Electronic Instrumentation

A7585 - DT5485P-PB Digital Controlled SiPM Power Supplies

Rev. 8 - 2 April 2021

Purpose of this Manual

This document is the **A7585 - DT5485P-PB Digital Controlled SiPM Power Supplies** User's Manual; it contains information about the installation, the configuration and the use of the units.

Change Document Record

Date	Revision	Changes
30 October 2017	0	Preliminary release
23 April 2018	1	Updated with DT5485P specification
13 June 2019	2	Updated LUT Mode
21 October 2019	3	Updated Pin Assignment, Electrical Char., I2C Address Calculation, I2C Interface
18 May 2020	4	Updated table Electrical Characteristics
8 July 2020	5	Updated Compatible temperature sensors
5 November 2020	6	Updated Analog Control, Mechanical Drawings
13 January 2021	7	Updated with DT5485PB specification
2 April 2021	8	Updated Register Map

Disclaimer

CAEN will repair or replace any product within the guarantee period if the Guarantor declares that the product is defective due to workmanship or materials and has not been caused by mishandling, negligence on behalf of the User, accident or any abnormal conditions or operations.

CAEN declines all responsibility for damages or injuries caused by an improper use of the Modules due to negligence on behalf of the User. It is strongly recommended to read thoroughly the CAEN User's Manual before any kind of operation.
CAEN reserves the right to change partially or entirely the contents of this Manual at any time and without giving any notice.

Disposal of the Product *The product must never be dumped in the Municipal Waste. Please check your local regulations for disposal of electronics products.*

Made In Italy: We stress the fact that all the boards are made in Italy because in this globalized world, where getting the lowest possible price for products sometimes translates into poor pay and working conditions for the people who make them, at least you know that who made your board was reasonably paid and worked in a safe environment. (this obviously applies only to the boards marked "Made in Italy", we cannot attest to the manufacturing process of "third party" boards).

Index

1. Overview

The A7585D is a high voltage regulator specifically designed for SiPM bias. It has a built-in temperature compensation controller with programmable coefficient.

The module can be digitally controlled by UART and I2C. Output voltage could be also controlled proportionally to an analog input.

A7585D can provide up to 10 mA and the output voltage could be regulated between 20V and 85V with a resolution of 1mV.

A7585DU version integrates a USB to UART bridge and it could be powered from USB.

The units are provided as PCB-mount modules (2.54mm pin pitch).

The DT5485P is a compact desktop format of the unit, with USB interface only (unit control and power supply). USB cable and TMP37 temperature probe are included in the kit.

The DT5485PB is a desktop format of the unit, with USB control only, and external +12V power supply. Desktop +12V power supply, USB cable and TMP37 temperature probe are included in the kit.

Moreover, the ZEUS control software is provided for free; ZEUS allows to monitor and control multiple modules at same time.

The Unit is developed in close collaboration with NUCLEAR INSTRUMENTS SRL.

Ordering Options

Board Models	Description	Product Code
A7585D	Digital Controlled SiPM Power Supply +85V / 10mA	WA7585DXAAAA
A7585DU	Digital Controlled SiPM Power Supply with USB +85V / 10mA	WA7585DUXAAA
DT5485P	Desktop USB Digital Controlled Power Supply for SiPM +85V / 10mA	WDT5485XPAAA
DT5485PB	Digital Controlled Power Supply for SiPM +85V 10mA , external power	WDT5485PBXAA

2. Safety and installation requirements

General safety information

This section contains the fundamental safety rules for the installation and operation of the board. Read thoroughly this section before starting any procedure of installation or operation of the product.

Injury Precautions

Review the following precautions to avoid injury and prevent damage to this product or any products connected to it. To avoid potential hazards, use the product only as specified. Only qualified personnel should perform service procedures.

Avoid Electric Overload.
To avoid electric shock or fire hazard, do not power a load outside of its specified range.

Avoid Electric Shock.
To avoid injury or loss of life, do not connect or disconnect cables while they are connected to a voltage source.

Do Not Operate Without Covers.
To avoid electric shock or fire hazard, do not operate this product with covers or panels removed.

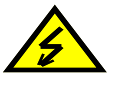
Do Not Operate in Wet/Damp Conditions.
To avoid electric shock, do not operate this product in wet or damp conditions.

Do Not Operate in an Explosive Atmosphere.
To avoid injury or fire hazard, do not operate this product in an explosive atmosphere.

Do Not Operate with Suspected Failures.
If you suspect this product to be damaged, have it inspected by qualified service personnel.

Safety Terms and Symbols on the Product

These terms may appear on the product:
DANGER indicates an injury hazard immediately accessible as you read the marking.
WARNING indicates an injury hazard not immediately accessible as you read the marking.
CAUTION indicates a hazard to property including the product.
The following symbols may appear on the product:

