GEIGER COUNTER MODULE

Radiation Detection Board

Vesion: 2.0  
Sep 14, 2025

DATASHEET & USER MANUAL

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# Introduction

This system is a two-board Geiger tube PSU and front-end:

* **Switcher** — ATmega328P-based flyback controller (PWM, OC/OV protection, burst-hold regulation, I²C slave).
* **MainBorad** — transformer, rectifier, HV divider (4.3 MΩ/10 k), range relays/connectors, fast pulse comparator to ESP32.

Firmware supports 4 channels (ranges), per-channel voltage/OV thresholds over I²C with EEPROM wear-levelled storage. **Danger: high voltage.** See Safety.

## Features

* 250–1000 V high-voltage output with **burst/skip hold** to minimize input power at steady state.
* 4 channels selectable via **RANGE1:RANGE0**; **break-before-make** switching with PWM inhibited.
* **I²C slave**: set/get per-channel Vtarget, OVtrip, OVclear; set/get control tuning; save/load defaults; wear-levelled persistence.
* **Protections**: Over-current via analog comparator; over-voltage latch with hysteresis; CRC-32 app integrity check at boot.
* **Status LEDs**: OK = lit during burst/hold; FAULT = coded blinks (configurable).

|  |  |
| --- | --- |
|  |  |

## Safety Notice

⚠️ High Voltage Warning:  
This module generates high voltages up to **1000 V**, which can pose a serious electric shock hazard. Always handle the board with care during operation, and ensure the system is powered down before adjusting or probing high-voltage areas. Relays switch HV paths: never hot-switch channels under load; firmware enforces break-before-make delay.

⚠️ Discharge Capacitors Before Handling:  
The output capacitor (typically 1 µF or larger) can retain dangerous voltage levels even after the power is disconnected. Always ensure high-voltage output lines are properly discharged before touching or handling the circuit.

⚠️ Use Proper Isolation:  
Do not operate the module on conductive or metallic surfaces. Use appropriate insulating spacers and enclosures if the module is installed in confined spaces or near user-accessible areas.

⚠️ Intended for Qualified Personnel:  
This device is intended for use by individuals with a basic understanding of electronics and high-voltage safety. Improper use may result in injury, equipment damage, or exposure to harmful voltages.

# System Overview

## Block Diagram

|  |
| --- |
| A black background with white squares  AI-generated content may be incorrect. |

At the core of the module is a programmable high-voltage power supply based on the **LT3751 flyback controller**, capable of generating up to **500–600 V** DC. The system features **four independent output channels**, each with its own voltage control and feedback path. Only one channel is active at a time.

Operating principle:

1. **Startup:** **Ramp** to setpoint with limited duty. This slowly charges output capacitor to target voltage.
2. **Voltage Regulation:** Burst/skip regulation phase to cut average input power.
3. **Radiation Detection:** When the active GM tube detects an event, it generates a discharge across the tube, which presents as an intermittent short-circuit.
4. **Pulse Conditioning:** The analog pulse is filtered and shaped by the comparator and output as a clean ~3–5 µs logic pulse.
5. **Microcontroller Processing:** The ESP32 receives the pulse on a GPIO pin and handles counting, timing, and display/output functions.

# Electrical Specification

This section outlines the key electrical parameters of the Geiger Counter Module, including operating conditions, signal characteristics, tube compatibility, and timing performance. All values are nominal unless otherwise stated.

## Operating Voltage and Current

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Parameter** | **Min** | **Typ** | **Max** | **Unit** | **Notes** |
| Input voltage | 8 | 12 | 20 | V | Regulated input recommended |
| Input current (idle) | - | 56 | 70 | mA | Average |
| Input current (charging) | - | 120 | 200 | mA | Average |
| Output voltage (HV) per channel | 250 | - | 1000 | V | Individually adjustable for each channel |
| Channels | - | 1 | 4 | - | One channel active at any time |

## Output Pulse Characteristics

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Value** | **Unit** | **Notes** |
| Pulse type | 3.3 | V | Digital (SQW). Selectable by JP3 |
| Pulse Width | ~ 2-5 | µs | Depends on GM tube used |
| Pulse Rise/Fall Time | < 10 / <500 | ns | Typ. |

## Geiger Tube Compatibility

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Value** | **Unit** | **Notes** |
| Tube Operating Voltage | 250-1000 | V | Adjustable via I2C per channel. |

## Timing and Performance Metrics

|  |  |  |  |
| --- | --- | --- | --- |
| **Metric** | **Value** | **Unit** | **Notes** |
| HV Rise Time | ~5 | s | Depends on input supply & load |
| Max Count Rate | > 10000 | CPS | Limited by GM tube dead time |
| ESP32 Max Pulse Rate | > 25000 | CPS | ESP32 GPIO + interrupt |
| Output Voltage Accuracy | ±1–5 | % | Typ. |

# Hardware Description

The Geiger Counter Module integrates all key hardware required to operate and interface a Geiger-Müller tube with a modern microcontroller. This section details the roles of the high-voltage supply, tube biasing, signal conditioning, and digital interfacing.

