SIR

SMART-1 Near Infrared Spectrometer

Data Handling ICD

Part of EID-B

S1-SIR-ICD-3004

Issue 5.2

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Approval Sheet

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Document change record:

Date	Page	Remarks
27.6.2000	All	Complete revised
31.8.2000	1	Modified commands list, two commands combined, usable as real time commands
31.8.2000	2	Use of only one APID
31.8.2000	3	Modified telecommands and parameters
31.8.2000	4	Error flags introduced in HK data
31.8.2000	4	Added software state diagram and description
14.12.2000	5	figure 1 updated
28.02.2001	1	Text updated
28.02.2001	4	Slight changes in “set measurement parameters”, new note on “set compression parameter”
28.02.2001	6	“Exposure time row” changed in table HK data as …
28.02.2001	6	Used EEM error flags inserted
28.02.2001	6	TBD removed in table “Spectral data as used for …”
28.02.2001	7	Text updated
15.05.2001	All	Complete revised
29.05.2002	3 – 9	IDA/Reiche
31.05.2002	3	Text updated
31.05.2002	9	Footnotes added
31.05.2002	10	Text updated
10.10.2002	6	Application data table updated
10.10.2002	10	Footnote changed, YSI added
10.10.2002	12	Shielding Bow Thermistor Calibration Curve added
10.10.2002	17	Conversion table for YSI added
10.10.2002	19-21	HK conversion tables/diagrams for voltages and currents added

Contents

1. Introduction / Basics

The SIR science data structure consists of two TM packets. The first includes the HK data (25 bytes) and the second the spectral data (512 bytes). The total science data consists of 537 bytes. It is possible to measure and to read only the housekeeping information.

We distinguish between the integration time and the measurement interval time. The measurement interval time is the time in which a single integration occurs (if spectral averaging is inactivated). The interval time is changeable via commanding. The standard value is set to 100 ms. This corresponds to a data rate of 47.41 Kbit/s (1.35 ms). The integration time is adaptable to the scientific needs. Values between 0.1 (@4MHz) and 528 ms (@2MHz) are feasible. The common integration time in Moon Orbit will be below 100 ms.

The total data length of all parts of one spectrum, consisting of science data (512 Bytes), HK data (25 Bytes) and the headers (2 times 6 Bytes) is 549 bytes.

The upgraded “set averaging parameter” contains:

- Mean spectra calculation
- ADC multiple read
- Clock frequency change

SIR´s internal spectra averaging capability allows to take several short time spectra in an interval time without an increase of CAN-Bus data rate. This mode is used for scenarios where short integration times are needed (e.g. high dark current intervals) and improve therefore the scientific output of the instrument[1]. The additional implemented clock frequency change and the multiple read capability of the ADC improves the S/N ratio[2].

It will be possible to reprogram SIR in flight. This patch capability is based on three commands for the (P)FM (see TC and TM list). The SIR time tagged command budged will be used to transport strings of time tagged commands, which will include parts of the changed SIR software.

The following time-tagged commands exist (all listed commands are also usable as real time commands, if necessary):

1. ON – Command (command to S/C to power SIR)
2. OFF – Command (command to S/C to power off SIR)
3. Standby – Command
4. Preparation – Command
5. Start Measurement – Command
6. Set Measurement Parameters – Command
7. Set HK Parameters – Command
8. Set Heater Parameters – Command
9. Set Averaging Parameters – Command
10. Memory Load – Command

[1] The averaging capability shouldn’t be activated for periods, which would lead to smearing of the ground spot.
[2] A lowering of the clock frequency and an increase of the multiple read reduces of course the number of obtained spectra per time.

11. Memory Dump – Command
12. Memory Check – Command
13. Reset – Command (for W/D test only, must not be sent during flight)

Time-tagged command budges:

Earth escape phase: In this mission phase it is planned to observe bright stars. The budged for time-tagged commands will not exceed approx. 6400 bytes and not the number of approx. 800 commands. The observations could be performed in a period of a few days length.

Moon observation phase: The time-tagged command budget will not exceed approx. 13280 bytes over a 4 days cycle. The maximum number of commands will not exceed approx. 1660 in a 4 days cycle. During the “mapping phase of the mission” (burst mode measurements over several hours) the budgets will be lesser. The maximum number of commands is needed when calibration stars and specific surface objects will be observed. The time tagged command budget will be also used for in flight reprogramming of SIR.

2. Telecommand

All telecommand data is in acc. to EID-A and uses “Big Endian” format, i.e. MSBs are sent first.

Common packet header for all SIR telecommand packets:

Packet Header								Packet Data Field	
Packet ID				Packet Source Control			Packet Length	Application Data	
Version Number	Type	Data Field Header	APID	Sequence Flags	Source ID	Sequence Count		Structure Identifier	Parameters
3	1	1	11	2	2	12	16	8	n * 8
000	1	0	APID	11	SID	Counter	Octets in Packet Data Field – 1	STID	

Supported APIDs (only APID 1001d will be used by SIR):

APID	Description
01111101001 (1001d)	SIR
00000000000 (0d)	Time Packet
11111111111 (2047d)	Idle Packet

Supported SIDs:

SID	Description
00	Ground all sources
01	Time Tag Commands
10	Reserved
11	Other on-board source

Supported application data:

Mnemonic	Description	Application Data Field	
		STID	Parameters (Number of letters in <> corresponds to bit sizes)
G0000C	NOP (for I/F test only)	00h	–
G0001C	Standby Mode	01h	–
G0002C	Preparation Mode	02h	–
G0003C	Measurement Mode	03h	–
G0004C	Set Measurement Parameters	04h	G040M= <eee> <mmmmm> ***Exposure Time*** Calculation using exponent & mantissa as follows (time in [ms]): $(Exp = 0):\ T_{EXP} = \frac{Mant \cdot 262144}{f_{CLK}}$ $(Exp > 0):\ T_{EXP} = \frac{(32 + Mant) \cdot 2^{(Exp-1)} \cdot 262144}{f_{CLK}}$ f_{CLK} is derived from G0007C
			Default: 0x32 = 3.277 ms
			G041M = <sssssssssssssss> ***Number of Spectra*** 0d = off (→ stand-by mode) 1d – 65534d = number of spectra 65535d = infinite burst (for test)
			Default: 0 = off
			G042M = <iiiiiiii> ***Measurement Interval Time*** 0d = 1d 1d – 255d = interval time in [5 ms] units **Note:** The "Telemetry Interval Time" is this time multiplied by the ***Number of Spectra for Mean*** (see G0007C below)
			Default: 0x14 = 100 ms
G0005C	Set HK Parameters	05h	G050M = <pppppppp> ***H/K Acquisition Period*** 0d = off (→ stand-by mode) 1d – 255d = period in [s] units
			Default: 0d = off
G0006C	Set Heater Parameters	06h	G060M = <aaaaaaaaaaaaaaaa> ***Deactivation Temperature*** 1d – 65534d = activation temperature (See temperature table)
			Default: 60265d = –72.9 °C

