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Revision 0

Selection of Components for the Remote, Canister-Monitoring System

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Changing the World's Energy Future

Evans D. Kitcher

Idaho National Laboratory

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SUMMARY

This report documents the selection of components as part of the efforts initiated to develop a remote, canister-monitoring system (RCMS) for determining and monitoring environmental conditions within dry fuel storage canisters containing aluminum-clad spent nuclear fuel (ASNF) at Idaho National Laboratory (INL). These efforts are in support of the Department of Energy Office of Environmental Management (DOE-EM) investigations into the technical issues associated with extended dry storage (50+ years) of ASNF. The capability to establish and monitor the performance of ASNF in situ provides the opportunity to (1) evaluate the appropriate technologies for monitoring, (2) collect canister environment conditions as soon as possible, (3) verify and validate current laboratory-based study results and analytic modeling approaches, and (4) potentially identify additional dry storage options for ASNF at the INL site. The improved understanding of ASNF behavior gained by performing this work would also contribute to the safety basis for extended dry storage in current and future configurations, as well as to provide information for future transportation, conditioning, and disposal of ASNF. It is important to resolve questions regarding storage because the ATR is expected to continue producing approximately 100 elements of spent fuel per year for at least another twenty years. The parameters to be monitored by the RCMS include temperature, relative humidity, hydrogen gas concentration, and radiation environment (dose). Components are selected based on the expected environmental conditions within the canister and fuel storage area and the desired performance of the RCMS. Several of these components have been purchased and received. Future activities include component testing and calibration, software development for operation of the integrated sensor module, and the fabrication of a representative test volume. The results of these tests and the changes to desired performance characteristics will inform subsequent activities.

CONTENTS

FIGURES

TABLES

ACRONYMS

ASNF	aluminum-clad spent nuclear fuel
ATR	Advanced Test Reactor
CAES	Center for Advanced Energy Studies
DOE	Department of Energy
DOE-EM	DOE Office of Environmental Management
IFSF	Irradiated Fuel Storage Facility
INL	Idaho National Laboratory
RCMS	remote, canister-monitoring system

Selection of Components for the Remote, Canister-Monitoring System

1. INTRODUCTION

This report documents the selection of components as part of the efforts initiated to develop a remote, canister-monitoring system (RCMS). The purpose of the RCMS is to determine and monitor the environmental conditions within dry-fuel storage canisters containing aluminum-clad spent nuclear fuel (ASNF) at Idaho National Laboratory (INL). These efforts are in support of Department of Energy, Office of Environmental Management (DOE-EM) investigations into technical issues associated with the extended dry storage (50+ years) of ASNF. A successful RCMS would improve the current understanding of how ASNF behaves during extended dry storage and would support a technical basis for the continued storage of this material. The capability to establish and monitor the performance of ASNF in situ provides the opportunity to (1) evaluate the appropriate technologies for monitoring, (2) collect canister environment conditions as soon as possible, (3) verify and validate current laboratory-based study results and analytic modeling approaches, and (4) potentially identify additional dry storage options for ASNF at the INL site. This can confirm the presence or absence of hydrogen buildup due to radiolysis, which would affect eventual sealed canister disposition/disposal. The improved understanding of ASNF behavior gained by performing this work would also contribute to the safety basis for extended dry storage in current and future configurations as well as to provide information for the future transportation, conditioning, and disposal of ASNF. It is important to resolve questions regarding storage because the ATR is expected to continue producing approximately 100 elements of spent fuel per year for at least another twenty years. The parameters to be monitored by the RCMS include temperature, relative humidity, hydrogen gas concentration, and radiation environment (dose). These parameters are important due to historical tests that indicated extreme high relative humidity, radiation and temperature can lead to significant decomposition of metallic aluminum. Components are selected based on the expected environmental conditions within the canister and fuel storage area, and the desired performance of the RCMS.

2. BACKGROUND

2.1 Previous Activities

Efforts from the 1999–2000 timeframe to develop a tool to measure properties of the internal environment resulted in an instrumentation package that could be installed on the canister lid to transmit the data by radio frequency (RF) to a data acquisition system. Figure 1 shows the first prototype made in FY2000. The sensors and electronics were placed in a shielded compartment with a penetration in the canister lid to allow gas circulation to the sensors and direct radiation monitoring. The prototype was capable of sensing temperature, relative humidity, hydrogen gas and the radiation field using a miniature Geiger Muller tube. For compactness, the shielding material was selected as tungsten.

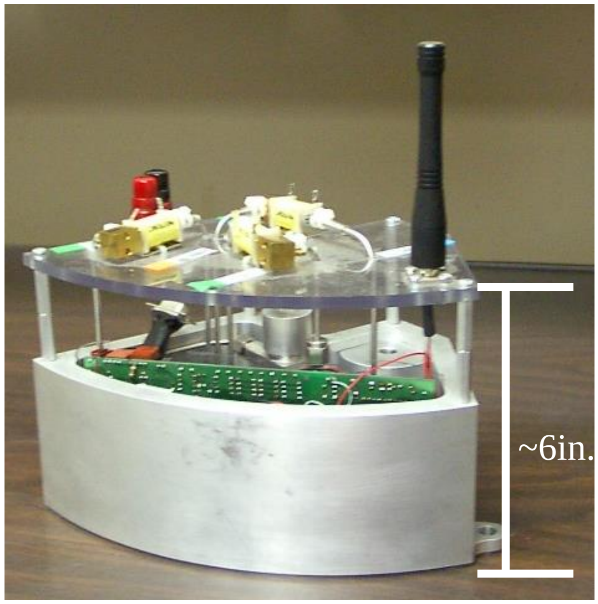


Figure 1: Integrated sensor system prototype fabricated in FY2000.

