Part 1: Description and operating of the Detector

Primo Galletti Aldo Aluigi

30 September 2000

This report describes a detector one of us (P. Galletti) conceived and built in 1994. The instrument is operating continuously since 26 April 1994 and graphs produced with the data recordered until 30 June 2000 are, here, presented.

The behavior of this *simple instrument*, which consists of Wheatstone bridge in one of the two arms is located a *cadmium sulphide photoresistor* (CdS) and illuminated with a constant source of light emitted by a vacuum diode, was considered, since the beginning, "anomalous".

After more than six year experiments and observations on its operating, we have decided to make these results known.

Perhaps, it is superfluous to remark that the instrument was built with other aims and the discovery of its anomalous behavior is the result of a combination of fortuitous circumstances happened in the beginning of 1994.

1 The sensor

The most important part of the detector is the sensor, which consists of a light emitting vacuum diode connected to a cadmium sulphide photoresistor as shown in **Figure 1**.

The vacuum tube filament (cathode) emits electrons which are accelerated by a constant voltage of approx. 12 V and hit a phosphorus fluorescent screen (anode). The light from the anode is measured through a cadmium sulphide photoresistor which is located in one of the two arms of a Wheatstone bridge as shown in **Figure 2**.

The Wheatstone bridge voltage difference is approx. 20 V. The reference arm of the brige consists of two 10 $k\Omega$ metal-film resistors with a low thermal coefficient. The other arm of the bridge consists of the cadmium-sulphide photoresistor and a digital (5 decades), metal-film, potentiometer box used to balance the bridge. All resistance values are at 1 %, with a low temperature coefficient. The photoresistor resistance at the working point is between 80 $k\Omega$ and 100 $k\Omega$.

We have used a FUTABA-6-LT-01 8D display for decimal counters as vacuum diode. **Photo 1** shows the FUTABA 9-LT-01 8D display for decimal counters

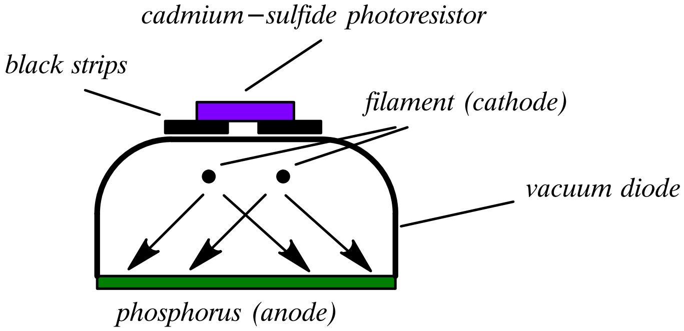
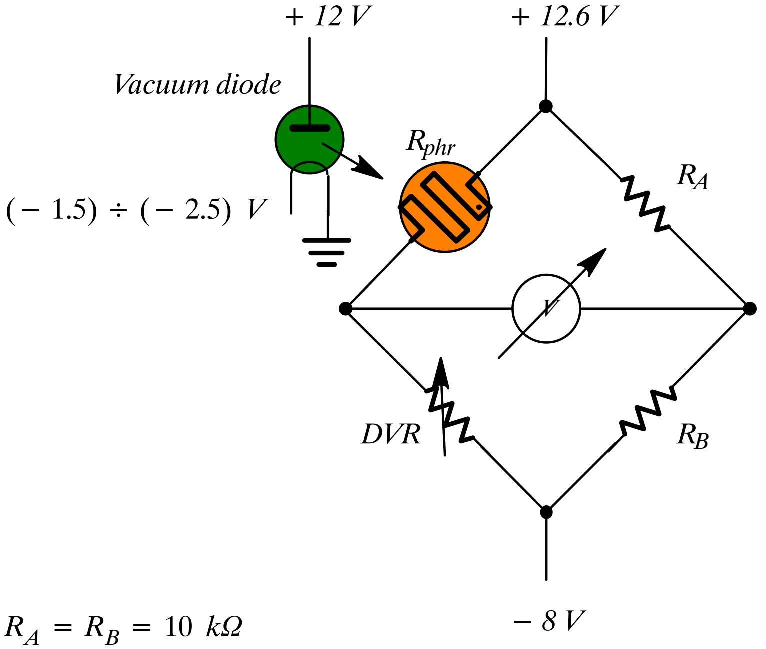


Figure 1: General arrangement of the detector



$R_A = R_B = 10\ k\Omega$

$R_{phr} = Cadmium - Sulphide\ photoresistor\ (80 \div 100\ k\Omega)$

$V = Digital\ Voltmeter\ (R_{in} \approx 100\ k\Omega)$

$DVR = Digital\ Variabile\ Resistor\ (5\ digits)$

Figure 2: Detector's Wheatstone bridge

having three more digits (9 instead of 6) than the detector used.

