LOW POWER AND HIGH EFFIENCY ENERGY ACQUISITION SYSTEMS FOR VOLCANO MONITORING

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Abstract- Two acquisition systems have been developed to acquire low sampling rate parameters (volcanic gases content and meteorological parameters) related with volcano activity. The first device (gDT316) is a 16 bits five-channel datalogger with a SD storage. The second one (gCNT16) is a simple three-channel 16 bits counter with EEPROM storage. Their main characteristics are low power consumption and low cost manufacturing. Here we describe both devices and the first three examples retrieved applying them on a volcano monitoring network (Tenerife Island, Spain).

I. Description

Different sciences are applied to volcano activity monitoring and the main are geophysics (i.e. seismology), geodesy and geochemistry [1]. Any superficial or deep processes that indicate a change in the status of the volcano being monitored should be integrated in that multidisciplinary network.

Volcanic areas are characterized by steep topography, extreme climatology, difficulty access path and hard work conditions mainly due to gas emissions.

All these factors force the design of any instruments installed in such areas should fit the following criteria: robustness, low power consumption and efficient data transmission; resulting in an expensive solution [2].

Instituto Geográfico Nacional (IGN) is responsible of the volcano monitoring in Spain since 2004. With this challenge, and the background experience of the group, IGN decided to produce its own dedicated geochemical instruments.

Both systems have been designed to measure crucial parameters that could help us understanding the inner processes taken place in a volcanic area such as soil temperature, atmospheric pressure, CO_2 and ^{222}Rn concentration in the air, pluviometry, etc.,
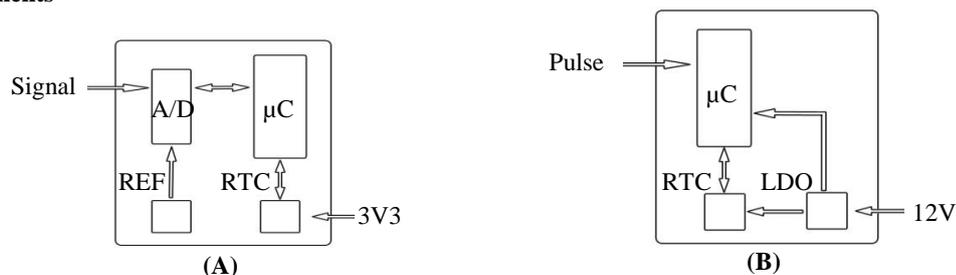
A. Components

Figure 1. Schematic of the datalogger (A) and counter (B)

Principal characteristics of gDT316 (block diagram in *Figure 1(A)*) are: three 16 bits and two 10 bits channels, an input pulse counter, SD storage, internal clock, programmable sampling rate and sensor´s preheating time and an optional GPS connection.

On the other hand, gCNT16 (block diagram in *Figure 1(B)*) has the following main characteristics: three 16 bits input pulse counters, EEPROM storage, internal clock and programmable sampling rate.

B. Operation

Both of the described devices remain most of the time in "sleep mode" for low energy consumption and wake up just for data acquisition and storage.

gDT316 is able to shutdown all the sensors and re-activate any of them in a programmable time lapse. When the buffer fills up, the data is transferred to the SD card, a function that minimizes the energy consumed.

gCNT16 remains permanently in "sleep mode". As the input pulses accumulated in the micro-controller, a counter increases while the gCNT16 continues in that mode, getting out of it only to save the input date during the sampling period that we had determined.

C. Power consumption

Table 1 provides theoretical consumption of each device calculated from data sheets of their components.

gDT316					
Component	Voltage (V)	Typical Current (mA) (on)	Power (mW)(on)	Typical Current (mA)(sleep)	Power (mW)(sleep)
Microcontroller	3.3	4	13.2	< 0.1	< 0.33
A/D Converter	3.3	0.4	1.32	0.4	1.32
A/D VRef	3.3	0.05	0.15	0.02	0.05
Real Time Clock	3.3	0.2	0.66	0.2	0.66
SD-Card	3.3	80	264	0.25	0.83
Total		**84.65**	**279.33**	**< 1**	**< 3.2**

gCNT316					
Component	Voltage (V)	Typical Current (mA) (on)	Power (mW)(on)	Typical Current (mA)(sleep)	Power (mW)(sleep)
Microcontroller	3.3	1	3.3	< 0.1	< 0.33
Real Time Clock	3.3	0.2	0.66	0.2	0.66
DC-DC Regulator	12	0.14	1.62	0.14	1.62
Inverter Regulator	12	0.4	4.80	0.4	4.8
EEPROM	3.3	0.45	1.49	1e-4	3.3e-4
Total		**2.19**	**11.87**	**< 0.9**	**< 7.5**

Table 1. Datalogger and counter power consumption.

Actual consumptions of each device are given in Table 2, measured with a DMM916 Tektronic multimeter [6], using a 12V battery for power supply.

MODE	gDT316 (mW)@3.3V	gCNT316 (mW)@12V
SLEEP	3.96	10.8
ON	6.60 (no SD access) 270.60 (SD access)	10.8

Table 2. Datalogger and counter measured power consumption.

