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A PORTABLE GAMMA DOSE-RATE METER FOR SURVIVAL USE

by

P.C. East and M.A. Periard

PROJECT NO.
16-03-01

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Abstract

50 //A miniature gamma dose-rate meter is described which uses three differently coloured flashing light emitting diodes to cover the dose-rate range 0.1 to 100 R/h. This low cost instrument has considerable potential as a survival instrument for both military and civilian applications.//

Résumé

Le rapport décrit un détecteur miniature de taux de radiations gamma. La portée de l'instrument est de 0.1 à 100 R/h et la lecture s'effectue à l'aide de trois diodes photogènes de couleurs différentes. Cet instrument à prix modique a d'énormes possibilités d'application militaire et civile en tant qu'instrument de survie.

INTRODUCTION

A portable gamma survey meter is used to obtain dose-rate information in an area where a radiation hazard exists. This information is of immediate concern to the operator who will use it to determine the hazard to himself, or any associates, and the course of his subsequent actions. This information may also be relayed to a control authority and could be used to control other personnel who have to operate in the area. There is a requirement for the relayed information to be accurate, since many persons may be involved and there may be a choice of action. In peacetime, exposure to low dose-rates only is normally considered, there is no immediate risk to personnel, only a potential long term risk, and only specialized personnel are involved.

In the event of a nuclear war, there is likely to be a large number of individuals or small groups of individuals who are isolated from any control authority and who may be exposed to dose-rates that pose an immediate risk and who will have a limited choice of action. That is, when a radiation hazard exists the only action they can take is to move out of the area or to find a more sheltered spot. To be aware that a hazard exists, a dose-rate meter is essential, but since this is a go, no-go situation high accuracy is not required.

The crew of a "downed" aircraft in wartime, could find themselves in this position and there is a Canadian Forces requirement for a dose-rate meter to fit into the aircrew survival pack. Small size and ruggedness are essential requirements for such an instrument.

This note describes an instrument that would meet this requirement and since it is also a low cost instrument it could find a wide civilian application.

DESCRIPTION OF INSTRUMENT

General

The instrument described in this note has been designed to measure dose-rates over the range 0.1 to 100 R/h using an 18529 Geiger-Mueller (G-M) tube.

A photograph of a low range model which uses an 18504 G-M tube to cover the dose-rate range 0.1 to 100 mR/h is shown in Figure 1. The only difference between this and the higher range instrument is the detector and mR/h instead of R/h on the face plate. The low range model was built so that the system could be demonstrated without exposing the user to high radiation levels.

The case is 4-1/8 x 2-1/2 x 7/8 inches and the weight including battery is 7-1/2 ounces. In production a plastic case could be used and this would reduce the weight to less than 6 ounces.

The readout consists of three different coloured light emitting diodes (LEDs) which flash at a rate proportional to the dose rate. This gives a simple and easy to read indication of the dose-rate level. An accurate reading can be obtained by counting the number of flashes during a counting period. Each counting period, about three seconds duration, is marked by a blank period of about one second during which time all the LEDs are off. A green LED flashes once during each counting period per 0.1 R/h of dose-rate, an orange LED flashes once per 1 R/h of dose-rate and a red LED flashes once per 10 R/h.

Circuit Operation

The circuit diagram of the counting circuit is shown in Figure 2. Pulses from the G-M tube are amplified and fed to four decade-counters connected in series. The output of the second decade-counter is also fed into a NAND gate and to a constant current stage driving the green LED. Similarly the third counter stage drives the orange LED and the fourth counter the red LED driver stage via an inverter. The NAND gates are connected so that only one of the three LEDs can be on at a time. This limits the peak current drain and makes the display simpler to read.

The counting period, approximately three seconds, is controlled by a simple multivibrator which drives a seven stage ripple counter. The last two stages of the ripple counter, fed to a NAND gate and an inverter, provide a pulse which resets and inhibits the decade-counters for a time equal to one third of the counting period. At 0.1 R/h, the 18529 G-M tube gives about 33 counts per second or 100 counts per counting period. The output stage of each counter goes positive at the end of the eighth count and stays positive for two counts, thus at 0.1 R/h the green LED is "on" for the last 0.6 seconds of each counting period. Similarly the orange and red LEDs are "on" for 0.6 seconds at 1 R/h and 10 R/h respectively. The instrument is calibrated by adjusting the counting period to give two red flashes in a field of 20 R/h. Second figure accuracy can be obtained by counting the flashes of the preceding stage. For example; at 25 R/h there will be two red flashes and five orange flashes after the second red flash and before the blank period. This is illustrated in the Timing Diagram shown in Figure 3. In practice the counts at 25 R/h will be less than the nominal count of 25,000 due to the G-M tube "dead time" losses.

