VADC16

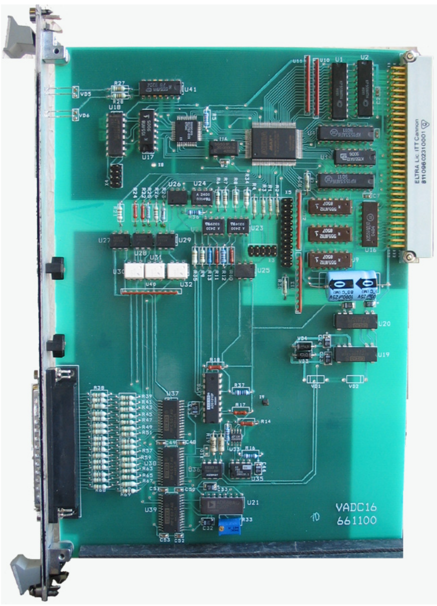
6-sep-2011
`Embedded software version 1.`

1. Features

This device is designed for using in different automation systems as a general purpose multi-channel precise voltmeter. The device is implemented in VME standard.

The device includes:

- 24-bits ADC;
- 24-channels input multiplexer. 16 channels are connected with connector on front panel;
- a temperature sensor, placed on the board;
- header, which allows to change base address of device;
- embedded microcontroller.



A photo of device.

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 generates an interrupt request after completion of procedure (if it was enabled). For investigation of powers supply behavior here may be used one-channel mode (digital oscilloscope mode). In this mode the device measures the only channel with defined time of measurements.

This device has galvanic isolation an analog circuitry from a digital part of device.

Hardware implementation of converter consist of delta-sigma ADC chip, and multi-channel multiplexer with overvoltage protection of inputs. The device requires for proper operation the only power supply (+5V).

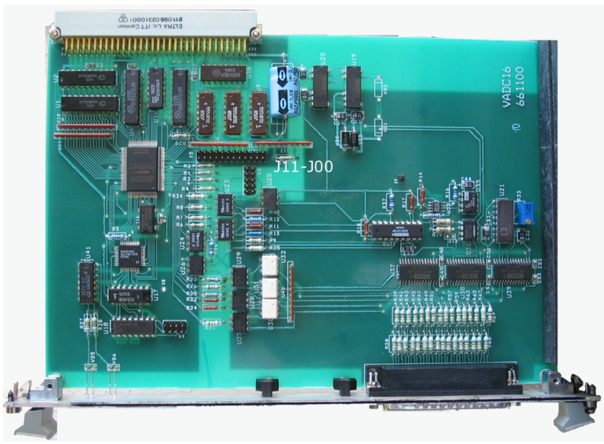
2. Specifications:

1. Resolution - 24 bits.
2. Effective resolution – from 15 bits (time of measurements is 1 ms) to 20 bits (time of measurements is 20 ms and more).
3. Offset error- 100 mcV.
4. Accuracy- 0,003%.
5. Input range- ±10V.
6. Input current- 1nA.
7. A maximal voltage between analog and digital parts – 200 V.
8. Common-mode rejection 100 dB.
9. Normal-mode rejection (for 50 Hz and T=20mS) – 60 dB.
10. Normal-mode rejection (for 60 Hz and T=20mS) – 48 dB.
11. Voltage between any input pins – 15 V.
12. Temperature sensitivity of on-board sensor – 1,9 mV/°C.
13. Output voltage of temperature sensor at +25 °C – 0.56 B ±10%.
14. Time of measurements- from 1 ms to 160 ms.
15. Voltage of power supply- +5V.
16. Power supply current- <1.0A (typical value- 0.8A).

3. External connections

A front panel of the device contains a connector (DRB-37M) for connection with signal sources and two LEDs. The first LED indicates a process of measurements. The second LED is ON during a calibration procedure.

3.1. Jumpers



The device has a set of jumpers which are used to change a base address of device. The device occupies two 16-bits registers (4 bytes) in input/output space of VME (AM=29 or 2A). These jumpers allow to change the base address with step equal 16. A presence of jumper means 1 and absence of jumper means 0.

Conformity jumpers and addresses.