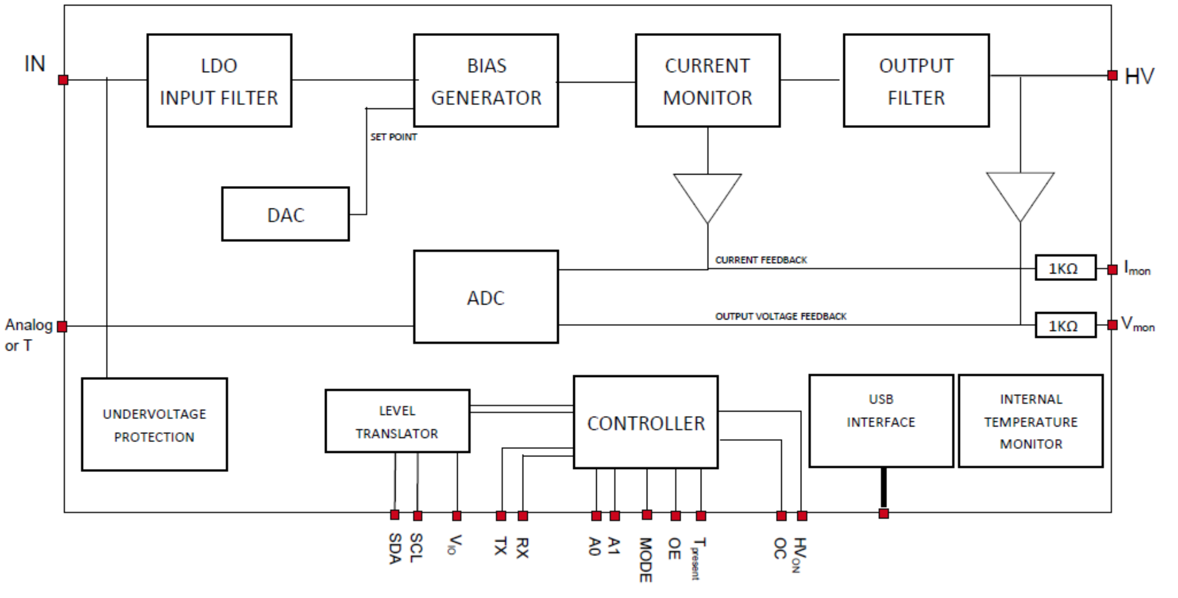


DANGER
High Voltage

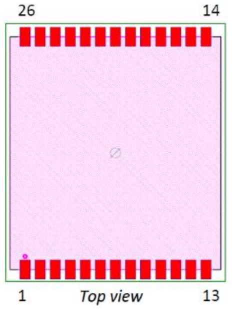
WARNING
Refer to Manual

3. Technical Specifications

Block Diagram



Pin Assignment A7585D

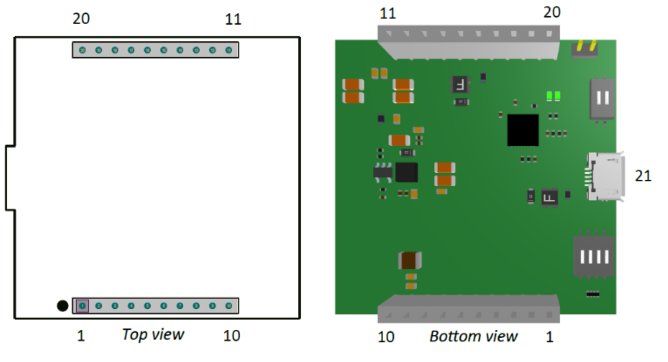


N	NAME	TYPE	DESCRIPTION
1	GND	POWER	
2	OUTPUT STATUS	OUT	Indicates the presence of HV power on output pin When logic 1 the HV output is enabled, when 0 the HV is off.
3	OVER-CURRENT	OUT	Module has been shut down due to overcurrent protection. The overcurrent protection is digitally programmable
4	TEMP SENSOR CONNECTED	IN	When high the temperature measurement is enabled
5	RESERVED	NC	
6	RESERVED	NC	
7	RESERVED	NC	
8	MODE SELECT	IN	Select control mode (pin must be stable on power on): 0 Digital, 1 Analog Control
9	POWER CONTROL	IN	Output enable pin: Analog Control Mode: when 1 HV output is on, when 0 HV output is off Digital Control Mode: On power on, when 1 HV output is on, when 0 HV output is off during operation: 0—>1 transition HV output is enabled, 1—>0 transition HV output is disabled
10	MODULE RESET	NC	Module hardware reset.
11	I2C ADDRESS 1	IN	I2C Address bit 1. Internally pull-up INTERNALLY INVERTED
12	I2C ADDRESS 0	IN	I2C Address bit 0. Internally pull-up INTERNALLY INVERTED
13	ANALOG IN	IN	Analog Control Mode: Reference voltage to regulate output voltage Digital Control Mode: Thermometer input
14	HV OUT	HV	HV Output
15	HV OUT	HV	HV Output
16	GND	POWER	
17	VMON	OUT	Analog V monitor output. Proportional to the output voltage in the range 0÷5V

18	IMON	OUT	Analog I monitor output. Proportional to the output current in the range 0÷5V
19	UART RX	IN	UART RX pin. 115200 bps,8,1,n. 5V ONLY
20	UART TX	OUT	UART TX pin. 115200 bps,8,1,n. 5V ONLY
21	I2C SDA	INOUT	Serial Data pin of I2C slave bus.
22	I2C SCL	IN	Serial Clock pin of the I2C slave bus
23	I2C VDD	POWER	Input pin to power the I2C voltage translator. 1.8V to 5V
24	POWER SUPPLY	POWER	6V to 28V
25	POWER SUPPLY	POWER	6V to 28V
26	GND	POWER	

WARNING! HV output contacts produce extremely hazardous high voltages at a potentially lethal current level; never connect or disconnect the HV OUTPUT with the ANALOG in and/or VDD in ON; always switch ANALOG in and/or VDD in OFF and wait at least 30s before connecting or disconnecting HV cables.

Pin Assignment A7585DU



N	NAME	TYPE	DESCRIPTION
1	ANALOG IN	IN	Analog Control Mode: Reference voltage to regulate output voltage Digital Control Mode: Thermometer input
2	I2C ADDRESS 1	IN	I2C Address bit 1. Internally pull-up INTERNALLY INVERTED
3	I2C ADDRESS 0	IN	I2C Address bit 0. Internally pull-up INTERNALLY INVERTED
4	POWER CONTROL	IN	Output enable pin: Analog Control Mode: when 1 HV output is on, when 0 HV output is off Digital Control Mode: On power on, when 1 HV output is on, when 0 HV output is off during operation: 0—>1 transition HV output is enabled, 1—>0 transition HV output is disabled
5	MODE SELECT	IN	Select control mode (pin must be stable on power on): 0 Digital, 1 Analog Control
6	GND	POWER	
7	IMON	OUT	Analog I monitor output. Proportional to the output current in the range 0÷5V
8	VMON	OUT	Analog V monitor output. Proportional to the output voltage in the range 0÷5V
9	GND	POWER	
10	HV OUT	HV	HV Output
11	I2C VDD	POWER	Input pin to power the I2C voltage translator. 1.8V to 5V
12	I2C SCL	IN	Serial Clock pin of the I2C slave bus
13	I2C SDA	INOUT	Serial Data pin of I2C slave bus.
14	UART TX	OUT	UART TX pin. 115200 bps,8,1,n. 5V ONLY
15	UART RX	IN	UART RX pin. 115200 bps,8,1,n. 5V ONLY
16	POWER SUPPLY	POWER	USB disconnected: power supply USB connected: Vin > 6V module powered from Vin, otherwise USB powered.
17	TEMP SENSOR CONNECTED	IN	When high the temperature measurement is enabled
18	OVER-CURRENT	OUT	Indicates the presence of HV power on output pin When logic 1 the HV output is enabled, when 0 the HV is off.
19	OUTPUT STATUS	OUT	Indicates the presence of HV power on output pin When logic 1 the HV output is enabled, when 0 the HV is off.
20	GND	POWER	
21	USB	USB connection	

WARNING! HV output contacts produce extremely hazardous high voltages at a potentially lethal current level; never connect or disconnect the HV OUTPUT with the ANALOG in and/or VDD in ON; always switch ANALOG in and/or VDD in OFF and wait at least 30s before connecting or disconnecting HV cables.

DT5485P Specification

Packaging	Shielded box; 84x76x22mm^3; 405g
HV OUT	LEMO connector; HV Output; WARNING! HV output produces extremely hazardous high voltages at a potentially lethal current level; never connect or disconnect the HV OUTPUT with the module powered ON; always switch OFF and wait at least 30s before connecting or disconnecting HV cables.
TEMP IN	3.5mm audio socket; temperature probe input
USB	Micro USB; USB connection and power supply input
BL	Boot Loader press-on contact; used for firmware update (refer to firmware documentation)

DT5485PB Specification

Packaging	Shielded box; 125x104x31mm^3; 290g
HV OUT	LEMO connector; HV Output; WARNING! HV output produces extremely hazardous high voltages at a potentially lethal current level; never connect or disconnect the HV OUTPUT with the module powered ON; always switch OFF and wait at least 30s before connecting or disconnecting HV cables.
TEMP IN	3.5mm audio socket; temperature probe input
USB	USB communication; B type USB connector
12V	Kycon KLDX-0202-A-LT 2.0mm DC Power Jack +12V DC Input
RESET	Boot Loader press-on contact; used for firmware update (refer to firmware documentation)
ON/OFF switch	Molveno A11331122000 A1 switch, O → power supply OFF, I → power supply ON
External power supply	XP Power VEC65US12 65 W Single Phase 12V 5.41A
LEDs	Power: lit when unit is on; HV-ON: lit when output is enabled; Fault: lit when alarm is detected

