"C-GM Project - *IoT*"

Connected Geiger-Müller Counter
for Radioactivity level long term monitoring

ENGLISH: The manual is only available in English.

FRANÇAIS : Le manuel n'est disponible qu'en Anglais.

中國語文 : 用戶手冊僅提供英文版本。

日本語 : このマニュアルは英語でのみ利用可能です

РУССКИЙ: Данное руководство доступно только на английском языке.

Last update: October 19, 2018

FOREWORD

The Radioactivity DIY GM Counter device was initially called A-GM Counter and has been renamed to **C-GM Counter** for a more clear distinction from the A-GM Manager, the web application in charge to manage the radioactivity level measures.

NOTES, REMARKS AND WARNING

ⓘ   Note related to use.

➲   Important remark for avoiding failures or damages.

△   Critical note to avoid major injury or death.

RECYCLING

Please dispose electronics devices in an environmental friendly manner.

COPYRIGHTS

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IMPORTANT

Lethal conditions might occur when human bodies are in contact with high voltage. Therefore, under no circumstances persons unskilled, not familiar or unaware of electrical risks are discouraged to get involved.

Operating the device is under the entire, whole and sole responsibility of the user.

This project has been provided for <u>educational purpose only</u> and is not aimed for commercial applications neither it has been approved for any kind of uses.

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OVERVIEW

The project is aimed for providing a **continuous measurement of the radioactivity level**. It is made of an open-source Web application running on a SOHO server (*e.g. QNAP sells Small Office Home Office servers*) connected to a C-GM Counter device or a compatible GMC-320 Geiger-Muller Counters from GQ Electronics LLC. Other compatible or DIY Geiger-Muller counters could also be used. This project has been developed and is provided AS IS by AdNovea®.

This document will make references to:

- **A-GM Manager**   A **web application** for long-term continuously monitoring and storing the Beta/Gamma radiation level acquired from Geiger-Muller Counters during the user set retention period on local servers.
  Data can be redirected to the GMC.MAP website for worldwide radiation data sharing using the user account.

- **C-GM Counter**   An open-source **hardware** and **firmware** for a G.M. counter device developed and provided by Ad'Novea® able to run with the A-GM Manager application.

- **GMC-320 device**   GMC-320/5xx/6xx devices are sold by GQ Electronics LLC© and allow the redirection of measures to the GMC.MAP website directly from the device using a WiFi connection. A-GM manager support these devices to log the radiation measure on your server as well as the redirection to the GMC.MAP website.
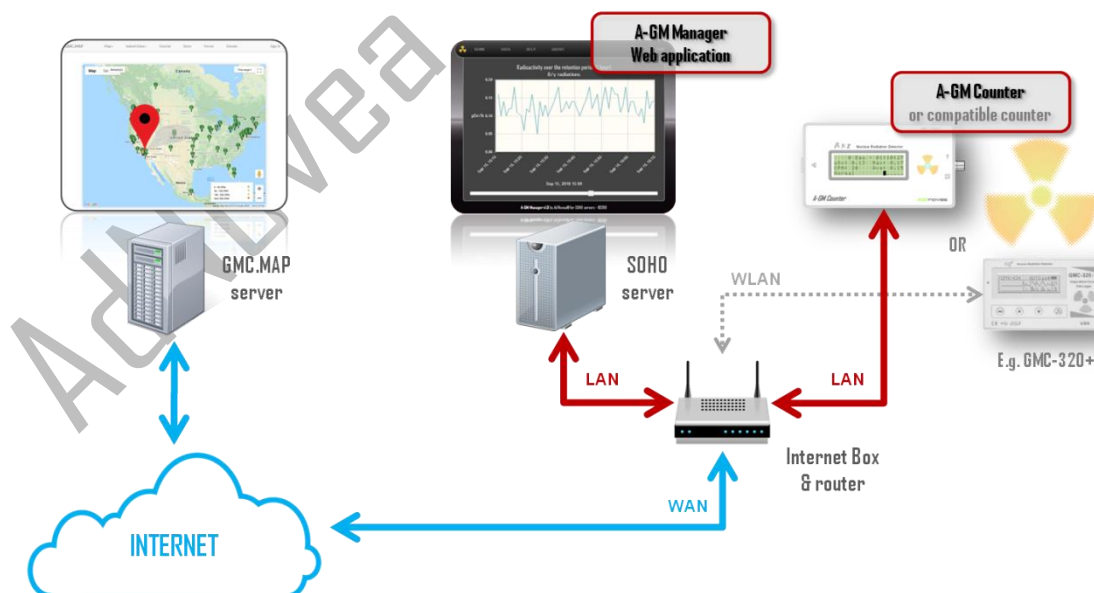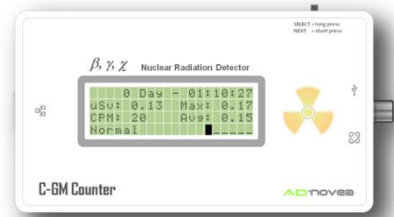

Project architecture

IMPORTANT: *This project is provided for training or education and in no case for commercial or professional purposes. It has not been approved for any kind of applications.*

C-GM COUNTER

ⓘ *Information required for assembling the C-GM Counter device hardware and firmware can be found and downloaded from* https://sourceforge.net/u/adnovea

FEATURES

- Radiation detection : β, γ, χ-ray
- GM tube : STS-5 (*CTC-5*) / SBM-20 (*400 V operating voltage*)
- Language support : English only
- Maximum value 65 535 CPM / 425 µSv/h (*theoretical*)
- Display values :
  - Current CPM
  - Current µSv/h
  - Maximum µSv/h since startup
  - Average µSv/h since startup
  - Elapsed time since startup
  - Level on bar graph
- Alarm
  - User defined threshold
  - LCD backlight blinking
  - Alarm messages on LCD
- LED flash for each beta/gamma radiation pulse
  - LED blink every second if GM tube is detective
  - LED still on when Network connection fail
- Audio sound
  - Beep for each beta/gamma radiation pulse
  - Audible sound alarm
- Device control from :
  - Device internal menu
  - USB (*require a serial console such as Termite*) or Ethernet (*using a web browser*)
- Network connection using DHCP
- Support for A-GM Manager web interface
- User defined parameters (*from Menu or through web interface*)
- GM tube conversion factor (*CPM to µSv/h*)
  - Alarm threshold in CPM
  - Buzzer On or Off
  - Display timeout
  - Enable Network for communication to A-GM Manager
  - A-GM server IP definition (*through USB or A-GM Manager*)
  - Internal H.V. voltmeter calibration (*through USB or A-GM Manager*)
  - Parameters can be permanently saved into EEPROM

USAGE

Properly install the device in a dust-free and dry environment. The GM tube device must be place outside and protected from direct exposure of the rain and sun light to avoid rust and fast aging.