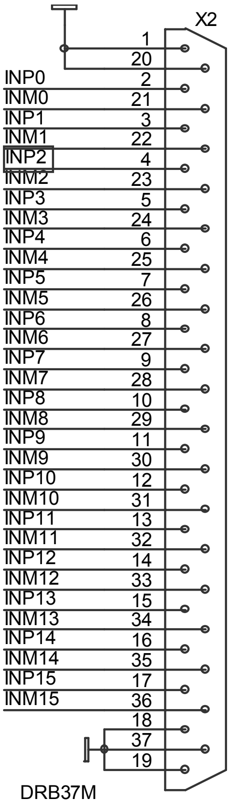
Jumper	J11	J10	J9	J8	J7	J6	J5	J4	J3	J2	J1	J0
Address	A15	A14	A13	A12	A11	A10	A09	A08	A07	A06	A05	A04

An example of address decoding.

Jumper	J11	J10	J9	J8	J7	J6	J5	J4	J3	J2	J1	J0
State	Off	On	Off	Off	On	Off	Off	Off	On	Off	Off	Off

A shown combination corresponds to address 0x4880. Correspondingly, the device uses addresses 0x4880 and 0x4882.

3.2 Front panel.



A front panel includes:
Run LED
Calibration LED
Reset button
Inputs connector

Run LED is ON during a measurements procedure.

Calibration LED is ON during a calibration procedure.

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

Inputs connector is intended for connection ADC inputs with external signals which should be digitized. The connector provides 16 pair of ADC inputs. There is used DRB37M as input connector. A connection of ADC inputs with a signal sources should be done by twisted pair. A mnemonics of pin designation is the following: INPx means "input positive x-number"; INMx means "input negative x-number".

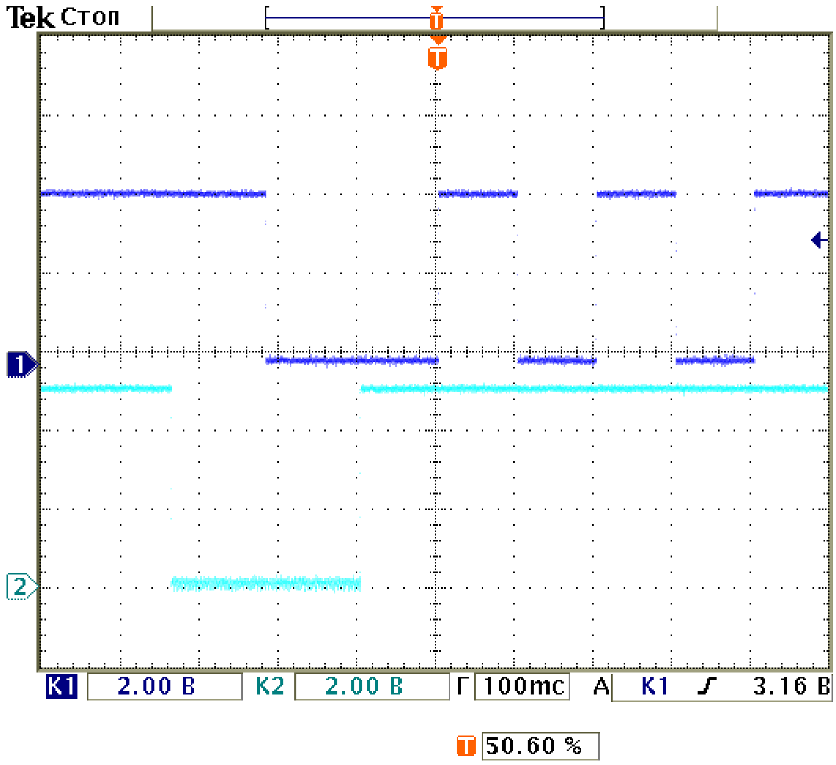
4. Basics of operations for VADC16

An operation of ADC is quite complicated. A converter consist of an ADC chip, a reference source an analog multiplexer and a calibration reference source. There 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 4 measured values in multi-channel mode. In single-channel mode a micro-controller don't discard any codes.

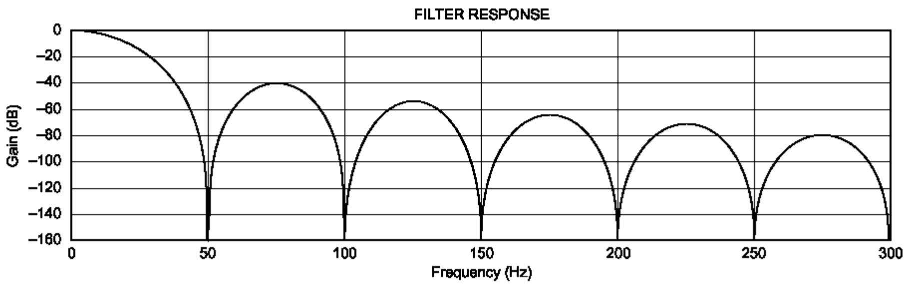
The described peculiarities lead to two consequences. At first, if time of measurement is defined 20 ms, the micro-controller will provide data to computer (or write data into internal memory) with the same rate 20 ms in case of single-channel mode. In case of multi-channel measurements the micro-controller discards first four measured values after changing channel number. It means that actually data rate will be 100 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 for 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 12 cycles (240ms for 20ms range).