In the low range model the 18504 G-M tube gives an average 2.2 counts per second at 0.1 mR/h or 10 counts in 4.5 seconds and uses only three of the four decade-counters. Due to the poor statistics accurate readings cannot be made at dose-rates below 1 mR/h. This is unimportant in a demonstration model but does require dose-rates above 1 mR/h to provide a satisfactory demonstration.

To give an indication that the instrument is working in the absence of radiation the red LED is turned on for 1 to 2 seconds when the instrument is switched on. This is effected by the CR circuit at the input of inverter G8. Apart from this red LED "on time" there is no "warm up" period required, the only operator control is the on-off switch.

Power Supply

The operating voltages, 500 V for the G-M tube and 3.5 V for the LED and counters, are obtained from a dc-dc converter powered by a single penlight, AA size, battery.

The circuit diagram of the converter is shown in Figure 4. Transister Q1 is a regulated swinging choke oscillator. Any difference between the 3.5 V output voltage and the zener voltage is fed to the base of Q2 which controls the base drive of Q1 and the power supplied to the output circuits.

With a battery voltage of 1.5 V the battery current drain varies from about 25 mA with no radiation to 35 mA at about 100 R/h. The battery current will increase to a maximum of about 60 mA at dose-rates over 100 R/h when the battery voltage is down to 1 V. The zinc carbon cell should give about 20 hours of operation, a manganese alkaline cell over 30 hours. This operating time should be satisfactory since this instrument will not be used continuously.

Scale Accuracy

The readout can be read to two figure accuracy which is as good or better than can be achieved with a three decade log scale meter, however to obtain this reading at least two counting periods, eight seconds, are required. Thus accuracy can be obtained at the expense of time. In practice an acceptable accuracy does not require an accurate count. One, two or three or possibly four flashes can be counted without making a conscious effort to count. An error of one count in four, five or six counts or an error of two counts in seven, eight or more counts is less than 30%. If there are only one or two orange or red flashes an estimate of the subsequent green or orange flashes enables the dose-rate to be easily read to better than ± 30%. For example in Figure 3 an error of two orange counts still gives a reading error of less than ± 10%.

The counting period is nominally set so that the G-M tube gives 100 counts at 0.1 R/h, thus statistical variations in the output can be neglected. For dose-rates above 10 R/h the G-M tube dead time, 11 microseconds, results in lost counts, amounting from 5 - 10% at 20 R/h to 35 - 40% at 100 R/h. By calibrating the instrument at 20 R/h the maximum error is limited to -30% at 100 R/h. This error is tolerable in this instrument since at very high dose-rate levels any action taken by the user is unlikely to be influenced by differences in dose-rate much less than two to one. A reasonable criteria for instrument accuracy would seem to be the minimum level change that would be required to influence the decision of the user. It should be noted that with a survey meter there are usually two users, the operator and the control authority; with a survival instrument there is only one user, the operator.

Readability

While the flashing LEDs can easily be read at night or in normal indoor or dull outdoor lighting conditions they cannot be seen in direct sunlight. The LEDs used in the model shown in Figure 1, Hewlett Packard 4684 series, can be read under bright light conditions using the appropriate filters however for any subsequent models using this system the brighter LEDs (Hewlett Packard 4658 series) would be used. To accomodate these larger diodes in this instrument would require the case thickness to be increased, this would permit a reduction in length to give overall dimensions of 3-1/2 x 2-1/4 x 1-1/4 inches.