2.2 Identified Approaches

Three approaches have been identified for investigation in the current efforts. The first approach is to perform a technology update on the prototype developed in FY2000. This first approach would acquire point estimate data by measuring the conditions inside the headspace of the canister. This is achieved either by inserting the integrated sensor into the canister headspace, or by actively pumping a sample of the headspace gas to the sensor for analysis. The second approach is to develop a wired sensor system that requires threading of wired sensors into the canister fuel bucket geometry. This second approach would allow the acquisition of intra-canister, vertical axis, spatial information for the parameters of interest. The third approach is a passive system that would also acquire intra-canister, vertical axis, spatial information for the parameters of interest, without the need for a wired system. This would be achieved by inserting discrete sensors packages that communicate wirelessly with the control unit situated in the shielded compartment on top of the canister lid. The passive system, if successful, could have benefits in terms of maintenance and operation within the storage facilities. Figure 2 shows a drawing of the three approaches. The green box is the electronics in the shielded compartment on top of the canister lid. The blue boxes indicate where sensors would be placed, and spatial information collected. Additional information on the identified approaches can be found in (Kitcher 2019). Feasibility studies into all three approaches are being conducted. The first two approaches are being pursued in collaboration with the University of Idaho [though an inquiry to the Center for Advanced Energy Studies (CAES)[a] system] (contract No. 154652). The selection of components documented here is in support of the first two approaches. The third approach is being pursued through a subcontract with Westinghouse (contract No. 228461).

[a] CAES is a research and education consortium between Boise State University, Idaho National Laboratory, Idaho State University, University of Idaho, & University of Wyoming.

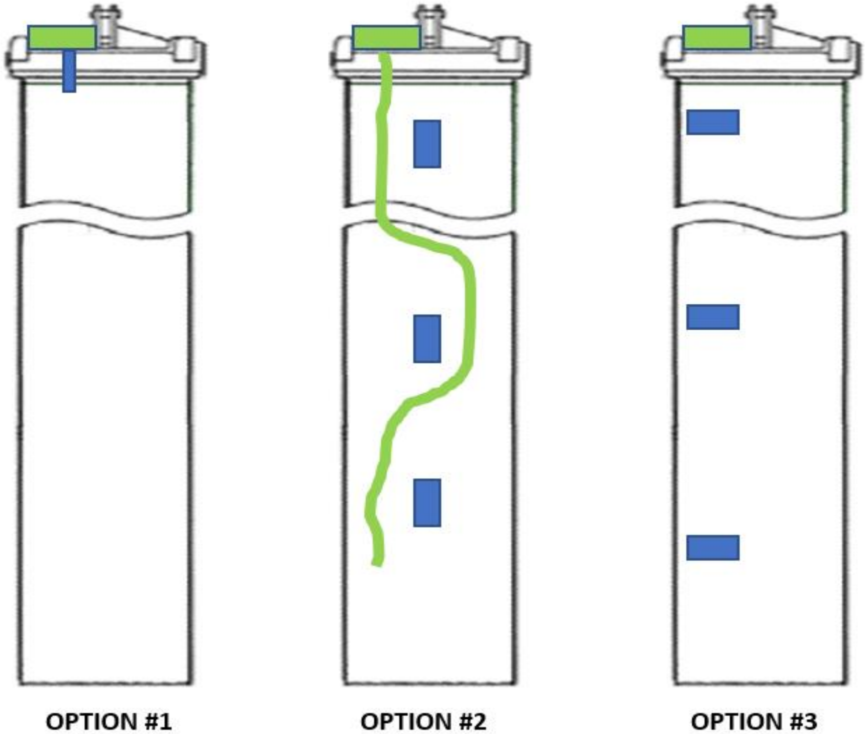


Figure 2: Identified design approaches for the RCMS.

2.3 Facility and Canister Descriptions

Brief descriptions of the Irradiated Fuel Storage Facility (IFSF), the Advanced Test Reactor (ATR) fuel elements (which constitute the majority of ASNF stored in the IFSF), the dry-fuel storage canisters used for storage of ASNF, and the various buckets used for the transfer and storage of the ASNF within the canisters can be found in (Kitcher 2019).

2.4 RCMS Package Performance Requirements

The purpose of the RCMS as stated are to (1) evaluate the appropriate technologies for monitoring, (2) collect canister environment conditions as soon as possible, (3) verify and validate current laboratory-based study results and analytic modeling approaches, and (4) potentially identify additional dry storage options for ASNF at the INL site. To this end, the parameters to be monitored by the RCMS include temperature, relative humidity, hydrogen gas concentration, and radiation (dose). The desired performance of the RCMS can be found in (Kitcher 2019). Table 1 shows a list of desired performance from the sensors in the RCMS. In addition to these sensors, additional components needed for the RCMS are a miniature air pump for air sample collection, a battery to power the RCMS, data transmission capability via Wi-Fi or RF, and a radiation shield. The battery should be able to power the RCMS for a minimum of 1 year of autonomous operations, starting with weekly data transfers to establish routine baseline. After the baseline is established, the sampling rate could potentially be reduced to monthly data transfers. The radiation shield should reduce the dose rate and total dose to the sensors and electronics to allow operation for a minimum of 1 year without degradation of performance. The data transmission capability should have a range of 600ft without line-of-sight. This should allow transmission to an antenna within the fuel storage area. The data can then be transmitted via a wired connection out of the fuel storage area to the data acquisition/processing system.

This list of desired performance characteristics is by no means complete and will be updated as additional desired performance characteristics are identified or design tradeoff encountered.

Table 1: Desired performance of sensors for RCMS.

Parameter	Range	Accuracy	Comments
Dose (mR/hr)	0–2000	± 20 mR/hr	Spatial information desired
Temperature (°C)	-25–125	± 2 °C	Spatial information desired
Relative humidity (%)	5–95	± 2 %	Spatial information desired
Pressure (psia)	13–30	± 2 psia	
Hydrogen concentration (vol. %)	0–4	± 0.1%	Need to establish the minimum detectable limit.

3. COMPONENT SELECTION

Additional design principles for the RCMS that have not yet been stated as requirements include low cost, small size, minimum weight of package and low power consumption, and acceptability for deployment in the CPP-603 facility. In selecting the necessary components, several candidates were surveyed for both approaches and different design options were considered. Table 2 shows a comparison of the components used in the FY2000 prototype and components considered for the new prototype.

Table 2: Comparison of components between the FY2000 prototype and the New prototype.