## SwitchBoard (ATmega328P)

The high-voltage required for Geiger-Müller tube operation is generated using the LTC3751, a dedicated high-voltage flyback controller. The converter steps up the 5 V input to user-selectable voltages in the 250–550 V range.

**Key Features:**

* Timer1 PWM @ 20 kHz drives MOSFET gate (OC1A).
* Analog comparator: + = 1.1 V bandgap, − = AIN1; falling edge IRQ kills PWM for the cycle.
* ADC0 samples buffered divider; EMA filtering; PI(+D) regulator and burst-hold.
* I²C slave interface for config + status.

## MainBoard

* Transformer + rectifier + HV reservoir.
* **4.3 MΩ / 10 k** divider to ADC.
* 4 range relays select active output channel

## Geiger Tube Driver and Biasing

The HV output of the active channel is fed to the anode of the Geiger-Müller tube. A **series resistor (2 MΩ)** limits discharge current and ensures proper tube operation. The cathode is connected to GND.

**Notes:**

* The output capacitor (typically 1 µF) stores energy for fast HV rise
* Proper output voltage selection ensures tube safety and long life
* Only one tube is biased at any time

## Pulse Detection

Ionizing radiation causes a brief discharge in the GM tube, resulting in a sharp voltage drop across the load resistor. This analog signal is sensed by the **LM311 comparator**, which outputs a clean digital pulse.

**Comparator Configuration:**

* Input signal filtered with a small RC network
* **Reference voltage** from the LM311’s internal 1.182 V REF pin
* Output swing from **GND to 3.3 V**.
* Hysteresis pin tied to REF or adjusted for noise immunity

Pulse output is stable, reproducible, and ideal for digital counting. A typical output pulse is ~2–5 µs wide and ~3.3 V high, active LOW.

# Pinout and Connectors

## Board Pin Description

|  |
| --- |
|  |
| **J6:** Input Voltage Connector |
|  |
| **GND:** GM tube cathode connector |
|  |
| **VOUT:** GM tube anode connector |
|  |
| **J5:** IDC GPIO Connector |

|  |  |  |
| --- | --- | --- |
| **IDC Connector Pinout** | | |
| **Pin Number** | **Pin Name** | **Description** |
| *4* | **R1** | Range 1 switch GPIO. HIGH = Selected |
| *3* | **R2** | Range 2 switch GPIO. HIGH = Selected |
| *2* | **R3** | Range 3 switch GPIO. HIGH = Selected |
| *1* | **R4** | Range 4 switch GPIO. HIGH = Selected |
| *6* | **ONOFF** | Regulator Enable/Soft Start Pin, see below for more information. HIGH = ON |
| *5* | **GEIGER\_OUT** | Pulse Output Pin |
| *8* | **3.3V** | 3.3 V power supply. Can be left NC when using 5V logic level |
| *9* | **5V** | 5 V power source. Supplied by internal regulator from regulator input. |
| *10* | **GND** | Ground |
| *7, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20* | **NC** | Not used |

## Jumper Settings

|  |  |
| --- | --- |
| **Jumper** | **Description** |
| TP1 | Feedback signal testpoint, before LP filter |
| TP2 | Feedback signal testpoint, after LP filter |
| JP3 | Logic level jumper, selects 5V or 3.3V logic level |
| JP4 | Not used |

|  |
| --- |
|  |
| **JP3 signal specification.** Short 1-2 to enable 3.3V logic level, or 2-3 to set 5V. Do not leave floating. |

# Getting Started

This section explains how to safely power the module, connect a Geiger-Müller tube, and interface the system with an ESP32 microcontroller. Proper startup and shutdown procedures are essential to avoid overcurrent or failed HV startup, especially at higher output voltages.

## Powering the Module

The module is powered from a regulated 12 V DC supply (adapter, lab PSU, or battery). Input current during high-voltage ramp-up can reach **> 3A in peak (<1ms)**, so ensure the power source has enough capacitance to cover this surge.