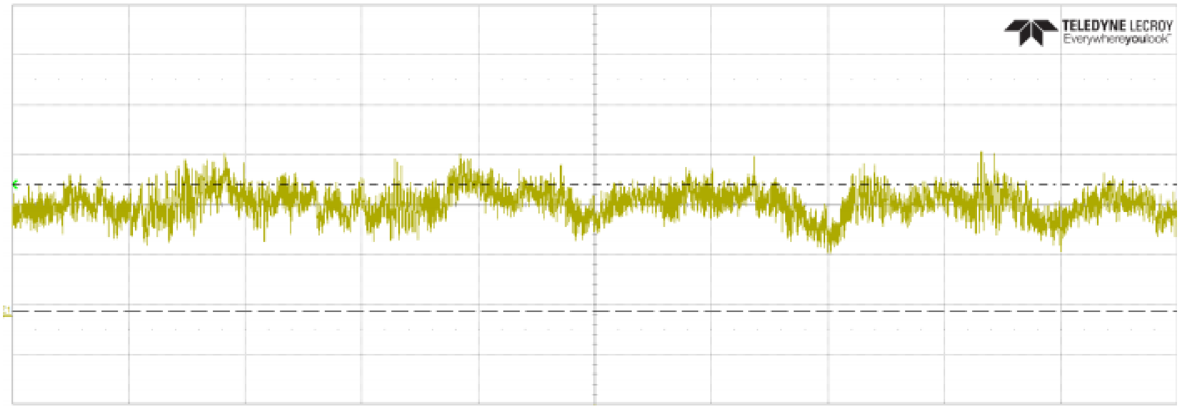
Electrical Characteristics

Parameter	Symbol	Condition	Min	Typ.	Max	Unit
Supply Voltage	Vs		6	12	24	V
Current Consumption	Icc	Vo = 50V	39			mA
Output Voltage	Vo		20		85	V
Output Current	Io	Vs=6V	0		10	mA
Output Voltage Ripple	Vn	Vo = 50V, after filter		0.1	0.2	mVp-p
Settling Precision	Vo-s	No Load		± 20		mV
Settling Resolution				1.2		mV
Temperature Stability		25 ± 10 °C				mV/°C
Output Impedance	Ro			10		Ω
DIGITAL I/O						
Digital I/O and UART High Level Input	Vio-IH		3		5	V
Digital I/O and UART Low Level Input	Vio-IL		0		0.5	V
Digital I/O Input Impedance	Rin			47		kΩ
Digital I/O and UART Output High Lev	Vio-OH			4.5	4.6	V
Digital I/O and UART Output Low Level	Vio-OL			0		V
Digital I/O Output impedance	Rout			500		Ω
UART Output Impedance	Ruout			20		Ω
I2C Power supply	Viic		1.8		5	V
I2C SDA/SCL High Level Input Voltage	Viic-IH			0.8 * Viic		V
I2C SDA/SCL Low Level Input Voltage	Viic-IL			0.2 * Viic		V
I2C SDA/SCL High Level Output Voltage	Viic-OH		0.8*Viic	Viic	Viic	V
I2C SDA/SCL Low Level Output Voltage	Viic-OL		0	0	0.2	V
Analog Input Range	Vai		0		5	V
Analog Output Range	Vao		0		5	V
Monitor pin output impedance	Raout			1		kΩ
INTERFACE						
Bus	UART, I2C, ANALOG, USB (order code A7585DU)					
UART Speed	Ubps			115200		bps
I2C speed	IICspeed	10		400	1000	kHz
I2C address			0x01	0x70	0x7f	

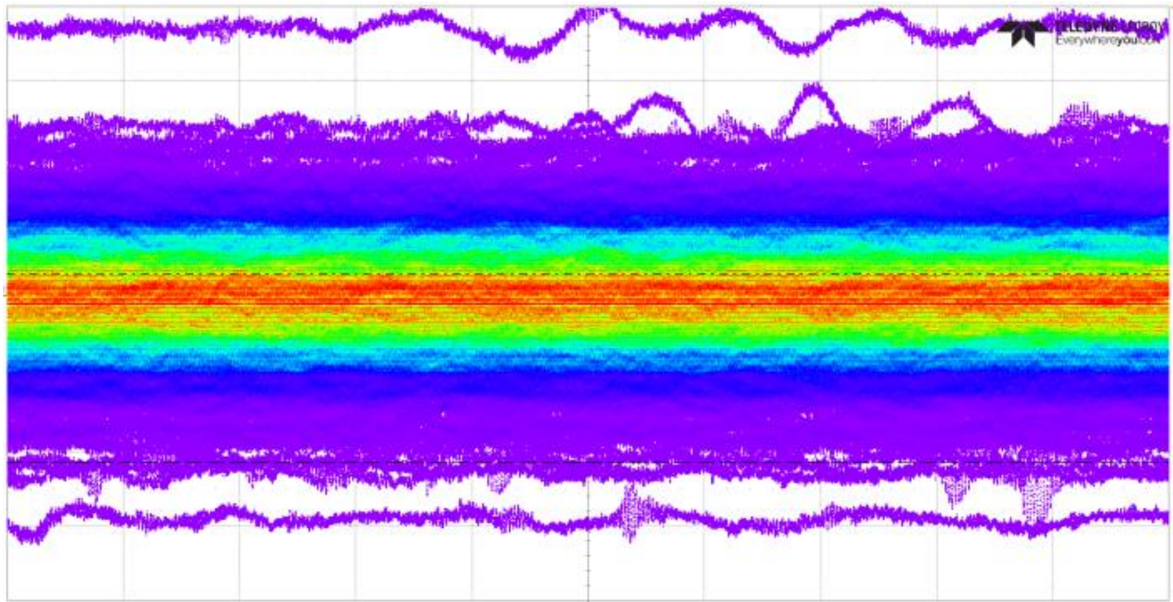
Absolute Maximum Range

Parameter	Min	Max	Unit
Supply Voltage	6	28	V
Maximum Input Current		210	mA
Maximum Power Consumption		5	W
Temperature Range (no load)	-20	80	°C
Storage Temperature	-40	120	°C

Electronic Noise

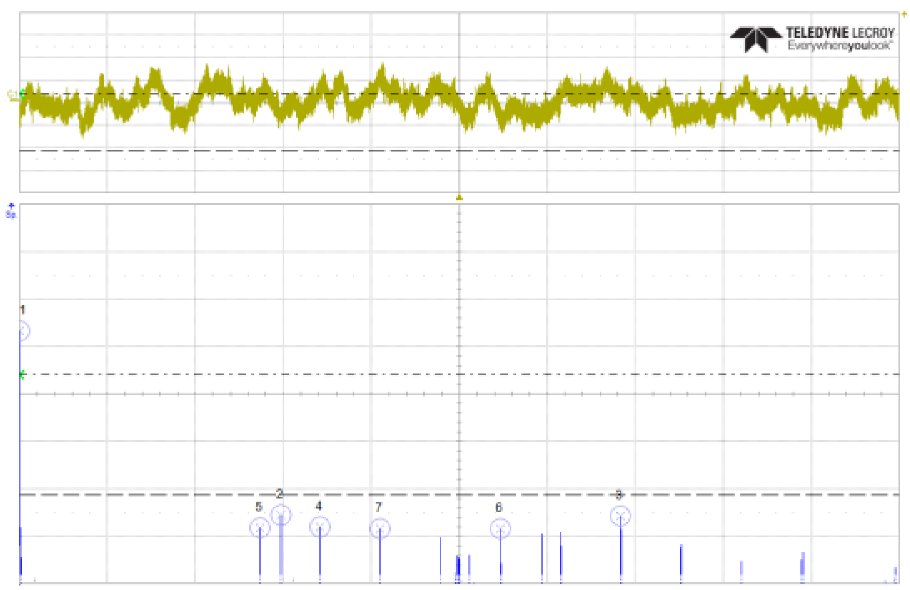


High and medium frequency ripple (>200KHz); Vertical Scale: 150uV/div Horizontal Scale: 1µs/div Bandwidth:20MHz



Low frequency stability; Vertical Scale: 1mV/div Horizontal Scale: 1µs/div Bandwidth:20MHz

Peaks	Frequency	Amplitude
1	19.1 Hz	-57.54 dBm
2	297.0054 kHz	-96.14 dBm
3	683.4922 kHz	-96.47 dBm
4	341.7457 kHz	-98.62 dBm
5	273.3966 kHz	-98.96 dBm
6	546.7935 kHz	-99.02 dBm
7	410.0951 kHz	-99.03 dBm



Output frequency spectrum. 500ms integration time

I2C Address Calculation

I2ADDRESS PIN [1]	I2ADDRESS PIN [0]	ADDRESS
1	1	(+0) 0x70 [default]
1	0	(+1) 0x71
0	1	(+2) 0x72
0	0	(+3) 0x73

Register Map

Registers from 14 to 27 and register 34 contain the module calibration coefficient. These coefficients are calculated by NI during the calibration process before delivery. Do not change these coefficients.