Fig. 1 Survival Meter

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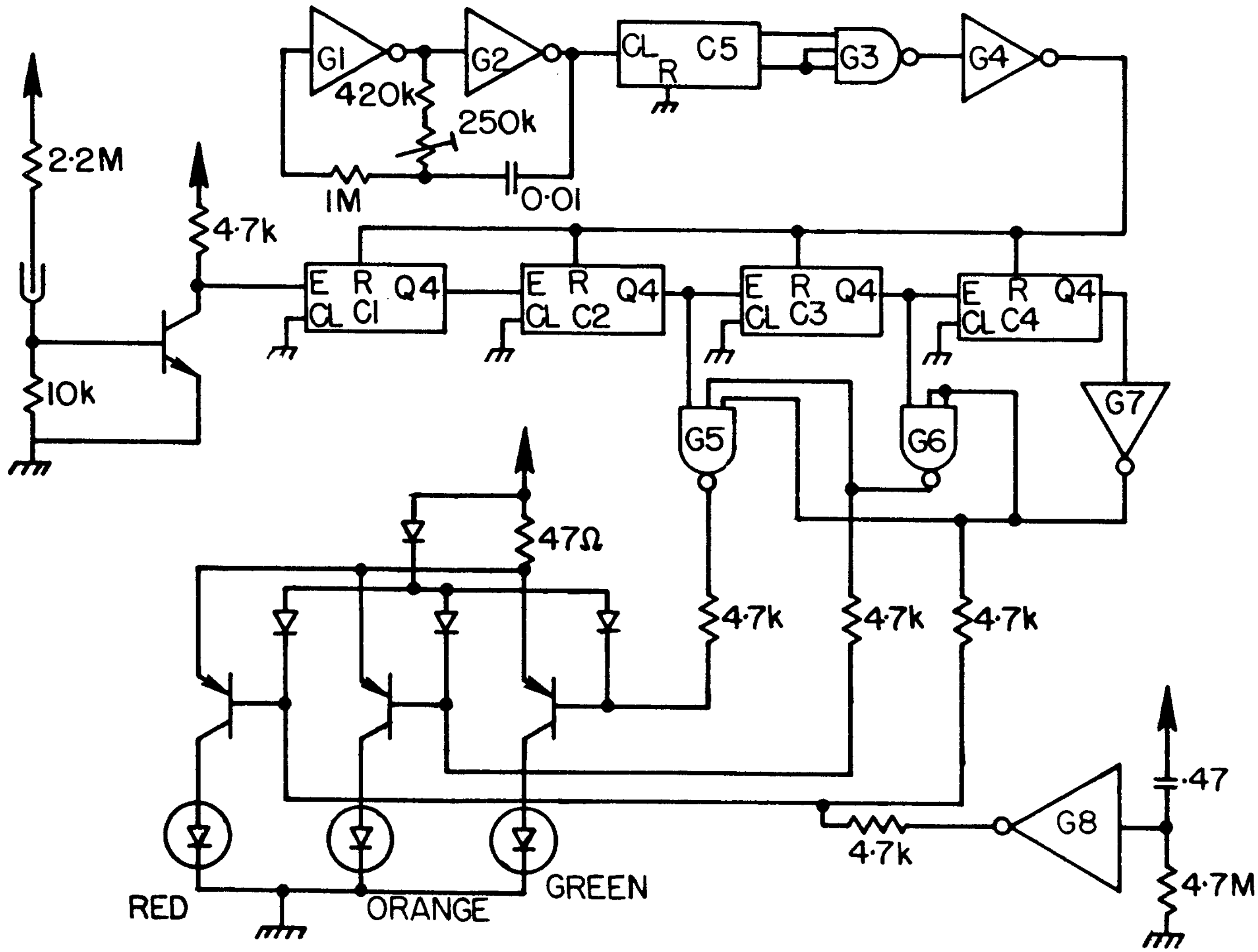

Fig. 2 Counting Circuit

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Dose–Rate = 25R/h

Counting period approximately 3 seconds

18529 G–M tube pulses 25,000 (Nominal)

Green Pulses (Blanked during orange or red pulses)	**250**
Orange Pulses (Blanked during red pulses)	**25**
Red Pulses	**2**

