User manual
StrainBUSter

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1 Introduction

There is an increasing tendency to study the behavior of large mechanical constructions like bridges, wind turbines, tower cranes, etc, under varying load conditions.
Usually it is quite inconvenient to apply half- or full straingauge bridges onto such constructions, for which reason mostly single (1/4 bridge) gauges are utilized. This, however, usually implies cumbersome wiring to the inputs of the (remote) measuring amplifiers.
StrainBUSter has been developed to overcome these problems by placing the measuring circuit in the direct vicinity of each point of measuring. Here all signal conditioning is done, after which all measured values are being transported via a CAN bus to one convenient central place, thus building one decentralized system. In this way, up to 120 measured values can be transported very reliably over longer distances.
One StrainBUSter module has 2 separate input channels.
The single straingauge, or the Pt100 sensor, is connected through a 3-wire connection, eliminating cable losses at the input side.
The CAN bus speed can be set between 10 and 1000Kbit/sec, allowing a maximum network cable length of some 30 meters at 1 Mbit/sec and 5 Kilometers at 10 Kbit/sec when the correct cable is being used. Each module has 2 identical sets of CAN bus connection terminals, to enable easy installation of a so-called Daisy Chain Network.
A maximum of 60 units can be connected to one bus.

For explanation of ¼, ½ and 1/1 bridge connections see 3.2 (page 11).

1.1 Principle of operation

A simplified block schematic diagram gives an idea of how the StrainBUSter unit is built.

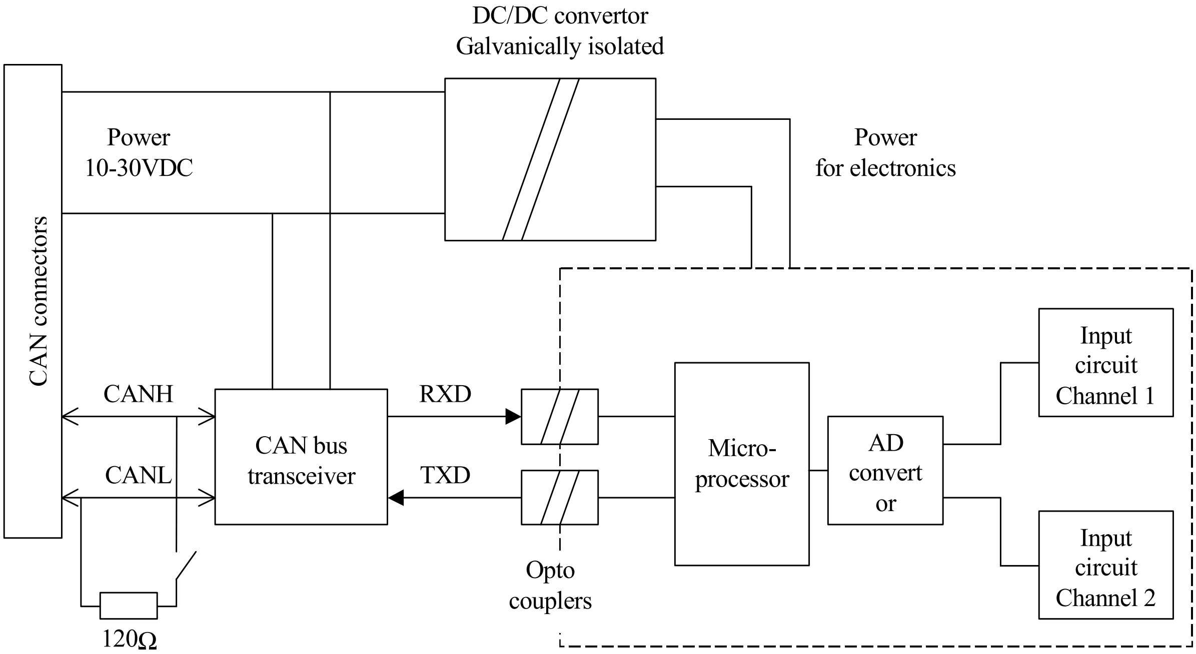


Figure 1-1: Block schematic diagram

Essential in the StrainBUSter is that the measurement electronics are galvanically separated from the CAN bus and from the power which is connected to the connector.
The two input channels are **not** galvanically separated from each other.
Due to this build-up, multiple StrainBUSter units can be connected to the same power supply, without the problem that all input channels are, galvanically, connected to each other.
A simple terminator resistor is mounted on the StrainBUSter. If other termination is required, this must be done on the connector.

1.2 StrainBUSter models

The StrainBUSter is available in several models. The basic two models are:

- housing for DIN rail mounting
- housing for panel mounting

The standard models hold just 1 StrainBUSter unit. However it is possible to order a model which hold more StrainBUSter units in 1 housing.
In this multi-unit model, a connection is made between adjacent units, which connects the power supply and CAN BUS of the 2 StrainBUSter units.