The picture illustrates the described above. A pale-blue beam shows a state of calibration flag and a blue beam shows a state of input multiplexer least address bit. The ADC is working in multi-channel mode with time of measurements equal 20 mS. You can see that the device spends 240 mSec for calibration procedure and 100 mS for digitizing each channel.

An on-board micro-controller allows to reduce these delays in some cases. To find out time of measurements an user should look in table below (in notes).



An user should keep in mind that ADC effectively rejects an interference with frequency equal to data rate 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.

The picture is taken from ADS1210 datasheet. It shows normal-mode rejection for 20 mS time of measurements. An experimental data for device coincides with this picture exactly.

4.1. Base modes of VADC16

A converter of device can work in a few modes as it was mentioned above. The main mode is a multi-channel measurement mode. In this mode the device is involved by START command. User should define a first and last channels before. There is a flag which points if it is required a single cycle of scanning or converter should scan channels up to STOP command. Another flag defines if the device should request for interrupt after each measurement or at the end of cycle.

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, requests for interrupt. Each input channel has a personal location in the memory. 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.

The device may request for interrupt after each measurement, after frame completion or don't request for interrupt at all. In the latest case an user has opportunity to know about cycle completion by reading an internal location. If flags RUN and RUNR equal zero then the device completed measurements and stay in "idle" state. It is possible to get measured values "on-the-fly" in arbitrary moment. To avoid reading during data update process an user may use a wide known trick- read voltages twice and then comparing values. If data aren't identical an user should read data once more.

Actually, ADC of device has 24 measurement channels. 16 channels from them (0-15) are intended for an external connection and they connected with connectors pins. A three inputs have on-board connections. 17th channel is connected with measurements "Ground" and 16th channel is connected with an output of calibration reference source (it's voltage is +10V). 16th and 17th channels are used by calibration procedure. 18th channel is connected with temperature sensor on-board. Logically all 24 channels are equal. An user can measure any combination of channels.

For investigation of powers supply behavior here may be used one-channel mode (digital oscilloscope mode). In this mode an input voltage isn't changing quickly and the device don't discard any values. 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.

In both modes an user can break measurements by special command in arbitrary moment.

Примечание:
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 some future models may allow some over-voltage without loosing accuracy. An user should keep it in mind to reach compatibility of software.

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

Different times for VADC16

Code	Integration time	Data rate for single-channel mode	Data rate for single-channel mode	Time required for 16-channels cycle
0	1 mS	1 mS	5 mS	92 mS
1	2 mS	2 mS	10 mS	184 mS
2	5 mS	5 mS	25 mS	460 mS
3	10 mS	10 mS	50 mS	920 mS
4	20 mS	20 mS	100 mS	1840 mS
5	40 mS	40 mS	200 mS	3680 mS
6	80 mS	80 mS	400 mS	7360 mS
7	160 mS	160 mS	800 mS	14720 mS

5. A command set for VADC16

VADC16 is SLAVE module and provides interaction with VME bus as A16:D16 (address modifier is 29_h or $2D_h$). It occupies two 16-bits words in address space. The device is able to request for interrupt for any IRQ line.

5.1. VME registers of VADC16

At XXX0 address there is located a 16-bits exchange register. All interaction of the device and VME (except of interrupts) is implemented by this register. During WRITE cycle the device delays signal DTACK on a few microsecond up to completion request procession. There isn't delay during READ cycle.

Exchange register consist of

For WRITE cycle

Most significant byte	Least significant byte
Command to device	Command modifier

For READ cycle

Most significant byte	Least significant byte
Command to device or Requested data	Command modifier or Requested data

During WRITE cycle the most significant data byte should be interpreted as command to the device and the least significant byte is a command modifier (or an additional data). If the command to device requires some data back the micro-controller writes required data during current VME cycle. These bytes may be read by next READ cycle. If the command don't require any data the exchange register keeps value was written before.

At address XXX1 there is located an interrupt register.

Most significant byte	Least significant byte
IRQ line number	Interrupt vector

A high byte of interrupt register contains IRQ line number which would be used and low byte contains interrupt vector which would be read during INTERRUPT cycle. Actually, high byte contains only three valid bits. Combinations from 1 to 7 defines used line from IRQ1 to IRQ7. A combination 0 disables "interrupt request" generation.