ADDRES	NAME	TYPE		DESCRIPTION	DEFAULT
0	HV ENABLE	BOOL	RW	HV Output Enable	0
1	MODE	INT	RW	Control mode: 0: Digital, 1: Analog, 2: Temperature Feedback	0
2	V TARGET	FLOAT	RW	Output voltage set point. Range: 20÷85V	30
3	RAMP SPEED	FLOAT	RW	Output voltage ramp (V/S). Range: 0.1÷10000	10
4	MAX V	FLOAT	RW	Compliance voltage. Range: 20÷85V. Output voltage will be limited to MAX V	85
5	MAX I	FLOAT	RW	Compliance current. Range: 0÷10mA. When MAX I is overcome the output will be shut down	10
7	C-TEMP M2	FLOAT	RW	Calibration Coefficient for temperature sensor. Quadratic Coefficient Temperature will be calculated with a conversion formula as a function of the voltage on the Vref input T=Vref2*TCm2+Vref*TCm+TCq	
8	C-TEMP M	FLOAT	RW	Calibration Coefficient for temperature sensor. Linear Coefficient	
9	C-TEMP Q	FLOAT	RW	Calibration Coefficient for temperature sensor. Offset Coefficient	
10	ALFA VOUT	FLOAT	RW	Digital Filter magnitude on the measured output voltage. Range: 0÷1 (1 is max)	0.8
11	ALFA IOUT	FLOAT	RW	Digital Filter magnitude on the measured output current. Range: 0÷1 (1 is max)	0.8
12	ALFA VREF	FLOAT	RW	Digital Filter magnitude on the measured analog reference voltage. Ran- ge: 0÷1 (1 is max)	0.8
13	ALFA TREF	FLOAT	RW	Digital Filter magnitude on the measured temperature voltage. Range: 0÷1 (1 is max)	0.8
28	TCOEF	FLOAT	RW	SiPM Temperature Compensation Coefficient. mV/°C considering a com- pensation of 0V at 25°C. When temperature compensation is enabled (MODE = 2) the output voltage will be Vout = Vset - Tcoef*(T-25)	0
29	LUT ENABLE	BOOL	RW	Replaces the Tcoef parameter compensation with a voltage— temperature look-up table. When temperature compensation is enabled (MODE =2) and LUT mode is enabled Vout = Vset - Vlut	0
30	ENABLE PI	BOOL	RW	Enables PI controller. A proportional/integrative controller will be used to minimize the settling error	0
31	EMERGENCY STOP	BOOL	W	Shut down HV without ramp	
32	IZERO	BOOL	W	Set measured current to 0	
36	LUT ADDRESS	INT	RW	Lookup table address to be written or read	
37	LUT PROGRAM TEMPERATURE	FLOAT	RW	Lookup table temperature to be written or read in the lut address specified in LUT ADDRESS [36] register	
38	LUT PROGRAM OUTPUT VALUE	FLOAT	RW	Lookup table output voltage to be written or read in the lut address specified in LUT ADDRESS [36] register	
39	LUT LENGTH	INT	RW	Number of valid address (filled with temperature vs Output value) of LUT	
40	I2C BASE ADDRESS	INT	RW	I2C Base Address	0x70
229	PIN STATUS	INT	R	Digital input pin status bit 0: IIC bit 1, 1: IIC, 2: MODE, 3: ON/OFF	
230	VIN	FLOAT	R	Input voltage (ADC read back)	
231	VOUT	FLOAT	R	Output voltage (ADC read back)	
232	IOUT	FLOAT	R	Output current (ADC read back)	
233	VREF	FLOAT	R	Reference input voltage (ADC read back)	
234	TREF	FLOAT	R	Temperature Detector	
235	V TARGET	FLOAT	R	Set Point	
236	R TARGET	FLOAT	R	Current Set Point	
237	cVT	FLOAT	R	Output voltage correction. Voltage due to SiPM temperature compensation	
249	COMPLIANCE V	BOOL	R	Compliance Voltage is active	

250	COMPLIANCE I	BOOL	R	Compliance Current is active	
251	PRODUCT CODE	INT	R	Product Code	50
252	FW VERSION	FLOAT	R	Firmware Version	
253	HW VERSION	FLOAT	R	Hardware Version	
254	SERIAL NUMBER	INT	R	Serial Number	
255	STORE ON FLASH	BOOL	W	Write all registers on flash	0.8

Registers from 14 to 27 and register 34 contain the module calibration coefficient. These coefficients are calculated by NI during the calibration process before delivery. Do not change these coefficients

Interfacing to the Module

The A7585 is a versatile SiPM HV generator. It could be controlled by several interfaces: Analog Input, UART, I2C and USB. USB is available on the ordering code A7585DU; DT5485P has the USB port only.
Multiple interfaces could be used at the same time to control the module. The arbitration logic follows the rule: "last write operation wins on previous one".
At the startup the module reads the status of the MODE pin. If MODE is 0 the module starts in Digital Control Mode, if MODE is 1 it starts as analog controlled. Any digital interface could be used to override the MODE pin status and change the Control mode in Analog, Digital or Temperature Feedback at any time.

Analog Control

In Analog Control mode (pin MODE set to 0) the device does not require any external logic to operate. The Vout is defined as

Vout = VAnalogIn/5 * (84-19.1) + 19.1

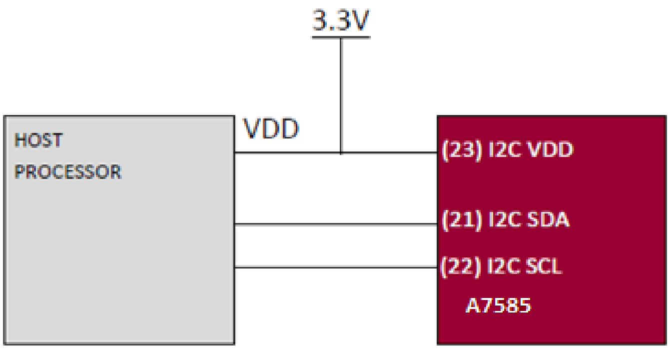
The POWER CONTROL pin is used to enable/disable the output voltage.
Ramp value programmed in the RAMP register (by default 10V/s) is used to limit the output voltage speed.
Output Voltage and Output Current could be monitored by reading the voltage on the VMON and IMON pin.

Vout = 18.978 VMON – 1.7811 (Vout and VMON expressed in volt)

Iout = 2.2616 IMON – 0.0309 (Iout expressed in mA and IMON expressed in volt)

N.B.: VMON and IMON pins are delivered across 1kOhm resistors.
OUTPUT STATUS and OVER-CURRENT pins could be used to monitor the module status. These two pins could be used to directly drive leds.

I2C Interface



The A7585 I2C module is compatible with the NXP I2C specification. This is the list of some of the module's features:
• 7-bit slave addressing
• Supports two clock rate modes:
- Standard mode, clock rates up to 100 kHz
- Fast mode, clock rates up to 1 MHz
• Support Multi-Master Applications

The I2C 10-bit addressing mode is not supported. The NXP I2C specification defines only the field types, field lengths, timings, etc. of a frame.
A7585 module has a I2C VDD pin that powers a level translator. It allows the user to set I2C interface operating voltage between 1.8V to 5V. A 10 kΩ internal pull-up is present inside the module. For operation speed higher than 100 kHz, an external 2.2 kΩ pull-up is suggested.

A device that sends data onto the bus is defined as transmitter, and a device receiving data as receiver. The bus must be controlled by a master device which generates the serial clock (SCL), controls the bus access and generates the START and STOP conditions. The A7585 device works as slave. Both master and slave can operate as transmitter or receiver, but the master device determines which mode is activated. Communication is initiated by the master (microcontroller) which sends the START bit, followed by the slave address byte. The first byte transmit-ted is always the slave address byte, which contains the device code, the address bits, and the read/write (R/W) bit.
The **Serial Data (SDA)** signal is the data signal of the device. The value on this pin is latched on the rising edge of the SCL signal when the signal is an input. Apart from the START and STOP conditions, the high or low state of the SDA pin can only change when the clock signal on the SCL pin is low. During the HIGH period of the clock, the SDA pin's value (high or low) must be stable. Changes in the SDA pin's value while the SCL pin is HIGH will be interpreted as a START or a STOP condition.
The **Serial Clock (SCL)** signal is the clock signal of the device. The rising edge of the SCL signal latches the value on the SDA pin. The MCP47X6 will not stretch the clock signal (SCL) since memory read access occurs fast enough. Depending on the clock rate mode, the interface will display different characteristics.
The serial clock is generated by the master. The following definitions are used for the bit states: Start bit (S), Data bit , Acknowledge (A) bit (driven low) / No Acknowledge (A) bit (not driven low) , Repeated Start bit (Sr), Stop bit (P).
A device that sends data onto the bus is defined as transmitter, and a device receiving data as receiver. The bus must be controlled by a master device which generates the serial clock (SCL), controls the bus access and generates the START and STOP conditions. The A7585 device works as slave. Both master and slave can operate as transmitter or receiver, but the master device determines which mode is activated. Communication is initiated by the master (microcontroller) which sends the START bit, followed by the slave address byte. The first byte transmit-ted is always the slave address byte, which contains the device code, the address bits, and the read/write (R/W) bit.
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Write Register

START	7 BIT ADDRESS	0	INTERNAL ADDRESS	DATA TYPE	BYTE 0	BYTE 1	BYTE 2	BYTE3	STOP

The address byte is the first byte received following the START condition from the master device. The A7585's slave address consists of a 5-bit fixed code ('11100') and a 2-bit code that the user can define by configuring the pin I2C ADDRESS 0/1 at the start up. The value of the I2CADDRESS PIN is internally inverted. The I2C slave address byte format contains the seven address bits and a read/write (R/W) bit (0=write, 1=read) . The slave acknowledges the master when the address byte matches with the slave address.
The following six bytes represent the packet payload:
INTERNAL ADDRESS: Register address. See table 4.
DATA TYPE: User could specify the data format choosing between: (0) integer, (1) decimal value multiplied by 10000, (2) unsigned integer, (3) floating point. See data format paragraph for more information.
BYTE 0...3: Data to be written in the register. Byte 0 is LSB, byte 3 the MSB.