Mnemonic	Description	Application Data Field	
		STID	Parameters (Number of letters in <> corresponds to bit sizes)
			G061M = <dddddddddddddddd>[1] ***Activation Temperature*** 1d – 65534d = deactivation temperature (See temperature table) When both parameters are set to: 0d = heater off 65535d = heater on
			Default: 60280d = –73.0 °C
G0007C	Set Averaging Parameters	07h	G070M = <mmm><cc><aaa>
			<mmm> ***Number of Spectra for Mean*** 0d – 7d = 2^N, 1 … 128 spectra
			Default: 0d = 1 spectrum
			<cc> ***ADC Clock Mode*** 0d = reserved (6 MHz, not operable) 1d = 4 MHz 2d = 3 MHz 3d = 2 MHz
			Default: 1d = 4 MHz
			<aaa> ***Multiple ADC Sampling*** 0d – 4d = 2^N, 1 … 16 samples 5d – 7d = 16 samples 3d = default $T_{sample} = N_{steps} * 64 *(256+7) / f_{clk}$
			Default: 3d = 8 sample
G0008C	Memory Load	08h	G080M = <aaaaaaaaaaaa> ***First Memory Address*** 0d – 65535d = memory address
			G081M = <llllllll> ***Memory Length*** 0d = 256 bytes 1d – 255d = number of bytes to load
			G082M = <dddddddd/0> ... <dddddddd/n-1> ***Memory Data*** 0d – 255d data pattern
G0009C	Memory Dump	09h	G080M = <aaaaaaaaaaaa> ***First Memory Address*** 0d – 65535d = memory address

[1] The G041M Parameter shall be update soon in DB.

Mnemonic	Description	Application Data Field	
		STID	Parameters (Number of letters in <> corresponds to bit sizes)
			G081M = <llllllll> ***Memory Length*** 0d = 256 bytes 1d – 255d = number of bytes to dump
G000A	Memory Check	0Ah	G080M = <aaaaaaaaaaaa> ***First Memory Address*** 0d – 65535d = memory address
			G081M = <llllllll> ***Memory Length*** 0d = 256 bytes 1d – 255d = number of bytes to check
G000B	Reset Instrument (for W/D test only)	0Bh	Not applicable for (P)FM

3. Telemetry

All telemetry data is in acc. to EID-A and uses Big Endian format, i.e. MSBs are sent first.

Common packet header for all SIR telemetry packets:

Packet Header							Packet Data Field
Packet ID				Packet Source Control		Packet Length	Source Data
Version Number	Type	Data Field Header	APID	Segmentation Flags	Sequence Count		Data
3	1	1	11	2	14	16	n * 8
000	0	0	1001d – 1004d (See below)	11	Counter	Octets in Packet Data Field – 1	

Supported APIDs:

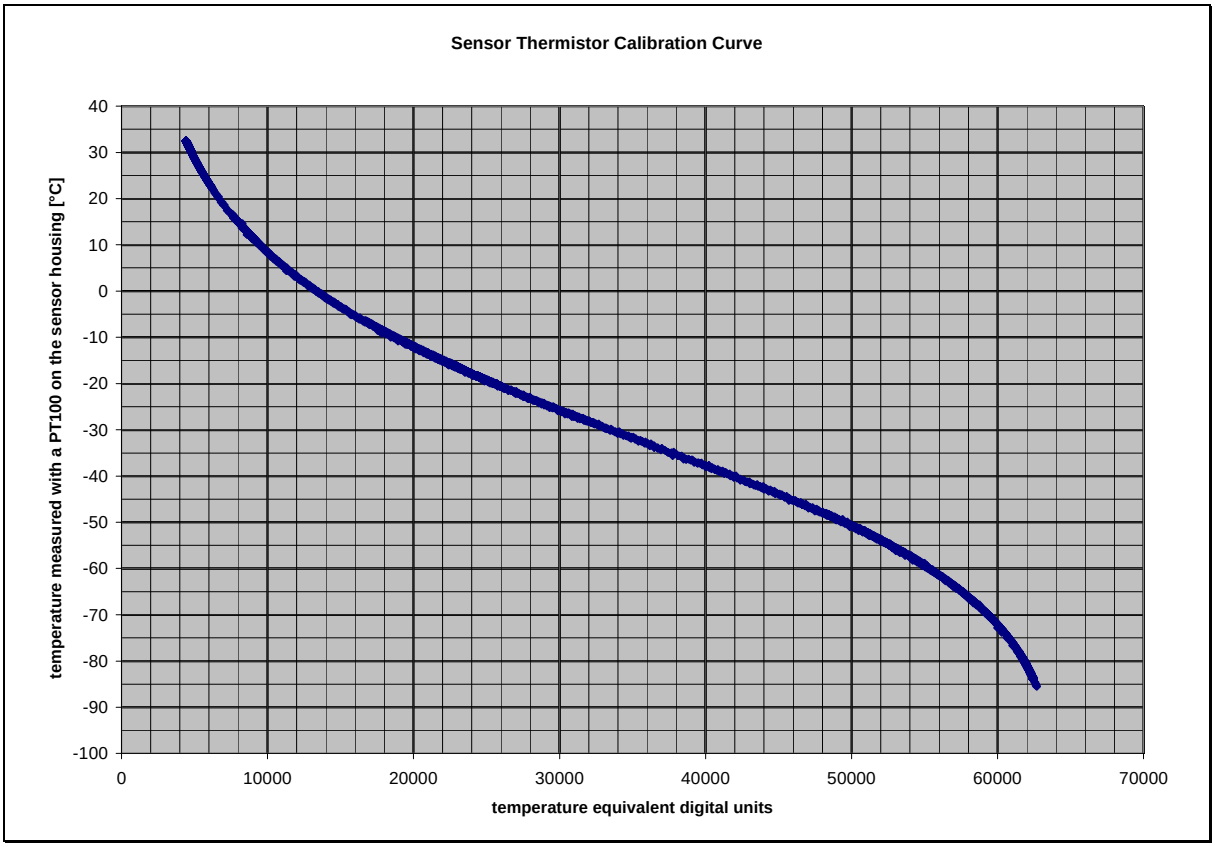
Mnemonic	Description	APID	Application Data Field (Number of letters in <> corresponds to bit sizes)
MSIR0001	HK	1001d	<hhhhhhhh/0> ... <hhhhhhhh/24> ***SIR H/K Data*** 25 octets H/K data (see table below)
MSIR0002	Science	1002d	<ssssssssssssssss/0> ... <ssssssssssssssss/255> ***SIR Spectral Data*** 256 pixels, 16 bits each
MSIR0004	Memory Dump	1003d	<aaaaaaaaaaaa> ***First Memory Address*** 0d – 65535d = memory address
			<llllllll> ***Memory Length*** 0d = 256 bytes 1d – 255d = number of dumped bytes
			<dddddddd/0> ... <dddddddd/n-1> ***Memory Data*** 0d – 255d data pattern