1. Connect the Geiger-Muller tube cinch plug into the RCA socket of the device ⚛.

2. Connect the Ethernet LAN RJ-45 plug into the network socket of the device 品.

3. Power-up the device by inserting the **5V DC pack** plug into the micro-USB socket ⚡.

The C-GM Counter device counts the number of radiation pulses (CPM) over a one minute period (*shifting window*), and convert this count into a micro Sievert per hour (*μSv/h*) value using the G.M. tube conversion factor.

C-GM Counter device
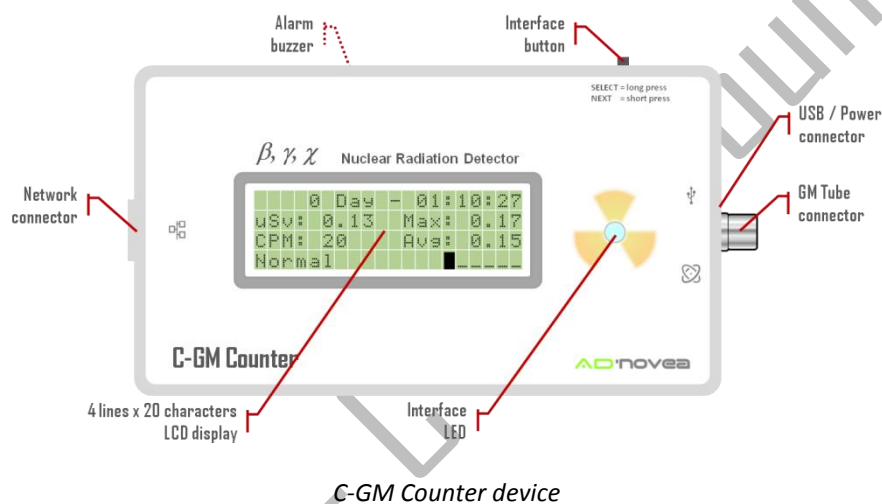
Since the device has been powered-up, there are also 3 additional pieces of information displayed:

- The elapsed time
- The Maximum value in μSv/h.
- The Average value in μSv/h.

At start-up, the splash screen displays the version and copyrights of the C-GM counter device firmware.

Check the website for the latest firmware version if needed.

About 5 seconds after the power-up, the splash screen closes and the counter starts the radiation measurement.

The splash screen can be closed by depressing the tack button
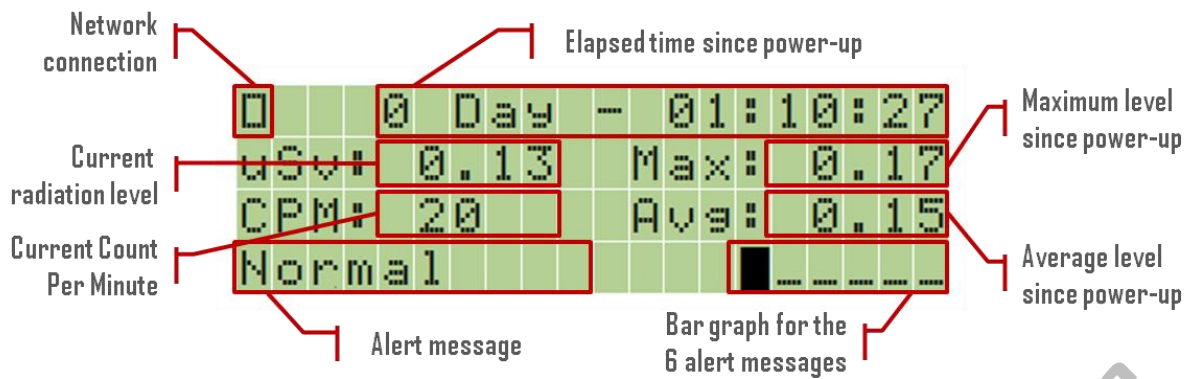
The measure screen displays:

Line #1:   The elapsed time since power-up. Network connection status icon is on the left side.

Line #2   The Current radiation level in µSv/h and the Maximum µSv/h since start-up.

Line #3   The Current radiation level in CPM and the Average µSv/h since start-up.

Line #4   The radiation status and the bar graph.

The Bar graph has 6 divisions and there are 6 messages corresponding to preset radiation levels set as below:

BAR GRAPH		RADIATION LEVEL	MESSAGE	COMMENT
	none	< 30 CPM (0.2 µSv/h)	Normal	Very low level
	1 bar	> 30 CPM (0.2 µSv/h)	Safe	Medium level
	2 bars	> 75 CPM (0.5 µSv/h)	Warning	Warning level
	3 bars	> 150 CPM (1.0 µSv/h)	HIGH LEVEL	Check environment
	4 bars	> 400 CPM (3.0 µSv/h)	CRITICAL	Abnormal level
	5 bars	> 1000 CPM (6.5 µSv/h)	EMERGENCY	Evacuation level
	6 bars	> 2000 CPM (13 µSv/h)	DANGER!	Extreme danger level

Keyboard

The user interface was made very simple and there is only one tack switch for control the device screens and menu.

According to the duration of the button push, there are two possible actions.

1. **Short press = SELECT**   User press the button less than half second.

2.   **Long press = NEXT**   User press the button more than half second.

To ENTER the Menu or validate a menu entry, make one **long press**.

To WAKE-Up the Display, jump to next screen or menu entry, make one **short press**.

Info screens

ⓘ *When LCD backlight is off, first wake-up the LCD with a short press to display the default screen.*

The information's screens can be toggled using the **NEXT** button (*short press*).