Photo 2 instead, shows the FUTABA 5-LT-01 9F display used in clocks. This latter has the same characteristics as a FUTABA 6-LT-01 8D display, and can be used without any change in the electric circuit.

Cadmium-sulphide photoresistors have been placed on the bulb of the display. Photoresistors are more than one in order to choose those generating the most similar graphs. **Photo 3** shows three kinds of photresistor used. Up to now, the first top one on the left, has generated the best graphs, in proving more sensitive and precise than the others.

Before placing the photoresistors to the display bulb, it is necessary to shield the sides of the vacuum tube with two small black adhesive strips, as shown in **Figure 3**, so that only a light slot of about 1.5 mm is left.

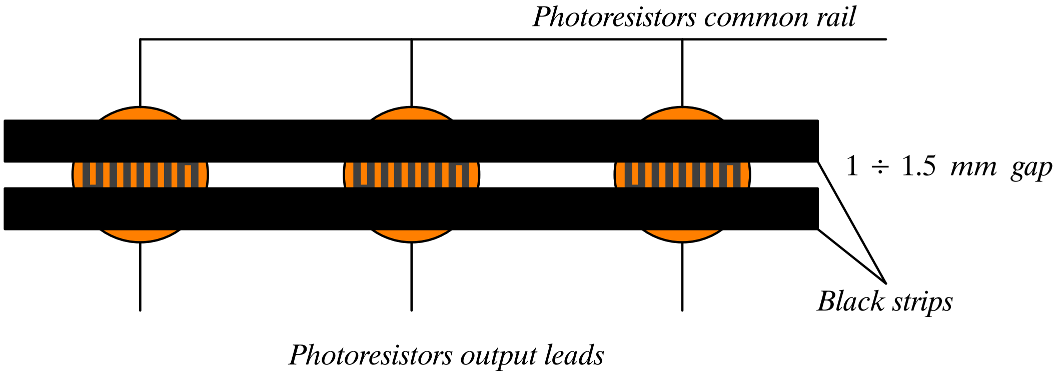


Figure 3: Photoresistors shielding

The photoresisotrs are fixed with a transparent cyanide glue to form one single body with the glass bulb. It is also necessary, that the photoresistor filament be perpendicular to the light slot.

2 Power supply and external parameter control

While time was passing, it was more and more evident that the instrument was very sensitive to any variation of the external and internal parameters [1]. The

---

[1] We are indicating hereunder the present values of the instrument sensitivity, that are the voltage variations measured at the ends of the bridge due to the outside parameters:

$$\frac{\Delta V}{\Delta T_{amb}} \approx 40\ mV/^oC$$

$$\frac{\Delta V}{\Delta I_a} \approx 1\ mV/mA$$

parameters that most affect the detector operating are the following:

- acceleration anode voltage, V_a
- anode electron current, I_a
- environment temperature, T_{amb}

The anode voltage of the vacuum diode and the voltage difference of the Wheatstone bridge, are generated by a regulated power supply. Integrated circuits LM 317 (positive) and LM 337 (negative) have been used, as they are variable regulators with a low temperature coefficient and long term stability. The stabilized power supplies are variable, as they are necessary to perform periodic calibrations of the detector and to regulate the anode current in the vacuum diode.

Figure 5 shows the complete electric diagram of power supply. Power supply can work both autonomously through batteries, and through an external d.c. source obtained by a transformer plus a diode rectifier. It is enough that the positive voltage is between +25 V and +40 V and the negative voltage between -12 V and -20 V. The power supply produces the following stabilized voltage levels:

- +18 V for the operational amplifiers positive rail;
- +12 V for the anode voltage of the vacuum diode;
- varying from -1.6 V to -2.0 V for the vacuum diode filament;
- -8 V for the operational amplifiers negative rail.

+12.6 V and -8 V voltages are, respectively, used for the Wheatstone bridge where the photoresistor is connected.

The anode current is controlled by Test Points (TP) located on the resistance in series with the supply output.

There are four 10 μF tantalium capacitors and another two 0.1 μF poliester capacitors, while the others are electrolitic capacitors with a voltage of, at least, 50 V.

The anode current is maintained constant by an electronic regulator that drives the stabilized power supply LM337 which, in its turn feeds the vacuum diode filament. **Figure 6** shows the electric diagram of the regulator.