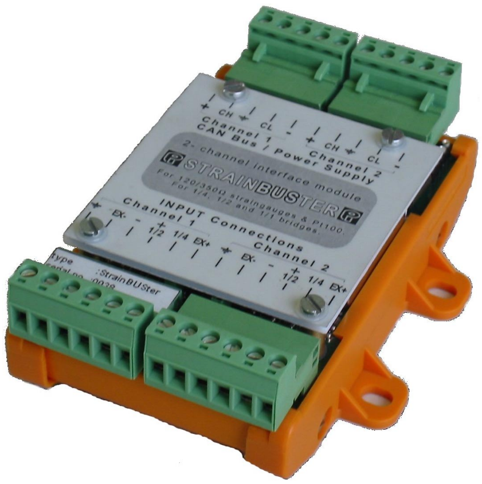


Figure 1-2: Panel mounting HCA-F/1

Figure 1-3: DIN rail mounting HCA-R/1

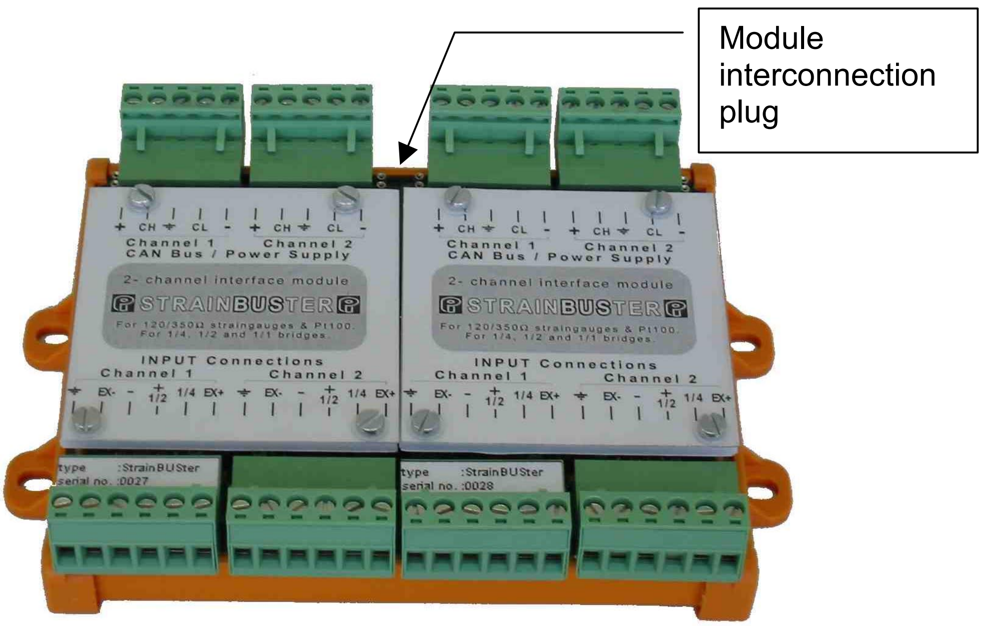


Figure 1-4: Multi-unit Panel mounting HCA-F/2

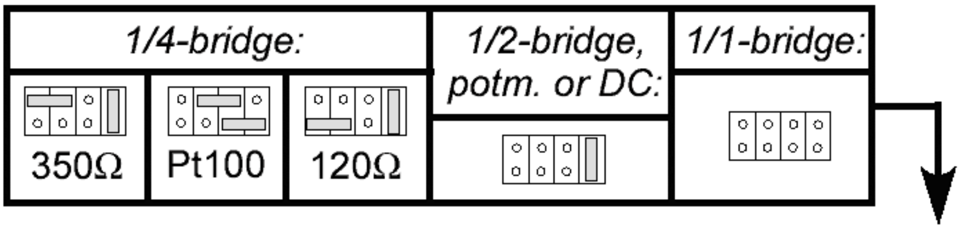
2 StrainBUSter configuration

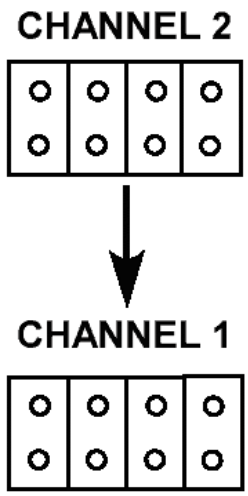
The operation of the StrainBUSter depends on several settings. By changing these settings the user can influence the operation of the StrainBUSter.
The settings are made by software through the CAN bus and by jumpers on the StrainBUSter.

2.1 Jumper settings

The bridge compensation of the input circuit can be altered by setting a jumper. The type of measurement is determined by this jumper setting. The following settings can be made:

Input jumpersettings :

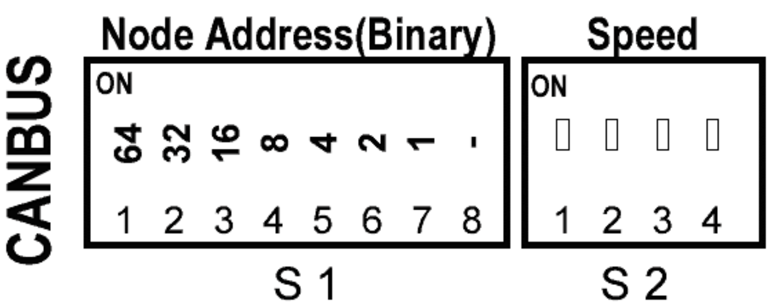




CANBUS Speed-settings(S2):

S2-1 On	S2-2 On	S2-3 On	CAN bus speed	Maximum Cable Length
			1000 Kb/sec	30m
		x	800 Kb/sec	50m
	x		500 Kb/sec	100m
	x	x	250 Kb/sec	250m
x			125 Kb/sec	500m
x		x	50 Kb/sec	1000m
x	x		20 Kb/sec	2500m

S2-4: Bus-terminatorswitch



Figuur 2-1: Layout dip switches & jumpers

2.1.1 Default settings

At factory, the StrainBUSter units are set at the following default setting:

- input: ¼ bridge: 350 Ω
- CANBUS speed: 500Kb/sec
- CANBUS address: 0

When more units in 1 housing are delivered, the CANBUS address starts at 0 and will be 1 higher for each extra unit

2.1.2 CAN bus dipswitch settings

On the StrainBUSter several jumpers and dipswitches are present.
The dipswitches are used to set the node address on the CAN bus and the speed of the CAN bus.

The CAN bus speed is set by S2:

S2-1	S2-2	S2-3	CAN bus speed	Maximum cable length
Off	Off	Off	1000 Kb/sec	30 m
Off	Off	**On**	800 Kb/sec	50 m
Off	**On**	Off	500 Kb/sec	100 m
Off	**On**	**On**	250 Kb/sec	250 m
On	Off	Off	125 Kb/sec	500 m
On	Off	**On**	50 Kb/sec	1000 m
On	**On**	**Off**	20 Kb/sec	2500 m

Just for reference the maximum cable length is mentioned in this table.

When switch 4 of S2 is in the **‘ON’** position, the internal termination resistor of 120 Ω is connected to the CAN bus lines.