Component	FY2000 prototype	New prototype
Hydrogen sensor	Figaro TGS2620 Figaro TGS821	Several off-the-shelf options (Figaro, H2scan, N5)
Radiation sensor	Gamma Labs G1300	Several off-the-shelf options (Mirion, Gamma Labs)
Temperature sensor	Digital thermocouple	Several off-the-shelf options (Hioki LR5011, Comet T3611, N5)
Humidity sensor	FSU-2K unit (EMD-2000)	Several off-the-shelf options (Hioki LR5011, Comet T3610, EMD-4000, N5)
Air sample collector	Miniature air pump	Miniature air pump
RF transmitter	RF (450MhZ, 600ft range)	Several off-the-shelf options (N5 has Wi-Fi)
Microprocessor	z80	Several off-the-shelf options (N5 use Arduino platform)
Onboard memory	128K EEPROM	Several off-the-shelf options (N5 use Arduino platform)

Software	N/A	Requires code development inhouse
Power source	Li-ion batteries	Li-ion batteries

In general, several options were identified that meet the required performance characteristics for each component. Several commercially available integrated sensor units were found featuring integrated temperature, relative humidity, and hydrogen. These units also had data transmission capability via Wi-Fi and some limited data storage and processing capabilities. Given that this represents a significant portion of the design effort, it was decided to proceed with such a unit as the core of the integrated system. Of the integrated sensor units, the offering from N5 digital multi-gas sensor module was selected as it offers low-power requirements, hydrogen concentration, temperature, and humidity sensing on a single chip. Figure 3 shows the N5 module. The N5 product sheet and datasheet can be found in Appendix A. Several options for miniature Geiger counters have been identified. Figure 4 shows several miniature Geiger counters available from Mirion Technologies. The product sheet can be found in Appendix B. The miniature Geiger detectors surveyed require high voltage DC power for operation. A suitable DC voltage converter has been identified as shown in Figure 5. The DC converter product sheet is attached in Appendix C. A suitable miniature air pump has been identified as shown in Figure 6. The miniature air pump data sheet is attached in Appendix D.

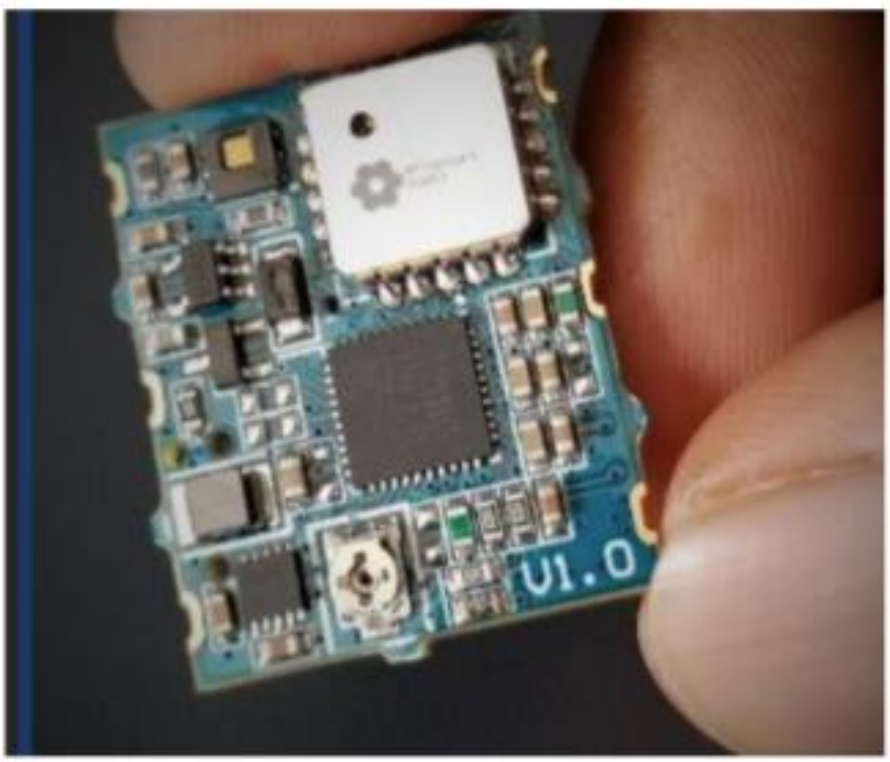


Figure 3: An image of the N5 digital gas module (Taken from the N5 module product sheet in Appendix A).

Figure 4: A range of Geiger detectors available (Taken from the Mirion product sheet in Appendix B).

Figure 5: An image of the LTC 1871 DC voltage converter (See Appendix C).

Figure 6: A miniature air pump (Taken from the Cole-Palmer Datasheet in Appendix D).

4. CONCLUSIONS AND FUTURE ACTIVITIES

As part of the collaboration with Idaho State University, several of these components have been purchased and received. Future activities include component testing and calibration, software development for operation of the N5 integrated digital gas module, and fabrication of a representative test volume. This list of desired performance characteristics is by no means complete and will be updated as they are identified, or design tradeoffs are encountered. The results of these tests and changes to desired performance characteristics will inform subsequent activities.

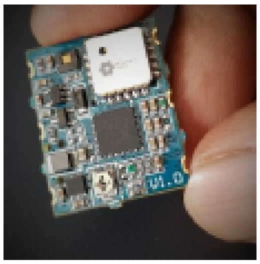
5. REFERENCES

Kitcher, E. D. 2019. "Status Report for the Development of a Remote, Canister-Monitoring System for Extended Storage of Aluminum Clad Spent Nuclear Fuel in the Irradiated Fuel Storage Facility" INL/EXT-19-55950, Idaho National Laboratory.

6. APPENDIX A – N5 DGM DATASHEET AND PRODUCT SHEET

N5 Sensors, Inc.
smart sensors for a safer world

Digital Gas Sensor Module (DGM) Version 1.0



The Digital Gas Sensor Module (DGM) is a digital multi-gas sensor module for low-power, specific detection of Toxic Gasses and Environmental Pollutants. The gas sensor module utilizes N5's patented low-power gas sensor technology which combines multiple gas sensors with tailored selectivity in a single chip. The module is an I2C peripheral with castellated mounting edges for easy system integration. The system provides calibrated, digital readings of gas concentration with an on-board humidity and temperature sensor for automatic result compensation.