The 1 $k\Omega$ variable resistance used to regulate the filament voltage must be multiturns, or better digital to allow a more precise control. The filament current and the working point of the regulator are controlled by the TPs placed on the resisance in series with the output.

The cadmium-sulphide photoresistor has a high positive temperature coefficient (PTC) therefore, further than the anode voltage and the filament current, it is also necessary to keep temperature constant.

$$\frac{\Delta V}{\Delta V_a} \approx 0.26\ mV/mV$$

On 21/02/1995 the sensor was placed into a first temperature-controlled enclosure made with electric heaters. The sensor temperature was kept constant at $25 \div 26\ ^oC$. In doing this, the temperature stability was about 100 times better.

At the end of May of 1995, the sensor working temperature began to increase as the environmental temperature had grown over the values the heated enclosure could control. To allow the sensor to operate at a constant temperature, the enclosure temperature has been gradually increased, and more precisely:

- on 29/05/1995 it was increased: $+2.0\ ^oC$
- on 02/06/1995 it was increased: $+1.0\ ^oC$
- on 06/06/1995 it was increased: $+1.5\ ^oC$
- on 17/06/1995 it was increased: $+1.0\ ^oC$
- on 22/06/1995 it was increased: $+2.0\ ^oC$

So that, in one month there has been a change, from the initial $25 \div 26\ ^oC$ to $25 \div 26\ ^oC$, which is the present working temperature of the sensor. While performing all the above operations there was a continuous zero-adjusting of the Wheatstone bridge in order to avoid uncalibration.

On 03/04/1995 a digital potentiometer (DVR) was put in series to the photoresistor. Since that time, the Wheatstone bridge zero-adjustings could be performed with more precision.

On 14/05/1995 an uninterruptable power supply unit (UPS) was set up in order to avoid power interruptions due to summer thunderstorms that, in the previous year, had caused the sensor several problems.

At the end of 1995 an anode current regulator was also used. In this way sensor calibrations could be performed with more precision as the regualtor was able to control anode current variations down to 1 mA.

In December 1995 it was noticed that in the electric circuit there was a defect contact in the wiring due to a cold welding. It took several months to detect this cold welding, as we did not want to switch the sensor off. The problem was completely solved only in June 1996.

Since the end of January 1996, no more modification has been made to the instrument.

At the end of August 1996 the instrument was placed into a second temperature-controlled enclosure made with Peltier cells. The temperature of this second enclosure has been kept constant at $26\ ^oC$.

With this further temperature-controlled enclosure the sensor temperature stability was approx. $0.001\ ^oC$.

The present measuring range of the instrument is about eight orders of magnitude. The first four orders are given by the direct signal from the Wheatstone bridge, while the remaining four orders can be achieved by amplifying 10^4 times the residual signal [2].

3 Data recording

For more than one year the recording of data has been performed manually with 8 readings per day, from 9 a.m. to 12 p.m.

Starting from the beginning of September 1995, the use of a Personal Computer (PC) has allowed to automatize the acquisition of data. Since that time, readings have been carried out every 20 minutes.

Owing to a fault of the PC in December 1995, the automatic recordings of that month went lost. For the reconstruction of the graphs, therefore, were used the manual readings, that anyway have been carried out once a day.

4 Zero-adjusting of the detector

To balance the Wheatstone bridge (zero-adjusting of the voltmeter V) one possibility is to change the anode current in the vacuum diode. In this way, the voltage sets quite well to zero, but this kind of operation unbalances the sensor in modifying its working point and consequently the temperature.

Another possible system is to change the resistance of the digital potentiometer (DVR) placed in series with the photoresistor on the same arm of the bridge. This second system is much better than the first one, as it allows to obtain the same result without any substantial sensor changes.

This periodic zero-adjusting of the bridge is necessary to avoid compression of the signal given by the Wheatstone bridge itself. The zero-adjusting of the bridge is usually performed when the voltage at the ends of the voltmeter shows variations of more than $\pm 0.5\ V$.

Appendix A.1 includes some details concerning the Wheatstone bridge.

5 Calibration of the detector

When performing the Wheatstone bridge zero adjusting, it was noticed that upon a voltage variation, *to bring back the bridge to zero voltage signal it is necessary to vary the anode current I_a of the vacuum diode in order to be in inverted quadratic relationship with the photoresistor resistance R_{phr}.* Namely,

$$\frac{\left(R_{phr}\right)_{zero}}{R_{phr}} = \frac{{I_a}^2}{\left({I_a}^2\right)_{zero}} \tag{1}$$

---

[2] All these tricks used in assembling the instrument have proved very useful later on to detect small variations too that, as we are going to see, are also very important.

where subscript "zero" indicates the values obtained when the Wheatstone bridge is balanced.