The CAN address is set by S1 & S2:

	ON	OFF	
S1/S2-7	**1**		LSB **L**east **S**ignificant **B**it
S1/S2-6	**2**		
S1/S2-5	**4**		
S1/S2-4	**8**		
S1/S2-3	**16**		
S1/S2-2	**32**		
S1/S2-1	**64**		MSB **M**ost **S**ignificant **B**it

This address is binary coded, when switch is in the **’ON’** position the corresponding bit is **‘1’**. Switch 7 is the **L**east **S**ignificant **B**it of the address.

2.1.3 LED’s

The Strainbuster has two LED’s onboard.
When red LED blinks with a frequency of about 0,5 Hz, this indicates that the firmware is normally running.
When communication on the CAN bus is detected the green LED with light for 0.5 seconds. With constant communication on the CAN bus, this LED will light always.

2.2 Software settings

The following settings can be made by software:

Type of measurement:	
	Quarter bridge
	PT100 temperature
	Half/Full bridge
	DC input

The standard StrainBUSter has the following ranges:

	Quarter bridge 350Ω	PT100 temp.	Half/Full bridge	DC input
Range setting:	+/- 3500 µm/m +/- 16000 µm/m +/- 70000 µm/m	-90 - +110 °C -100 - +300 °C	-2 - +2 mV/V -8 - + 8 mV/V - 40 - +40 mV/V	- 5 - +5 mV -20 - +20 mV -100 - +100 mV -250 -+250 mV

The StrainBUSter with the potentiometer option has the next ranges:

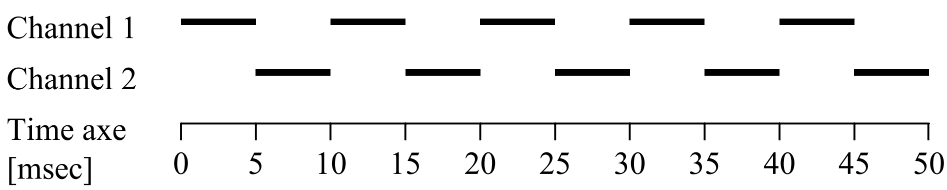
	Quarter bridge 350Ω	PT100 temp.	Half/Full bridge	DC input
Range setting:	+/- 3500 µm/m +/- 16000 µm/m +/- 70000 µm/m	-90 - +110 °C	-2 - +2 mV/V -8 - + 8 mV/V - 40 - +40 mV/V	- 5 - +5 mV -20 - +20 mV -100 - +100 mV -1.7 - +2.0 V

When the potentiometer option is used, measured value will be between 0 and 100 %.

2.2.1 Measurement speed

The measurement speed can be set between 10msec and 1 second, in steps of 10 msec.
At maximum speed both channels are measured every 10 msec. This measured value is an average of four values measured directly after each other. The total duration of these 4 measured values is 5 msec.
When the measurement speed is decreased, more values will be used to determine the average. Both channels will still be measured every 10 msec, but more values will be used to calculate an average over the measurement time.

Example with a measurement speed of 50 msec



During the thick lines a channel is measured. After 50 msec an average value is calculated for each channel.

2.2.2 Automatic measurement

Every 10 msec both channels are measured by the StrainBUSter. When a value is requested through the CAN bus the last average value is read.
It is also possible to set the StrainBUSter in an “Auto send” mode. When this mode is active, the StrainBUSter will send its channel values after each measurement period. So when this period is set at 60 msec, every 60 msec both average channel values will be sent over the CAN bus.

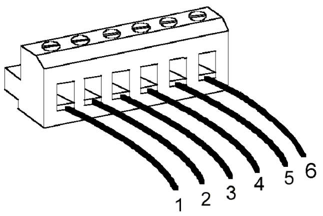
It is the responsibility of the receiving unit, to handle all those channel values.
When more StrainBUSter units are present on the CAN bus, the load on the CAN bus will become higher when the measurement interval is shorter. This can result in a load which is too high. In this case the StrainBUSter units with the lowest priority (that is those with the highest address number) will not be able to send its channel values over the bus.

3 Measurement input

3.1 Measure connector

At the sensor side of the StrainBUSter there are two 6-pin connectors present. These are the connectors for the connection of the input signals.

The cable shall be connected to the counter part of this connector. The numbering of the connector pins is shown in the next picture:



1	⏚	Screen
2	EX-	0V
3	-	- input
4	+/ ½	+input
5	¼	¼ bridge
6	EX+	2,5V

Figure 3-1: Input connector pinout

The bridge supply is present at pins 2 and 6 of the connector. This is 2.5VDC, with a maximum output current of 20 mA. (min impedance 120 Ω).
At pins 3&4 the differential input is measured. In case of a half and/or quarter bridge, pin 3 represents the voltage of the mid point of the internal half bridge.

With a quarter bridge measurement the internal complementation resistor is connected to pin 5 of the connector.

When a screened cable is used, the screen can be connected to pin 1. This pin is connected to pins 1 & 3 of the Can bus connector.

For each input channel a separate input connector is present.

