CANADC 40*24

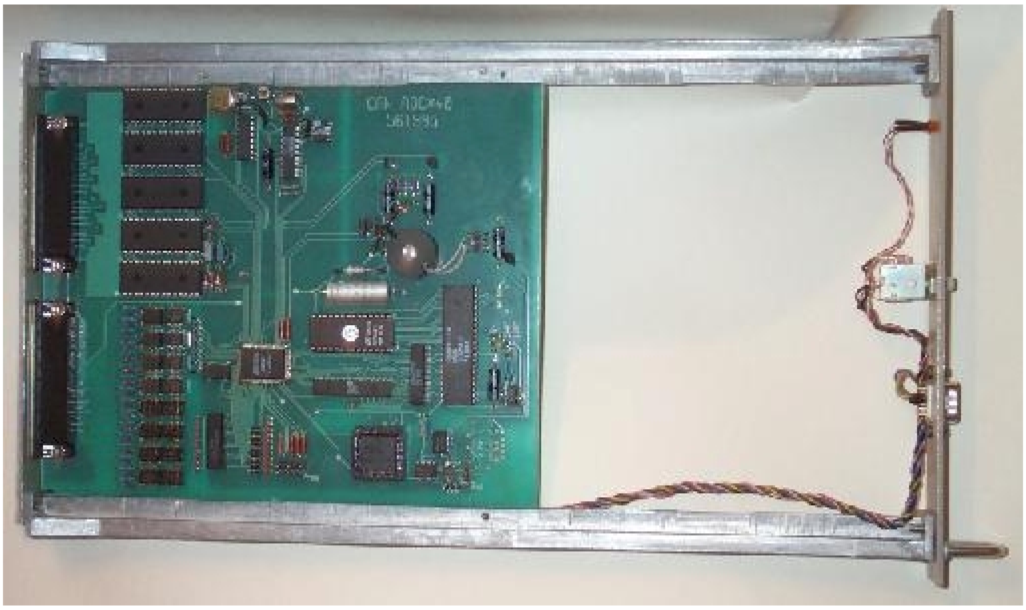
Revision 1.
`Embedded software version 2.`

1. Features

This device is designed for voltage measurements in control systems of accelerators as embedded converter in multi-channel power supplies. The device may be used as general purpose multi-channel analog-to-digital converter.

The device includes:

- 40-channels ADC;
- 8-channel output register with galvanically isolated outputs;
- 8-channel input register with galvanically isolated inputs;
- CANbus interface for interaction with control computer;
- micro-controller.



CANDAC 40*24.

As ADC the device may work in different modes. The base mode is a multi-channel mode. In this mode the device scans predefined channels, measures them, stores measured values in internal memory and sends data in CANbus (if it was required by mode). For investigation of powers supply behavior may be used one-channel mode (digital oscilloscope mode). In this mode the device measures the only channel with defined gain and time of measurements and sends these values to network. In order to record and analyze occasional spices of output current there may be used mode of continual recording. In this mode the device measures chosen channel and stores measured values in internal ring buffer with capacity 4096 values. A control computer can break the process any time, request a pointer of ring buffer, read date which was written before break and then analyze behavior of chosen channel. Actually, both latest modes are the one mode. The only difference is a value of flag in mode specification. This flag defines behavior of device- the information should be sent to network or it should be stored in ring buffer.

All ADCs in CANbus network or predefined group of ADC might be started in multi-channel mode simultaneously by broadcast message. This property is implemented by using labels. An user can assign label to device when it is started in multi-channel mode. Later, if device receives broadcast start message, it compares label in broadcast message with label assigned to multi-channel mode. If both label are identical the broadcast start accepts like address start command. The are stop command only address type or global type, group stops are not defined in protocol.

Hardware implementation of converter consist of delta-sigma ADC chip, programmable gain amplifier (with gain 1, 10, 100 and 1000) and 40-channel bi-wire multiplexer. All analog inputs are not galvanically isolated each from other and have common ground plane. The device is intended to be embedded in power supply racks. The device requires for proper operation the only power supply with voltage +5V (±5%).