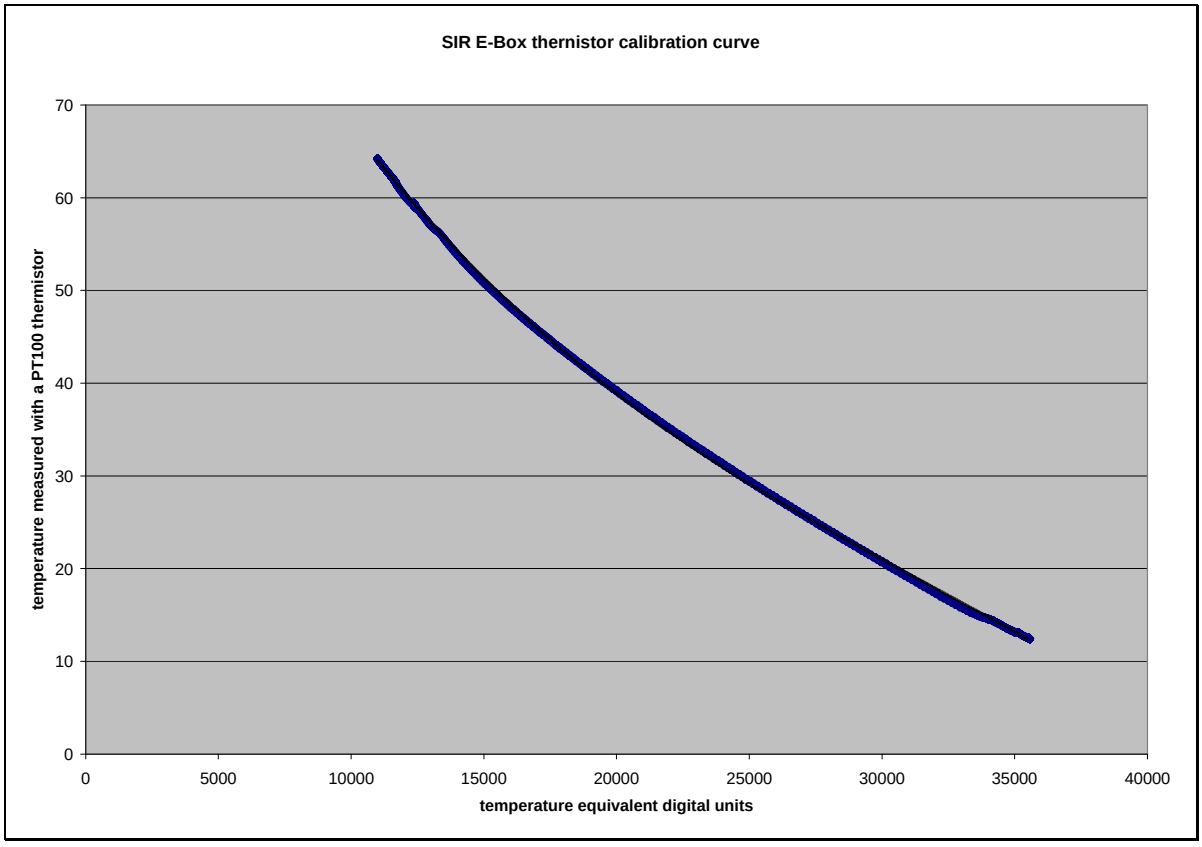
Mnemonic	Description	APID	Application Data Field (Number of letters in <> corresponds to bit sizes)
MSIR0005	Memory Check	1004d	<aaaaaaaaaaaa> ***First Memory Address*** 0d – 65535d = memory address
			<llllllll> ***Memory Length*** 0d = 256 bytes 1d – 255d = number of checked bytes
			<ccccccccccccccc> ***Memory Checksum*** 0d – 65535d = checksum (acc. to CRC-16)

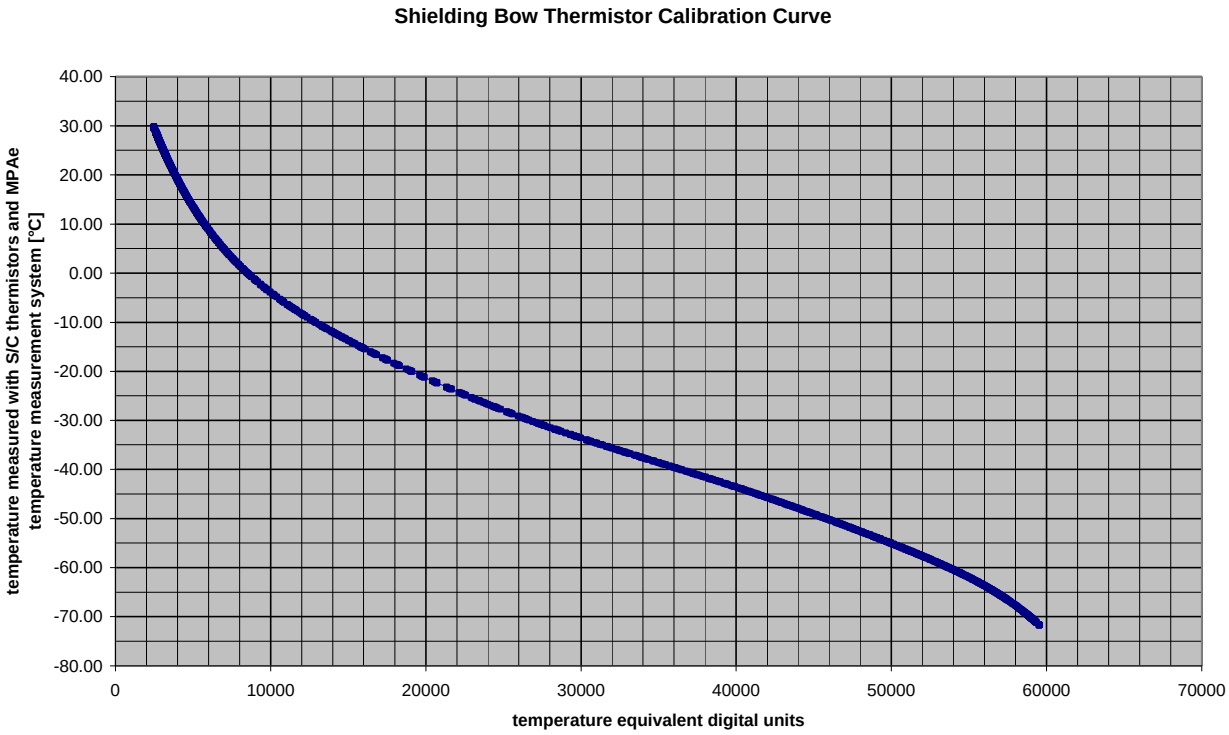
HK data:

Description	Number of Octets	Range	Resolution
Start of exposure	5	SCET	2^{-8} s (2^{-5} s internal)
W/D reset counter	1	0d … 255d	–
Exposure time	1	See corresponding telecommand	–
Detector temperature[3]	2	See table	
YSI temperature[4]	2	See table	
E–box temperature	2	See table	
+5V voltage	2	0.0 … 6.76 V	~ 103 µV
+3.3V voltage	2	0.0 … 4.36 V	~ 66 µV
+5V E-Box current	2	-60 … 1509 mA	~ 24 µA
+5V sensor head current	2	-9 … 324 mA	~ 5.1 µA
CAN RX overruns	1	0d … 255d	–
CAN TX errors	1	0d … 255d	–
µ-Controller processing load	1	0 … 100 %	0.39 %
Averaging parameters	1	See corresponding telecommand	–
Total	25		

[3] Measured on test unit, PFM correction to be applied
[4] Measured on PFM Instrument unit with commercial E-Box, PFM E-Box correction to be applied