To prevent inrush and enable reliable HV charging at high voltages, the module requires a **soft start sequence**:

**⚡ Soft Start Procedure**

* **ON/OFF** pin is connected to the **CHARGE** input of the LT3751
* Instead of applying logic high constantly, the ONOFF pin should receive a series of short **PWM-like pulses** with gradually increasing duty cycle

**Recommended Soft Start:**

* Pulse **every 10 ms**, starting from ~10% duty (1 ms width)
* Increase duty linearly to ~100% over **~1 second**
* After 1 s, leave ONOFF pin permanently HIGH (5 V or 3.3 V depending on system)

This allows the output capacitor (e.g., 1.1 µF) to charge more gradually, avoiding high peak current and startup failure — especially when output is set above 400 V or the input source is a current-limited lab supply.

## Connecting the Geiger Tube

Each of the 4 channels has a dedicated HV output path for a single Geiger-Müller tube. Only **one tube should be active at a time**.

**Connection Guidelines:**

* **Anode (positive side)** → Channel HV output screw-terminal
* **Cathode (negative side)** → GND screw-terminal
* Optionally, a **quench capacitor** (e.g., 10–100 pF) between cathode and GND can improve pulse shape

⚠️ *Make sure the HV output is* ***disabled*** *(ONOFF LOW) before connecting/disconnecting tubes.*

## ESP32 Integration Example

The LTC1440 provides a **clean digital pulse** on each radiation event. This is ideal for use with **ESP32 interrupts**.

*Remember to set logic voltage via JP3 before powering up the device.*

**Example Wiring:**

|  |  |
| --- | --- |
| **GM Board** | **ESP32** |
| GEIGER\_OUT | GPIO4 |
| ONOFF | GPIO5 |
| GND | GND |
| 3.3V | 3.3V must be able to source current |

🌀 **Switching Channels (Voltage Ranges)**

To change the active channel:

1. **Disable output:** Set ONOFF = LOW
2. **Switch range**: Set GPIOs to new channel
3. **Soft-start ONOFF again** (see above)

⚠️ *Failing to disable before switching may result in overcurrent or startup failure.*

# Calibration and Testing

This section describes how to validate module functionality and fine-tune each channel’s high-voltage output. Proper testing ensures accurate tube operation and reliable pulse detection.

## Verifying Pulse Output

To confirm correct operation of the pulse detection circuit:

1. **Power up the module** using the soft-start sequence
2. Ensure a **Geiger-Müller tube is connected** to the active channel
3. Use a known radioactive source or wait for background radiation
4. Connect the **OUT pin (via jumper TP1, TP2 or GPIO header)** to an oscilloscope or ESP32 GPIO
5. Observe pulses:
   * Voltage level: ~3.3 V
   * Width: ~20–30 µs
   * Rate: Depends on radiation intensity (typically 10–100 CPM for background)

*Tip: Use a 10× scope probe and confirm clean rising edges. ESP32 can detect pulses via GPIO interrupt if signal is ~20 µs or longer.*

## Measuring High Voltage

To check output voltage of a specific channel:

**⚠️ Safety First**

* **Discharge output capacitor** before touching any HV parts
* Use an appropriate **high-voltage probe** (e.g., 1:100)

**Procedure:**

1. Set the **ONOFF** to enable output (see Powering the module section)
2. Use a high-voltage probe to measure across HV output and GND of the active channel
3. Confirm voltage matches expected value (e.g., 400–500 V)

*For relative comparison or rough estimates, you can use a high-value voltage divider (e.g., 100 MΩ + 1 MΩ) to step down to multimeter-safe levels.*

## Adjusting Output Voltage via POT

Each channel includes a trimmer potentiometer to set the target high voltage.

**Adjustment Steps:**

1. Locate the trimpot for the desired channel
2. Use a ceramic or insulated screwdriver to rotate:

* Clockwise → Increase output voltage
* Counter-clockwise → Decrease output voltage

1. Measure HV with a scope or HV probe
2. Repeat steps 2-3 to fine-tune

⚠️ **Important Safety & Handling Notes:**

* ⚠️ **The trimpot is extremely sensitive** — small adjustments can change the output by tens of volts
* ⚠️ **Be very careful while adjusting the HV output while regulator is active** — Over-adjusting risks arc-over, damage to surrounding components, or personal injury
* ⚠️ **Always disable HV and wait for discharge** before touching the board
* Over-adjusting the trimpot may cause the output voltage to exceed **the safe limits of the flyback diode or transformer**, possibly creating spark gaps or catastrophic failure

*If unsure, stay within 300–550 V range per channel unless properly rated parts and layout clearances are verified for 550+ V.*

*Allow the output to stabilize for a few seconds before taking readings.*

# Troubleshooting

This section provides solutions to common problems encountered during setup and operation of the Geiger Counter Module. Causes are listed from most probable one to the least.