2. Specifications:

1. Resolution – 24 bits.
2. Effective resolution – from 10 bits (time of measurements is 1 ms) to 16-18 bits (time of measurements is 20 ms and more).
3. Offset error- 1 mV.
4. Accuracy- 0.03%.
5. Input ranges- ±10V and ±1V (main ranges), ±0.1V and ±0.01V (additional ranges).
6. Input resistance- 10 Mom (it is defined by discrete resistors which might be removed in some applications).
7. Common-mode input range- 10.5V.
8. Common-mode rejection- 75 dB.
9. Time of measurements- from 1 ms to 160 ms.
10. Channels of output register- 8.
11. Maximal voltage for output register- 50V.
12. Maximal current for output register- 100 ma.
13. Channels of output register- 8.
14. Voltage for input register- 2.5-6.0V.
15. Input resistance for input register- 510 Ohm.
16. CANbus transceiver is galvanically isolated from network and it is in compliance with ISO 11898-24V (chip PCA82C251).
17. Voltage between transmission line and device- 1000V.
18. Hardware implementation allows using both standard and extended CANbus frames. Software implementation is based on standard frames (short identifier).
19. Baud rates- 1000, 500, 250, 125 Kbaud (may be chosen by jumpers).
20. Voltage of power supply- +5V, ±5%.
21. Power supply current- <1A (typical value- 0.7A).

3. External connection

The device is implemented as module in “WISHNYA” standard, width is 40 mm. A front panel of device contains a network connector (DB-9M), RESET button and LED. The LED is blinking during processing CANbus message. Connection with external channels of control and measurements carry out by DHR-62F connectors on back panel. Analog inputs of device are are connected with pins of X1 and X2 connectors. Outputs and inputs of registers are connected with X2 connector.

3.1. Jumpers

The device CANADC 40*24 has the following set of jumpers:

X14 defines reference source to be used. If middle pin is connected with upper pin ADC chip uses external reference source AD780. In this case CANADC 40*24 has better accuracy. For low requirement application external reference source may not be installed on board. In this case middle pin of X14 must be connected with lower pin.

X4 includes 8 jumpers. 6 jumpers defines number (address) of device in network (this number is used to compose identifier of messages) and 2 jumpers defines baud rate.

Jumpers location is shown below on board photo.

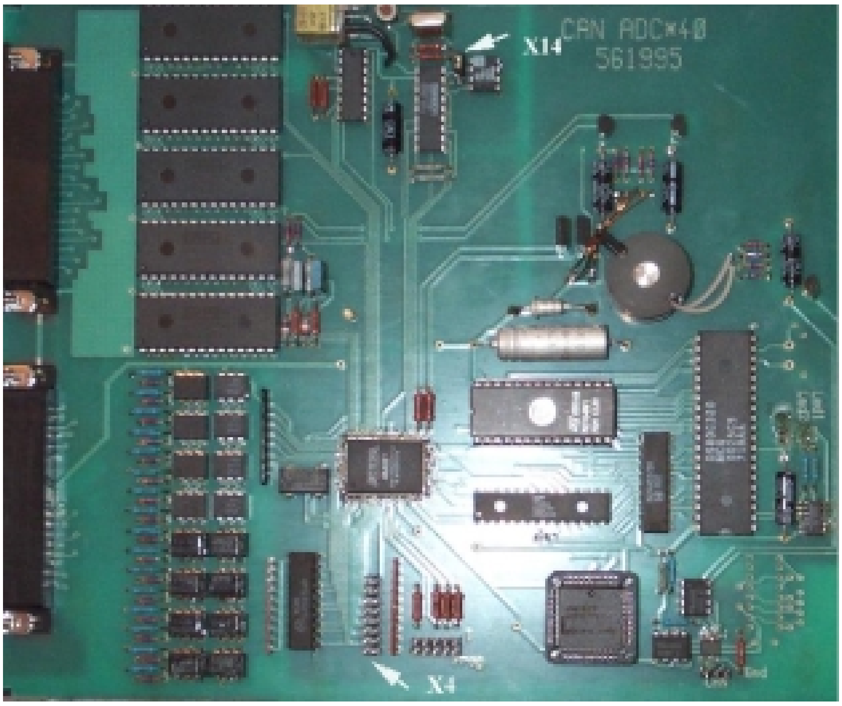
Destination of jumpers in X4 group.