3.2 Signal connections

3.2.1 Quarter bridge/PT100 connection

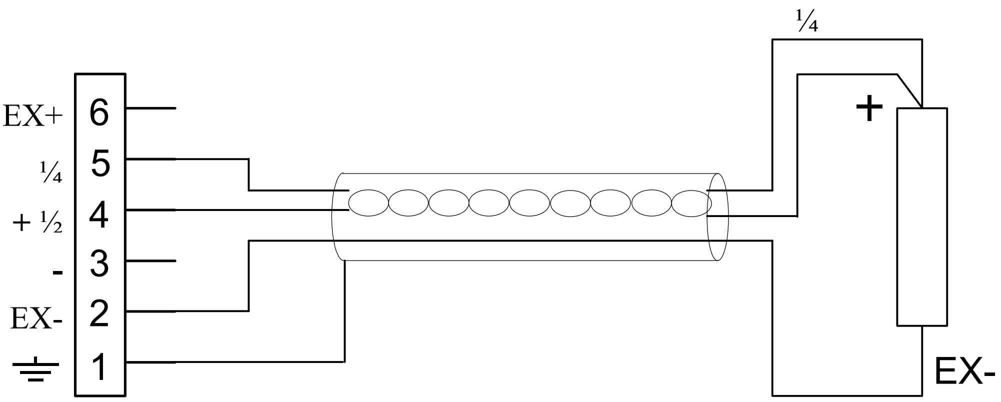


Figure 3-2: Quarter bridge /PT100 connection

3.2.2 Half bridge connection

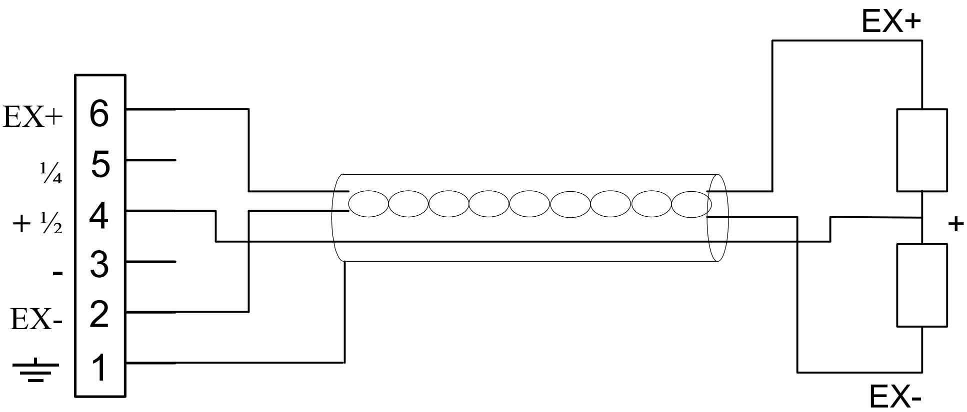


Figure 3-3: Half bridge connection

3.2.3 Full bridge connection

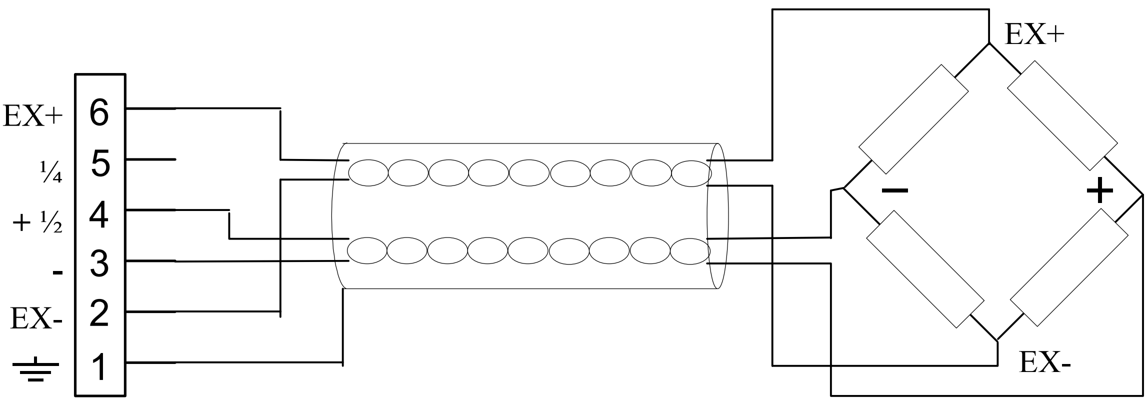


Figure 3-4: Full bridge connection

3.2.4 Potentiometer connection

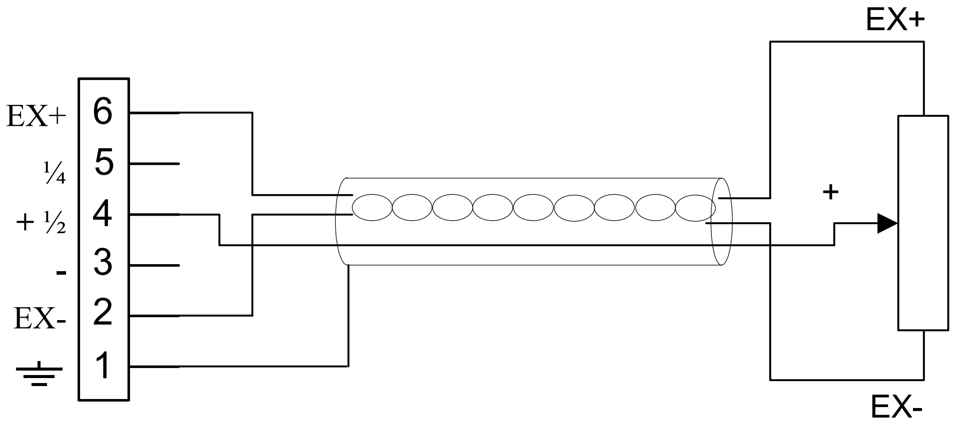


Figure 3-5: potentiometer connection

For this potentiometer measurement the jumpers configuration of the half bridge must be used.

3.2.5 DC signal connection

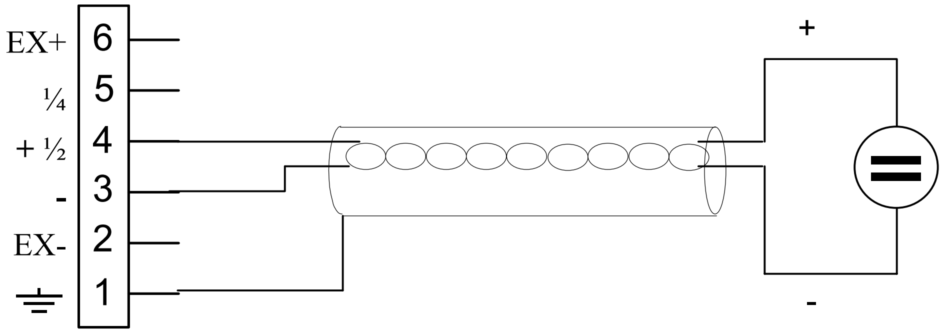


Figure 3-6: DC signal connection

For this DC measurement the jumpers configuration of the half bridge must be used.