Sensor Thermistor Calibration Curve
temperature measured with a PT100 on the sensor housing [°C]
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
0
10000
20000
30000
40000
50000
60000
70000
temperature equivalent digital units


SIR E-Box thernistor calibration curve
temperature measured with a PT100 thermistor
70
60
50
40
30
20
10
0
0
5000
10000
15000
20000
25000
30000
35000
40000
temperature equivalent digital units


Shielding Bow Thermistor Calibration Curve
temperature measured with S/C thermistors and MPAe temperature measurement system [°C]
40.00
30.00
20.00
10.00
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
-60.00
-70.00
-80.00
0
10000
20000
30000
40000
50000
60000
70000
temperature equivalent digital units

Sensor thermistor conversion table[5]

digital value		temperature [°C]
0x0000	0	51.1
0x0100	256	49.8
0x0200	512	48.5
0x0300	768	47.3
0x0400	1024	46.0
0x0500	1280	44.8
0x0600	1536	43.6
0x0700	1792	42.4
0x0800	2048	41.2
0x0900	2304	40.1
0x0A00	2560	38.9
0x0B00	2816	37.8
0x0C00	3072	36.6
0x0D00	3328	35.5
0x0E00	3584	34.4
0x0F00	3840	33.3
0x1000	4096	32.3
0x1100	4352	31.2
0x1200	4608	30.2
0x1300	4864	29.1
0x1400	5120	28.1
0x1500	5376	27.1
0x1600	5632	26.1
0x1700	5888	25.2
0x1800	6144	24.2
0x1900	6400	23.2
0x1A00	6656	22.3
0x1B00	6912	21.4
0x1C00	7168	20.5
0x1D00	7424	19.6
0x1E00	7680	18.7
0x1F00	7936	17.8
0x2000	8192	16.9
0x2100	8448	16.1
0x2200	8704	15.2
0x2300	8960	14.4
0x2400	9216	13.6
0x2500	9472	12.8
0x2600	9728	12.0
0x2700	9984	11.2
0x2800	10240	10.4
0x2900	10496	9.6
0x2A00	10752	8.9
0x2B00	11008	8.1
0x2C00	11264	7.4
0x2D00	11520	6.7
0x2E00	11776	6.0
0x2F00	12032	5.2
0x3000	12288	4.6
0x3100	12544	3.9
0x3200	12800	3.2
0x3300	13056	2.5
0x3400	13312	1.9
0x3500	13568	1.2
0x3600	13824	0.6
0x3700	14080	0.0
0x3800	14336	-0.6
0x3900	14592	-1.3
0x3A00	14848	-1.9
0x3B00	15104	-2.4
0x3C00	15360	-3.0
0x3D00	15616	-3.6
0x3E00	15872	-4.2
0x3F00	16128	-4.7
0x4000	16384	-5.3
0x4100	16640	-5.8
0x4200	16896	-6.4
0x4300	17152	-6.9
0x4400	17408	-7.4
0x4500	17664	-7.9
0x4600	17920	-8.4
0x4700	18176	-8.9
0x4800	18432	-9.4
0x4900	18688	-9.9
0x4A00	18944	-10.3
0x4B00	19200	-10.8
0x4C00	19456	-11.3
0x4D00	19712	-11.7
0x4E00	19968	-12.2
0x4F00	20224	-12.6
0x5000	20480	-13.0
0x5100	20736	-13.5
0x5200	20992	-13.9
0x5300	21248	-14.3
0x5400	21504	-14.7
0x5500	21760	-15.1
0x5600	22016	-15.5
0x5700	22272	-15.9
0x5800	22528	-16.3
0x5900	22784	-16.7
0x5A00	23040	-17.1
0x5B00	23296	-17.4
0x5C00	23552	-17.8
0x5D00	23808	-18.2
0x5E00	24064	-18.5
0x5F00	24320	-18.9
0x6000	24576	-19.2
0x6100	24832	-19.5
0x6200	25088	-19.9
0x6300	25344	-20.2
0x6400	25600	-20.6
0x6500	25856	-20.9
0x6600	26112	-21.2
0x6700	26368	-21.5
0x6800	26624	-21.8
0x6900	26880	-22.1
0x6A00	27136	-22.4
0x6B00	27392	-22.8
0x6C00	27648	-23.1
0x6D00	27904	-23.4
0x6E00	28160	-23.6
0x6F00	28416	-23.9
0x7000	28672	-24.2
0x7100	28928	-24.5
0x7200	29184	-24.8
0x7300	29440	-25.1
0x7400	29696	-25.4
0x7500	29952	-25.6
0x7600	30208	-25.9
0x7700	30464	-26.2
0x7800	30720	-26.5
0x7900	30976	-26.7
0x7A00	31232	-27.0
0x7B00	31488	-27.3
0x7C00	31744	-27.5
0x7D00	32000	-27.8
0x7E00	32256	-28.1
0x7F00	32512	-28.3
0x8000	32768	-28.6

[5] PFM correction to be applied.

0x8100	33024	-28.8
0x8200	33280	-29.1
0x8300	33536	-29.4
0x8400	33792	-29.6
0x8500	34048	-29.9
0x8600	34304	-30.1
0x8700	34560	-30.4
0x8800	34816	-30.6
0x8900	35072	-30.9
0x8A00	35328	-31.2
0x8B00	35584	-31.4
0x8C00	35840	-31.7
0x8D00	36096	-31.9
0x8E00	36352	-32.2
0x8F00	36608	-32.4
0x9000	36864	-32.7
0x9100	37120	-33.0
0x9200	37376	-33.2
0x9300	37632	-33.5
0x9400	37888	-33.8
0x9500	38144	-34.0
0x9600	38400	-34.3
0x9700	38656	-34.6
0x9800	38912	-34.8
0x9900	39168	-35.1
0x9A00	39424	-35.4
0x9B00	39680	-35.7
0x9C00	39936	-36.0
0x9D00	40192	-36.2
0x9E00	40448	-36.5
0x9F00	40704	-36.8
0xA000	40960	-37.1
0xA100	41216	-37.4
0xA200	41472	-37.7
0xA300	41728	-38.0
0xA400	41984	-38.3
0xA500	42240	-38.6
0xA600	42496	-38.9
0xA700	42752	-39.2
0xA800	43008	-39.5
0xA900	43264	-39.8
0xAA00	43520	-40.2
0xAB00	43776	-40.5
0xAC00	44032	-40.8
0xAD00	44288	-41.2
0xAE00	44544	-41.5
0xAF00	44800	-41.8
0xB000	45056	-42.2
0xB100	45312	-42.6
0xB200	45568	-42.9
0xB300	45824	-43.3
0xB400	46080	-43.6
0xB500	46336	-44.0
0xB600	46592	-44.4
0xB700	46848	-44.8
0xB800	47104	-45.2
0xB900	47360	-45.6
0xBA00	47616	-46.0
0xBB00	47872	-46.4
0xBC00	48128	-46.8
0xBD00	48384	-47.2
0xBE00	48640	-47.6
0xBF00	48896	-48.0
0xC000	49152	-48.5
0xC100	49408	-48.9
0xC200	49664	-49.4
0xC300	49920	-49.8
0xC400	50176	-50.3
0xC500	50432	-50.8
0xC600	50688	-51.2
0xC700	50944	-51.7
0xC800	51200	-52.2
0xC900	51456	-52.7
0xCA00	51712	-53.2
0xCB00	51968	-53.7
0xCC00	52224	-54.2
0xCD00	52480	-54.8
0xCE00	52736	-55.3
0xCF00	52992	-55.9
0xD000	53248	-56.4
0xD100	53504	-57.0
0xD200	53760	-57.5
0xD300	54016	-58.1
0xD400	54272	-58.7
0xD500	54528	-59.3
0xD600	54784	-59.9
0xD700	55040	-60.5
0xD800	55296	-61.1
0xD900	55552	-61.8
0xDA00	55808	-62.4
0xDB00	56064	-63.0
0xDC00	56320	-63.7
0xDD00	56576	-64.4
0xDE00	56832	-65.1
0xDF00	57088	-65.7
0xE000	57344	-66.4
0xE100	57600	-67.1
0xE200	57856	-67.9
0xE300	58112	-68.6
0xE400	58368	-69.3
0xE500	58624	-70.1
0xE600	58880	-70.8
0xE700	59136	-71.6
0xE800	59392	-72.4
0xE900	59648	-73.2
0xEA00	59904	-74.0
0xEB00	60160	-74.8
0xEC00	60416	-75.6
0xED00	60672	-76.5
0xEE00	60928	-77.3
0xEF00	61184	-78.2
0xF000	61440	-79.0
0xF100	61696	-79.9
0xF200	61952	-80.8
0xF300	62208	-81.7
0xF400	62464	-82.6
0xF500	62720	-83.6
0xF600	62976	-84.5
0xF700	63232	-85.5
0xF800	63488	-86.5
0xF900	63744	-87.4
0xFA00	64000	-88.4
0xFB00	64256	-89.4
0xFC00	64512	-90.5
0xFD00	64768	-91.5
0xFE00	65024	-92.5
0xFF00	65280	-93.6