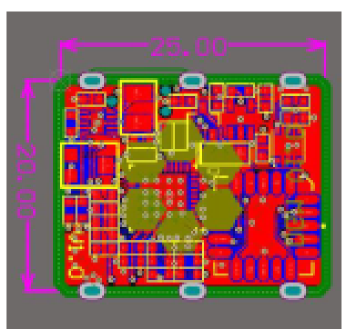
Applications

IoT and Connected Devices, Toxic Gas Detection, Smart Cities, Environmental Monitoring, Distributed Sensor Systems, Smart Homes, Appliances

Specifications

Operating Voltage:	1.8 – 5.5 V
Communication:	I2C
Power Consumption (continuous):	100 mW
Dimensions:	20 x 25 mm (0.8" X 1")
Number of Individual Sensors:	Options for 1, 2, or 4 sensors, plus Humidity & Temperature
Detection Range and Resolution	1 – 1,000 ppm w/ 1 ppm or 500 – 50,000 ppm /w 50 ppm Varies by sensor and application
Gas Sensors Available:	NOx, Hydrogen, Chlorine, Alcohol, Aldehyde, (HCN, CO, SO2, H2S, NH3, O2)

Dimensions



All Dimensions are in millimeters

For more information please email at info@n5sensors.com.

This product is protected by U.S. Patent No. 9,476,862. Additional patents may be pending in the U.S. and elsewhere.

N5 Sensors, Inc.
smart sensors for a safer world

N5-1GCl2 Datasheet

Multiple Robust and Reliable Chlorine Sensors in One Single Package

FEATURES

- 6 individually-addressable chlorine sensors in one package
- Detection range: 1 – 50 ppm
- 20 pins, ceramic LCC or QFN package
- No cross-sensitivity to humidity or organic compounds
- Resistant to silicones
- Surface-mount process compatible

TARGET APPLICATIONS

- Hazmat Detection
- Monitoring of Industrial cooling
- Bottle cleaning facilities
- Agriculture
- Waste water treatment

Description

The N5-1G series is a solid-state gas sensor which combines wide-bandgap semiconductor with advanced photocatalytic oxides for reliable, low power sensing of different gases.

This generation of sensor (N5-1GCl2) is designed to detect chlorine gas with no known cross sensitivity to organic compounds, silicones, and natural gas. There are 6 individual chlorine sensors in the 20 pin LCC (8.8 x 8.8 x 2 mm) package. The sensing element exhibits an increase in resistance in presence of chlorine gas.

The sensors can be easily integrated into any new or existing system, for industrial and consumer applications. The device includes reference elements which can be used as on-chip passive elements, for voltage divider or bridge implementation.

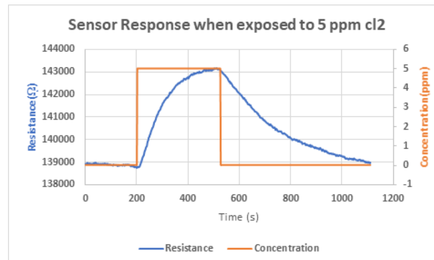
Multiple sensing elements in one package provides redundancies and system-design flexibility.

For more information, please contact N5 Sensors Inc.
301-337-8314 | 9610 Medical Center Drive, Suite # 200,
info@n5sensors.com | Rockville, MD 20850

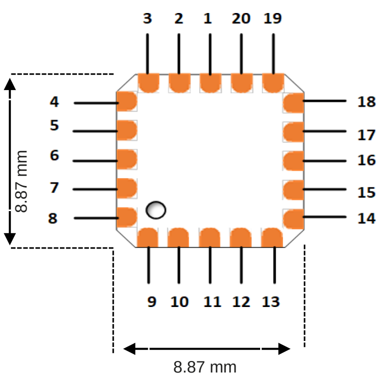
N5-1GCl2 Datasheet

Sensor Data	
DC Operating Voltage	3.3 – 5 V
Detection Range	1 – 50 ppm
Response Time	~60 s
Recovery time	~ 120 s
Power Consumption	10 - 50 µW (UV off)*
Storage Temperature	0ºC to 60ºC
Operating Humidity	0% to 90%

Sensor Response



Physical Drawing



Note – Reference purpose, not to scale

Gas Ingress

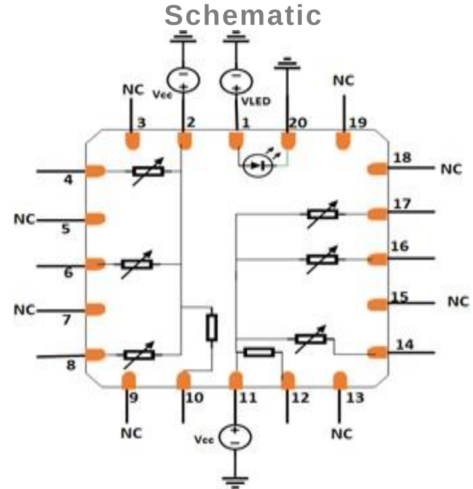
Circular hole of 1 mm on the top of the chip carrier is the gas ingress point and is shipped with a filter. Contact us for customized filter options for your application

Pin Connection

Pin	Connection
1	VLED+ (10 mA)
2	Vcc (5 V)
3	NC
4	Sensor 1
5	No Connect
6	Sensor 2
7	NC
8	Sensor 3
9	No Connect
10	Passive 1
11	Vcc (5 V)
12	Passive 2
14	Sensor 7
15	No Connect
16	Sensor 6
17	Sensor 5
18	No Connect
19	No Connect
20	LED GND

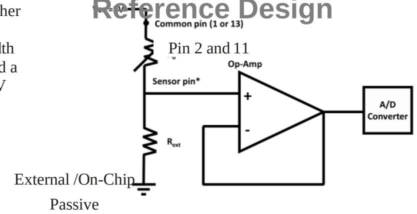
The LED requires either a constant current source or a pulse width modulated source and a forward drop of 3.4 V

Schematic



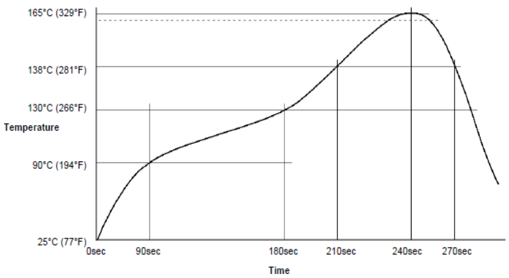
Note – Reference purpose, not to scale

Reference Design



Disclaimer - Specifications can change at any time without prior notice.