3.3 3-wire measurement PT100

The strain & PT100 measurement is done with the 3-wire measurement method. The following schematic explains how the wire resistance is placed in the measurement circuit:

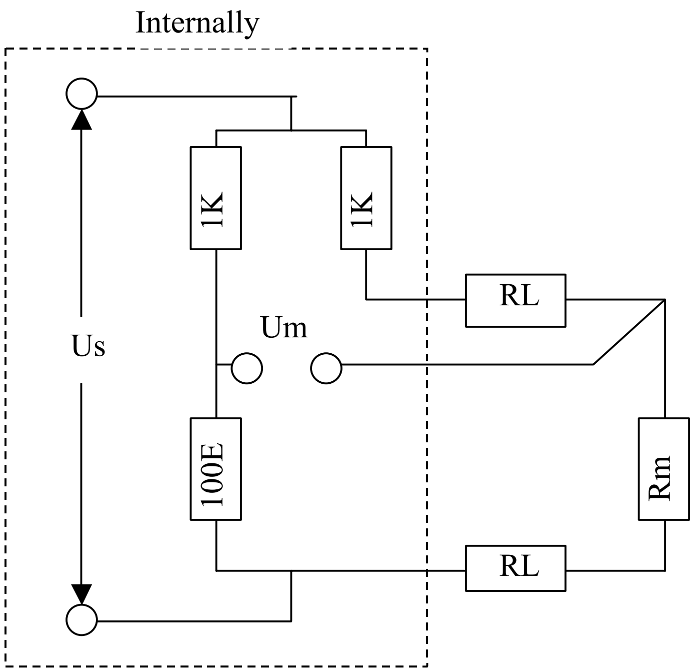


Figure 3-7: Input circuit diagram

The wire resistance RL influences the measurement error. This error is found as an offset error, which can be removed with a balance command, and a gain error, which cannot be compensated.
The error values in the next table are valid after a balance command at 0 µm/m or 0 °C

3 m	5 m	10 m	15 m
0,02 %	0,03%	0,05%	0,08%

3.4 3-wire measurement Strain

The strain measurement is done with the 3-wire measurement method. The following schematic explains how the wire resistance is placed in the measurement circuit:

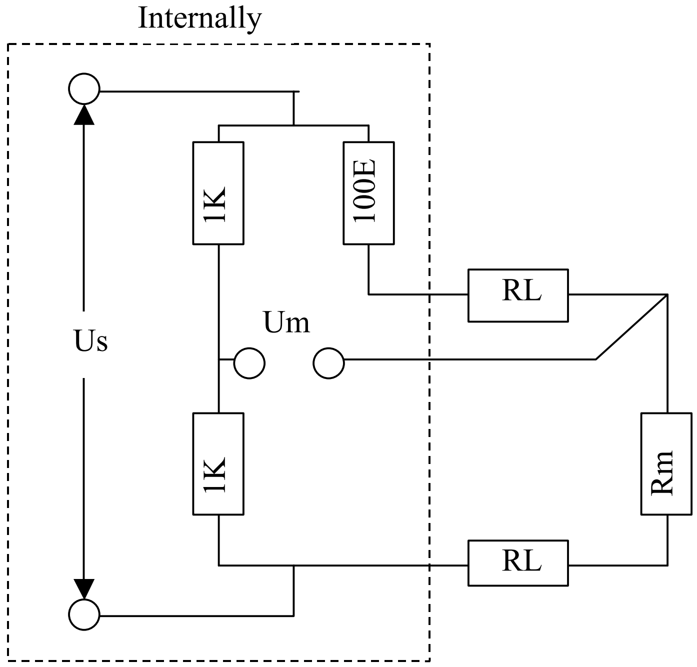


Figure 3-8: Input circuit diagram

The wire resistance RL influences the measurement error. This error is found as an offset error, which can be removed with a balance command, and a gain error, which cannot be compensated.

4 CAN bus communication

For the communication between the PC and the StrainBUSter nodes, the CAN bus is used. This bus can be used with high speed over a short distance or with low speed over a long distance.
The maximum CAN bus speed depends on the total cable length and the cable specifications.
Please bear in mind that the CAN bus speed will, in some cases, limit the measuring speed of the StrainBUSter node.

4.1 Bus speed versus measure interval

As mentioned before, the CAN bus speed will limit the maximum number of channel values it can transfer every second.
The following table gives an idea of the number of channels which can be supported at different CAN bus speeds and measurement speeds:

CAN bus speed	Maximum cable length	Measurement speed			
		100 Hz	20 Hz	10 Hz	1 Hz
1000 kbit /s	30 m	91 channels	120 channels	120 channels	120 channels
800 kbit/s	50 m	73 channels	120 channels	120 channels	120 channels
500 kbit /s	100 m	45 channels	120 channels	120 channels	120 channels
250 kbit /s	250 m	22 channels	110 channels	120 channels	120 channels
125 kbit /s	500 m	11 channels	55 channels	110 channels	120 channels
50 kbit /s	1000 m	4 channels	22 channels	54 channels	120 channels
20 kbit /s	2500 m	1 channels	9 channels	18 channels	120 channels

In the gray area the channel count is 120. The limit here is not the CAN bus speed, but the number of nodes connected to the CAN bus. At maximum this is 60 nodes.
In the above table the CAN bus load is about 80%. This is possible when there are only a few bus errors. The CAN bus will respond with error frames when those errors occur. There must be space in time on the bus to send these frames.
The actual achievement of the maximum speed mentioned in the table, depends on the signal quality of the bus.
This signal quality depends on several parameters, such as:

- cable impedance
- cable capacitance
- cable screen and noise.

When the speed is too high for the cable length, bus errors will occur, which will increase the CAN bus load.

If the CAN bus load is too high, caused by bus error(s) or just too much channel values (say 100 channels at 1000KB/sec), the StrainBUSter nodes with the lowest priority will not be able to send their channel values. On the receiving device (usually a PC) this is seen as missed channel values.

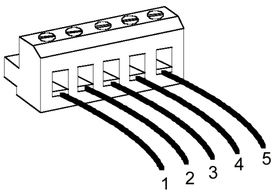
In such a case the CAN bus load must be decreased. This can be done by one or more of the following actions:

- Increase CAN bus speed (be cautious with the maximum cable length!!)
- Set measurement speed at a lower rate
- Decrease the number of channels.