E-Box thermistor conversion table

digital value		temperature [°C]
0x0000	0	115.1
0x0100	256	113.6
0x0200	512	112.1
0x0300	768	110.6
0x0400	1024	109.1
0x0500	1280	107.6
0x0600	1536	106.2
0x0700	1792	104.8
0x0800	2048	103.4
0x0900	2304	102.0
0x0A00	2560	100.6
0x0B00	2816	99.3
0x0C00	3072	98.0
0x0D00	3328	96.6
0x0E00	3584	95.3
0x0F00	3840	94.1
0x1000	4096	92.8
0x1100	4352	91.5
0x1200	4608	90.3
0x1300	4864	89.1
0x1400	5120	87.9
0x1500	5376	86.7
0x1600	5632	85.5
0x1700	5888	84.3
0x1800	6144	83.2
0x1900	6400	82.1
0x1A00	6656	80.9
0x1B00	6912	79.8
0x1C00	7168	78.7
0x1D00	7424	77.7
0x1E00	7680	76.6
0x1F00	7936	75.5
0x2000	8192	74.5
0x2100	8448	73.5
0x2200	8704	72.5
0x2300	8960	71.5
0x2400	9216	70.5
0x2500	9472	69.5
0x2600	9728	68.6
0x2700	9984	67.6
0x2800	10240	66.7
0x2900	10496	65.8
0x2A00	10752	64.9
0x2B00	11008	64.0
0x2C00	11264	63.1
0x2D00	11520	62.2
0x2E00	11776	61.3
0x2F00	12032	60.5
0x3000	12288	59.7
0x3100	12544	58.8
0x3200	12800	58.0
0x3300	13056	57.2
0x3400	13312	56.4
0x3500	13568	55.6
0x3600	13824	54.8
0x3700	14080	54.1
0x3800	14336	53.3
0x3900	14592	52.6
0x3A00	14848	51.8
0x3B00	15104	51.1
0x3C00	15360	50.4
0x3D00	15616	49.7
0x3E00	15872	49.0
0x3F00	16128	48.3
0x4000	16384	47.6
0x4100	16640	47.0
0x4200	16896	46.3
0x4300	17152	45.7
0x4400	17408	45.0
0x4500	17664	44.4
0x4600	17920	43.8
0x4700	18176	43.1
0x4800	18432	42.5
0x4900	18688	41.9
0x4A00	18944	41.3
0x4B00	19200	40.7
0x4C00	19456	40.2
0x4D00	19712	39.6
0x4E00	19968	39.0
0x4F00	20224	38.5
0x5000	20480	37.9
0x5100	20736	37.4
0x5200	20992	36.8
0x5300	21248	36.3
0x5400	21504	35.8
0x5500	21760	35.2
0x5600	22016	34.7
0x5700	22272	34.2
0x5800	22528	33.7
0x5900	22784	33.2
0x5A00	23040	32.7
0x5B00	23296	32.2
0x5C00	23552	31.7
0x5D00	23808	31.3
0x5E00	24064	30.8
0x5F00	24320	30.3
0x6000	24576	29.9
0x6100	24832	29.4
0x6200	25088	28.9
0x6300	25344	28.5
0x6400	25600	28.1
0x6500	25856	27.6
0x6600	26112	27.2
0x6700	26368	26.7
0x6800	26624	26.3
0x6900	26880	25.9
0x6A00	27136	25.4
0x6B00	27392	25.0
0x6C00	27648	24.6
0x6D00	27904	24.2
0x6E00	28160	23.8
0x6F00	28416	23.4
0x7000	28672	22.9
0x7100	28928	22.5
0x7200	29184	22.1
0x7300	29440	21.7
0x7400	29696	21.3
0x7500	29952	20.9
0x7600	30208	20.5
0x7700	30464	20.1
0x7800	30720	19.7
0x7900	30976	19.3
0x7A00	31232	18.9
0x7B00	31488	18.5
0x7C00	31744	18.1
0x7D00	32000	17.7
0x7E00	32256	17.4
0x7F00	32512	17.0
0x8000	32768	16.6
0x8100	33024	16.2
0x8200	33280	15.8
0x8300	33536	15.4
0x8400	33792	15.0
0x8500	34048	14.6
0x8600	34304	14.2
0x8700	34560	13.8