Slave acknowledges all bytes.

Read Register

START	7 BIT ADD.	0	INTERNAL ADD.	DATA TYPE	REP	7 BIT ADD.	1	BYTE 0	BYTE 1	BYTE 2	BYTE 3	STOP

Read process is similar to write process except that, after writing the DATA TYPE, the master generates a repeat start condition and then tries to access to the slave in read mode (last bit of address byte is set to 1).
The master specifies the internal slave address and the data type in the first write access to the device. Then the master accesses to the slave for reading. The slave replies to the master with a 4 byte word. Byte 0 is the LSB, byte 3 the MSB.
The master acknowledges the slave on byte 0,1,2, while it does not acknowledge the slave for byte 3 to notify the slave the end of the transmission.

Data Format

Registers inside the module have different data formats. User could write any register using any data format that is capable to represent the value. Boolean registers accept only true/false values. When user writes a value in a boolean register, any value different from 0 is considered as a true.
The user could write data in a register using one of the following formats:

Integer (Data Format 0)

The number is interpreted as a 32 bit integer. Valid range is from −2,147,483,648 to 2,147,483,647.
The integer number is converted in a 4 byte data. The first byte is the LSB while the last byte is the MSB.
Examples:

	CHIP ADDRESS	REGISTER ADDRESS	DATA TYPE	DATA LSB			DATA MSB
1	0x70	0x02	0x00	0x01	0x00	0x00	0x00
1530	0x70	0x02	0x00	0xF0	0x05	0x00	0x00
-30	0x70	0x02	0x00	0xE2	0xFF	0xFF	0xFF

Fixed Point (Data Format 1)

The number is interpreted as a 32 bit fixed point number. Valid range is from −2,147,48.3648 to 2,147,48.3647.
This data format allows the user to simply transfer a decimal value without making a floating point conversion. It uses a 4 digit fixed point conversion. For example, to transfer the number 30.345 the user should multiply the number by 10000. The number that should be transferred will be 303450. The number must be transferred as an integer.
Examples:

	CHIP ADDRESS	REGISTER ADDRESS	DATA TYPE	DATA LSB			DATA MSB
14.23 >> 14.23*10000 = 142300 142300	0x70	0x02	0x01	0xDC	0x2B	0x02	0x00
0.3456 >> 0.3456*10000 = 3456 3456	0x70	0x02	0x01	0x80	0x0D	0x00	0x00

Unsigned Integer (Data Format 2)

The number is interpreted as a 32 bit unsigned integer.

Floating Point (Data Format 3)

Floating-point arithmetic is arithmetic using formulaic representation of real numbers as an approximation to support a trade-off between range and precision. A number is, in general, represented approximately to a fixed number of significant digits (the significand) and scaled using an exponent in some fixed base; the base for the scaling is normally two, ten, or sixteen. A number that can be represented exactly is of the following form:
Significand x base $^{\text{exponential}}$
where the significand is an integer (i.e., in Z), the base is an integer equal or greater than two, and exponent is also an integer. For example:
$1.2345 = 12345 * 10^{-4}$
Floating-point representation is conceptually similar to scientific notation. Logically, a floating-point number consists of:
- A signed (meaning negative or non-negative) digit string of a given length in a given base (or radix). This digit string is referred to as the significand, mantissa, or coefficient. The length of the significand determines the precision to which numbers can be represented. The radix point position is assumed

always to be somewhere within the significand, often just after or just before the most significant digit, or to the right of the rightmost (least significant) digit.
- A signed integer exponent (also referred to as the characteristic, or scale), which modifies the magnitude of the number.
he common IEEE formats in the binary single-precision (32-bit) floating-point representation, significand is a string of 24 bits while exponential has 8 bits.
Example:
Convert 0.1015625 to IEEE 32-bit floating point format.
0.1015625 × 2 = 0.203125 0 Generate 0 and continue.
0.203125 × 2 = 0.40625 0 Generate 0 and continue.
0.40625 × 2 = 0.8125 0 Generate 0 and continue.
0.8125 × 2 = 1.625 1 Generate 1 and continue with the rest.
0.625 × 2 = 1.25 1 Generate 1 and continue with the rest.
0.25 × 2 = 0.5 0 Generate 0 and continue.
0.5 × 2 = 1.0 1 Generate 1 and nothing remains.
So $0.1015625^{10} = 0.0001101^{2}$
Normalize: $0.0001101^{2} = 1.101^{2} \times 2^{-4}$
Mantissa is 10100000000000000000000, exponent is -4 + 127 = 123 = 01111011^{2}, sign bit is 0.
0.1015625 is 0 01111011 10100000000000000000000 = 0x3DD00000

0 SIGN	01111011 EXPONENT	10100000000000000000000 EXPONENT

If the user want to write this number in the register using the I2C bus he should write the number 0x3DD00000 setting the cast byte to 3.

CHIP ADDRESS	REGISTER ADDRESS	DATA TYPE	DATA LSB			DATA MSB
0x70	0x02	0x03	0x00	0x00	0xD0	0x3D

Floating point to integer cast could be easy performed in C using a pointer. The following example shows how to perform a register write trasmit-ting a 32 bit floating point.

```
float data;
uint32_t *pdata;
data= 60.45;
pdata = (uint32_t *) &data;
I2c_module_write(CHIP_ADDRESS, REGISTER_ADDRESS, *pdata);
```

The pointer *pdata will point to data but it will be interpreted as an unsigned 32 bit hex; the value of the pointer *pdata will be 0x4271cccd.

To convert a read value to floating point representation the order of the operations has to be inverted:

```
uint32_t data;
float *pdata;
I2c_module_read(CHIP_ADDRESS, REGISTER_ADDRESS, &data); //data for example is 0x4271cccd
pdata = (float *) &data;
```

The pointer *pdata will point to data but it will be interpreted as a 32 bit floating point value; the value of the pointer *pdata will be 60.45.

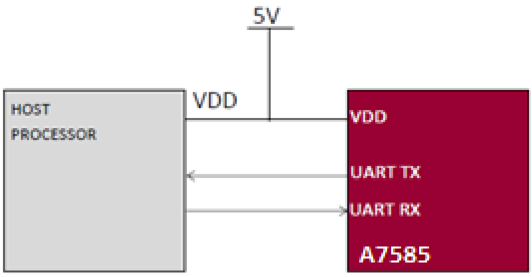
4. UART Interface

The A7585 integrates a standard UART interface.
The universal asynchronous receiver/transmitter (UART) takes bytes of data and transmits the individual bits in a sequential fashion. At the destination, a second UART re-assembles the bits into complete bytes. Each UART contains a shift register, which is the fundamental method of con-version between serial and parallel forms.
The idle, no data state, is logic high-voltage. Each character is framed as a logic low start bit, data bits, and one stop bits. The least significant data bit (the one on the left in this diagram) is transmitted first.
The start bit notifies the receiver that a new character is coming. The 8 bits represent the character. The next one bit is always 1 and called the stop bit. Since the start bit is logic low (0) and the stop bit is logic high (1), there are always at least two guaranteed signal changes between characters.
All operations of the UART hardware are controlled by a clock signal which runs at a multiple of the data rate. The receiver tests the state of the incoming signal on each clock pulse, looking for the beginning of the start bit. If the apparent start bit lasts at least one-half of the bit time, it is valid and notifies the start of a new character. If not, it is considered as a spurious pulse and it is ignored. After waiting for a further bit time, the state of the line is again sampled, and the resulting level is clocked into a shift register. After the required number of bit periods for the character length have elapsed, the contents of the shift register are made available (in parallel fashion) to the receiving system. The UART will set a flag indicating that new data is available. Communicating UARTs usually have no shared timing system. Baud rate must be known by both the transmitter and the receiver.
A7585 uses a 5V UART interface configured using the following parameters:
BAUD RATE: 115200 bps
DATA BIT: 8
STOP BIT: 1
PARITY: 0
FLOW CONTROL: NONE
MODE: FULL-DUPLEX
Communication protocol uses standard AT commands. Commands are strings always starting with “AT” and terminated by a CRLF (Carriage Return, Line Feed) sequence (known as \r\n sequence in C-like language). All strings must be written in capital letters.
The UART service does not echo the user incoming data (there is no visible feedback for the sent string); user views only the answers to the sent command.