After the timeout delay, the display backlight switches off and the display returns to the default Radiation screen.

```
0    0 Day - 01:10:27
uSv: 0.13   Max:  0.17
CPM: 20     Avg:  0.15
Normal           ■..._.._..
```

RADIATION SCREEN

The default information screen displays the current radiation values such as the current µSV/h measure, the maximum µSV/h value since power-up, the current CPM value and the average µSV/h since power-up. Messages are displayed on bottom line.

```
     0 Day - 01:10:27
COUNTS  : 1750
DOSE uSv: 11.05
     uRe: 1105.0
```

DOSIMETER SCREEN

This screen displays values since power-up including the elapsed time, the total number of counts and the equivalent dose expressed both in micro-Sievert and micro-Rem.

```
Tube Factor= 150.2
Tube H.V.  = 401 V
Alarm Thres= 50 CPM
Modify with USB/LAN
```

GM TUBE SCREEN *

Display the GM tube conversion factor CPM to µSv/h, the current high voltage value (*read from internal voltmeter*) and the Alarm threshold (*in CPM*).

```
NETWORK IP:
Dev=192.168.0.120
Srv=192.168.0.180
Modify with USB/LAN
```

NETWORK SCREEN *

Display the device (Dev) IP address (*allocated by the DHCP service*) and the A-GM remote server (Svr) IP address.

```
C-GM v1.0
Aug 27 2018 12:02:31

AdNovea(r) - 2018(c)
```

CREDITS SCREEN

Display the firmware version and date as well as the copyrights.

* * To modify GM tube factor, alarm threshold or IP addresses, see Commands and GM tube's conversion factors sections.*

ⓘ *Button actions can be inefficient or delayed during network initialization.*

Alarm

Alarm threshold value can be checked from the device Menu.

➲ Alarm threshold CANNOT BE MODIFIED directly from the Menu but using the serial connection or from the A-GM web interface (*see Network connection section*).

Alarms cannot be masked and will be active even when the sound is off or the display is blanked.

During alarm, the display shows a message (*left-bottom*) and the level (*bar graph*). A sound is audible and the LCD backlight is continuously blinking.

Alarms are active while the alarm threshold is exceeded and stops when the level returns below the threshold. Nevertheless, without any user action on the keyboard, the LCD backlight will stay on after an alarm as a reminder. Max value gives the maximum level that has been reached during the alarms.

Entering the Menu stop the alarm.

Current values can be clear using the CLEAR COUNTERS command from the Menu.

Network connection

The C-GM Counter device can be connected to a LAN (*Local Area Network*) for remote control or to broadcast radiation measurement.

The NETWORK ACTIVATION should be enabled. The DHCP allocated IP address can be found from the INFO screens.

ⓘ   Until the A-GM Manager has been found on the network, the LED will **steadily stay ON**.

    The device will continuously try to connect until it gets connected. This will slow down the menu interactivity. The DHCP timeout is 1 minute.

    Network status is reported on the serial communication port to help debugging the LAN connection.

See the A-GM Manager documentation for the Web Interface.

Commands

The C-GM Counter device can be controlled from the **Serial communication port** (*through the USB*) using a terminal application (*e.g. Termite application*) or from the **Ethernet communication port** (*through the LAN*), using the A-GM Manager interface. The available commands are:

FACTOR=xxx.x	Set the conversion factor for the GM tube installed in the C-GM device. Factor for SBM-20 is 153.8 and 150.02 for STS-5 tubes. *See "GM tubes' conversion factors" section.*
HV=xxx	Set the ADC conversion level to Voltage, multiplied by 100 in range [0-255]. This value is given by : $$HV = \frac{R1}{(R1 + R2) \times Vref} \times 1023$$ Where R1=10MΩ, R2=15kΩ, VRef=1.1V. With the values above HV = 139 and for a 400 Volts high voltage the ADC outputs level=556 (1.39 x 400)
ALARM=xx	Set the alarm threshold in CPM. Default value is 50 CPM. Max is 9999.
RESET	Clear all counters: elapsed time, maximum and average values.
BEEP=ON or OFF	Enable/disable the audible beeps for each radiation pulse. Default value is ON.
TIMEOUT=xx	Set the timeout in seconds for the backlight display (0= disable). The maximum is 120 seconds. It also defines the time before the menu exits. If disabled, the backlight stays on. Default value is 10 seconds.
LCD=ON or OFF	Blank the LCD display and turn-off the backlight. Default value is ON.

NETWORK=ON or OFF	Enable/disable the network support. If disabled, the C-GM counter works as a standalone device. Default value is ON.
MAC=xxx:xxx:xxx:xxx:xxx:xxx	Set the C-GM Counter device MAC address entering six decimal values separated by colon (:). Default value is 116:105:105:45:48:53 (HEX: 74:69:69:2D:30:35). *Fixed/Static device IP can be configured on your LAN router by associating the desire IP address and the device MAC address.*
SERVER=xxx.xxx.xxx.xxx	Set the A-GM Manager remote server IP address. Default value is 192.168.0.180
MEMORY	Display the free memory space
OPTIONS	Display the values of the parameters.
EEPROM	Save permanently the parameters values into the EEPROM. Saved values are restored at device start-up.
VERSION	Return the C-GM Counter device version, date and credits

Remote control from web browser

ⓘ   Commands (*in upper case*) can be sent directly to the C-GM Counter device using an Internet Web Browser and entering the following URL format.

`http://<device IP addresse>/?<commmand>=<value>`

E.g. http://192.168.0.120/?BEEP=ON

The server web page displays the list of parameters as follow:

```
C-GM Manager - webserver

Cur. uSv/h: 0.13
Max. CPM  : 38
Avg. CPM  : 21.27
Tot counts: 1237
Elasped(s): 3463

GM Factor : 153.80
GM Voltage: 401.3V - HV=140
Alarm     : 50
Sound     : On
Timeout   : 10
Network   : On
Dev IP    : 192.168.0.120
MAC (hex) : 74:69:69:2D:30:35
Server    : 192.168.0.180
EEPROM    : OK
Free (B)  : 616
Version   : 1.0 (Oct  2 2018 10:42:47)
```

Data Output

The C-GM Counter sends every second over the Serial communication ports (*through the USB and Ethernet if connected*) the radiation data values as:

**?CPM=0&MAX=0&TOT=0&AVG=0&ELP=0**

Where respectively are the Current count in CPM, the Maximum count in CPM, the Total number of counts since power-up, the Average count in CPM since power-up and the Elapsed time since power-up.

If the High Voltage is out of range, the CPM value is set to '0'.