Designation	Location	Назначение
X4-7	Upper	N5- included in device number (most significant bit)
X4-6	…	N4- included in device number
X4-5	…	N3- included in device number
X4-4	…	N2- included in device number
X4-3	…	N1- included in device number
X4-2	…	N0- included in device number (least significant bit)
X4-1	…	BR1- defines baud rate
X4-0	Lower	BR0- defines baud rate

Jumpers N5…N0 defines logical number (address) of device which is used to compose message identifier for CANbus network (for more detail see PROTOCOL part of this description). An installed jumper should be interpreted as logical 0 and absence of jumper should be interpreted as logical 1/

Baud rate defining

BR1	BR0	Baud rate
Connected	Connected	1000 Kbit/sec
Connected	Disconnected	500 Kbit/sec
Disconnected	Connected	250 Kbit/sec
Disconnected	Disconnected	125 Kbit/sec



Jumpers location on board

NOTES:

1. CANbus is bus with multiple access and incorrect baud rate setting may affect on transfer messages of other devices in addition to impossibility of access to this device.
2. In network may exist concurrently devices with identical numbers (addresses). Formally it is permissibly, but actually it do cause a lot of problem. Connecting to network devices with identical numbers is strictly not recommended.
3. It is forbidden to change X14 by user.

3.2 Front panel.

A front panel includes:

LED **Line**

Button **Reset**

Connector **CANbus**

Line LED is blinking during processing CANbus messages by onboard processor. Processor and CANbus chip receive and analyze all messages from line. So, this LED can be interpreted as traffic indicator and it's brightness corresponds to level of traffic.

Reset button is intended for hardware reset. It isn't intended for daily using.

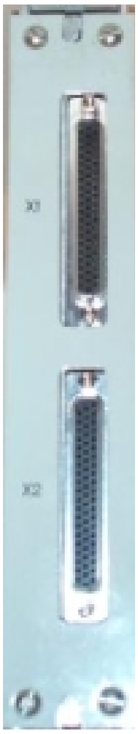
CANbus connector (DB-9M) is intended for connection to media. Pin designations follows below in table.

2	CAN-L	One wire in pair
3	GND	Shield of cable
7	CAN-H	One wire in pair

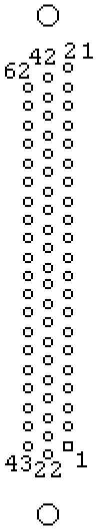
Shielded twisted pair is used as media. According to the ISO 11898-2 it should has a nominal impedance 120 Ohm. Line termination has to be provided through termination resistors of 120 Ohm located at both ends of the line.

3.3 Back panel.

A two connectors (DHR-62F) are placed on the back panel. Connection external signals with device should be done through these connectors. X1 connector contains ADC inputs and X2 connector includes ADC inputs, outputs and inputs of registers and power supply pins.



3.3.1 X1 connector.



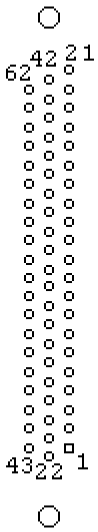
62	INP1	42	INM0	21	INP0
61	INM2	41	INP2	20	INM1
60	INP4	40	INM3	19	INP3
59	INM5	39	INP5	18	INM4
58	INP7	38	INM6	17	INP6
57	INM8	37	INP8	16	INM7
56	INP10	36	INM9	15	INP9
55	INM11	35	INP11	14	INM10
54	INP13	34	INM12	13	INP12
53	INM14	33	INP14	12	INM13
52	INP16	32	INM15	11	INP15
51	INM17	31	INP17	10	INM16
50	INP19	30	INM18	9	INP18
49	INM20	29	INP20	8	INM19
48	INP22	28	INM21	7	INP21
47	INM23	27	INP23	6	INM22
46	INP25	26	INM24	5	INP24
45	INM26	25	INP26	4	INM25
44	INP28	24	INM27	3	INP27
43	INM29	23	INP29	2	INM28
		22	INM30	1	INP30

X1 connector provides 31 pair of ADC inputs. ADC inputs are not galvanically isolated each from other. They have common ground. A connection of ADC inputs with a signal source should be done by twisted pair.

A mnemonics of designation is the following: INPxx means “input positive xx-number”; INMxx means “input negative xx-number”. X1 contains 31 ADC inputs (31 pair of pins). The others 9 ADC inputs is placed on X2 connector.

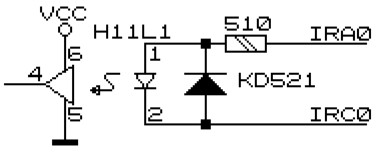
3.3.2 X2 connector.