Reflow profile for Sn42/Bi57.6/Ag0.4 solder assembly



3

7. APPENDIX B – MIRION TECHNOLOGIES GEIGER DETECTOR PRODUCT SHEET

MIRION TECHNOLOGIES

Geiger Mueller

Detectors

FEATURES

- Product Reliability

  The Mirion Geiger Mueller detector has been carefully researched and developed to provide a rugged, reliable, long-lasting means of monitoring nuclear radiation levels. These detectors offer guaranteed advantages, including manufacturing consistency, product reliability and competitive pricing. Many of our detector types are manufactured and tested to withstand rigorous shock and vibration per military standards.

  All Mirion GM detectors comply with our stringent quality assurance policies, consistent with ISO 9001.

OUR WARRANTY

- Mirion warrants that its Geiger Mueller detectors will be free from defects in materials and workmanship for a period of one (1) year from the date of initial shipment.

DESCRIPTION

Guaranteed Analysis

As an end user of Geiger Mueller detectors for over 60 years, we have successfully bridged the gap between technical conception, detector design and field application to achieve the quality performance you demand.

Consider the Source

More than six decades of nuclear instrumentation design enables us to incorporate quality and reliability into an outstanding line of Geiger Mueller detectors, including 2000 Series pancake detectors. We offer extensive experience as both a manufacturer and end user of all types of radiation detectors. Over the years, our detectors have met and exceeded customer needs in laboratory, military and harsh industrial environments.

Our Geiger Mueller detectors are the obvious choice for the discerning user. These detectors are built to exhibit superior performance, reliability and long-term stability. Our extensive product line provides direct (or near equivalents) for industry-standard detectors, including all versions of pancake detectors and frisker probes.

Manufacturing Excellence

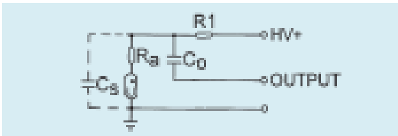
Mirion's manufacturing operation has refined the development and production of GM detectors. We utilize state-of-the-art instrumentation and the finest equipment to monitor and control all manufacturing processes. Our painstaking attention to every detail ensures contamination-free assemblies. We use only the highest quality materials to fabricate critical detector components. Our adherence to stringent design parameters and quality assurance ensures performance that meets or exceeds exacting commercial and military standards.

Mirion's growing detector division can offer substantial volume cost reductions for large orders.

www.mirion.com

Test Circuits

Use HV+, R_a and R1 from the chart.



Cs = Stray capacitance typically < 1 pF.
Co = High voltage blocking capacitor.

Figure 1 - Anode Output

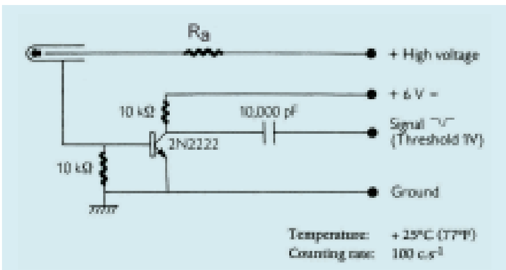
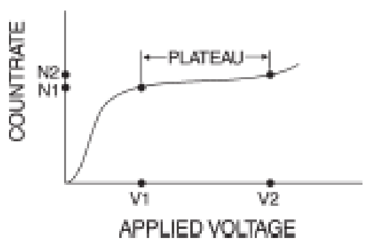


Figure 2 - Cathode Output

Plateau Calculations

Plateau slope for this data sheet is calculated using the formula below, and given in units of percent change per 100 volts.



$$\frac{N2-N1}{1/2(N1+N2)} \times \frac{100}{V2-V1} \times 100 = \% \text{ per 100 volts}$$

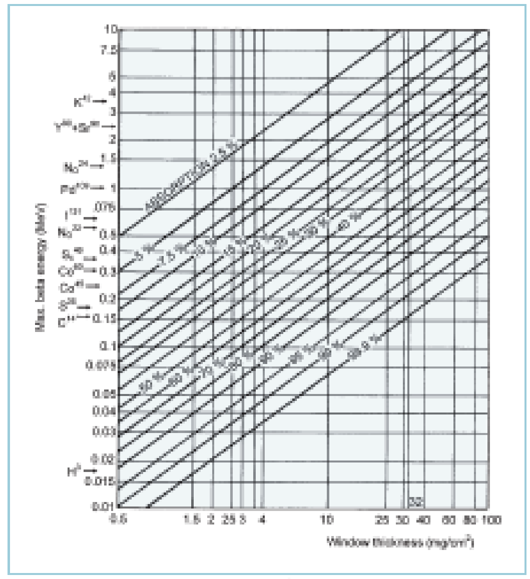
Alpha Particle Detection

The table below shows the initial energy required to penetrate a given mica window thickness. This assumes a negligible air gap between the source and the window. Note the range of alpha particles of various energies in air at atmospheric pressure.

Mica Window	α Energy	α Range in Air
1.0 mg/cm²	1.9 MeV	10 mm
2.0 mg/cm²	2.6 MeV	15 mm
3.0 mg/cm²	3.6 MeV	22 mm
4.0 mg/cm²	4.5 MeV	29 mm

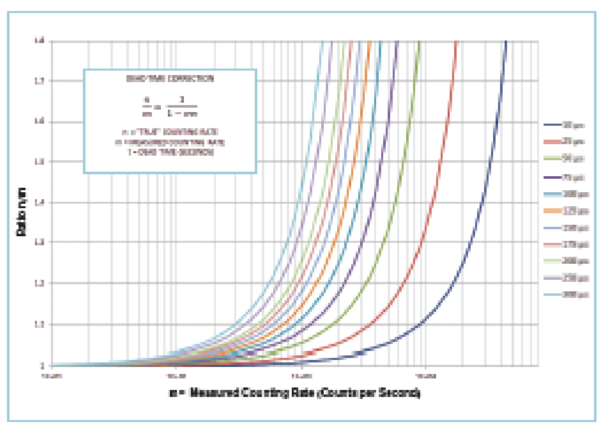
Beta Particle Detection

The chart below shows the effects of mica window thickness (mg/cm²) on beta particle absorption percentage.



Dead Time Correction

GM detectors using conventional counting circuitry all exhibit counting losses due to the Dead Time factor. These factors cited in the Mirion detector data tables are based on the recommended operating voltages and test circuits. The chart below enables the user to estimate the counting losses due to the Dead Time factor at high count rates.