4.2 CAN bus connector

On the CAN bus side of the StrainBUSter there are two 5 pins connectors. Those are the connectors for the connection of the power and CAN bus signals.

The cable shall be connected to the mating-part of this connector. The numbering of the connector pins is shown in the next picture:



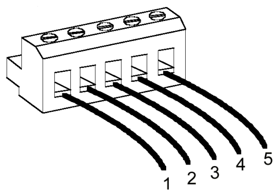
1	-	0V
2	CL	CAN L
3	⏚	screen
4	CH	CAN H
5	+	+10-30V

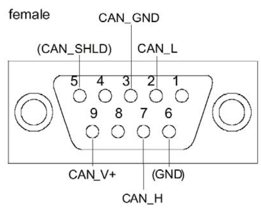
Figure 4-1: CAN bus connector pin out

The two 5 pin connectors are interconnected on the StrainBUSter. In this way a simple daisy chain connection can be made.

4.2.1 StrainBUSter – CAN cable

To connect the StrainBUSter to the CAN interface, a special cable with sub D9 connector must be used.
The CAN interfaces as supplied by Peekel Instruments all use the connector pin layout as defined by CAN OPEN.
This cable must have the following connections:





front view

StrainBUSter		Description	Sub D9 female
1	-	0V	
2	CL	CAN L	2
3	⏚	screen	3
4	CH	CAN H	7
5	+	+10-30V	

Figure 4-2: StrainBUSter CAN Cable connection

When the Sub D9 connector is the last CAN device on the bus, a termination resistor must be mounted in this connector between pins 2 & 7.
Standard cables delivered by Peekel Instruments have this termination resistor already mounted.

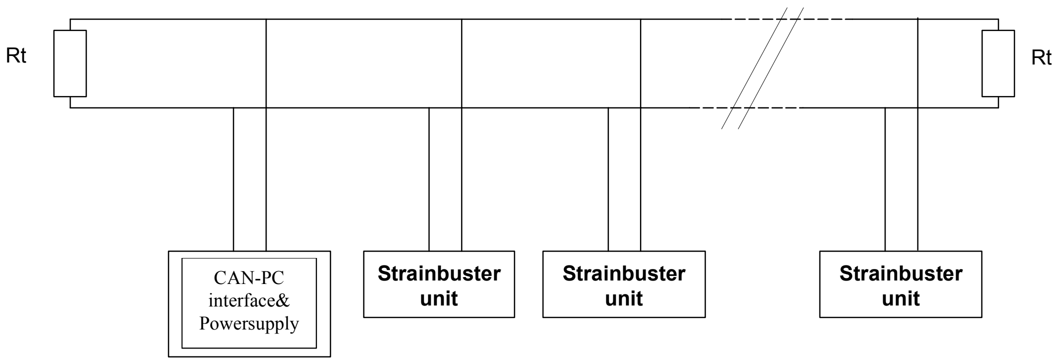
4.3 CAN bus termination

The cables, connectors, and termination resistors used in the CAN network must meet the requirements as defined in ISO 11898. In addition, here are some guidelines for selecting cables.

Recommended cable AC parameters:

- 120-Ω impedance
- 5-ns/m specific line delay

For drop cables a wire cross-section of 0.25 to 0.34 mm^2 would be an appropriate choice in many cases.



Figuur 4-3: normal CAN bus layout

note: Rt is the bus termination resistor with a value of 120Ω This resistor is already present on each Strainbuster. It must be connected through a dip switch

4.4 CAN bus topology

As mentioned in 4.2 the StrainBUSter has 2 identical CANbus/power connectors. This gives the following connection possibilities:

4.4.1 Using both connectors:

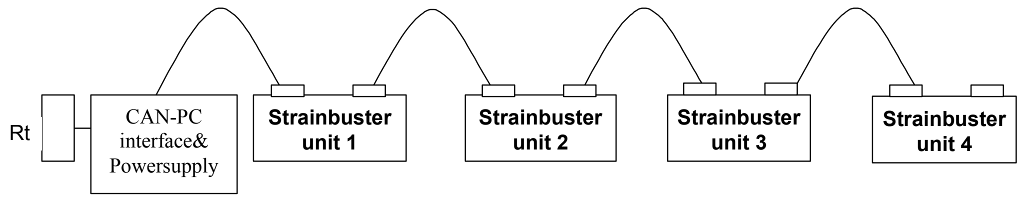


Figure 4-4: StrainBUSter network using both bus connectors

Advantage:

Easy cable connection. Each cable can be mounted on a single connector

Disadvantage:

When a StrainBUSter is removed, both connectors must be disconnected. At that time the subsequent StrainBUSters are all cut off. When StrainBUSter 2 is removed, StrainBUSter 3 & 4 are disconnected from the bus.

4.4.2 Using one connector:

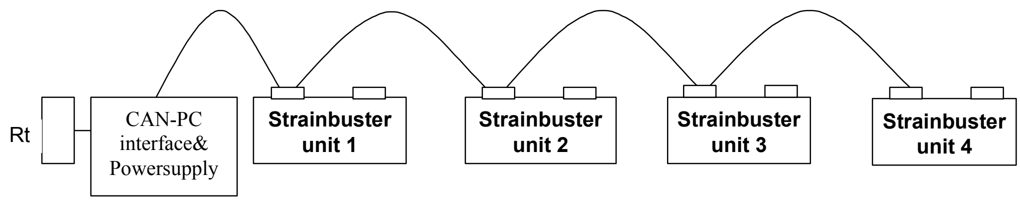


Figure 4-5: StrainBUSter network using one bus connector

Advantage:

When one StrainBUSter is disconnected, all the other StrainBUSters stay connected.

Disadvantage:

A more complex cable connection must be made at the connecting points.

4.4.3 Using stub lines

The CAN bus is a daisy chain bus. The bus cable must be routed from one StrainBUSter to the next StrainBUSter. The use of stub lines must be avoided as much as possible.

However, if it cannot be avoided, the following guide lines must be taken into account to get the best CAN bus performance. Using stub cables will always decrease CAN bus performance, resulting in a lower bus speed or data transfer rate.