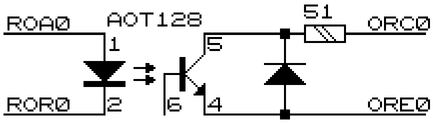
X2 connector provides 9 pair of ADC inputs and pins of input and output registers. Powering of the device should be done through pins of X2. The device requires the only external power supply with voltage +5V (±5%). There is shown a location of signals on the connectors pins. A fragment of circuitry is included to show an implementation of input and output registers. Both registers are designed with galvanic isolation which is provided by optocouplers.



62	INP32	42	INM31	21	INP31
61	INM33	41	INP33	20	INM32
60	INP35	40	INM34	19	INP34
59	INM36	39	INP36	18	INM35
58	INP38	38	INM37	17	INP37
57	INM39	37	INP39	16	INM38
56	GND	36	GND	15	GND
55	GND	35	GND	14	GND
54	+5V	34	+5V	13	+5V
53	+5V	33	+5V	12	+5V
52	IRC1	32	IRC0	11	IRA0
51	IRA3	31	IRA2	10	IRA1
50	IRC4	30	IRC3	9	IRC2
49	IRA6	29	IRA5	8	IRA4
48	IRC7	28	IRC6	7	IRC5
47	ORC1	27	ORC0	6	IRA7
46	ORE2	26	ORE1	5	ORE0
45	ORC4	25	ORC3	4	ORC2
44	ORE5	24	ORE4	3	ORE3
43	ORC7	23	ORC6	2	ORC5
		22	ORE7	1	ORE6

Design of input register is based on a chip H11L1. It is intended for detection external voltage or current. Input voltage range is from 3V to 12V. Input current range is from 4mA to 20mA. Unconnected input (no current in LED) is interpreted as logical 1.





Output register design is based on transistor optocoupler and it is able to provide output current up to 32mA. Output voltage may be up to 30V.

4. Basics of operations for CANADC 40*24

The device includes multi-channel ADC, input register, output register and a micro-controller. The micro-controller integrates all parts together and provides a connection with a control computer by CANbus. Logically input and output registers are not connected with ADC and are controlled by specific messages. After power-up the micro-controller writes into output register zero.

An operation of ADC is quite complicated. A converter consist of an ADC chip, a reference source, a programmable gain amplifier (PGA) and an analog multiplexer. The is used a delta-sigma ADC chip. A delta-sigma converter technology has some specific properties which affects on operations of all device. It is useful to observe this properties for good understanding of device operations.

Delta-sigma converters provide very high resolution with low noise level, but they have low stability. There is used a calibration procedure in order to compensate this instability. An on-board micro-controller performs the calibration procedure in hidden way from an user, but this procedure consumes an extra time and leads to delays in measurements.

Delta-sigma converters use very complicated digital signal processing and as a rule they cannot process any step change of input signal. If voltage is changing on significant value (or on unknown value) as it is in multi-channel measurements, first measured codes may not be authentic. To avoid errors due this effect the micro-controller discards unauthentic (or perhaps unauthentic) codes. This discarded codes are first 2-3 measured values in multi-channel mode.

The described peculiarities lead to two consequences. At first, if time of measurement is defined 20 ms, the micro-controller will send data into network (or write data into internal memory) with the same rate 20 ms. In case of multi-channel measurements the micro-controller discards first three measured values after changing channel number. It means that actually data rate will be 80 ms. The second consequence is a result of calibration procedure. In digital oscilloscope mode processor performs the calibration procedure once, then it provides fast measurements chosen channel. In multi-channel mode the calibration procedure is being performed each start of scanning (before processing first channel). This procedure leads to delay of measured data at 10-11 cycles (approximately 200ms for 20ms range).

An user should keep in mind that ADC effectively rejects an interference with period equal to time of measurements or more in integer times. It is good practice to use ranges 20ms or more. A high frequency interference are rejected by ADC and passive circuitry.

4.1. Base modes of CANADC 40*24

A converter of CANADC40*24 device can work in a few modes as it was mentioned above. The mode is a multi-channel measurement mode. In this mode the device is involved by CANbus message with code 1. Bit fields of message specifies this mode in detail. They define a first and last channels in a scanning frame, gain for even (0, 2, 4…) and odd (1, 3, 5…) channels. There is a flag which points if it is required a single cycle of scanning or converter should scan channels up to STOP message. Another flag defines if a measured information should be sent in network or it should be stored in on-board memory. One byte contains a label of this mode to allow using a group start message.