ⓘ *CPM values equal to '0' are managed by the A-GM Manager web application as GM tube failure and will sent an e-mail to the administrator address. CPM=0 is not possible in normal condition because the background radiation which is about 0.041-0.081 μSv/h and will continuously generate 6 – 13 CPM.*

IoT integration using JSON Data

For integration into IoT (*Internet of things*) environment using *Node-RED* for example, you can issue requests to the C-GM counter and get a JSON formatted data reply.
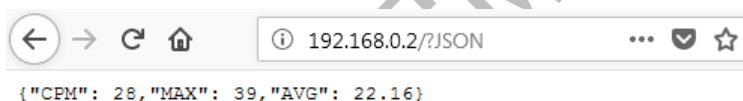
Example of http GET request returning a JSON formatted string

In Node-RED (*e.g. on QNAP server there is an IoT environment using Node-RED*), you can trigger a request every minute on an HTTP GET using the URL=< YOUR_C-GM_COUNTER_IP/?JSON >/*?JSON*. The "json" function will split the JSON string into variables. Finally you can use a function for computing the conversion of data into μSv/h using the GM tube conversion factor.
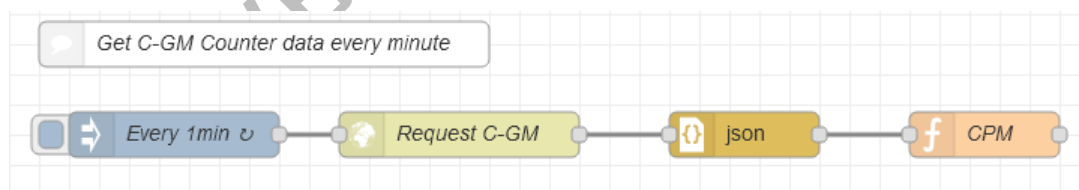
Rule for retrieving C-GM Counter data every minute

CONFIGURATION

ⓘ *When the LCD backlight is off, first wake-up the LCD with a short press to display the default screen.*

Menu navigation is operated through the single tack button.

To ENTER the Menu, make one **long press** (SELECT).

Press **NEXT** (*short press*) to jump to the next menu entry.

Press **SELECT** (*long press*) to change an option.

➲ When the Network support is enabled, the button action can be delayed after power-up due to the network connection retries.

Menu automatically exits after the TIMEOUT set by the user.

```
MENU:

SELECT to Quit
```
Press SELECT for returning to the radiation values default screen.

Release the button when the display blanks.

```
CLEAR COUNTERS?

SELECT to clear
```
Press SELECT for clearing all counters. Maximum and Average µSv/h, CPM and Elapsed time will be reset.

```
SOUND:
On
SELECT to modify
```
Press SELECT for enabling (On) or disabling (Off) the beeps when radiations are detected.

Alarm sound cannot be disabled.

```
LIGHT TIMEOUT:
30
SELECT to modify
```
Press SELECT for setting the display timeout. Each press increases the value by 10 seconds until 120 seconds (2 minutes). If equals to 0, the timeout is disabled.

```
NETWORK ACTIVATION:
On
SELECT to modify
```
Press SELECT for enabling (On) or disabling (Off) the Network management.

```
SAVE TO EEPROM:

SELECT to save
```
Press SELECT for saving the current parameters into the device permanent EEPROM memory.

```
TURN-OFF DISPLAY:

SELECT to turn-off
```
Blank the LCD screen and turn-off the backlight (ECO mode).

Wake-up the display by depressing the SELECT button.

GEIGER-MÜLLER TUBES

Conversion factors

The G.M. tube CPM to µSv/h conversion factor (*µSv/h = CPM / Factor*) depends on the type of Geiger-Muller tube. There are some values given below for different types of GM tubes (*all these tubes are not suitable for the C-GM counter*).

TYPE	FACTOR (CPM per µSv/h)	HIGH VOLTAGE (Volts)	LOAD (Ohms)	DEAD TIME (µs)	MANUFACTURING (year)
LND-712	168.35		10 MΩ		
M4001	158.35				
SBM-19	666.67				
SBM-20	158.35	350-475	~5.1 MΩ	190µs	1970-1990
SBM-21	20.83				
SBT-9	91.74				
SI-1G	166.67				
SI-16BG	200.00				
SI-22G	583.43				
SI-29BG	100.00				
SI-3BG	1.58				
SI180G	321.00				
STS-1	166.67				
STS-5 (CTC-5)	150.02	360-400	5-10 MΩ		mid 1960-1970

- Some GM tubes are very sensitive to background radiation which can be seen as a pseudo uniform emission source of particles whereas they become much less sensitive to radiation sources than are more point sources.

- Some GM tubes such as the M4001 are reported to be also light sensitive.

- GM tube conversion factor can depend of the isotopes (*type of radiation's source*). For example, the SBM-20 is reported with a conversion factor of 1/150 (0.00664) for a Cobalt 60 (^{60}Co) sources, 1/171 (0.00584) for a Cesium 137 (^{137}Cs) sources and 1/197 for the Radon (^{226}Ra) sources. Most of the time, the SBM-20 factor is given for 158.3 or 175.43.

- The Anode load resistor in series with the GM tube prevents the tube to enter in constant avalanche. The resistor value is given in the GM tube datasheet.

- For long cables between the tube and High Voltage power supply, DO NOT USE SHIELDED CABLE because the cathode IS NOT AT GROUND LEVEL. Cathode sensing that is used in the C-GM Counter device is the preferred method but does not provide cathode at ground level.

- Dead time is the time after an event in which the tube will not register a count. It's like the tube is resetting. Most specs on tubes list the dead time (in µS). The SBM-20 has a dead time of 190 µS. The Dead time impact is very low at low count but becomes significant at higher rates.

➲ **IMPORTANT**: Most of STS-5/CTC-5 Geiger-Müller tubes sold over the Internet have been manufactured at the end of the cold-war and are date 1969/70 (*e.g. CTC 5 marking on the photo is VI ⵔ 69 for manufacturing in June 1969*). Therefore these GM tubes are half-century old and have been exposed during about 50 years to background radiation.

STS-5 / M4001 / SBM-20 GM tubes

All these tubes have sensitivity around 150 and can use the abacus below for CPM to µSv/h conversion.

