.

CS5525 16-Bit Output Coding	
Bipolair Input	Two's Complement
Voltage >(VFS-1.5 LSB)	7FFF
VFS-1.5 LSB	7FFF ----- 7FFE
-0.5LSB	0000 ---- FFFF
VFS+0.5 LSB	8001 ----- 8000
<(VFS+0.5 LSB)	8000

Conversion.

First a channel must be selected and the Port-Flag mode must be set. The message to be send to the ADC will be **84 X0 00 20(H)** where “X” stands for the number of the wanted channel. After 20mSec, the command **C0(H)** can be send. This will start a conversion. The ADC set the Do-line (Port-Flag) high and, when the conversion is finest, it reset it to low.

Now, 32 pulses on the Clk pin will results in 4 data bytes on the Do pin. The first byte does not contain relevant information. The second and third bytes are the H- and L-data bytes respectively. The fourth byte contains a couple of flag bits.

The received data (15 bits + sign) represent a voltage of 0...100mVolt on the input of the ADC. With the help of the temperature conversion table the temperature can now be found. With the help of calibration tables belonging to the conditioner and their Hall sensors, and the CERN read-out software, the strength en the direction of the magnetic field can be found.

NTC table					
T (°C)	T(°F)	ADC (D)	T (°C)	T(°F)	ADC (D)
-10	14	-18913	50	122	25034
0	32	0000	60	140	26017
10	50	10878	70	158	26663
20	68	17274	80	176	27102
30	86	21135	90	194	27400
40	104	23527	100	212	27609
Thermometrics NTC Type DC95 - 5kOhm F W					

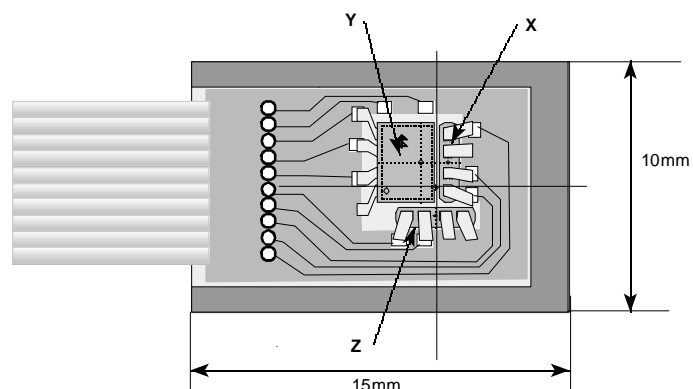
Initialisation.

As a result of an error, e.g. disconnecting of a cable, the communication with the ADC may be lost. If this happens the communication with the ADC can be restored by sending “ FFFF FFFF FFFF FFFF FFFF FFFF FFFF FFFE (H)” (minimal 15 x F followed by an E) over the Di line. Doing so does not alter the content of the registers. As usually the error source is unknown, it is advisable to reset the ADC and redo the calibration procedure.

Switching on.

Switching on the module (ADC) has, after a start up time of about 600mSec, as result that all register get there default state and it RV bit (Reset Valid) set. Therefore calibration is needed to get maximum accuracy.

Orientation of the Hall elements.



Adjustments during production.

Adjustments should be done after Offset- and Full scale-calibration.

Select channel 15.

Adjust R21 to 19439 (D) on the ADC with correspond to 25°C or 77°F.