In multi-channel mode the device performs a calibration procedure before any measurements. Then micro-controller connects an ADC with input channel defined as first, performs a few measurements, discards possible invalid values, stores correct value in on-board memory and, if it defined, sends it into network. A latest measured data can be requested from on-board memory. Each input channel has a personal location in the memory and on external request the micro-controller sends into network a contents of requested location. If requested channel was not measured at all the contents would have an arbitrary value. After processing first channel in frame the micro-processor connects ADC to next input channel and process it. When the last channel in frame was processed micro-controller or goes to idle state (for single frame case) or begins all actions from calibration procedure and so on. If multi-channel mode request contained label (not equal zero) a broadcast message can start measurements all devices with the same value of label simultaneously.

Don't forget that in multi-channel mode an output data rate is four times slower than it should be with defined time of measurements.

For investigation of powers supply behavior may be used one-channel mode (digital oscilloscope mode). In this mode the device is involved by CANbus message with code 2. Bit fields of message specifies this mode in detail. They chose a measured channel, defines a gain, a time of measurement. There is a flag which points if it is required a single measurement or converter should work up to STOP message. Another flag defines if a measured information should be sent in network or it should be stored in ring-buffer of on-board memory. After receiving an one-channel mode command the micro-controller performs a calibration procedure and then begin measure a chosen channel. A data rate correspond to chosen time of measurements in this mode. Measurements may be stopped by message with code 0. If data is sending into network they aren't storing in on-board memory.

If "send to line" flag is zero then flag "continuous" is considered as 1. So, the device perform continuous measurements and stores data in on-board memory. These values can be requested by message with code 4. A current value of ring-buffer pointer can be requested by message "Status request". The counter point at measurement location but not at byte.

Note:

An ADC data is coded as 24-bit signed integer value. A correspondence between codes and voltages is seen in a table below. An user should take in consideration that ADC allows some over voltage. In this case the ADC remains accuracy but codes exceed limit values.

Code (hexadecimal)	Voltage
3FFFFF	+10V
000000	+0.0V
FFFFFF	-0.0V
C00000	-10V

5. A command set for CANDAC 40*24

Identifier bits distribution

Identifier bits	ID10…ID08	ID07...ID02	ID01…ID00
Bit field	Field 1	Field 2	Field 3
Destination	Priority	Address	Reserve

Comments to bits distribution:

Field 1 – priority field (type field):
Code 5 – a broadcast message (field 2 is ignored).
Code 6 – ordinary (address) message.
Code 7 – response (reply for type 6 message).
Code 0 is forbidden, other combination is not used (they are reserved for future extensions).

Field 2 – a physical address field. It defined address device (this address is defined by jumpers on-board).

Field 3 – is not used yet. User should set zero in this field.

Any device on receiving address message interprets an information by its content. If received message requires a reply, the device sends required information by message with code 6 (response type message). A broadcast messages should be received by all devices simultaneously and required actions should be done in all devices.

An interpretation of data fields:
On receiving message a device interprets data in following way: a first byte (byte 0) is descriptor of message, the other bytes are an additional information.

There is a list of message descriptors (codes are hexadecimal).

00 - break a measurements procedure
01 - define and start multi-channel measurements
02 - define and start one-channel measurements
03 - request of a multi-channel value from on-board memory (measured before request)
04 - request for value from a ring-buffer
F8 - request for data from input and output registers
F9 - write to output register
FE - device status request
FF - device attributes request

Detail description of messages for CANADC40*24
(all codes are hexadecimal)

Message 00 – break a measurements procedure. There is not additional information. An addressed devices should not reply on this message.

Message 01 – configuration and start multi-channel measurements procedure. The message looks as:

01	ChBeg	ChEnd	Time	Mode	Label

ChBeg- first channel of multi-channel frame.
ChEnd- end channel of multi-channel frame. Channel numbers are from 0 to 39.
Time- time of measurements code. Valid codes are from 0 to 7.
Mode- bit flags to detail procedure.
Label- label for group start command. If label is 0 it means "no label".

Mode includes the following flags:

Bits 0 and 1 defines gain for even (0, 2…) channels.
Bits 2 and 3 defines gain for odd (1, 3…) channels.
Bit 4: 0 means single scanning cycle; 1 means continuous measurements (up to STOP message or message 1 or 2).
Bit 5: 0 means that measured values should be stored in on-board memory and should be sent into network. If this bit is 0 then measured values should not be sent into network.