The photoresistor resistance R_{phr} is inversely proportional to the luminous energy $\dot{E}_\nu$ per unit of time striking it [3]:

$$\frac{R_{phr}}{\left(R_{phr}\right)_{zero}} = \frac{\left(\dot{E}_\nu\right)_{zero}}{\dot{E}_\nu} \tag{2}$$

therefore, we have,

$$\frac{\left(\dot{E}_\nu\right)_{zero}}{\dot{E}_\nu} = \frac{\left({I_a}^2\right)_{zero}}{{I_a}^2} \tag{3}$$

The current I_a emitted by the vacuum diode filament, if stable, does not affect the operating of the instrument at all, therefore, it can be used to perform the periodic calibrations of same.

What do these periodic calibrations mean? Periodic calibrations are necessary to define the k constant of the instrument defined as the relative variation (or percentage) of the anode current I_a, per unit variation of the potential difference V_{CD} at the ends of the bridge [4]. That is,

$$k = \frac{I_a - \left(I_a\right)_{zero}}{\left(I_a\right)_{zero}} \frac{1}{V_{CD}} \tag{4}$$

Appendix A.2 describes the calibration procedure and shows calculations to obtain the k constant [5].

6 Description of the detector graphs

The detector has been operating without interruption since the end of April 1994. And we report hereafter the graphs of the recordings carried out until June 2000.

The graphs refer to the voltage values directly measure at the detector terminals without any amplyfication and/or attenuation.

Graphs 1994_1 and 1994_2. These two graphs show the first continuous recordings made by the just set up detector. They are manual recordings taken from April

---

[3] It seems said relationship is working correctly, at least after the "formatting" period of the photoresistor.

[4] The problem of the physical meaning of the voltage variations measured at the ends of the Wheatstone bridge, which is related to the solution for the detector "puzzle", will be discussed later.

[5] During the first operating periods the instrument calibrations had to be performed more frequently because the sensor "formatting" was not yet complete. At present, calibrations areperformed about once a year.

26th until December 1999 (during that period were performed 8 readings per day, from 9 a.m. to 12 p.m).

The horizontal lines on the Graphs 1994_2 concern interruptions in recording (due to summer holidays!). The instrument was kept into operation. Furthermore, it is possible to see on the graphs, starting from the beginning of October 1994, an increase in the voltage signal noise. This noise was due to the effect of the environment temperature variation caused by room heating. The problem was solved when, during the second half of February 1995, the detector was placed inside a temperature-controlled enclosure.

Graph 1994_3. In this graph recordings performed from May 1st to 31st October 1994 are compared.

If you carefully observe the upper part of this graph, attention is drawn on circles 1, 2, 3 and 4, where a peculiar signal can be noticed, we can describe same as "fork" shaped. It is characterized by two narrow peaks, whose primary (sharp) peak is lower than the secondary (round) one.

In the lower part of the graph, circles marked with 5, 6 and 7, there is an inverse situation where it is possible to notice signals having a reverse "fork" shape, whose primary (sharp) peak is lower than the secondary (round) one.

These single signals last about 10 days, while the distance between the two "fork" peaks, representing somehow the event characteristic time, is always more or less the same, and it results of about 4 days. The amplitude of the single signals too, representing somehow the magnitude of these events, is more or less always the same.

Graph 1994_4. This graph represents a magnification of the big "fork" recorded between the end of September and the beginning of October 1994.

It is possible to see how voltage in the final part of the first peak had had, in one day only, an increase by about 1.2 V, representing more than 10 % of the overall voltage with a decrease, of more than 22 %, of the photoresistor resistance!

Comparing it with previous signals, in this case the distance between the peaks has increased, going from 4 days to about 8 days, while the amplitude results 2 times larger. It can be noticed how sharp the primary peak is, while the secondary one is much more rounded.

Graph 1994_5. This graph shows the recordings of the last three months of 1994 as well as those of January 1995.

After the big "fork" of September and October, the voltage continued increasing up to a maximum value, reached in November 1994, of about 2.4 V.

In this graph (see circle 8), it is possible to see the primary peak of another "fork", even if disturbed by the noise due to room temperature variations, while the secondary peak can be detected with more difficulty as overlapped by other signals detected in the meantime by the detector. As it results, the distance between the "fork" peaks of this signal is, more or less, the same.