On READ cycle at this address the user reads an information were written before.

5.2. Command of VADC16

Command 0- break a measurement procedure. There isn't any modifier. This command is intended to break measurements in arbitrary moment.

Command 1- start a measurement procedure. On receiving this command the micro-controller arranges a measurements procedure using parameters defined before (channel numbers, time of measurements). A command modifier defines a mode of measurement procedure. The command modifier consist of following bits:

b0- single-channel mode (0) or multi-channel mode (1).

b1- single measurement (0) or infinite cycle (1).

b2- request for interrupt should be in the end of the cycle (0) or after each measurement (1). It refers only to multi-channel mode. In single-channel mode this bit enables a request for interrupt on each measurement (1) or disables it (0).

Command 2- write of a measurement time. A modifier defines a measurement time. There are three valid bits. A correspondence between a code and a time are listed in table above.

Command 3- write of a start channel (for multi-channel mode) or measured channel (for single-channel mode). A modifier defines a channel number. Valid combinations are from 0 to 23.

Command 4- write of a end channel (for multi-channel mode). A modifier defines a channel number. Valid combinations are from 0 to 23.

Command 5- request data from micro-controller memory. A modifier defines a required location address. On receiving this command the micro-controller writes two data bytes into exchange register. It places the required location content into low byte of exchange register. In high byte of exchange register is placed contents of location with next address.

5.3. Micro-controller memory map in VADC16

Here is shown a memory map of on-board micro-controller. Some comments are included below the table.

Address Decimal	Address Hexadec.	Name	Destination
255	FF	Reserved	Not used
254	FE	Ch31DATAhigh	31-th channel data (high byte) (not exist)
253	FD	Ch31DATAmiddle	31-th channel data (middle byte) (not exist)
252	FC	Ch31DATAlow	31-th channel data (low byte) (not exist)
…	…	…	…
135	87	Reserved	Not used
134	86	Ch01DATAhigh	01-th channel data (high byte)
133	85	Ch01DATAmiddle	01-th channel data (middle byte)
132	84	Ch01DATAlow	01-th channel data (low byte)
131	83	Reserved	Not used
130	82	Ch00DATAhigh	00-th channel data (high byte)
129	81	Ch00DATAmiddle	00-th channel data (middle byte)
128	80	Ch00DATAlow	00-th channel data (low byte)
		ACC	Accumulator with current measured value

114	72	HWversion	Hardware revision
113	71	SWversion	Software revision
40	28	ADTIME	Time of measurement
39	27	CHCUR	Processed channel number
38	26	CHEND	End channel number
37	25	CHBEG	Start channel number
34	22	FLAG1	Bit flag
33	21	FLAG0	Bit flag

FLAG0 presents copy of command 1 modifier.

FLAG1 consist of the following bits:

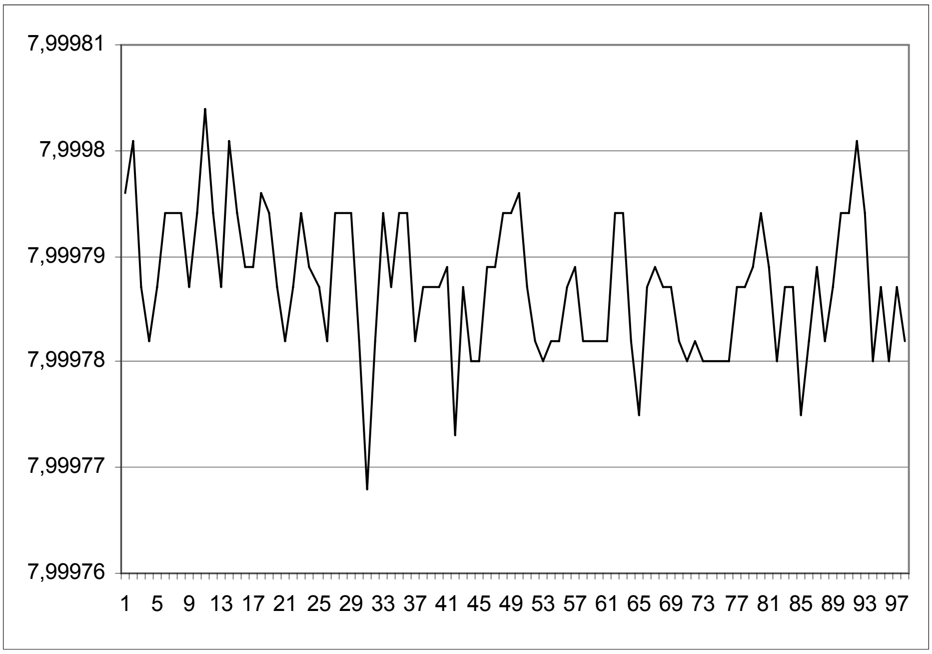
b0 – Run – measurement procedure in process.

b1 – RunR – request for measurement is received but the procedure isn’t work while.