Abacus for C-GM Counter
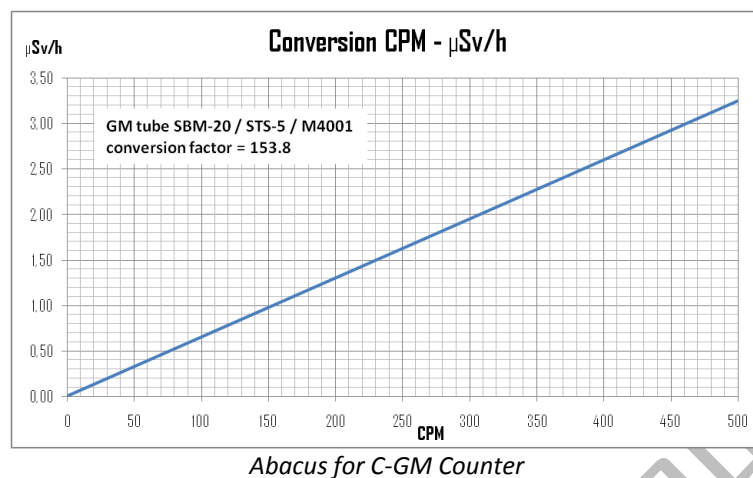
External probe

The 400V high voltage RCA connector receives the external GM tube probe. We use a 3-meter 2-wire 0.5mm² cable. The GM tube is located on a piece of PCB (vero board) inside a 32mm diameter PVC tube and fixed using two fuse-holder clips. The PVC tube is about 21 cm long to offer enough room on the top/bottom parts for the mounting brackets. Both extremities are closed using sealed plastic plug. The probe fixation must not shadow the GM tube. The probe shall be placed vertically and make a kink on the cable before the plastic knob (*water drop effect*).

External GM probe
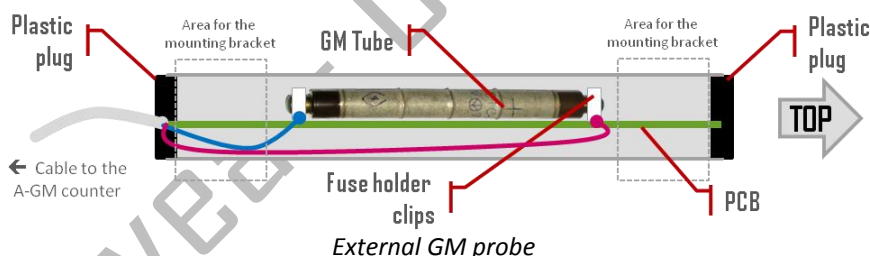
GM tube anode (+) must be connected to +400V.

HIGH VOLTAGE ADJUSTMENT

ⓘ *Due to the important internal output impedance (~800kΩ) of the high voltage power supply, there is a tradeoff to find between the current delivered by the module (~260 µA) and the maximum voltage output (< 450V). Moreover, output voltage measurement will be affected the multimeter impedance.*

➲ **High voltage value depends of the actual 5V power supply value.**

Therefore, High voltage adjustment will be required whenever the C-GM Counter 5V DC pack is replaced because not all DC packs provide the same output voltage. High voltage measure must be done when the LCD backlight is off (*after the timeout period*) using a multimeter (*position: voltmeter DC ⎓*).

Internal voltmeter calibration

Internal voltmeter must be calibrated first using the "HV" parameter.

Once the HV parameter value will been set correctly, the high voltage value can be adjusted using only the internal voltmeter according to the GM tube specification (*e.g. 400V for STS/CTC-5 tube*), Then it can be used to setup the 400V high voltage.

Output 400 V must be adjusted with the 5V DC pack in place and LCD backlight off.
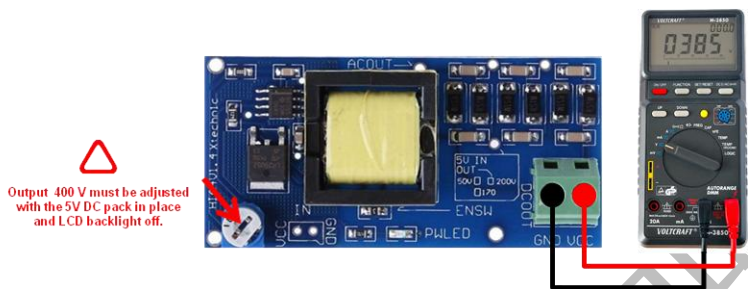
WARNING: Multimeter impedance affects the voltage reading.
Module must be connected to the C-GM circuitry.

If the High Voltage read on the multimeter is 385V for example, the internal voltmeter must give the same value +/- 5V. To do so, you must change the HV parameter value, and modify it using the USB connection and then save it into the EEPROM.

High Voltage read on the Multimeter	High Voltage read on the C-GM Voltmeter	Action to match both readings

	```Tube Factor= 150.2```
	```Tube H.V. = 378 V```
	```Alarm Thres= 50 CPM```
	```Modify with A-GM```
		Decrease HV parameter value : 139 ↓
		
		-1 = ~+3V

	```Tube Factor= 150.2```
	```Tube H.V. = 401 V```
	```Alarm Thres= 50 CPM```
	```Modify with A-GM```
		Increase HV parameter value : 139 ↑
		
		+1 = ~-3V

➲ *The default HV parameter value (**139**) must be adjusted due to the tolerances on divider bridge resistors (+/-5% to 10%). The internal voltmeter HV parameter can be entered using the USB or Ethernet connection. For example, on our prototype we had to set the HV value to **141**.*

The GM tube high voltage tolerances are set between 360V and 440V (*suitable for CTC/STS-5*). If the high voltage is out of range, the display will show a warning message.


```
WARNING:
High Voltage= 312V
```
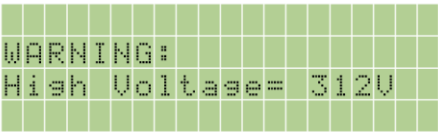
ⓘ *The output of the high voltage module shall be filtered with a 10nF / 2kV (2000 volts) to reduce the switching noise (about 20V without the capacitor) and loaded to limit the voltage drop when there are discharges in the GM tube.*

C-GM COUNTER RADIACTIVITY CALIBRATION

Ensure you have correctly installed the GM tube into the probe casing. Due to the intrinsic nature of β, γ radiations (*high energy*), the plastic tube has no significant impact on the radioactivity level detection.

The easiest way for the C-GM counter calibration is to use a radioactivity source (*e.g. fluorescent clock with radium-226, smoke detector with americium-241*) and already calibrated GM counters. Expose the two counters to the source at the same distance and match the **µSv/h** value from the C-GM counter with the calibrated counter reading by modifying the **FACTOR** parameter through the USB or Ethernet connection.