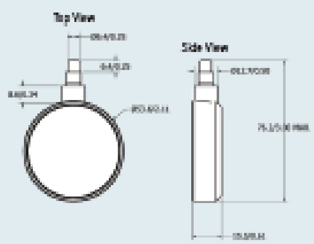


PERFORMANCE DATA

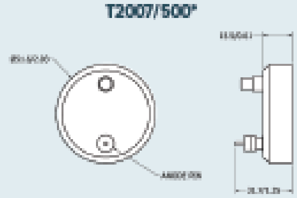
Pancake Detectors – For α, β, γ Applications					
Characteristics ↓ Detector Type →	T2000/8767	T2000/500*	T2006/900	T2006/500*	T2007/500*
Application	α, β, γ	α, β, γ	α, β, γ	α, β, γ	α, β, γ
Sensitivity*** ^{137}CS cpm at 1 mR/h	3500	3500	3500	3500	3500
Window Area Density (mg/cm²)	1.8 – 2.0	1.8 – 2.0	2.0 – 2.2	2.0 – 2.2	2.0 – 2.2
Window Effective Diameter (mm, in.)	44.5, 1.75	44.5, 1.75	44.5, 1.75	44.5, 1.75	44.5, 1.75
Recommended Operating Voltage	900	500	900	500	500
Plateau Length Volts min.	850-1000	450-600	850-1000	450-600	450-600
Plateau Slope (%/100 V max.)	10	10	10	10	10
Dead Time (µs max.)	50	50	50	50	50
Background (c/m)*** Shielding 2" Pb + 1/8" Al	30 max.	30 max.	30 max.	30 max.	30 max.
Test Circuit	Figure 1	Figure 1	Figure 1	Figure 1	Figure 1
Resistor, Ra (MΩ)	3.3	3.3	3.3	3.3	3.3
Resistor, R1 (MΩ)	1.0	1.0	1.0	1.0	1.0
Operating Temp (°C)	-20 to +55	-20 to +55	-20 to +55	-20 to +55	-20 to +55
Cathode Material	Cr/Fe	Cr/Fe	Cr/Fe	Cr/Fe	Cr/Fe
Window Recess (mm, in.)	1.6, 0.062	1.6, 0.062	1.6, 0.062	1.6, 0.062	1.6, 0.062

Pancake Detectors:

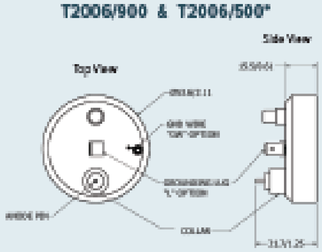
T2000/8767 & T2000/500*



T2007/500*



T2006/900 & T2006/500*

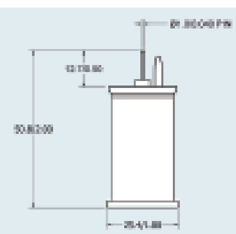


* Alternate grounding options available.
** Energy compensated versions available.
*** At recommended operating voltage.

Mica End Window – For α, β, γ Applications	
Characteristics ↓ Detector Type →	T2121*
Application	α, β, γ
Sensitivity*** ^{137}CS cpm at 1 mR/h	1700
Window Area Density (mg/cm²)	1.8 – 2.0
Window Effective Diameter (mm, in.)	19.8, 0.78
Recommended Operating Voltage	500
Plateau Length Volts min.	450-650
Plateau Slope (%/100 V max.)	5
Dead Time (µs max.)	100
Background (c/m)*** Shielding 2" Pb + 1/8" Al	30 max.
Test Circuit	Figure 1
Resistor, Ra (MΩ)	3.3
Resistor, R1 (MΩ)	1.0
Operating Temp (°C)	-40 to +75
Cathode Material	Cr/Fe
Cathode Wall	1.3, 0.050
Window Recess (mm, in.)	1.6, 0.062

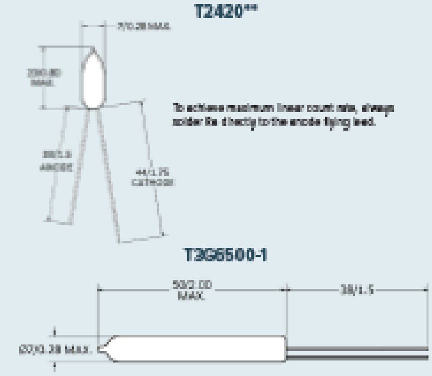
Mica End Window:

MIL Version
2121 M Window
2.8–3.4 mg/cm²



Gamma Sensitive Miniature Detectors – For γ Applications			
Characteristics ↓	Detector Type →	T2420**	T3G6500-1
Application		γ	γ
Sensitivity*** ¹³⁷CS cpm at 1 mR/h		4.2	270
Recommended Operating Voltage		500	460
Plateau Length Volts min.		450-550	420-520
Plateau Slope (%/100 V max.)		35	30
Dead Time (µs max.)		20	60
Background (c/m)*** Shielding 2" Pb + 1/8" Al		6 max.	25 max.
Test Circuit		Figure 2	Figure 2
Resistor, Ra (MΩ)		4.7	4.7
Resistor, R1 (MΩ)		N/A	N/A
Operating Temp (°C)		-51 to +71	-20 to +60
Cathode Material		Cr/Fe	Cr/Fe
Cathode Wall		360-400 mg/cm²	280 mg/cm²

Gamma Sensitive Miniature Detectors:



** Energy compensated versions available.
*** At recommended operating voltage.

ORDERING INFORMATION

Pancake Detectors

Part Number	Notes
T2000/8767	—
T2000/500	—
T2000/500GW	T2000/500 with Ground Wire
T2006/500	—
T2006/500-NC	T2006/500 without Anode Support Collar
T2006/500GW	T2006/500 with Ground Wire
T2006/500GW-NC	T2006/500GW without Anode Support Collar
T2006/500L	T2006/500 with Ground Lug
T2006/500L-NC	T2006/500L without Anode Support Collar
T2006/900	—
T2007/500	—
7084948	T2007/500 with Ground Wire with Solder Lug