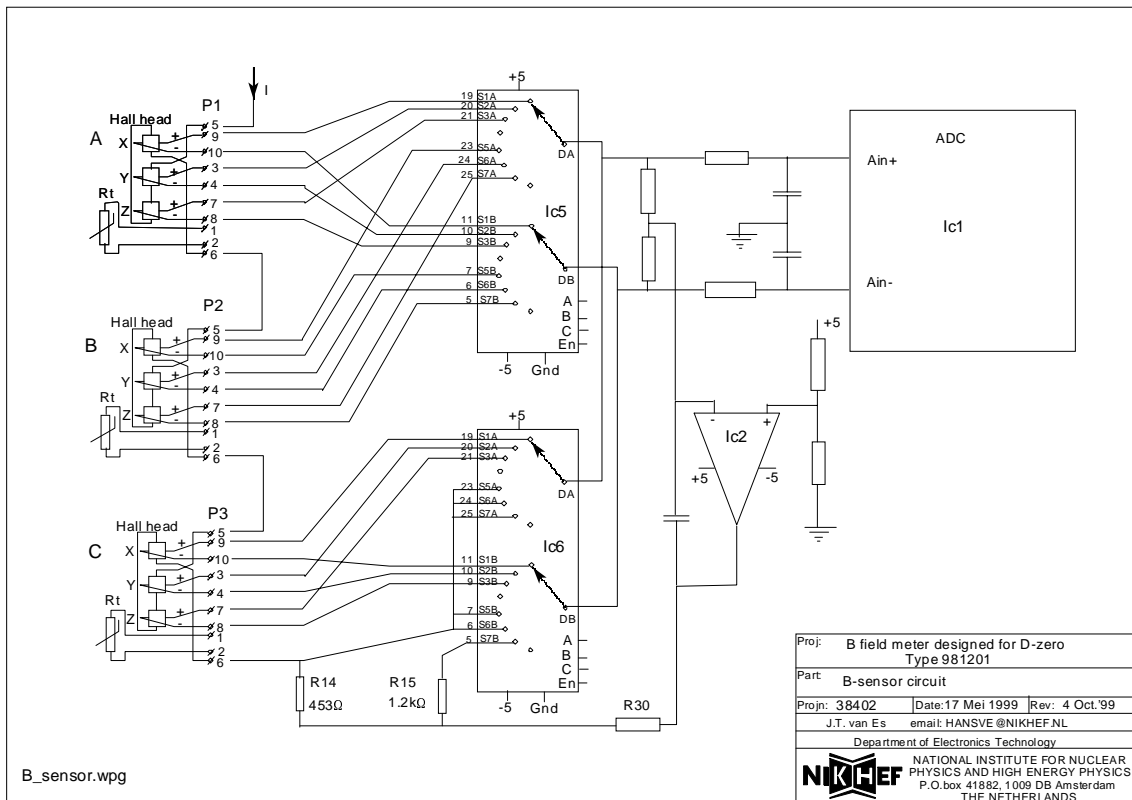
Part list

C1, 15	Capacitor	1µF 25V	SAL ⁴	PHILIPS 2222 128 36108 ⁵
C2, 8	Capacitor	10µF 6.3V	SAL	PHILIPS 2222 128 33109
C3, 5	Capacitor	100nF	Z5U Cer.	
C4	Capacitor	15nF	X7R Cer.	
C6	Capacitor	4.7nF	X7R Cer.	
C7	Capacitor	470nF	Z5U Cer.	
C9	Capacitor	22pF	NP0 Cer	
C10, 11	Capacitor	1nF	NP0 Cer.	
C12	Capacitor	390pF	NP0 Cer	
C13, 14	Capacitor	10nF	X7R Cer	
D1	Diode	BAV99 W		Philips
Ic1	ADC	CS5525AS		CRYSTAL
Ic2, 3, 4	Opamp	LMC7101BIM5		Nat. Sem.
Ic5, 6	Multiplexer	DG407DN		Vishay
Ic7	Regulator	LM2936Z5.0		Nat. Sem
Ic8	Logic Inverter	NC7S04M5		Farchild Farnell 685-914
		SN74AHC1G04DBV		Texas Inst.
IcH 9x	Hall Sensor	KSY44		SIEMENS Q62705-K265
P1	Connector	10pol		3M3793-5302 Farnell 468-447
P2,3,4	Printconnector	10Pol		Odu 515.067.035.010.010
P2,3,3	Cableconnector	10Pol		Odu 525.060.035.010.010
	Cable Miniflex	10Pol (10feet)		Odu 921.659.031.010.000
Q1	P-Fet	BSS84		Philips Farnell 516-557
R1	Resistor	5.76kΩ 0.5% 25ppm		VITROHM 526-0 5K76 0.5% T9
R2	Resistor	12.4kΩ 0.5% 25ppm		VITROHM 526-0 12K4 0.5% T9
R3	Resistor	18.2kΩ 0.5% 25ppm		VITROHM 526-0 18K2 0.5% T9
R4	Resistor	3.65kΩ 0.5% 25ppm		VITROHM 526-0 3K65 0.5% T9
R5	Resistor	22kΩ 2% 100ppm		VITROHM 526-0 22K 2% T0
R6	Resistor	1kΩ 2% 100ppm		VITROHM 526-0 1K0 2% T0
R7	Resistor	100Ω 2% 100ppm		VITROHM 526-0 100R 2% T0
R8	Resistor			
R9, 12, 13	Resistor	15kΩ 2% 100ppm		VITROHM 526-0 15K 2% T0
R10, 11	Resistor	120Ω 2% 100ppm		VITROHM 526-0 120R 2% T0
R14	Resistor	453Ω 0.5% 25ppm		VITROHM 526-0 453R 0.5% T9
R15	Resistor	1.2kΩ 2% 100ppm		VITROHM 526-0 1K2 2% T0
R16,17,18,19,20	Resistor	392kΩ 0.5% 25ppm		VITROHM 526-0 392K 0.5% T9
R21	Resistor trim	1kΩ Cermet		BOURNS 3314J Farnell 514-755
R22	Resistor	15.8kΩ 0.5% 25ppm		VITROHM 526-0 15K8 0.5% T9
R23	Resistor	4.99kΩ 0.5% 25ppm		VITROHM 526-0 4K99 0.5% T9
R24, 25	Resistor	18kΩ 2% 100ppm		VITROHM 526-0 18K 2% T0
R26, 27	Resistor	10MegΩ 2% 100ppm		VITROHM 526-0 10M 2% T0
R28	Resistor	56.2kΩ 0.5% 25ppm		VITROHM 526-0 56K2 0.5% T9
R29	Resistor	4.87kΩ 0.5% 25ppm		VITROHM 526-0 4K87 0.5% T9
R30	Resistor	390Ω 2% 100ppm		VITROHM 526-0 390R 2% T0
Rth 3x	Thermistor	5kΩ@25°C ±0.2°C		THERMOMETRICS DC95F
X1	Crystal	32.768kHz		IQD 6x2mm Farnell 221-533
	2x	PLCC socket	28pin	3M 228-7161-71-3857 Farnell 547-554
		Print		
		Conditioner Box		
		Mounting plate		
	3x	Hall Sensor assembly		