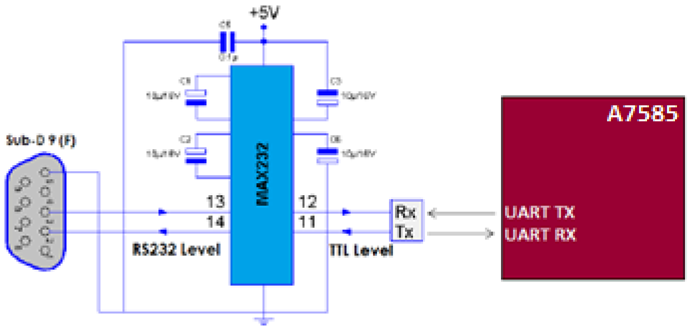
COMMAND	DESCRIPTION	RESPONSE
AT	The command has no function. It must be present by standard AT. The A7585 always replies with string ERROR. Some OS try to communicate with any device connected to the PC serial port to investigate if a Modem is connected to the port. Answering ERROR to the AT command stops the OS to investigate the modem presence on that serial port, releasing the serial port.	ERROR
AT+CGMI	Device manufacturer	CAEN
AT+CGMM	Device model	A7585
AT+HUMAN	Enters in human interface command mode. It opens a VT100 GUI to control the device using a simple VT100 terminal (Putty, Minicom, Hyperterminal).	
AT+MACHINE	Enters in machine mode interface. It allows to write and read register using the two commands AT+SET and AT+GET.	
AT+SET	Set register. Syntax: AT+SET, REGISTER NUMBER, REGISTER VALUE Examples: AT+SET,0,1 (enable power) AT+SET,2,34.567 (set output voltage)	OK
AT+GET	Read register. Syntax: AT+GET, REGISTER NUMBER Examples: AT+GET,0 answer: OK=true (power is enabled) AT+GET,231 answer: OK=34.560 (output voltage is 34.560)	OK=Register Value

There are two different operative modes:
HUMAN MODE: shows a VT100 compatible Textual User Interface. It allows to control the module in a very simple way without installing any software on the user computer.
MACHINE MODE: it allows to control the device by a PC software (like Zeus) or through microcontroller.

Interfacing A7585 using UART



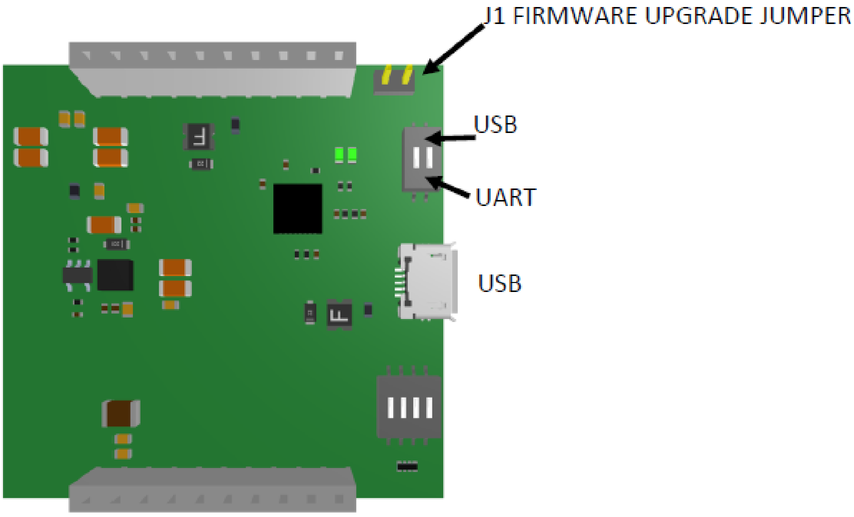
Direct interfacing to 5V tollerant uC



Direct interfacing to RS232

UART on A7585DU

A7585DU has an integrated UART to USB converter (FTDI FT232R). A switch allows the user to select if the serial port is connected to the USB converter or to external PIN.
In the figure is shown the two switches to control the routing of the UART bus. When the two switches are in OFF position, the UART is connected to the UART to USB bridge, otherwise the UART is connected to UART TX and UART RX pins.
When USB mode is selected, UART pins are floating.



Upgrade A7585DU

A7585DU could be upgraded using USB bus. To upgrade the firmware short the jumper J1 and use ZEUS firmware upgrade function to down-load the new firmware.

Upgrade DT7585P

DT7585P could be upgraded using USB bus. To upgrade the firmware, press the BL pin and use ZEUS firmware upgrade function to down-load the new firmware.

UART Human Interface

In HUMAN MODE the device generates a VT100 compatible Textual User Interface. It allows to control the module in a very simple way without installing any software on the user computer. Any VT100 terminal emulator like Putty, Tera Term, Hyperterminal or Minicom could be used to control the module.
To enter in HUMAN MODE digit at any time AT+HUMAN followed by ENTER key.

```
HV OUT    VOUT(V)   VSET(V)   IOUT(mA)   Vref(V)   Temp(°C)
  ON      50.041    50.000    0.000051   0.003     0.003


 0) Power Off HV
 1) Power On  HV
 2) Set Compliance Vout       80.00 V
 3) Set Compliance Iout       9.00 mA
 4) Set HV Voltage            50.00 V
 5) Set Reference Mode        DIGITAL
 6) Set Temperature Sensor
 7) Set Voltage Output ramp   10.00 V/s
 8) Save parameters on flash
 9) Others

Select a menu option:
```

Using the keyboard numbers, the user could set almost all the parameters of the module, except the values to program the LUT and the calibration coefficients. (This could be done using ZEUS software only).
To exit from HUMAN MODE a power cycle is required.

UART Machine Interface

Machine interface allows the user to configure and interact with the module using a textual protocol.
To enter in MACHINE MODE send to the A7585 the string AT+MACHINE followed by the sequence CRLF (\n\r).
The module does not feedback the user.
There are two commands to set and get registers value: AT+SET and AT+GET.
AT+SET syntax is:
AT+SET,<REGISTER NUMBER>,VALUE followed by the sequence CRLF
The value could be written as integer or decimal value.
Examples:
Set output voltage: AT+SET,2,24.560 Enable output: AT+SET,0,1
The module casts the user value to the correct format.
AT+GET syntax is:
AT+SET,<REGISTER NUMBER> followed by the sequence CRLF.
The returned values are always decimal strings or Boolean (true/false) terminated by a CRLF sequence.
Examples:
Get output value: AT+GET,2 OK=24.560(CRLF) Get output value: AT+GET,0 OK=true(CRLF)
To exit from MACHINE MODE a power cycle is required.

Save parameters on Flash

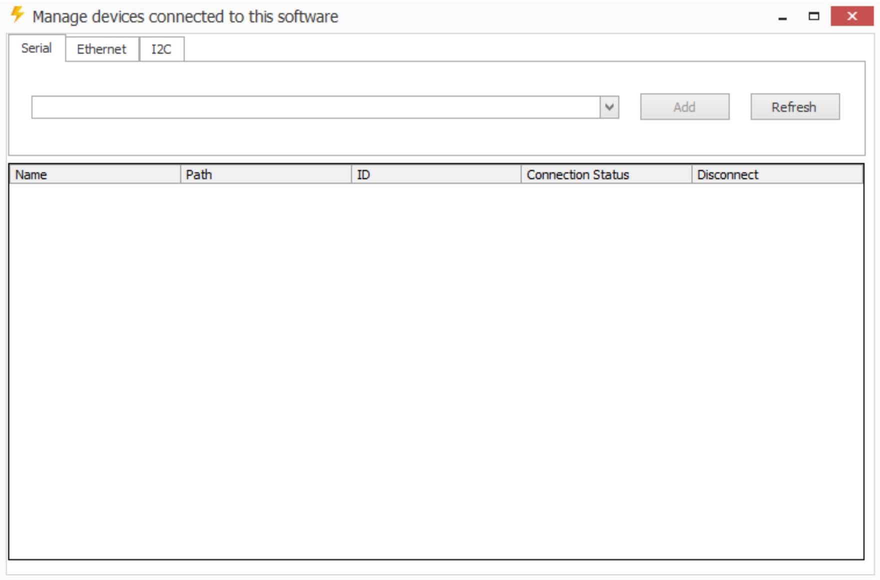
To save all current register values on flash (except register 0) user must write 1 in register 255 using or I2C or UART communication.
Example to save parameters using UART: AT+SET,255,1
Example to save parameters using I2C: Write 0x70,0xFF,0x00,0x00,0x00,0x00,0x01