## No Pulses Detected

**Symptom:** No pulses on scope or ESP32

|  |  |
| --- | --- |
| **Possible cause** | **Solution** |
| Tube not connected properly | Verify tube polarity: anode to HV, cathode to GND |
| Voltage too low for used GM tube | Increase HV output voltage |
| No radiation source or background too low | Use a known radiation source |
| GEIGER\_OUT not connected to ESP32 properly | Check wiring, use scope to verify signal at OUT pin |
| LTC1440 faulty | Replace the component |
| Faulty tube or expired GM tube | Try a known working tube |

## HV Not Starting

**Symptom:** Output voltage remains 0 V or doesn’t hold required level.

|  |  |
| --- | --- |
| **Possible cause** | **Solution** |
| Soft-start not implemented | Apply increasing PWM pulses on ONOFF pin for ~1s |
| No input current spike | Increase HV output voltage |
| Output voltage set too high | Dial back the trimpot (very carefully!) and try again |
| Weak PSU | Try powering from battery or use PSU with higher current limit |
| Faulty flyback diode or transformer | Replace the component |

# Mechanical Information

This section outlines the physical characteristics of the Geiger Counter Module, including board size, mounting options, and electrical interface details.

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AI-generated content may be incorrect.

## Board Dimensions

|  |  |
| --- | --- |
| **Parameter** | **Value** |
| Width | 173.5 mm |
| Height | 62 mm |
| PCB thickness | 1.6 mm |

📏 *Measurements are approximate and may vary slightly by revision.*

## Mounting Holes

The PCB includes **three corner mounting holes** for secure installation in enclosures or onto standoffs.

|  |  |
| --- | --- |
| **Parameter** | **Value** |
| Hole diameter | 3.2 mm |
| Mounting pattern | 145 x 55 mm |
| Compatible Hardware | M3 screws or standoffs |

🛠 *Ensure adequate standoff height to maintain HV isolation from the mounting surface.*

## Connector Types

|  |  |  |  |
| --- | --- | --- | --- |
| Connector | Description | Pin Count | Voltage Level |
| J6 | 5.08mm TBlock | 2 | 12V typ. |
| VOUT, GND | 5.08mm TBlock | 4 | Up to 1000 V |
| J5 | 2x10 2.54mm IDC | 20 | 3.3-5 V |

# Revision History

|  |  |  |  |
| --- | --- | --- | --- |
| **Revision** | **Date** | **Author** | **Description** |
| V1.0 | 2025-07-30 | DV | Initial release — full system documentation including electrical, mechanical, and software interface |
|  |  |  |  |

# Appendix A: Safety Notices and Disclaimer

⚠️ **Electrical Hazard Notice**  
This product operates at potentially dangerous high voltages. Contact with live components may cause electric shock, burns, or death. Always ensure the system is powered down and fully discharged before performing any modifications or maintenance.

⚠️ **Usage Restriction**  
This device is **not certified** for use in medical, life-support, or safety-critical systems. It is intended for research, prototyping, or educational use by qualified individuals only.

⚠️ **User Responsibility**  
The end user is responsible for ensuring safe operation, proper insulation, and compliance with all relevant local electrical codes, safety standards, and handling procedures.

⚠️ **Product Modification**  
Unauthorized modifications, including changing resistor values, output voltage range, or firmware behavior, may result in unsafe operation. Do so only if you understand the full implications.

📝 **Document Accuracy**  
While all efforts have been made to ensure the accuracy of this document, it may contain technical inaccuracies or typographical errors. Always cross-check critical specs against the official datasheets of referenced ICs (e.g., LTC3751, LTC1440, ESP32).

# Appendix B: Reference Datasheets

|  |  |  |
| --- | --- | --- |
| Component | Manufacturer | Notes / Link |
| LT3751 | Analog Devices | [AD](https://www.analog.com/media/en/technical-documentation/data-sheets/lt3751.pdf) |
| LTC1440 | Analog Devices | [AD](https://www.analog.com/media/en/technical-documentation/data-sheets/144012fd.pdf) |
| GA3460-BL | Coilcraft | [Coilcraft](https://www.coilcraft.com/getmedia/eb987d97-6bee-4e60-8a64-a66d4e6e447b/ga3459.pdf) |