0x8800	34816	13.4
0x8900	35072	13.0
0x8A00	35328	12.6
0x8B00	35584	12.2
0x8C00	35840	11.8
0x8D00	36096	11.4
0x8E00	36352	11.0
0x8F00	36608	10.6
0x9000	36864	10.2
0x9100	37120	9.7
0x9200	37376	9.3
0x9300	37632	8.9
0x9400	37888	8.5
0x9500	38144	8.1
0x9600	38400	7.6
0x9700	38656	7.2
0x9800	38912	6.8
0x9900	39168	6.3
0x9A00	39424	5.9
0x9B00	39680	5.4
0x9C00	39936	5.0
0x9D00	40192	4.5
0x9E00	40448	4.1
0x9F00	40704	3.6
0xA000	40960	3.2
0xA100	41216	2.7
0xA200	41472	2.2
0xA300	41728	1.7
0xA400	41984	1.2
0xA500	42240	0.7
0xA600	42496	0.2
0xA700	42752	-0.3
0xA800	43008	-0.8
0xA900	43264	-1.3
0xAA00	43520	-1.8
0xAB00	43776	-2.3
0xAC00	44032	-2.9
0xAD00	44288	-3.4
0xAE00	44544	-3.9
0xAF00	44800	-4.5
0xB000	45056	-5.0
0xB100	45312	-5.6
0xB200	45568	-6.2
0xB300	45824	-6.8
0xB400	46080	-7.3
0xB500	46336	-7.9
0xB600	46592	-8.5
0xB700	46848	-9.1
0xB800	47104	-9.8
0xB900	47360	-10.4
0xBA00	47616	-11.0
0xBB00	47872	-11.7
0xBC00	48128	-12.3
0xBD00	48384	-13.0
0xBE00	48640	-13.6
0xBF00	48896	-14.3
0xC000	49152	-15.0
0xC100	49408	-15.7
0xC200	49664	-16.4
0xC300	49920	-17.1
0xC400	50176	-17.8
0xC500	50432	-18.6
0xC600	50688	-19.3
0xC700	50944	-20.1
0xC800	51200	-20.8
0xC900	51456	-21.6
0xCA00	51712	-22.4
0xCB00	51968	-23.2
0xCC00	52224	-24.0
0xCD00	52480	-24.8
0xCE00	52736	-25.6
0xCF00	52992	-26.4
0xD000	53248	-27.3
0xD100	53504	-28.1
0xD200	53760	-29.0
0xD300	54016	-29.9
0xD400	54272	-30.8
0xD500	54528	-31.7
0xD600	54784	-32.6
0xD700	55040	-33.5
0xD800	55296	-34.5
0xD900	55552	-35.4
0xDA00	55808	-36.4
0xDB00	56064	-37.4
0xDC00	56320	-38.4
0xDD00	56576	-39.4
0xDE00	56832	-40.4
0xDF00	57088	-41.4
0xE000	57344	-42.5
0xE100	57600	-43.5
0xE200	57856	-44.6
0xE300	58112	-45.7
0xE400	58368	-46.8
0xE500	58624	-47.9
0xE600	58880	-49.1
0xE700	59136	-50.2
0xE800	59392	-51.4
0xE900	59648	-52.5
0xEA00	59904	-53.7
0xEB00	60160	-54.9
0xEC00	60416	-56.1
0xED00	60672	-57.4
0xEE00	60928	-58.6
0xEF00	61184	-59.9
0xF000	61440	-61.2
0xF100	61696	-62.5
0xF200	61952	-63.8
0xF300	62208	-65.1
0xF400	62464	-66.5
0xF500	62720	-67.8
0xF600	62976	-69.2
0xF700	63232	-70.6
0xF800	63488	-72.0
0xF900	63744	-73.4
0xFA00	64000	-74.9
0xFB00	64256	-76.3
0xFC00	64512	-77.8
0xFD00	64768	-79.3
0xFE00	65024	-80.8
0xFF00	65280	-82.4

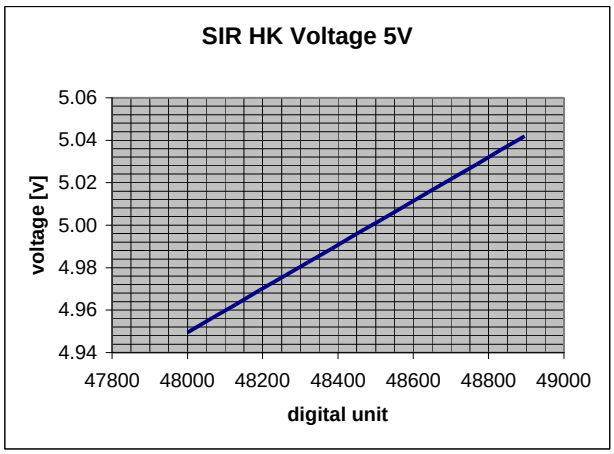
Conversion table for "shielding bow thermistor" (YSI)[6]

digital value		temperature [°C]
0x0000	0	54.9
0x0100	256	51.8
0x0200	512	48.8
0x0300	768	45.9
0x0400	1024	43.1
0x0500	1280	40.5
0x0600	1536	38.0
0x0700	1792	35.6
0x0800	2048	33.3
0x0900	2304	31.2
0x0A00	2560	29.1
0x0B00	2816	27.1
0x0C00	3072	25.2
0x0D00	3328	23.4
0x0E00	3584	21.7
0x0F00	3840	20.1
0x1000	4096	18.5
0x1100	4352	17.0
0x1200	4608	15.6
0x1300	4864	14.2
0x1400	5120	12.9
0x1500	5376	11.7
0x1600	5632	10.5
0x1700	5888	9.4
0x1800	6144	8.3
0x1900	6400	7.2
0x1A00	6656	6.2
0x1B00	6912	5.2
0x1C00	7168	4.3
0x1D00	7424	3.4
0x1E00	7680	2.6
0x1F00	7936	1.7
0x2000	8192	1.0
0x2100	8448	0.2
0x2200	8704	-0.5
0x2300	8960	-1.3
0x2400	9216	-2.0
0x2500	9472	-2.6
0x2600	9728	-3.3
0x2700	9984	-3.9
0x2800	10240	-4.5
0x2900	10496	-5.1
0x2A00	10752	-5.7
0x2B00	11008	-6.2
0x2C00	11264	-6.8
0x2D00	11520	-7.3
0x2E00	11776	-7.8
0x2F00	12032	-8.4
0x3000	12288	-8.9
0x3100	12544	-9.4
0x3200	12800	-9.8
0x3300	13056	-10.3
0x3400	13312	-10.8
0x3500	13568	-11.2
0x3600	13824	-11.7
0x3700	14080	-12.2
0x3800	14336	-12.6
0x3900	14592	-13.0
0x3A00	14848	-13.5
0x3B00	15104	-13.9
0x3C00	15360	-14.3
0x3D00	15616	-14.7
0x3E00	15872	-15.1
0x3F00	16128	-15.5
0x4000	16384	-16.0
0x4100	16640	-16.4
0x4200	16896	-16.8
0x4300	17152	-17.1
0x4400	17408	-17.5
0x4500	17664	-17.9
0x4600	17920	-18.3
0x4700	18176	-18.7
0x4800	18432	-19.1
0x4900	18688	-19.5
0x4A00	18944	-19.8
0x4B00	19200	-20.2
0x4C00	19456	-20.6
0x4D00	19712	-20.9
0x4E00	19968	-21.3
0x4F00	20224	-21.7
0x5000	20480	-22.0
0x5100	20736	-22.4
0x5200	20992	-22.8
0x5300	21248	-23.1
0x5400	21504	-23.5
0x5500	21760	-23.8
0x5600	22016	-24.1
0x5700	22272	-24.5
0x5800	22528	-24.8
0x5900	22784	-25.2
0x5A00	23040	-25.5
0x5B00	23296	-25.8
0x5C00	23552	-26.2
0x5D00	23808	-26.5
0x5E00	24064	-26.8
0x5F00	24320	-27.1
0x6000	24576	-27.5
0x6100	24832	-27.8
0x6200	25088	-28.1
0x6300	25344	-28.4
0x6400	25600	-28.7
0x6500	25856	-29.0
0x6600	26112	-29.3
0x6700	26368	-29.6
0x6800	26624	-29.9
0x6900	26880	-30.2
0x6A00	27136	-30.5
0x6B00	27392	-30.8
0x6C00	27648	-31.1
0x6D00	27904	-31.4
0x6E00	28160	-31.6
0x6F00	28416	-31.9
0x7000	28672	-32.2
0x7100	28928	-32.5
0x7200	29184	-32.8
0x7300	29440	-33.0
0x7400	29696	-33.3
0x7500	29952	-33.6
0x7600	30208	-33.8
0x7700	30464	-34.1
0x7800	30720	-34.4
0x7900	30976	-34.6
0x7A00	31232	-34.9
0x7B00	31488	-35.1
0x7C00	31744	-35.4
0x7D00	32000	-35.7
0x7E00	32256	-35.9
0x7F00	32512	-36.2
0x8000	32768	-36.4
0x8100	33024	-36.7
0x8200	33280	-36.9

[6] Update for PFM E-box instead of "commercial" E-Box possibly necessary.