End Window Detectors

Part Number	Notes
T2121	—
T2121M	Military Version, Mica Thickness 2.8-3.4 mg/cm²
D102130	Energy Compensated T2121M, for RDS-110
9303666A	Energy Compensated T2121M, for ADM300
9335514A	Energy Compensated T2121M, for ADM300SI
T2121MG	T2121 with 0.0125" Metal Window

For additional information: www.mirion.com

Miniature Detectors

Part Number	Notes
T2420	—
9302553A	Energy Compensated T2420, for ADM300
7085395	Energy Compensated T2420, for NASRAMS
7086975	Energy Compensated T2420, for Seawater Probe
D3085197-GRN	Energy Compensated T2420 in Green Housing
D3085197-YEL	Energy Compensated T2420 in Yellow Housing
D703386-01	Energy Compensated T2420 in Gray Housing
T3G6500-1	—

ISO 9001 SYSTEM CERTIFIED — MERIDEN CT, SMYRNA GA, OAK RIDGE TN, CONCORD ON

CANBERRA

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C49256 - 02/2017

8. APPENDIX C – LTC DC CONVERTER DATASHEET

LINEAR TECHNOLOGY

LTC1871

Wide Input Range, No R_{SENSE}™ Current Mode Boost, Flyback and SEPIC Controller

FEATURES

- **High Efficiency (No Sense Resistor Required)**
- **Wide Input Voltage Range: 2.5V to 36V**
- **Current Mode Control Provides Excellent Transient Response**
- **High Maximum Duty Cycle (92% Typ)**
- **±2% RUN Pin Threshold with 100mV Hysteresis**
- **±1% Internal Voltage Reference**
- Micropower Shutdown: I_Q = 10µA
- Programmable Operating Frequency (50kHz to 1MHz) with One External Resistor
- Synchronizable to an External Clock Up to 1.3 × f_{OSC}
- User-Controlled Pulse Skip or Burst Mode® Operation
- Internal 5.2V Low Dropout Voltage Regulator
- Output Overvoltage Protection
- Capable of Operating with a Sense Resistor for High Output Voltage Applications
- Small 10-Lead MSOP Package

APPLICATIONS

- Telecom Power Supplies
- Portable Electronic Equipment

DESCRIPTION

The LTC®1871 is a wide input range, current mode, boost, flyback or SEPIC controller that drives an N-channel power MOSFET and requires very few external components. Intended for low to medium power applications, it eliminates the need for a current sense resistor by utilizing the power MOSFET's on-resistance, thereby maximizing efficiency.

The IC's operating frequency can be set with an external resistor over a 50kHz to 1MHz range, and can be synchronized to an external clock using the MODE/SYNC pin. Burst Mode operation at light loads, a low minimum operating supply voltage of 2.5V and a low shutdown quiescent current of 10µA make the LTC1871 ideally suited for battery-operated systems.

For applications requiring constant frequency operation, Burst Mode operation can be defeated using the MODE/SYNC pin. Higher output voltage boost, SEPIC and flyback applications are possible with the LTC1871 by connecting the SENSE pin to a resistor in the source of the power MOSFET.

The LTC1871 is available in the 10-lead MSOP package.

TYPICAL APPLICATION

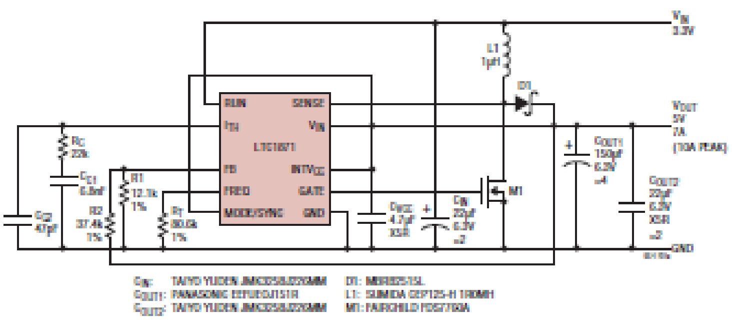
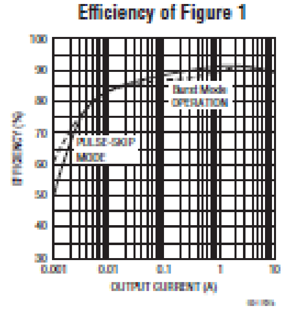


Figure 1. High Efficiency 3.3V Input, 5V Output Boost Converter (Bootstrapped)

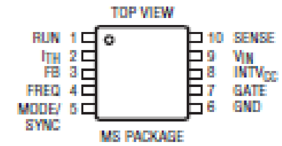


ABSOLUTE MAXIMUM RATINGS

(Note 1)

V_{IN} Voltage .... –0.3V to 36V
$INTV_{CC}$ Voltage.. –0.3V to 7V
$INTV_{CC}$ Output Current.. 50mA
GATE Voltage .... –0.3V to V_{INTVCC} + 0.3V
I_{TH}, FB Voltages .... –0.3V to 2.7V
RUN, MODE/SYNC Voltages .... –0.3V to 7V
FREQ Voltage .... –0.3V to 1.5V
SENSE Pin Voltage.................................... –0.3V to 36V
Operating Temperature Range (Note 2)
LTC1871E... –40°C to 85°C
LTC1871I.. –40°C to 125°C
LTC1871H .... –40°C to 150°C
Junction Temperature (Note 3)
LTC1871E/LTC1871I.. 125°C
LTC1871H .... 150°C
Storage Temperature Range................... –65°C to 150°C
Lead Temperature (Soldering, 10 sec) .... 300°C

PIN CONFIGURATION



MS PACKAGE
10-LEAD PLASTIC MSOP
T_{JMAX} = 125°C, θ_{JA} = 120°C/W

ORDER INFORMATION

LEAD FREE FINISH	TAPE AND REEL	PART MARKING	PACKAGE DESCRIPTION	TEMPERATURE RANGE
LTC1871EMS#PBF	LTC1871EMS#TRPBF	LTSX	10-Lead Plastic MSOP	–40°C to 85°C
LTC1871IMS#PBF	LTC1871IMS#TRPBF	LTBFC	10-Lead Plastic MSOP	–40°C to 125°C
LTC1871HMS#PBF	LTC1871HMS#TRPBF	LTCXS	10-Lead Plastic MSOP	–40°C to 150°C
LEAD BASED FINISH	**TAPE AND REEL**	**PART MARKING**	**PACKAGE DESCRIPTION**	**TEMPERATURE RANGE**
LTC1871EMS	LTC1871EMS#TR	LTSX	10-Lead Plastic MSOP	–40°C to 85°C
LTC1871IMS	LTC1871IMS#TR	LTBFC	10-Lead Plastic MSOP	–40°C to 125°C
LTC1871HMS	LTC1871HMS#TR	LTCXS	10-Lead Plastic MSOP	–40°C to 150°C

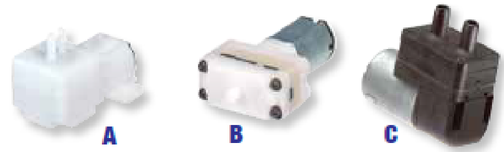
Consult LTC Marketing for parts specified with wider operating temperature ranges.