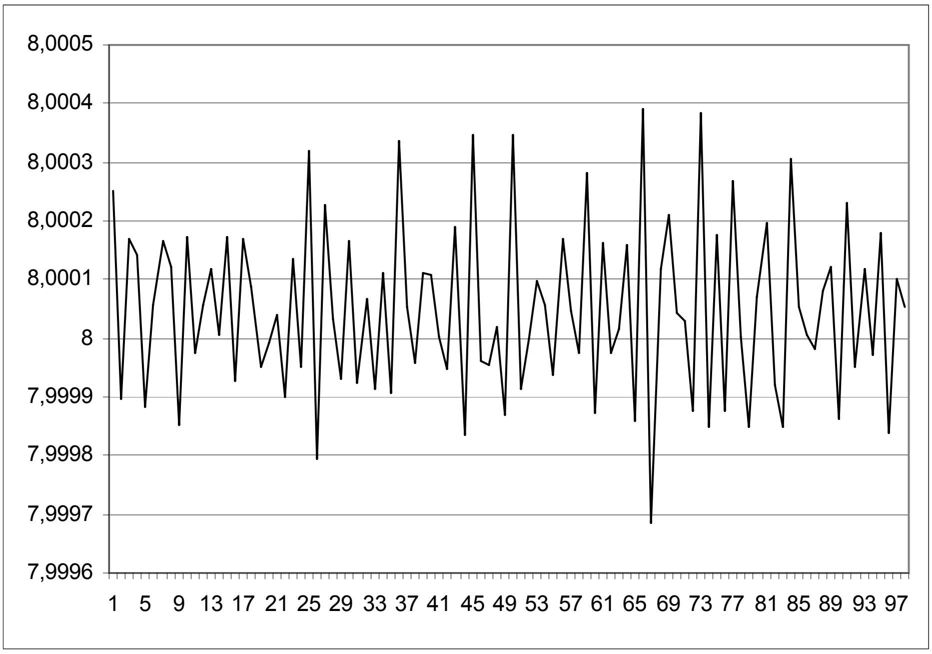
b2 – Calibration – ADC calibration procedure in process.

b3 – ACC content is updated. This bit is cleared by reading ACC location.

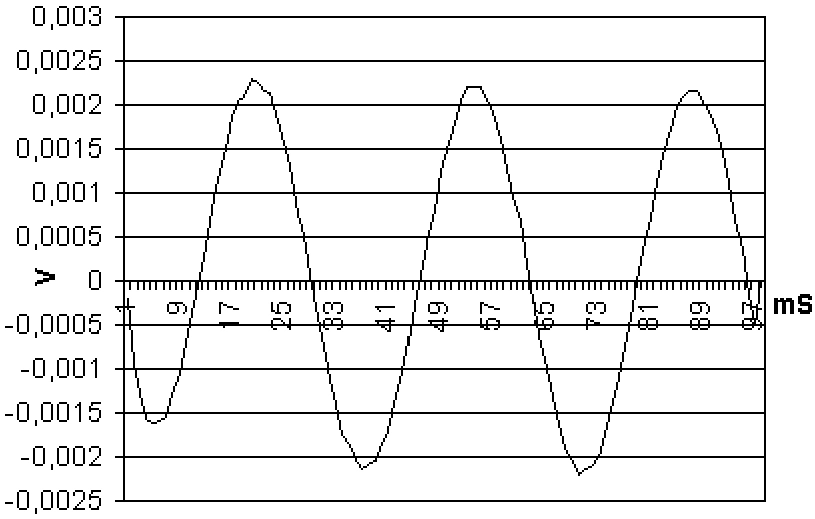
6. Some typical performance curves for VADC16



A typical noise of ADC. Data were collected in single-channel mode, data rate was 20 ms/measurement.



A typical noise of ADC. Data were collected in single-channel mode, data rate was 1 ms/measurement.



A fast measurements of low-level signal with frequency 30 Hz. A data were collected in single channel mode, data rate was 1 kHz (time of measurements was 1 ms/point).