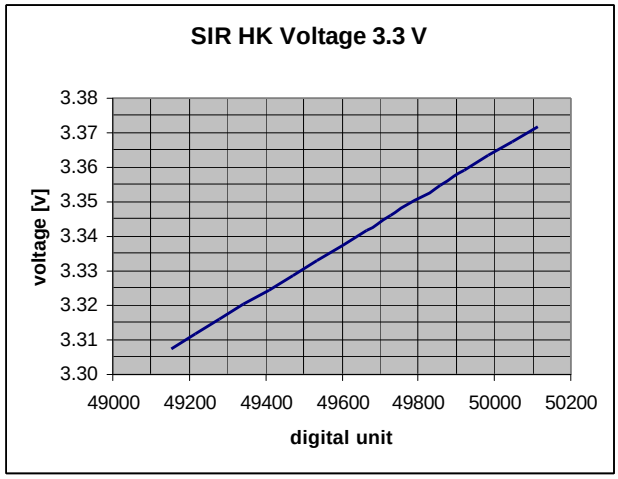
0x8300	33536	-37.2
0x8400	33792	-37.4
0x8500	34048	-37.7
0x8600	34304	-37.9
0x8700	34560	-38.2
0x8800	34816	-38.4
0x8900	35072	-38.7
0x8A00	35328	-38.9
0x8B00	35584	-39.2
0x8C00	35840	-39.4
0x8D00	36096	-39.7
0x8E00	36352	-39.9
0x8F00	36608	-40.2
0x9000	36864	-40.4
0x9100	37120	-40.7
0x9200	37376	-41.0
0x9300	37632	-41.2
0x9400	37888	-41.5
0x9500	38144	-41.7
0x9600	38400	-42.0
0x9700	38656	-42.2
0x9800	38912	-42.5
0x9900	39168	-42.8
0x9A00	39424	-43.0
0x9B00	39680	-43.3
0x9C00	39936	-43.6
0x9D00	40192	-43.8
0x9E00	40448	-44.1
0x9F00	40704	-44.4
0xA000	40960	-44.6
0xA100	41216	-44.9
0xA200	41472	-45.2
0xA300	41728	-45.4
0xA400	41984	-45.7
0xA500	42240	-46.0
0xA600	42496	-46.3
0xA700	42752	-46.6
0xA800	43008	-46.8
0xA900	43264	-47.1
0xAA00	43520	-47.4
0xAB00	43776	-47.7
0xAC00	44032	-48.0
0xAD00	44288	-48.3
0xAE00	44544	-48.6
0xAF00	44800	-48.9
0xB000	45056	-49.2
0xB100	45312	-49.4
0xB200	45568	-49.7
0xB300	45824	-50.0
0xB400	46080	-50.3
0xB500	46336	-50.6
0xB600	46592	-50.9
0xB700	46848	-51.2
0xB800	47104	-51.5
0xB900	47360	-51.9
0xBA00	47616	-52.2
0xBB00	47872	-52.5
0xBC00	48128	-52.8
0xBD00	48384	-53.1
0xBE00	48640	-53.4
0xBF00	48896	-53.7
0xC000	49152	-54.0
0xC100	49408	-54.3
0xC200	49664	-54.7
0xC300	49920	-55.0
0xC400	50176	-55.3
0xC500	50432	-55.6
0xC600	50688	-55.9
0xC700	50944	-56.3
0xC800	51200	-56.6
0xC900	51456	-56.9
0xCA00	51712	-57.3
0xCB00	51968	-57.6
0xCC00	52224	-57.9
0xCD00	52480	-58.3
0xCE00	52736	-58.6
0xCF00	52992	-59.0
0xD000	53248	-59.4
0xD100	53504	-59.7
0xD200	53760	-60.1
0xD300	54016	-60.5
0xD400	54272	-60.8
0xD500	54528	-61.2
0xD600	54784	-61.6
0xD700	55040	-62.0
0xD800	55296	-62.5
0xD900	55552	-62.9
0xDA00	55808	-63.3
0xDB00	56064	-63.8
0xDC00	56320	-64.2
0xDD00	56576	-64.7
0xDE00	56832	-65.2
0xDF00	57088	-65.7
0xE000	57344	-66.3
0xE100	57600	-66.8
0xE200	57856	-67.4
0xE300	58112	-68.0
0xE400	58368	-68.6
0xE500	58624	-69.2
0xE600	58880	-69.9
0xE700	59136	-70.6
0xE800	59392	-71.3
0xE900	59648	-72.1
0xEA00	59904	-72.9
0xEB00	60160	-73.7
0xEC00	60416	-74.5
0xED00	60672	-75.5
0xEE00	60928	-76.4
0xEF00	61184	-77.4
0xF000	61440	-78.5
0xF100	61696	-79.6
0xF200	61952	-80.7
0xF300	62208	-81.9
0xF400	62464	-83.2
0xF500	62720	-84.6
0xF600	62976	-86.0
0xF700	63232	-87.4
0xF800	63488	-89.0
0xF900	63744	-90.7
0xFA00	64000	-92.4
0xFB00	64256	-94.2
0xFC00	64512	-96.1
0xFD00	64768	-98.1
0xFE00	65024	-100.2
0xFF00	65280	-102.5

5V HK Value



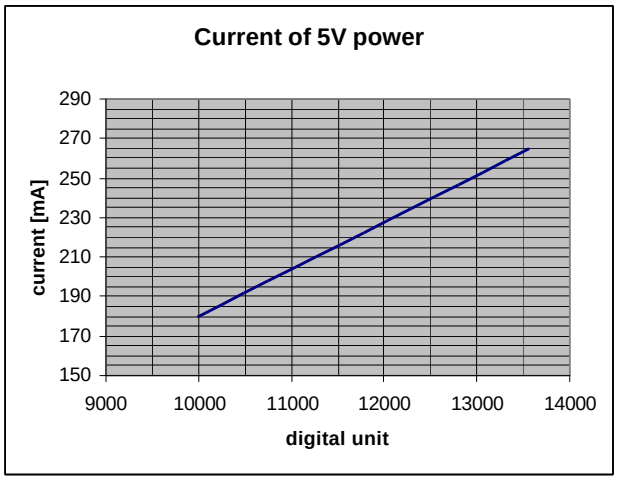
digital value		voltage [V]
0xBB80	48000	4.95
0xBBC0	48064	4.96
0xBC00	48128	4.96
0xBC40	48192	4.97
0xBC80	48256	4.98
0xBCC0	48320	4.98
0xBD00	48384	4.99
0xBD40	48448	5.00
0xBD80	48512	5.00
0xBDC0	48576	5.01
0xBE00	48640	5.02
0xBE40	48704	5.02
0xBE80	48768	5.03
0xBEC0	48832	5.04
0xBF00	48896	5.04