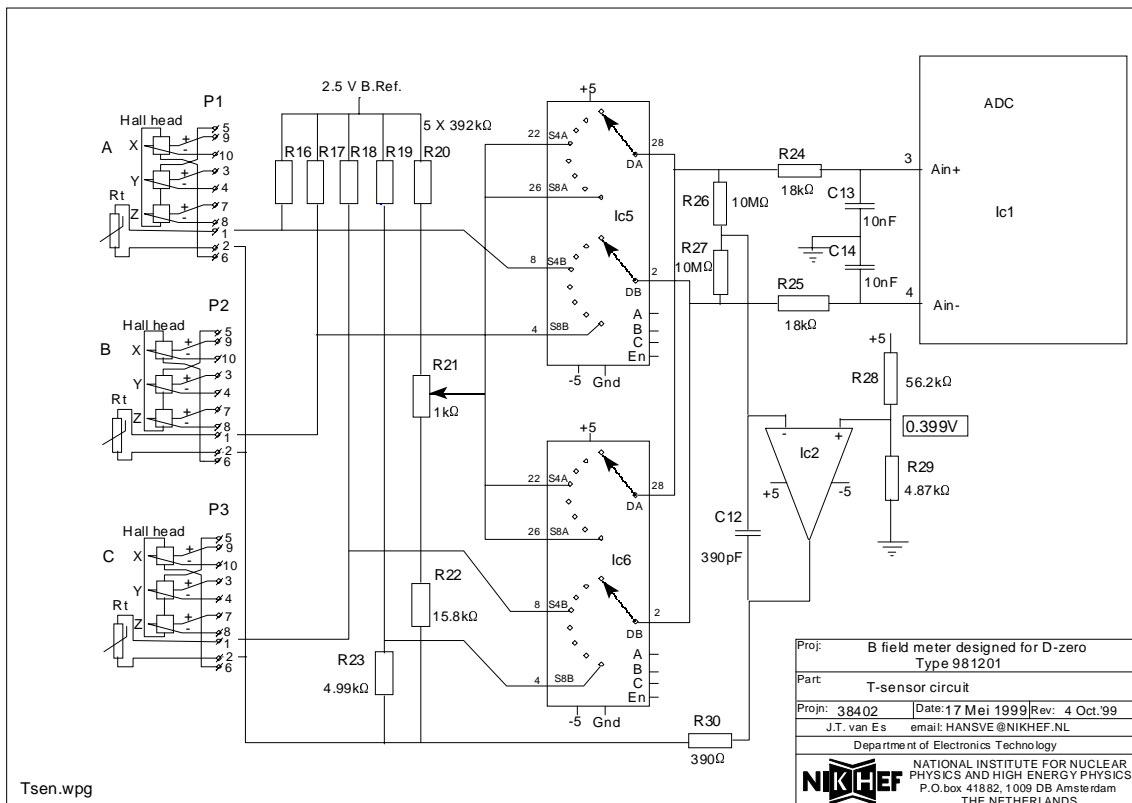
⁴ SAL Solid Aluminium Electrolytic Capacitor.