For more information on lead free part marking, go to: http://www.linear.com/leadfree/
For more information on tape and reel specifications, go to: http://www.linear.com/tapeandreel/

9. APPENDIX D – COLE-PALMER AIR PUMP DATASHEET

Compact Vacuum Pumps

Complete your OEM application



A–B. Miniature OEM Vacuum/Pressure Pumps

These pumps will achieve a vacuum level of 5.9" Hg or pressure up to 6.8 psi. Use for lab applications where only a small amount of pressure or vacuum is needed—ideal for low-pressure aeration.

C. Micro-Boxer Diaphragm Pumps

This latest advance in technology reaches a previously unexplored size-to-performance ratio. The miniature pump comes with a coreless DC motor for extra long life. Diaphragm and valves are made of silicone.

D. Single-Head Miniature Diaphragm Pumps

These brushless DC motor driven pumps are designed to handle air and gases. The compact design utilizes technologies that allow it to operate harder, hotter, quieter and longer than other existing pump designs. They offer multiple component configurations, allowing them to be used for either vacuum or pressure operation.

E. Cole-Parmer® Air Cadet® Diaphragm Pumps

Vacuum/pressure pumps have excellent vacuum/pressure capabilities with continuous operation up to 20" Hg or 18 psi. Long-life convoluted diaphragm minimizes stress and heat build-up. The head is made of non-contaminating plastics, Noryl® body, nitrile diaphragm, and PTFE valves.

F. Oil-Free Rotary Vane Pumps

These pumps require little maintenance and reduce risk of contamination. Ideal for use in low-pressure or high-capacity applications. Pumps include vacuum gauge, filter, carrying handle, and a 6-ft (1.8-m) cord (115 VAC models have a US standard plug).

G. Oiled Rotary Vane Pump

Centrifugal force holds woven linen vanes against finely polished cast-iron body interior for a vacuum-tight seal—the self-adjusting vanes automatically compensate for wear. Pumps include separate vacuum and pressure gauges, vacuum and pressure regulators, oil trap, air filter, carrying handle, and a 6-ft (1.8-m), three-wire cord (115 VAC models have a three-prong plug and a two-prong adapter with ground wire).

H. Variable-Speed Pumps

Enable easy vacuum system integration. Ultimate pressure down to 2.0 Torr (29.85" of Hg). Standard duty (79600-71) and chemical duty (79600-72) versions, analog or PWM control.

Free air capacity cfm (L/min)	Max vacuum " Hg (Torr)	Max pressure psi (bar)	Temp range	Service life (hrs)	Power connection	Noise rating	Port size	Power	Amps	Dimensions (L x W x H)	Catalog number	Price
A. Vacuum/pressure pumps												
0.01 (0.4)	5.9 (149.9)	6.8 (0.47)	41 to 113°F (5 to 45°C)	150	Solder tabs	65 dB(A)	3-mm barb	3 or 6 VDC	0.45	1 5/8" x 1 1/16" x 1/2"	GH-79600-02	
0.04 (1)							4.5-mm barb		0.9	1 3/16" x 1 1/8" x 15/16"	GH-79600-04	
B. Pressure pumps												
0.02 (0.5)	—	5.8 (0.4)	41 to 113°F (5 to 45°C)	150	Solder tabs	65 dB(A)	3-mm barb	3 VDC	0.3	1 1/4" x 3/4" x 5/16"	GH-79600-06	
0.04 (1)									0.46	1 1/2" x 7/8" x 1/2"	GH-79600-08	
C. Micro-boxer diaphragm pumps												
0.05 (1.4)	14.2 (360.7)	8.1 (0.56)	–4 to 113°F (–20 to 45°C)	12,000	Solder tabs	65 dB(A)	2.8-mm tubing ID	6 VDC	43 mA	1 1/2" x 5/8" x 1 1/2"	GH-79600-14	
								12 VDC	22 mA		GH-79600-16	
D. Single-head miniature diaphragm pumps												
0.05 (1.5)	12 (304.8)	10 (0.69)	41 to 158°F (5 to 70°C)	20,000	Pigtails	—	1/8" barb	12 VBLDC	0.195	2 1/8" x 1 1/8" x 2 1/8"	GH-79600-21	
0.05 (1.5)	12 (304.8)	10 (0.69)						24 VBLDC	0.11		GH-79600-22	
0.09 (2.5)	16 (406.4)	20 (1.38)						12 VBLDC	0.35		GH-79600-23	
0.09 (2.5)	16 (406.4)	20 (1.38)						24 VBLDC	0.175		GH-79600-24	
E. Cole-Parmer Air Cadet vacuum/pressure diaphragm pumps												
0.6 (17)	20 (508)	18 (1.24)	41 to 95°F (5 to 35°C)	4000	Pigtail	72 dB(A)	3/8" NPT(F)	115 VAC	1.2	7 1/4" x 4" x 5 1/2"	GH-07530-85	
	18 (457.2)	15 (1.03)						12 VDC	4	8" x 4" x 5 1/2"	GH-07532-25	
F. Oil-free rotary vane pumps												
4.7 (133)	26 (660.4)	10 (0.69) cont., 15 (1.03) inter.	40 to 100°F (4 to 38°C)	10,000	Standard plug	72 dB(A)	1/4" NPT(F)	115 VAC, 50/60 Hz	7	11 5/8" x 5 5/8" x 6 9/16"	GH-07055-60	
3.99 (113)								220 VAC, 50/60 Hz	2.8		GH-07055-65	
G. Oiled rotary vane pumps												