To determine the maximum stub cables length, the CANopen documentation gives a rule of thumb to calculate this. There is also a maximum to the sum of all stub cables.

CAN bus speed	max. stub cable length [m]	max. length of all stub cables [m]
1000 Kb/sec	0,5	2,5
800 Kb/sec	0,5	2,5
500 Kb/sec	0,5	2,5
250 Kb/sec	1	5
125 Kb/sec	2	10
50 Kb/sec	5	25
20 Kb/sec	12,5	75

Figure 4-6: max. stub cable length

The use of stub cables will decrease the maximum trunk cable length with the sum of all stub cable lengths.

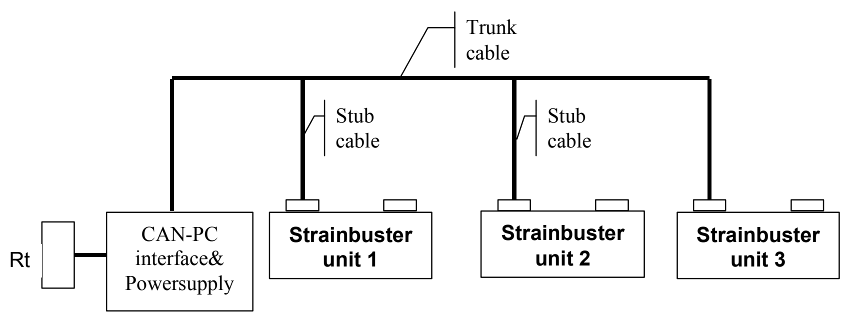


Figure 4-7: StrainBUSter network using one bus connector

4.4.4 PC – CANbus connection

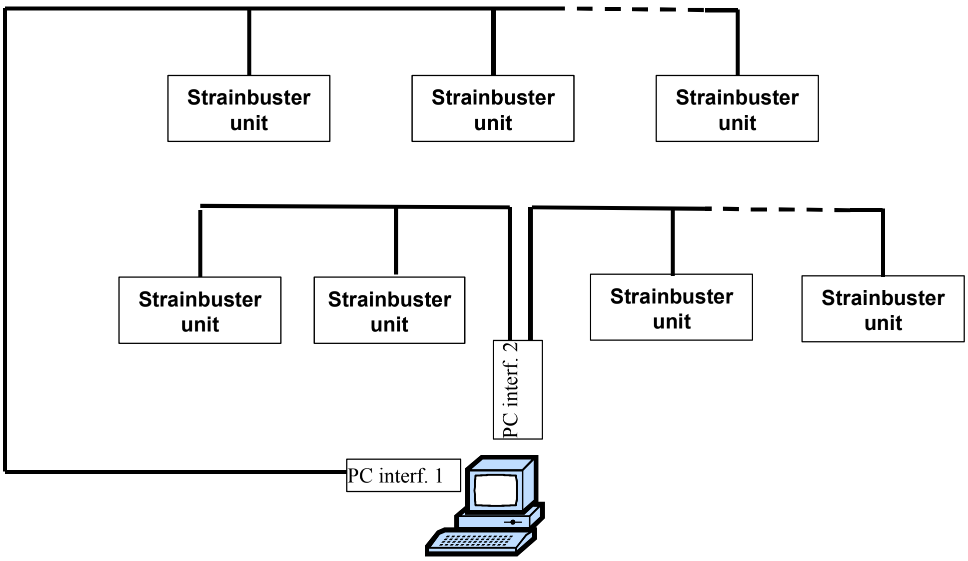
To control the StrainBUSter units and to collect the measured data, a PC must be connected to the CANbus. This can be done with one of the following PC interfaces:

- USB – CAN interface
- LPT – CAN interface
- PCI – CAN interface

The use of the USB- CAN interface is advised in all situations, except where this is not supported by the PC and its OS. An example of this situation is when the PC runs under Windows NT 4.0. In this configuration an LPT-CAN interface can be used.

This interface must be connected to the CAN bus. This can be done on every location of the bus, before the first StrainBUSter, after the last StrainBUSter or anywhere in between.

When the cable length is too long for the required bus speed, more than 1 interface can be used. This will split the actual CAN bus in more CAN busses, each with its own PC interface.



Figuur 4-8: PC - CAN bus example

4.5 StrainBUSter network cable

4.5.1 Communication cable

All StrainBUSter modules in a network must be connected to a CAN bus. This CANbus must be controlled by a PC.
The cable to be used to connect the StrainBUSter modules to the CANBUS must have the following characteristics:

nom. capacitance between conductors at 1 MHZ:	40 pF/m.
nom. impedance:	120 Ω
max delay:	5 ns/m

It is advisable to use a screened twisted pair for the communication to minimize the noise pickup. A wire cross section of 0.35 mm^2 is sufficient.

4.5.2 Power cable

Also, each StrainBUSter unit needs some power. A power supply can be mounted near each StrainBUSter unit. In this case the ‘zero’ line of each power supply must be connected to a common ground, to prevent the common mode of the CANBUS signal being too high.

Another solution is to use 1 central power supply, and to connect each StrainBUSter module to this power supply. Now care must be taken that the voltage drop on the cable is not too high.
Normally a central power supply voltage will be 24VDC nominal.
The minimum power supply voltage of a StrainBUSter is 10V.
For calculations, the maximum current drawn by each StrainBUSter unit is 0.1A.

To calculate the voltage drop on the cable, the cable resistance must be known.
The next table holds typical values of the single conductor resistance:

Cross section mm^2	AWG	Number of wires in each conductor	Single conductor resistance at 20° C in Ω/Km
0,141	26	7	132
0,227	24	7	77,5
0,355	22	7	52,6
0,563	20	7	32,5
0,897	18	7	20,4
1,43	16	7	12,8

note: these are typical values that can differ for a specific cable. Check the cable characteristics for exact values.

Let us assume the following network:
PC with CAN interface
StrainBUSter module at a distance to the PC of : 20 m, 30m, 50m, 65m, 85m, 95m, 110 m
The cable used has AWG22 conductors.
Voltage drop per meter, per StrainBUSter unit is 0,0526Ω * 0,1 A * 2= 10,52 mV.
We call this value “Vsb-m”
Now to calculate the voltage drop at each StrainBUSter, we multiply the cable length, number of StrainBUSter connected and the Vsb-m. Keep in mind that through the first distance a current will flow to supply all the StrainBUSters, dropping of course with each next unit!