3.3 V HK Value



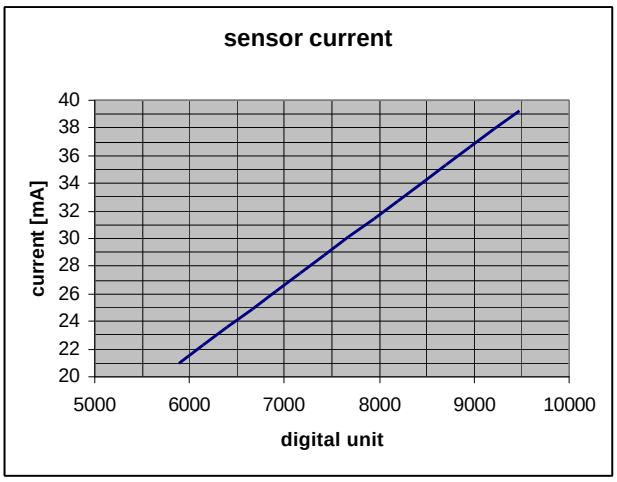
digital value		voltage [V]
0xC000	49152	3.31
0xC040	49216	3.31
0xC080	49280	3.32
0xC0C0	49344	3.32
0xC100	49408	3.32
0xC140	49472	3.33
0xC180	49536	3.33
0xC1C0	49600	3.34
0xC200	49664	3.34
0xC240	49728	3.35
0xC2C0	49856	3.35
0xC300	49920	3.36
0xC340	49984	3.36
0xC380	50048	3.37
0xC3C0	50112	3.37

Current (5V power) HK Value



digital value		current [mA]
0x2700	9984	179
0x2800	10240	185
0x2900	10496	192
0x2A00	10752	198
0x2B00	11008	204
0x2C00	11264	210
0x2D00	11520	216
0x2E00	11776	222
0x2F00	12032	228
0x3000	12288	235
0x3100	12544	241
0x3200	12800	247
0x3300	13056	253
0x3400	13312	259
0x3500	13568	265

Sensor Current HK Value



digital value		current [mA]
0x1700	5888	21
0x1800	6144	22
0x1900	6400	24
0x1A00	6656	25
0x1B00	6912	26
0x1C00	7168	27
0x1D00	7424	29
0x1E00	7680	30
0x1F00	7936	31
0x2000	8192	33
0x2100	8448	34
0x2200	8704	35
0x2300	8960	37
0x2400	9216	38
0x2500	9472	39

4. Software State Diagram

Figure 1 illustrates the operation of the instrument software. After power up, the unit enters the **Standby** mode. Standby mode and **Preparation** mode clocks the sensor at the measurement rate without reading data. All parameter commands (G004C, G005C, G006C and G007C) are accepted in **Standby** and **Preparation** mode. During **Measurement** mode, the Set Measurement Parameter (G0004C) will not take effect. This command is executed after the measurement is finished to ensure that a running measurement is not altered. A measurement can be stopped by setting the instrument to Standby or Preparation Mode. All Errors are mentioned in the HK-Data Error Flags. Only complete measurements are sent. If a measurement is uncomplete (due to errors) it will be ignored and the next measurement will be sent.

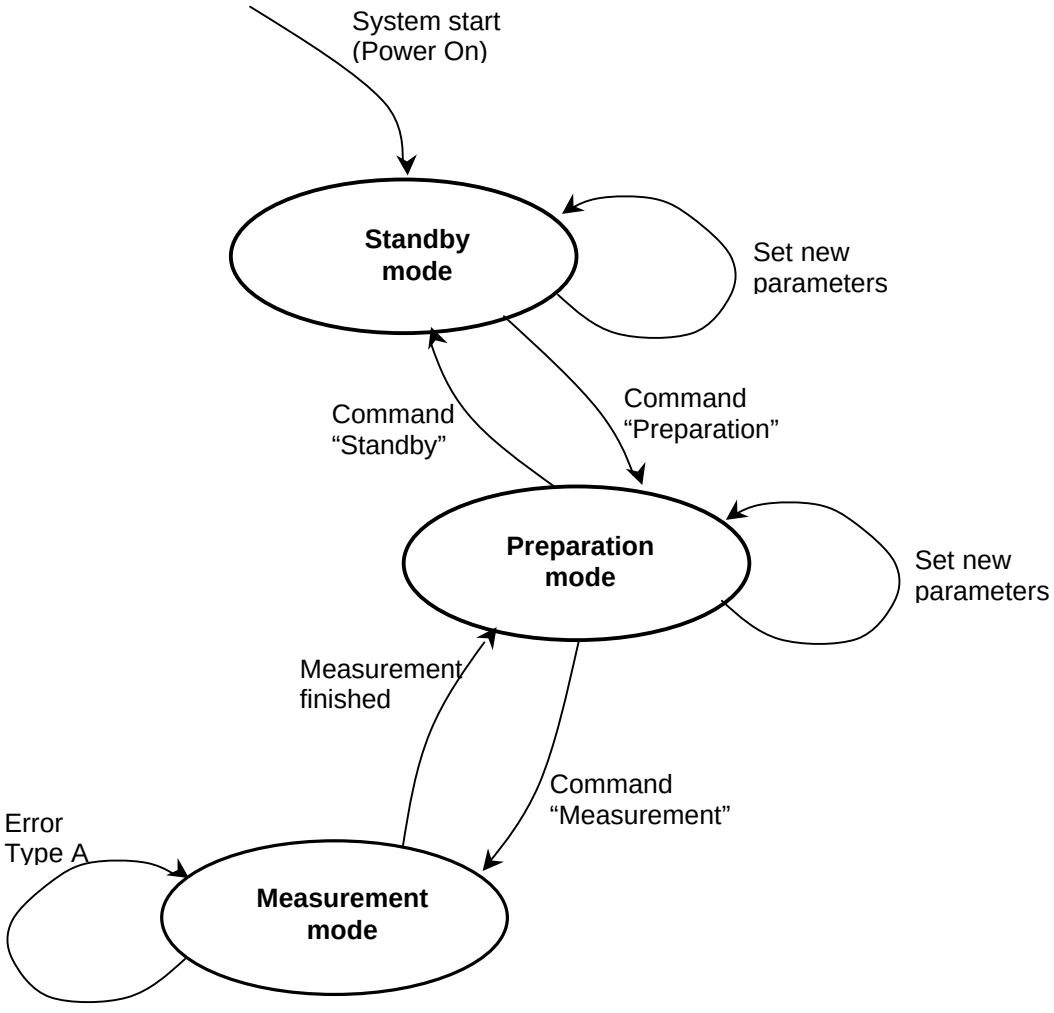


Figure 1: State diagram of the SIR instrument software.