⁵ Warning. This ordernumber is the number for a reel of 2000 units

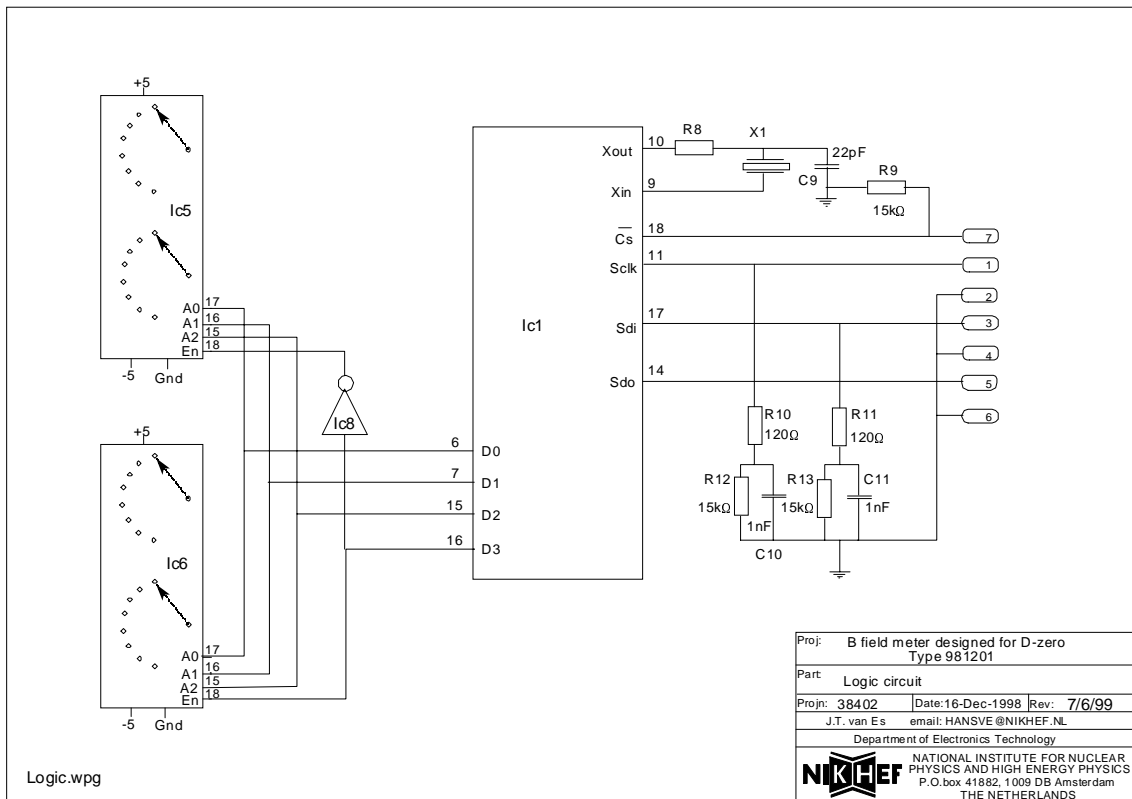
B-sensor circuit.