ⓘ *CPM depends of the GM tube sensitivity whereas the µSv/h is a tube independent unit thanks to the GM tube Factor.*

Example of the comparison between our C-GM Counter and a GMC-320+ gave:

- GMC-320 : Total counts during 12:46:42 = 16 666 → Average of 21.74 CPM
- C-GM : Total counts during 14:06:00 = 18 357 → Average of 21.70 CPM

Therefore both tubes (M4001 and STS-5) have the same sensitivity with the same conversion factor of **153.80**.

DEBUGGING USING THE USB PORT

To debug the C-GM Counter hardware and firmware, you can connect the device to an USB port of your PC and run a Terminal console such as the "Termite" (https://www.compuphase.com/software_termite.htm) application. Select the **COM** port corresponding to the C-GM device and the **115200** baud rate.

Debugging information will be displayed and command (*see Commands section above*) can be issued.

SCHEMATIC
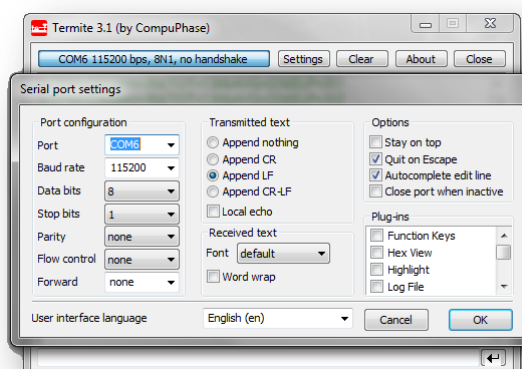
BILL OF MATERIAL

The cost of the C-GM Counter device hardware is less than **50 USD** or **43 EUR**.

Supplier	Reference / ASIN	Designation	Quantity	P.U.	Price €
				TOTAL	**42.69 €**
Amazon / TOOGOO	Nano B00QLOSFDS	Arduino Nano V3.0 AVR ATmega328 P-20AU with USB cable	1	2.99	2.990
eBay / FR Aurora	263047098173	Ethernet module	1	4.32	4.320
Amazon / Sodial	018366 B00L11JDIC	4x20 LCD display blue	1	4.17	4.170
Amazon / Xinte	$X05699 B00GBSWOWW	I2C module for LCD display	1	1.48	1.480
eBay / ShopDoro	163131506351	High Voltage DC-DC 2mA To 20mA Boost Converter (400V H.V. Module)	1	8.95	8.95
eBay / Arthur Bernard UK	172971837532	G.M. Tube STS-5 / CTC-5 Soviet Army	1	9.35	9.347
Ebay / 9-hk353	223084318182	Piezo buzzer	1	0.10	0.10
Amazon / Toogoo	021430 B00LO2U134	LED 5mm	1	0.0129	0,013
Amazon	STK0151001508 B01FJUOEFW	Tact Switch Micro 6x6x16mm	1	0,021	0,021
eBay / Tiny Heaven	391791911461	Vero board 10 x 20 cm	1	2.95	2.950
Amazon / Toogoo		6x resistors, 3x capacitors, 1x Zener	10	0.010	0,100
Amazon / Pinzhi	058768 B01DBKRRU6	Black plastic box 158 x 90 x 60mm	1	4.21	4.210
Amazon / FXCO	BBB123 B07FKKPYBN	5V DC pack with mini USB plug	1	1.83	1.83
Amazon / TOOGOO	066268 - B01H01JCXW 061299 - B01EYD79KC	CINCH male + female	1 + 1	0.1015 0.1060	0.2075
		Miscellaneous e.g. 2-wire cable 0.5mm²			2.00

Resistors: R1=2.2MΩ, R2=3.3kΩ, R3=5.6MΩ, R4=8.2kΩ, R5=100kΩ, R6=47kΩ

Capacitances: C1=10nF/2kV, C2=47pF, C3=330pF

Diodes: Zener 4V7, LED white Ø5mm

# CHARACTERISTICS

- Radiation detection types   β, γ, χ-ray
- Detector   Geiger-Müller tube STS-5 / SBM-20 (400 V) with 5m cable
- Maximum values   65535 CPM / 425 µSv/h (*theoretical*)
- Display   LCD with backlight, 4 lines x 20 characters, dot matrix 5x7
- Keyboard   1 tack switch
- Sound   Buzzer piezo
- Indicator   LED white

- Connectivity
  USB
  Ethernet 10-100 Mb/s, RJ45 socket, DHCP only
- MAC address
  User defined (default 74:69:69:2D:30:35)
- Interface language
  English only
- Dimensions
  W : 158mm x H: 90mm x D: 60mm
- Weight
  315g w/o cables and power supply
- Power supply
  5V USB DC pack / 2 Watts
- Accessories
 RJ45 cable, USB cable, 5V DC pack

BUILDING THE C-GM COUNTER HARDWARE

The assembly of the C-GM counter hardware has been made the simplest as possible using minimum components available from the selves (*e.g. Amazon or eBay*) and the minimum of wiring. There is no dedicated printed circuit board (*PCB*) but instead an inexpensive single face dot board (*aka Perfboard*) with solder pad for each hole (*Veroboard*).
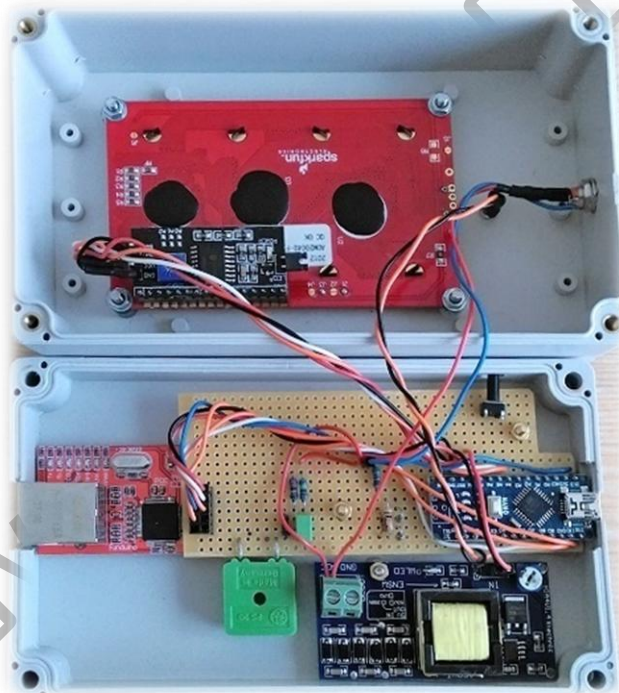
The Perfboard receives the resistors, capacitances, diodes, switch and piezo.