Change I2C Base Address

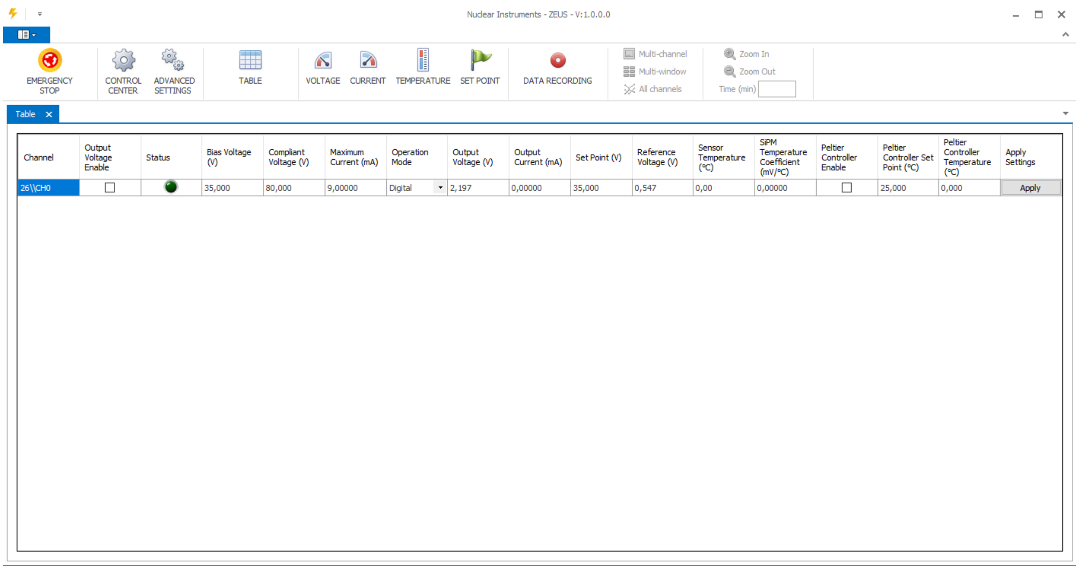
Up to 127 different A7585 modules could be simultaneously connected to a single I2C bus. A7585 are factory programmed with address 0x70. This address could be changed by the user writing the new address in the register 40.
Valid values are number between 0 and 127. Even if it is not mandatory, it is recommended to use only multiples of 4. The last 2 bits could be selected using the two physical bits IIC A0 e IIC A1.

5. ZEUS Software

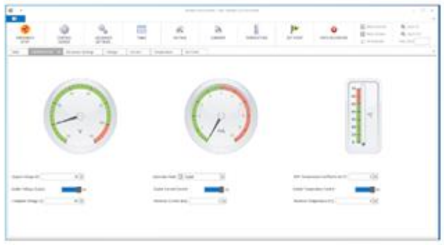
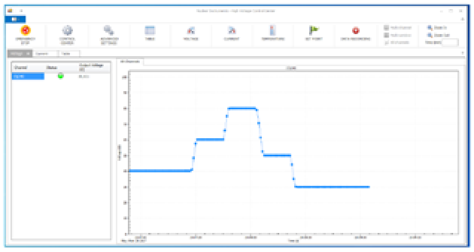
ZEUS is a Windows compatible software that allows to control multiple A7585 and A7585DU modules using RS232 or USB connection. It controls DT5485P via USB.
Supported connections are Serial, Ethernet and I2C.
The software is based on a user-friendly GUI that allows the parameters configuration and the data logging on file. It integrates realtime plot capabilities (voltage, current and temperature) with the possibility to superimpose measurements from several modules. ZEUS software is the simplest way to program temperature LUT compensation.
ZEUS can be downloaded at the Software section of the www.caen.it website; simply launch the setup file and the application will be installed.
When the application is launched, the connection menu will be displayed, listing the connected devices:



Add the desired item, and its functional parameters will be displayed in the “Table” menu:



The “Tool Bar” has several options:

EMERGENCY STOP	Turns off the HV output at the fastest available rate	
CONTROL CENTER	Live time control of output voltage, current and temperature monitor	
ADVANCED SETTINGS	Settings of operation modes, temperature sensor, calibration, low pass and peltier filters	
VOLTAGE	HV out vs. time plot	
CURRENT	Output current vs. time plot	
TEMPERATURE	Monitored temperature vs. time plot	
SET POINT	Voltage set point vs. time plot	
DATA RECORDING	Writes functional parameters values into log file	

6. SiPM Temperature Compensation

The unit has integrated advanced bias voltage vs temperature compensation.
The modules can operate in temperature feedback mode (set register MODE [2] to temperature value [2]). In Temperature feedback mode the module samples one time per second the SiPM temperature and adjusts the output voltage to compensate for the temperature drift.
There are two compensation techniques:
• SiPM Compensation Coefficient
• LookUp Table Output Voltage vs Temperature

SiPM Compensation Coefficient

Output voltage is linearly compensated using the following formula:
$V_{out} = V_{set} - T_{coef}*(T-25)$
For example, if V_{set} = 50v, T_{coef} =50mV/°C and T=35°C V_{out} will be corrected of 500mV. So the V_{out} = 49.5v
To enable the compensation user must write 2 as value in the MODE register (2). Temperature compensation could be used only when I2C, UART or USB are used to control the module.

LUT Mode

A LookUp table is an matrix of Output Voltage vs Temperature. The module samples the thermometer analog input every seconds, looks in the LUT the temperature and apply the correct output voltage.

LUT Address	Temperature	Output Voltage
0	15	50
1	20	49.5
2	25	49.3
3	30	49.2
4	35	49.1
5	40	49.15
6	50	49.05

The module linear interpolate the output values to calculate the correct output value at a specific temperature. Considering the previous table, for T=32°C the output value will be V_{out}=49.16v

$$49.2 \times \frac{35-32}{35-30} + 49.1 \times \frac{32-30}{35-30}$$

Lookup table could be programmed with up to 32 different couples of Temperature/Output Value. The number of valid LUT values should be writ-ten in the LUT LENGTH register. The lookup table must be programmed using or Zeus software or direct writing in the configuration registers.
The procedure is the following
1) Write the address of the LUT in the LUT ADDRESS register
2) Write the temperature in the LUT TEMPERATURE VALUE register
3) Write the output value in the LUT OUTPUT VALUE register
4) Repeat from step 1 until all Temperature vs Output Value couples are written in the table
5) Write the number of LUT points in the LUT LENGTH register

For examples, to program the values of the example table using serial port user should execute the following step:
AT+SET,36,0 AT+SET,37,15 AT+SET,38,50 *(write point 0)*
AT+SET,36,1 AT+SET,37,15 AT+SET,38,49.5 *(write point 1)*
……
AT+SET,36,6 AT+SET,37,50 AT+SET,38,49.05 *(write point 6)*
AT+SET,39,7 *(update LUT length)*
To enable the LUT compensation user MUST set to 1 the register LUT ENABLE and select temperature mode [2] in the register MODE.