The voltage drop at each StrainBUSter is noted in the next table

from	to	formula	value	total
PC	StrainBUSter 1	= 20 * 7* Vsb-m	1.472 V	1.472 V
StrainBUSter 1	StrainBUSter 2	= 10 * 6* Vsb-m	0,631 V	2,103 V
StrainBUSter 2	StrainBUSter 3	= 20 * 5* Vsb-m	1,052 V	3,155 V
StrainBUSter 3	StrainBUSter 4	= 15 * 4* Vsb-m	0, 631 V	3,786 V
StrainBUSter 4	StrainBUSter 5	= 20 * 3* Vsb-m	0, 631 V	4.417 V
StrainBUSter 5	StrainBUSter 6	= 10 * 2* Vsb-m	0,210 V	4,627 V
StrainBUSter 6	StrainBUSter 7	= 15 * 1* Vsb-m	0,158 V	4,785 V

So with a small number of StrainBUSters the voltage drop will be low.
With more StrainBUSter units and longer distances between the units, the voltage drop must be calculated to be sure that all StrainBUSters have a proper power supply.

Consequently, cable selection for the power cable depends on the number of StrainBUSters and cable length.
For the CANBUS communication, the capacitance and cable impedance are important. When the capacitance is larger, the maximum data speed will be lower.

The conductors for data communication and power supply can be combined in 1 multi-wire cable.

4.5.3 Recommended CAN bus cable

The following cable is specially developed for CANBUS communication. It combines the communication and power conductors in 1 cable.
Make: Belden
Type: 3082A

ELECTRICAL CHARACTERISTICS:	

MAX. OPERATING VOLTAGE:	300 V UL PLTC, CMG
MAX. OPERATING VOLTAGE:	300 V C(UL) AWM
MAX. OPERATING VOLTAGE:	600 V UL AWM
MAX CURRENT/CONDR @ 25C (18 AWG):	5 A
MAX CURRENT/CONDR @ 25C (15 AWG):	8 A
NOM. CAPACITANCE BETWEEN CONDUCTORS OF DATA PAIR @ 1 MHZ:	12 PF/FT.
NOM. IMPEDANCE (DATA PAIR ONLY):	120 OHMS+/-12 OHMS
MAX. DELAY (DATA PAIR ONLY):	1.36 ns/FT
MIN. VELOCITY OF PROPAGATION (DATA PAIR ONLY):	75%
MAX. ATTENUATION (DATA PAIR ONLY):	
@ 125 KHZ:	.13 DB/100 FT
@ 500 KHZ:	.25 DB/100 FT
@ 1 MHZ:	.36 DB/100 FT
MAX. CONDUCTOR DC RESISTANCE @ 20 DEG C (18 AWG)	6.92 OHMS/1000 FT
MAX. CONDUCTOR DC RESISTANCE @ 20 DEG C (15 AWG)	3.60 OHMS/1000 FT
NOM. SHIELD DC RESISTANCE @ 20 DEG. C	1.8 OHMS/1000 FT.
NOM. LOOP INDUCTANCE (15 AWG)	.174 MICROHENRIES/FT
(18 AWG)	.258 MICROHENRIES/FT

Note: in less critical situations, a cheaper cable might be used. Always use different pairs for communication and power lines. A overall screen, which must be connected to earth at only 1 side is always preferred.

5 Specifications

General
Linearity accuracy: < 0.1%
Bandwidth (-3dB): 20 Hz
Sample rate: 100 samples / second / channel
Operating temperature: -20 °C...+50 °C
Max. sensor cable length: 3 m
Bridge supply:2.5V(fixed), +/- 0.1%

Measuring input (2 channels for each unit)
Galvanically separated from CAN bus
and power supply

- 3-wire single 350Ω strain gauge
- 3-wire single 120Ω strain gauge
- 3-wire Pt100 temp. sensor
- 3-wire half bridge
- 4 wire full bridge
- 3 wire potentiometer
- DC measurement

On-board microcontroller
A/D converter resolution: 18 bits

Communications
1 x CAN interface
Bus speed selectable between 1 Mbit/sec and 20Kbit/sec

Power supply 10 - 30 VDC, 1,6 VA

Housing dimensions 30 x 105 x 68 (mm, h x l x w)

Housings
The strain buster is delivered in the following housings:
SB HCA-R/xx: for DIN rail mounting
SB HCA-F/xx: for flange mounting.
xx holds the number of StrainBUSters modules mounted in the housing

StrainBUSter types:
SB SG-TEMP for extended PT100 measurement (Standard type)
SB SG-POT for the StrainBUSter type with potentiometer measurement.

Measurement ranges

	Quarter bridge 350Ω	PT100 temp.	Half/Full bridge	DC input
Range setting:	+/- 3500 µm/m +/- 16000 µm/m +/- 70000 µm/m	 -90 - +110 °C	-2 - +2 mV/V -8 - + 8 mV/V - 40 - +40 mV/V	- 5 - +5 mV -20 - +20 mV -100 - +100 mV
Only for Type 01		-100 - +300 °C	-100 - +100 mV/V	-250 -+250 mV
Only for Type 02				-1.7 - +2.0 V

Bus speed versus measure interval

CAN bus speed	Maximum cable length	Measurement speed			
		100 Hz	20 Hz	10 Hz	1 Hz
1000 kbit /s	30 m	91 channels	120 channels	120 channels	120 channels
800 kbit/s	50 m	73 channels	120 channels	120 channels	120 channels
500 kbit /s	100 m	45 channels	120 channels	120 channels	120 channels
250 kbit /s	250 m	22 channels	110 channels	120 channels	120 channels
125 kbit /s	500 m	11 channels	55 channels	110 channels	120 channels
50 kbit /s	1000 m	4 channels	22 channels	54 channels	120 channels
20 kbit /s	2500 m	1 channels	9 channels	18 channels	120 channels