- The GM 5.6MΩ resistor is sold directly on the RCA socket.

- The Ethernet board is connected to the Arduino Nano using a 2x5 connector.

- Ethernet board connector pins pass through the Perforboard to ensure its fixation.

- The Arduino Nano is weld on the Perfboard.

- The C1 capacitance (10nF/2kV) is weld on the output connector on the back of the H.V. module.

- There is a strap wire weld on the back of the H.V. module between the input and output GND.

- The R6 resistor (47KΩ) is weld directly on the ground pin of the LED.

- The W5100 Ethernet module RST is not connected to the Arduino RST. On the RST pin of the W5100 module pin there is a resistor and capacitance. If connected to the Arduino RST, this prevents

downloading new firmware in the Arduino. The drawback is the need to switch off the power supply for resetting the Ethernet.
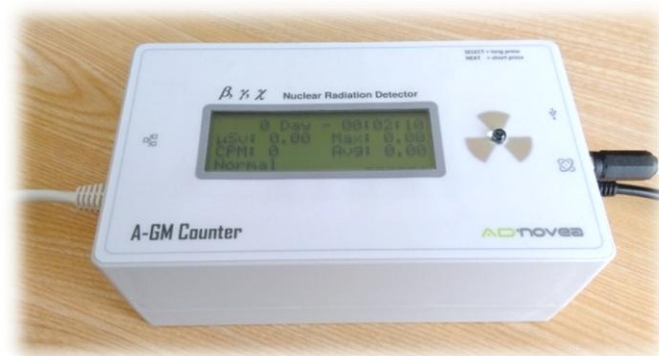
C-GM Counter in operation

C-GM Counter with its external probe and power supply

FLASHING THE C-GM COUNTER FIRMWARE

The C-GM Counter Device programming can be done using the C-GM Counter device **HEX file** and the **Xloader** utility. "*Xloader*" application can be downloaded from the author website at http://xloader.russemotto.com/

Select the "*Duemilanove/Nano (ATmega328)*" device, the serial port where the C-GM Counter device is connected to and browse to the HEX file. Click on "*Upload*" to proceed with the programming.
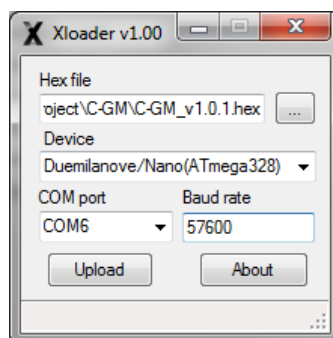
There are two HEX files that can be flashed:

- **CGM_vx.x.x.hex**   Use this file to keep the native bootloader of your Arduino Nano.
- **CGM_v1.x.x.x_bootloader.hex**   Use this file to flash the C-GM firmware and its bootloader.

ANNEXES

GLOSSARY

The list below contents abbreviations and acronyms.

|	
µRem	The roentgen equivalent man (Rem) is an older CGS unit. **1 Rem = 100 Sv**
µSv/h	Micro-Sievert per hour – The Sievert (Sv) is a derived unit of ionizing radiation dose in the International System of Units (SI) and is a measure of the health effect of low levels of ionizing radiation on the human body.
Alpha particles (α)	Alpha particles have a typical kinetic energy of 5 MeV and a speed of about 15,000,000 m/s, or 5% of the speed of light. They can be stopped by few centimeter of air, a piece of paper or the epidermis
Beta particles (β)	Beta particles have medium energy and most can be stopped by a few millimeters of aluminum. Beta radiations are in the range of 0.25 to 3.5.
CPM	Count Per Minute.
Gamma particles (γ)	Gamma particles have very high energy and require shielding by dense material such as lead or concrete to be stopped. Gamma radiations are in the range of 0.1 to 1.25 MeV.
GM	Short for Geiger and Muller who are the inventors of the vacuum tube with low pressure gas able to detect ionizing radiations from X-Ray, alpha, beta and gamma particles.
GM Counter	Device able to count the number of radiation impulses per minute (CPM).
GM Factor	Each GM tube manufactured type has its own sensitivity to radiation and a specific factor to convert the number of impulse (CPM) into micro-Sievert per hour (µSv/h).
GUI	Graphic User Interface includes the display and keyboard systems.
Ionizing radiations	Radiation carrying enough energy to liberate electrons from atoms or molecules, thereby ionizing them (Alpha, Beta, Gamma or X-Ray radiations)
LAN	Local Area Network: private network installation
LCD	Liquid Crystal Display is a dot-matrix display for text and semi-graphic characters.
QPKG	Packaged application module compatible with QNAP servers
Sv (Sievert)	Unit of ionizing radiation dose in the International System of Units (SI) measuring the health effect of low levels of radiation on the human body.
Tack switch	Push button made of micro-switch system.
X-Ray	X-ray radiations are in the range of 30 keV to 3.0 MeV.

TYPES OF RADIATIONS
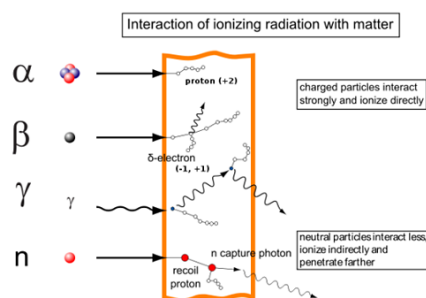
Alpha:

Alpha radiation are positively (+2) charged particles emitted from atom nucleus in the process of decay. These particles are also very dense and their strong positive charge precludes them from penetrating more than an inch of air or a sheet of paper. Alpha particles are not a serious health hazard, except when they are emitted from within the body as a result of ingestion, for instance, when their high energy poses an extreme hazard to sensitive living tissue. This weak form of ionizing radiation is only detectable by some models of Geiger counters equipped with Geiger-Muller tubes having a thin mica window at one end.

Beta:

Beta radiation are negatively charged (-1) particles emitted from an atom in the process of decay. These relatively light particles can penetrate deeper than Alpha particles, though still only through a few millimeters of aluminum at best. If ingested, Beta radiation can be hazardous to living tissue. This relatively weak form of ionizing radiation is detectable by many Geiger counters.