These consumption values assure a long autonomy for the equipment. For example, using a normal 12V 7Ah battery, gDT316 can continuously work for 243 days and gCNT316 for 324 days.

D. Price

Costs of each device are shown in Table 3, calculated from prices for each component provided by RS (international electronic component reseller) [7], while PCB manufacturing costs were given by PCBCART (Professional China Prototype PCB Manufacturer) [8].

gDT316			
Component	Units	Price (€)	Total (€)
Microcontroller	1	6.58	6.28
A/D Converter	1	8.48	8.48
A/D VRef	1	3.20	3.20
Real Time Clock	1	2.84	2.84
SD-Slot	1	5.84	5.84
SD-Card	1	4.00	4.00
PCB Manufacture	1	1.00	1.00

Total (€)	31.64

gCNT316			
Component	Units	Price (€)	Total (€)
Microcontroller	1	6.58	6.58
Real Time Clock	1	2.84	2.84
DC-DC Regulator	1	7.79	7.79
Voltage Regulator	1	3.61	3.61
EEPROM	1	3.63	3.63
PCB Manufacture	1	1.00	1.00

Total (€)	25.45

Table 3. Datalogger and counter prices.

II. Results and Discussion

Energy consumption for both devices is really low. For the gDT316 is about 1 mA @ 3V3 in sleep mode and 2 mA @ 3V3 in measurement mode (without storage activity). For the gCNT16 is about 0.9 mA @ 12V in sleep mode and 0.9 mA @ 12V in measurement mode (without EEPROM activity).

The fact that the devices are own designed, their low cost (less than 50 €) and that the necessary components for their assembly can be purchased at any electronic component reseller, allow a quick deployment of a geochemical network, facilitate their maintenance, as well as a potential improvement in their design.

A. Implementations

Water extraction galleries in the Canaries are sub-horizontal drillings that could have a length up to 4000m [3]. In this ambient the relative humidity can reach 100% and the air temperature is almost stable all year around. gDT316 has been running through the last 4 years in a gallery (Tenerife island) recording data of CO_2 and ^{222}Rn air concentration along with barometric pressure, ambient and soil temperature (*Figure 2)*.
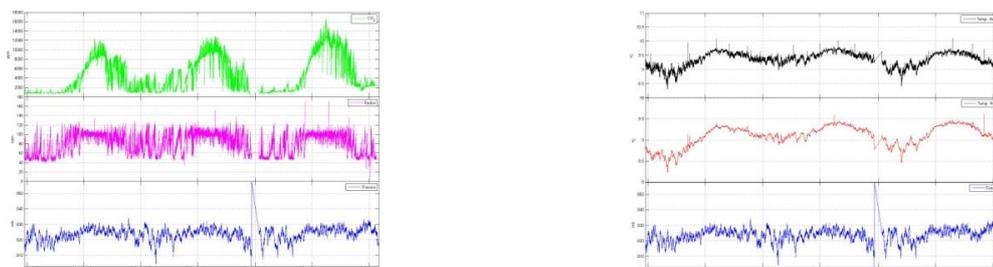

Figure 2. Data plotted from 2008 to 2012. Left: CO_2air concentration (green), ^{222}Rn counts per minute (pink)and Barometric pressure (blue). Right: ambient Tº (black), soil Tº (red) and Barometric pressure (blue).

In "Las Cañadas del Teide" National Park (Tenerife Island) the rainfall [4] is very irregular throughout the year. For better understating of gas emissions data we should have a detail record of the rainfall. gCNT16 was used all over the NP to obtain these data from small rain gauges [5], modified to increase their accuracy (Figure 3). It has been also deployed in two wells (where the humidity can reach up to 100%) in the El Hierro Island, to measure the radon air-concentration [9] and is running without any malfunctioning up today.
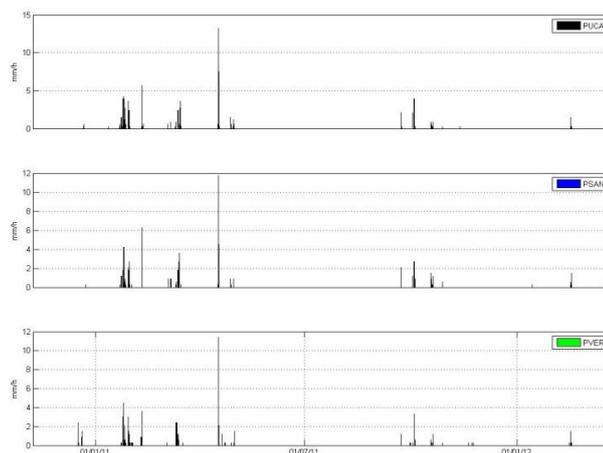

Figure 3. Two years rainfall registry at three locations in Parque Nacional de las Cañadas.

B. Conclusions

During the last 4 years, gDT316 & gCNT16, have been measuring several parameters related to the volcano activity. All of the chosen locations suffer extreme conditions (high humidity, acid ambient, etc.) but we can assure that the devices have proofed their robustness. All data, except Rn, have been validated with different instruments.
Low power consumption increases the autonomous operation and minimizes battery shifting. Low cost design allows a high density sampling network along with the fast maintenance and substitution (if the case).

Funding

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