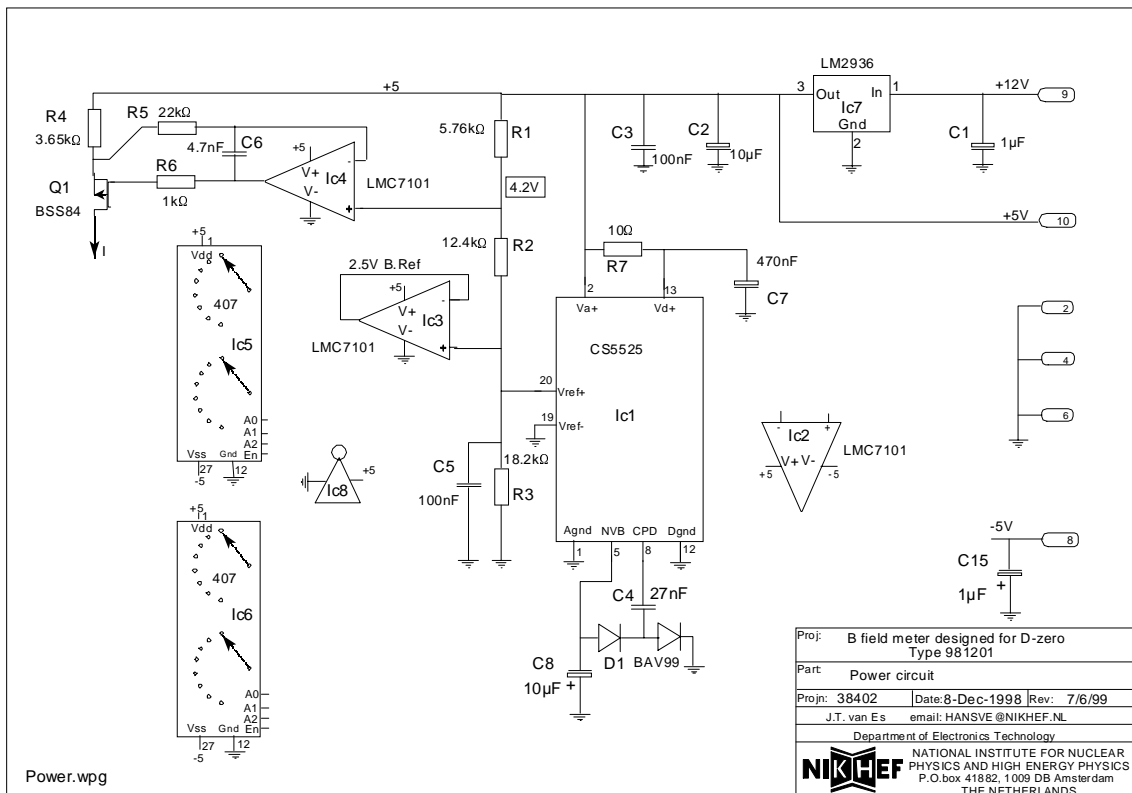
T-sensor circuit.



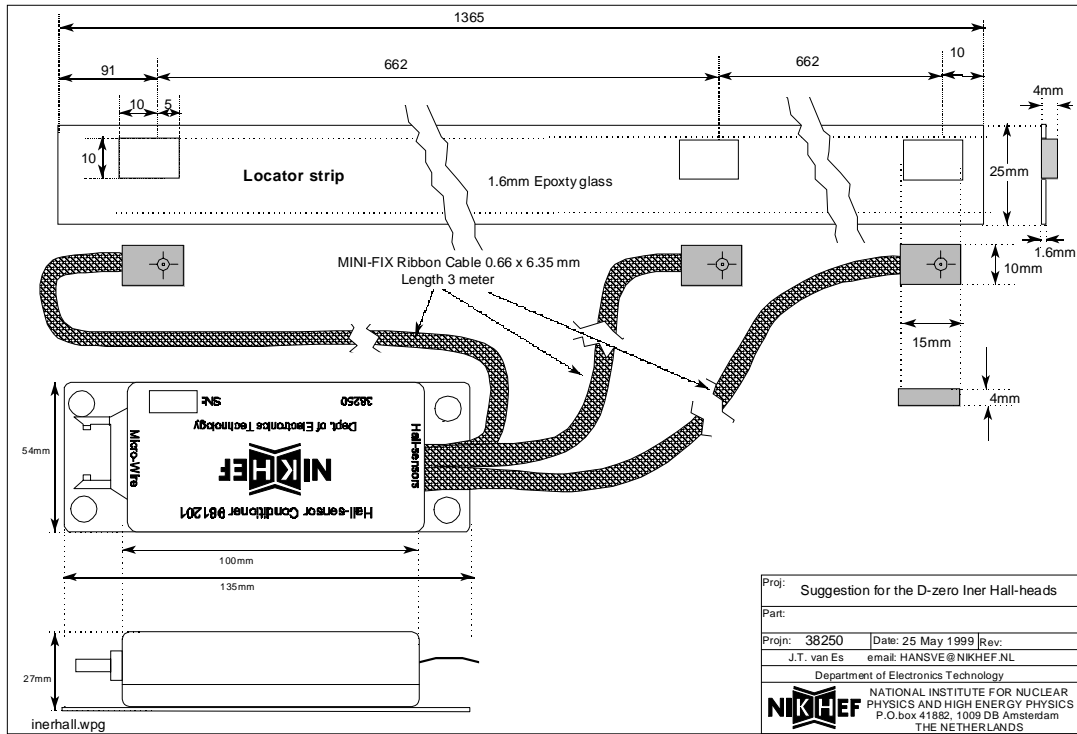
Logic circuit.



Power circuit.



Mechanical layout.



Mounting plate.