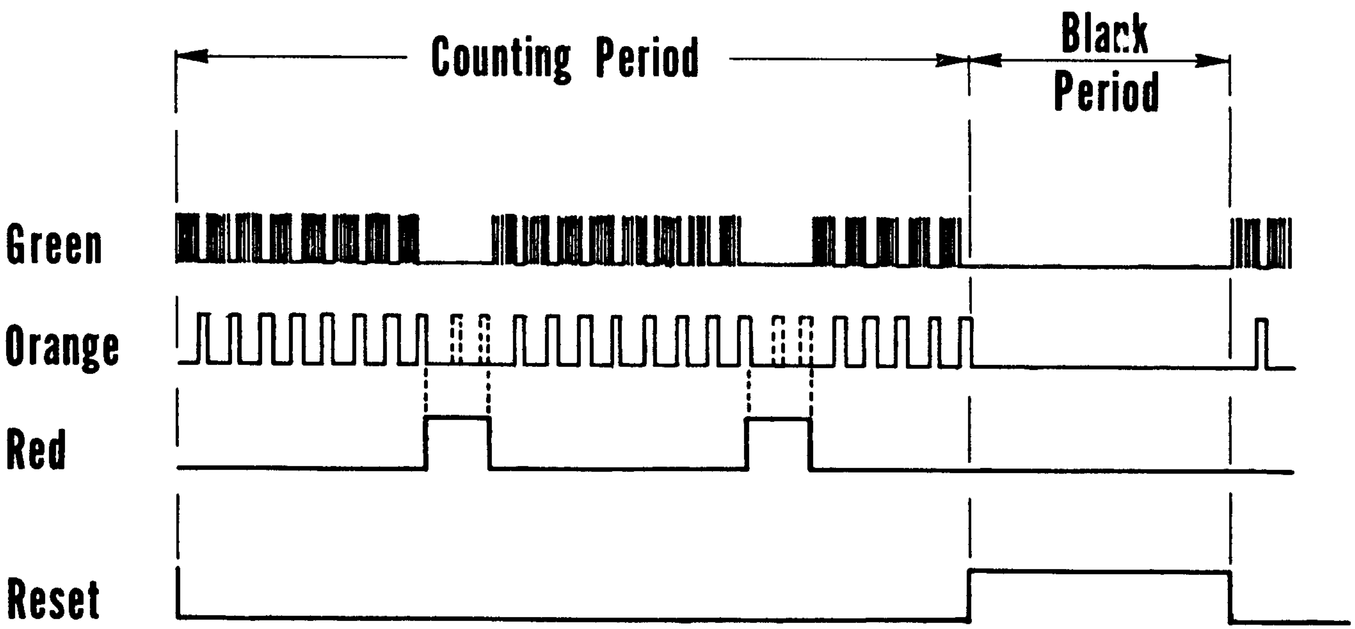

Fig. 3 Timing Diagram

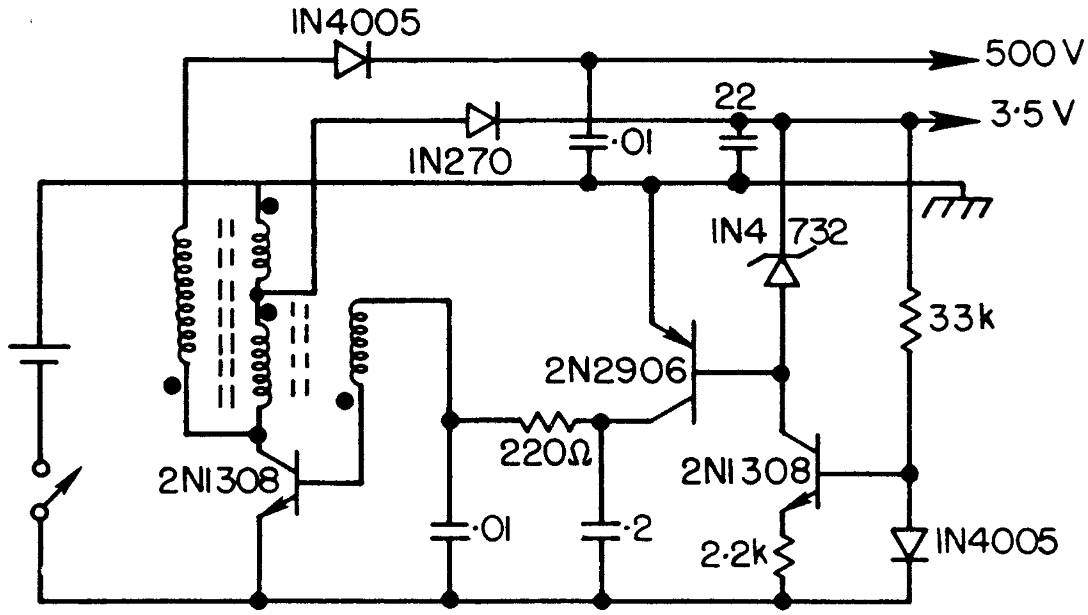

Fig. 4 Power Supply Circuit

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Fallout measuring equipment
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