Gamma:

Gamma radiation are one extreme of the electromagnetic spectrum, particularly that radiation with the highest frequency and shortest wavelength. (*That same spectrum also includes the more familiar X-rays, ultraviolet light, visible light, infrared rays, microwaves, and radio waves, listed in order of decreasing frequency and increasing wavelength from Gamma rays*.) Gamma rays can pass through virtually anything, and are effectively shielded or absorbed only by materials of high atomic weight such as lead. Gamma rays are produced naturally by the sun and other bodies in outer space, their transmission to earth being known as "*cosmic radiation*". A very powerful and potentially very dangerous type of ionizing radiation detectable on virtually all Geiger counters.
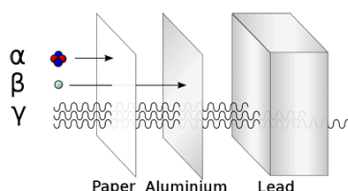
Background radiation:

Certain earth's minerals contain the radioactive elements such as Uranium and/or Thorium which also emit Gamma rays. This radiation along with the cosmic radiation (*Gamma rays which come from the sun and other stars*) combine to produce the "*background count*" of a Geiger counter. This might typically be in the range of 15 to 60 counts per minute, but will vary depending upon your location on the earth, your altitude, and also

the efficiency (*sensitivity*) of the Geiger counter tube. The background count should always be factored in or "subtracted" from the overall reading derived from a specific radioactive source.

Common background radiation goes from 0.041μSv/h to 0.081μSv/h (3650 - 7200μSv/year).

DOSE RATE EXAMPLES

All conversions between hours and years have assumed continuous presence in a steady field, disregarding known fluctuations, intermittent exposure and radioactive decay. Converted values are shown in parentheses.

Source Wikipedia.

<1 mSv/a	< 0.1 μSv/h	Steady dose rates below 100 nSv/h are difficult to measure
1 mSv/a	0.11 μSv/h avg*	ICRP recommended maximum for external irradiation of the human body, excluding medical and occupational exposures.
2.4 mSv/a	0.27 μSv/h avg	Human exposure to natural background radiation, global average
3.7 mSv/a	0.42 μSv/h avg	.Average radioactivity level at the entrance of the Chernobyl exclusion zone.
24 mSv/a	2.7 μSv/h avg	Natural background radiation at airline cruise altitude
41 mSv/a	4.6 μSv/h avg	Radioactivity level at the Chernobyl memorial near the nuclear plant before the new sarcophagus.
130 mSv/a	15 μSv/h avg	Ambient field inside most radioactive house in Ramsar, Iran. Radioactivity level in sewer drain in Pryp'yat', Ukraine.
(800 mSv/a)	92 μSv/h	Natural radiation on a monazite beach near Guarapari, Brazil
(9 Sv/a)	1 mSv/h	NRC definition of a high radiation area in a nuclear power plant, warranting a chain-link fence
	2–20 mSv/h	Typical dose rate for activated reactor wall in possible future fusion reactors after 100 years. After approximately 300 years of decay the fusion waste would produce the same dose rate as exposure to coal ash, with the volume of fusion waste naturally being orders of magnitude less than from coal ash. Immediate predicted activation is 90 MGy/a
(1.7 kSv/a)	193 mSv/h	Highest reading from fallout of the Trinity bomb, 32 km away, 3 hours after detonation
(2.3 MSv/a)	262 Sv/h	typical PWR spent fuel bundle, after 10-year cool down, no shielding
(4.6–5.6 MSv/a)	530–650 Sv/h	The radiation level inside the primary containment vessel of the second BWR-reactor of the Fukushima power station, as of February 2017, six years after a suspected meltdown

*avg   The equivalent average dose over one year (1y = 8766h).

TROUBLESHOOTING

Problems	Solutions
C-GM COUNTER	
LED stays still	• Network or A-GM server cannot be found. Check cable, IP address and A-GM server.
LED blinks every second	• The GM tube is defective. No pulse is detected. Check High Voltage value with very high impedance (>100MΩ) multimeter (voltage must be 400V)
High Voltage value is wrong and/or always displayed	• There is an internal voltmeter inside the C-GM counter. Its accuracy requires a calibration because of the tolerances on the divider bridge used by the voltmeter. Check if the displayed value matches the actual high voltage value measured with a multimeter. • The High Voltage module can be defective. Check the output voltage.
Button does not work at start-up	• When the network feature is enabled, the device tries and retries to connect. Each try introduce lag in the button's action processing.
Normal or safe is displayed but LCD backlight toggle	• The Alarm threshold is probably too low. Check the Alarm threshold against the different messages in the USAGE section.
Display does not return to Radiation screen when timeout is reached or exiting sleep mode	• The timeout switches off the LCD backlight and exit the Menu screens but does not return Info screen to the radiation. • Display wake-up will show the Dosimeter screen. • Exiting the Menu return to the Radiation screen.
Cannot connect to network	• Check cable and switch if any, verify RJ-45 socket LED. • Check Menu configuration • Check for potential IP address conflicts • Unplug and plug again the power supply USB cable to reset the Ethernet card • DHCP tries during about one minute to connect
Display locks/freezing or lag LCD freezes with only the time line displayed	• Unplug and plug again the power supply USB cable to reset the Ethernet card • Check the RJ-45 socket LED. If there are not active, check the cable and the internal Ethernet module connections. • The LCD looks like it is freezing at start-up when the network is enabled and no connection can be performed. You must disable the network connection using the USB connection. Open a console (e.g. Putty), type NETWORK=OFF and <u>wait one minute</u> for the DHCP timeout. This will disable the Network and the display will return to normal.
High Voltage warning message	• The LCD displays a warning message about the high voltage whereas the voltage is correct. Adjust the HV potentiometer and check the voltage in the INFO menu.

LICENSES

We are proud to release our project under free licenses. Feel free to use it the way you like in accordance with the licenses below.

A-GM Manager Web application	*License : GPL v3 (open-source)* https://www.gnu.org/licenses/gpl-3.0.en.html
C-GM Counter Firmware	*License: Free to use for personal application only* No source code released

SUPPORT

This project is provided "AS IS" and is not committed to provide support of any type.

Nevertheless you may find some helpful pieces of information and exchanges from the SourceForge repository.

https://sourceforge.net/u/adnovea