If a multi-channel measurements was started, a device sends measured data in following message (if bit 5 in Mode is set):

01	Attribute	Low byte	Middle byte	High byte

Byte Attribute consist of a measured channel number (least 6 bits) and a gain code (most 2 bits). Other 3 bytes contain measured value.

Message 02 – configuration and start one-channel measurements procedure. The message looks as:

02	Channel	Time	Mode

Channel- consist of channel number (least 6 bits) to be measured and gain code (most 2 bits). Channel numbers are from 0 to 39.
Time- time of measurements code. Valid codes are from 0 to 7.
Mode- bit flags to detail procedure.

Mode includes the following flags:

Bit 4: 0 means single measurement; 1 means continuous measurements (up to STOP message or message 1 or 2).
Bit 5: 0 means that measured values should be stored in on-board memory and should be sent into network. If this bit is 0 then measured values should not be sent into network and device stores them in ring-buffer.

Comment: if bit 5 in mode byte is 0 then bit 4 will be ignored (No sense to store a single measurement).

If a one-channel measurements was started, a device sends measured data in following message (if bit 5 in Mode is set):

02	Attribute	Low byte	Middle byte	High byte

Byte Attribute consist of a measured channel number (least 6 bits) and a gain code (most 2 bits). Other 3 bytes contain measured value.

Message 03 – request data from multi-channel buffer (request for previous measured and stored data). The message looks as:

03	Channel

Channel- a channel number. A request refer to previous measured data for channel specified in this command.

As a response a device sends measured data in following message:

03	Attribute	Low byte	Middle byte	High byte

Byte Attribute consist of a measured channel number (least 6 bits) and a gain code (most 2 bits) which was set at measurement moment.. Other 3 bytes contain measured value.

Message 04 – request date from ring-buffer. The message looks as:

04	Low byte	High byte

Here low and high bytes compose pointer at current measurement in a ring-buffer. The ring-buffer can hold 4096 measurement values. A micro-controller begins to store measured data with pointer value 0. After write al last address (4095) a micro-controller continues storing data from first address (0) again. For correct interpretation data (oldest and youngest) user should read current value of ring-buffer pointer. It may be done by "request status" message (code FE).

As a response a device sends measured data in following message:

04	Attribute	Low byte	Middle byte	High byte

Byte Attribute consist of a measured channel number (least 6 bits) and a gain code (most 2 bits) which was set at measurement moment.. Other 3 bytes contain measured value.

Message F8 – request date from registers. This message has not additional information. In reply a device sends a message with output register byte and input register byte.

F8	Output Register Data	Input Register Data

Message F9 – write data to output register.
Byte 1 contains information to be written into output register. A device don't respond on this message.

F9	Output Register Data

Message FE – request device status. There is not additional information. In reply a device sends the following message:

FE	Device Mode	Label	Low pointer	High pointer	Reserve

Here:

Device Mode- bit field. There are flags:

Bit 0 – RUN- if this flag is set it means that a device process measurements procedure (multi-channel or one-channel).

Bit 1 – SCAN- if this flag is set it means that a device process multi-channel measurements procedure.

Label- label value.

Low pointer, High pointer- bytes of ring-buffer pointer. It points at location which would be updated by next measurement. If ring-buffer was overwritten (after long time) the pointer points at oldest data.

Message FF – device attribute request. There is not additional parameters. In reply a device sends the following message:

FF	Device Code	HW version	SW version	Reason

Device Code- device type (for CANADC40*24 it is equal 2).

HW version- hardware version of device.

SW version- software version of device.

Reason- reason of sending this message:

0- After power-up.

1- After reset by button on front panel.
2- On request by address message with code FF.
3- On request by broadcast message (who is here?).

BROADCAST messages

For broadcast messages all devices analyze only field 1 in CANbus identifier. Valid combination is 5. A first byte of date present a broadcast command.. CANADC40*24 uses the following broadcast commands:

3- STOP- to stop measurements procedure.
4- group START, group code (label) is placed in second data byte.
FF- request “Who is here”. On this broadcast request all devices on-line must send into network message with their attributes (and identifier).

Some additional information.

Channel gain is defined as shown in table:

Binary code	Gain
00	1
01	10
10	100
11	1000

You should use gain 1 and 10. Using other ranges is not recommended.

Measurement time

Code decimal	Measurement time
0	1 ms
1	2 ms
2	5 ms
3	10 ms
4	20 ms
5	40 ms
6	80 ms
7	160 ms