If measured temperature is outside the LUT limits the Output Voltage will be clamped to the LUT limits voltages. In the previous examples, for temperature below 15°C the output voltage will be set to 50V while for temperature above 50°C the output voltage will be set to 49.05V

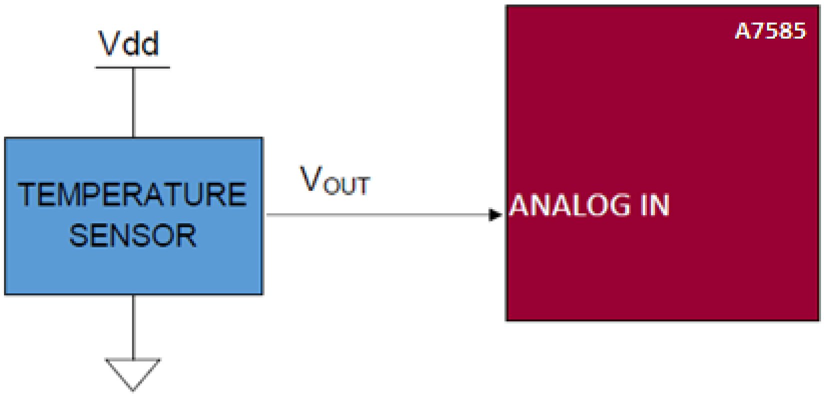
Compatible temperature sensors

The unit is compatible with all analog temperature sensors whose output linearly depends by the temperature. The temperature sensors must be place as close as possible to the detector. The designer should avoid placing any fast switching digital close to the detector to avoid interferences. For this reason, we choose to do not support digital temperature sensor and support only active analog sensor.
We suggest the following two sensor model:
• Texas Instruments LM94021
• Analog Devices TMP37
In general, any temperature linear sensor could be used after a proper calibration.
The measured temperature is calculated as:

$T=Vref^2*TCm^2+Vref*TCm+TCq$

Cm2 is the square coefficient expressed in °C/V^2
Cm is the linear coefficient expressed in °C/V
TCq is the temperature offset coefficient expressed in °C

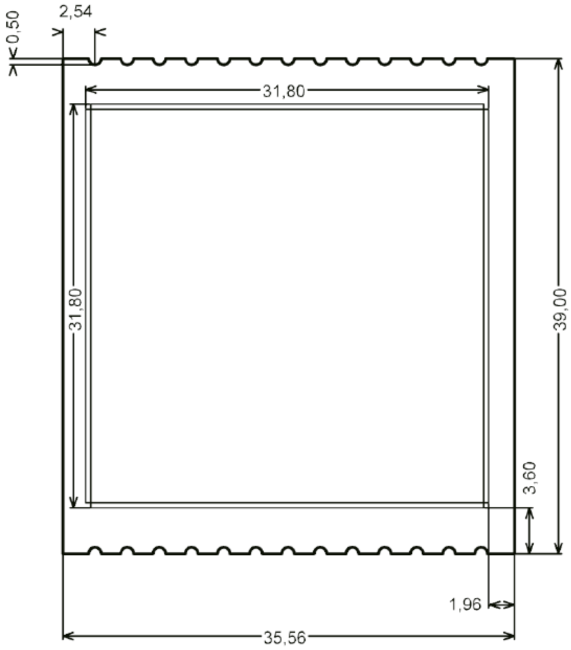
Sensor Model	Cm2	Cm	TCq
LM94021	0	-73.53	193.9
TMP37	0	50	0

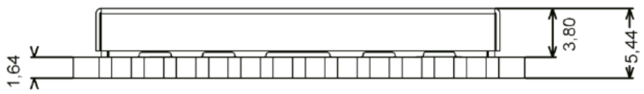


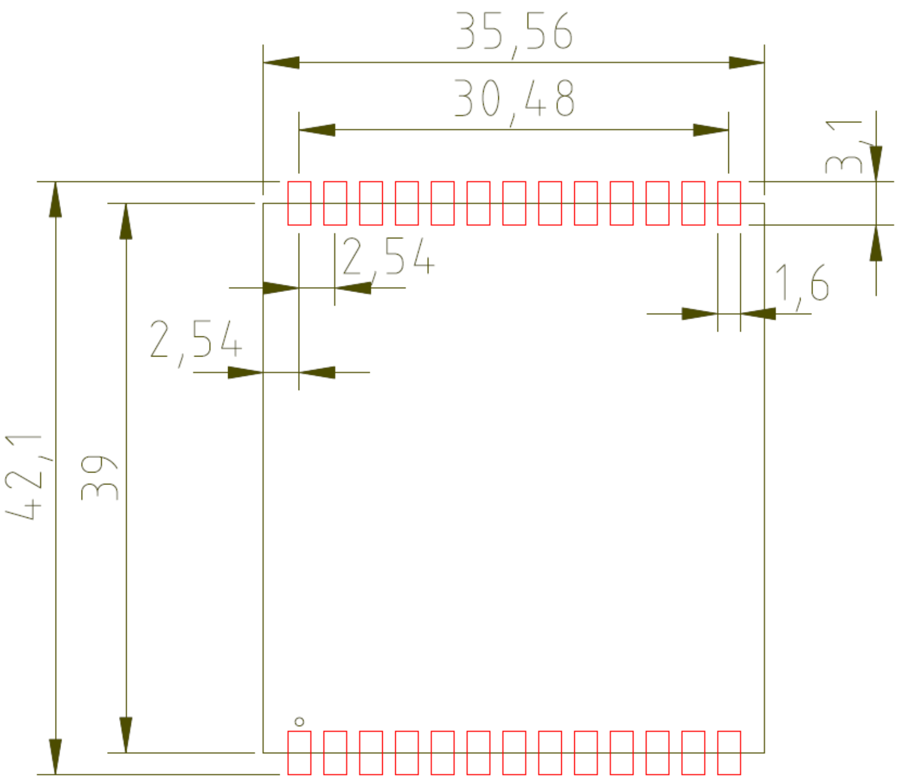
The calibration values for the sensor LM94021 are valid for gain sensor gain –13mV/°C [pin GS0,1 = 1] only. Please connect pin GS0 and GS1 to V_{DD}

7. Mechanical Drawings

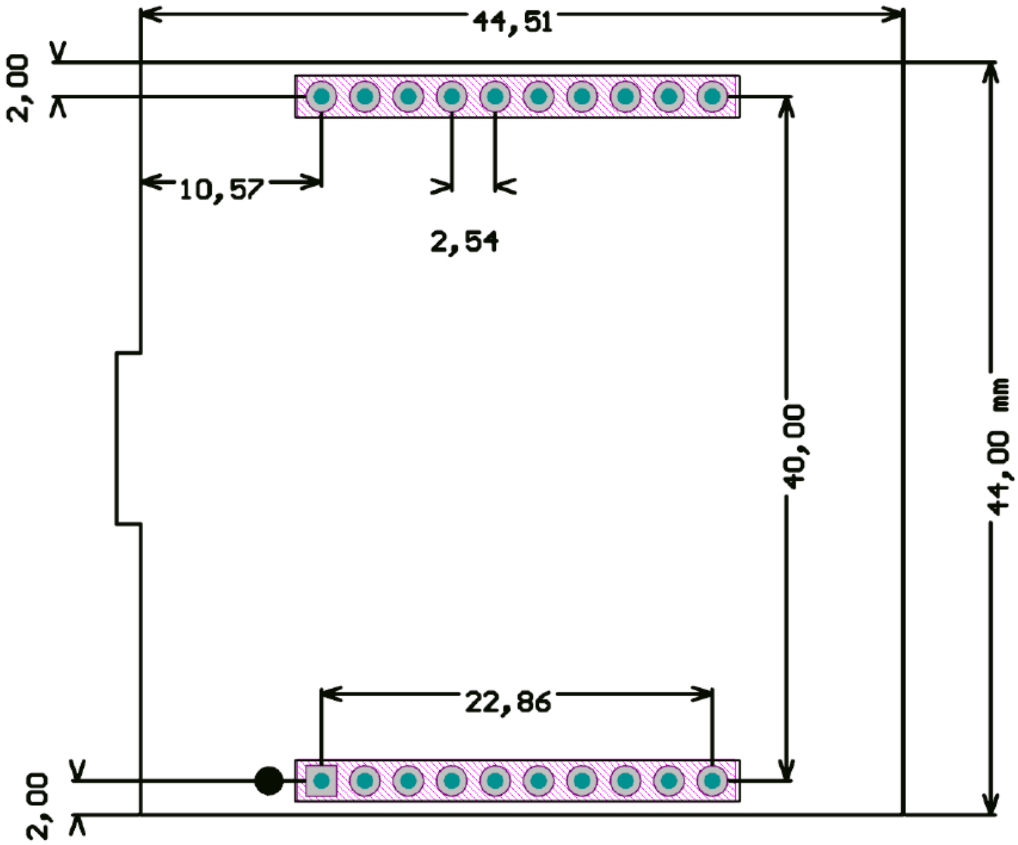
A7585D Drawings







A7585DU Drawings



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