Starting from the second half of November 1994, there was a continuous voltage decrease characterized by some pauses (see circles 9, 10, 11 and 12) that might correspond to secondary peaks of partially overlapped forks in their extinguishing phase.

The phenomenon seems to cease by mid January 1995, when the voltage at the ends of the sensor reached -0.7 V, under the 0 V line we had arbitrarily set at the beginning of the recordings.

Graphs 1995_1 and 1995_2. These two graphs show the recordings going from the 1st January to the 30th June 1995 and from the 1st July to the 31st December 1995. It is possible to notice how the setting up of the first temperature-controlled enclosure remarkably reduced the noise over the voltage signal.

Up to August 1995 the data used for the graphs were taken manually, while starting from September 1995 the acquisition of data has been automatic with a Personal Computer (PC). The readings are taken every 20 minutes.

In December 1995, owing to a PC fault, the data recorded were lost and the graph was completed in using data that in the meantime were taken manually once a day.

Graphs 1995_3 and 1995_4. Graph 1995_3 is nothing but a magnification of Graph 1995_1 and shows an interesting detail. In the second half of February there was a quick rise of voltage at the ends of the sensors, after which (see circle 14) instead of having the usual double peak, there was a continuous and gradual decay of voltage, like a hyperbolic shape, that lasted 90 days altogether. Some days before there were intense oscillations of the signal (see circle 13).

Graph 1995_4 shows some details of this event. The voltage growth lasts about 6 days while the stop phase is about one day. The signal amplitude is of about 2.3 Volts. Another interesting fact to remark on the graph, is the extremely regular course of the signal decay, showing how this phenomenon met no disturb.

After this last episode, all phenomena stopped and until mid June 1995 the instrument did not record anything interesting.

Graphs 1995_5 and 1995_6. Graph 1995_5 compares the signals of 1994 with those of the first six months of 1995, while Graph 1995_6 compares all signals recordered from the 1st November 1994 until the 31st October 1995.

The signals recordered in summer 1995 have a lower intensity and their shapes are (apparently) irregular and last a longer time than those recorded in 1994.

Graph 1995_7. This graph is a magnification of the recordings going from the 1st June 1995 to the 30th September 1995. The whole recording period lasted about 120 days.

When carefully observing this graph, it is possible to distinguish two ”forks” partially overlapped (see circles 2 and 3). The distance between the peaks is more or less the same, about 15÷16 days, and also roughly corresponding to the distance between the peaks of the reversed fork" that it is possible to observe on the graph between the end of June 1995 and the begining of July 1995.

What looks evident in these comparisons is that, starting from June 1995, a series of new events takes place. The waves arrived to the detector, however, result as much widther and attenuated when compared with those observed in 1994.

Graphs 1996_1 and 1996_2. These two graphs include recordings going from the 1st January to the 30th June 1996 and from the 1st July to the 31st December 1996. All data were acquired through the use of a PC.

Since the end of August, after using the second temperature-controlled enclosure the noise due to environment temperature has further reduced.

The recordings of December 1995 and January 1996 are not too reliable because of some troubles in the detector electric circuit.

According to these data there is, apparently, nothing interesting, as the signals recordered by the sensor seeem of low intensity, quite irregular and confused.

The recordings of March 1996 show the lowest voltage value ever had at the ends of the bridge which reached -1.5 V. From the middle of September to the middle of November 1996 the signal practically remained quite constant.

Graph 1996_3. This graph shows the activity of the detector from the 1st June 1995 to the 30th September 1996, in comparing more than one year recordings.

After the two "forks" recordered in summer 1995, it is possible to notice a continuous lowering of the detector voltage, that lasted until March 1996, characterized by a sequence of peaks (see circles 4, 5, 6, 7, 8, 9, and 10) that caused a decreasing of the detector voltage down to about -1.4 V (see circle 11) which results as the lowest value recorded up to now.

After reaching this minimum, the detector voltage started increasing again and reached about 0 V by mid August 1996. Also this period is characterized by a sequence of peaks (see circles 11, 12, 13, and 14).

If you carefully observe those peaks, it is possible to identify during the rise of voltage starting on March 1996 a series of positive "forks" and a series of negative "forks" in the previous decreasing of voltage. In circles 12 and 13 the "fork" shaped signal is still noticeable, while in circle 11 and 14 it cannot be well distinguished. The distance between the peaks is more or less the same, about 15 ÷ 16 days, and also roughly corresponding to the distance between the peaks of the "forks" recordered during the summer 1995.

After August 1996 and for three months the voltage has remained practically constant, but already in the second half of November 1996, it started again remarkably varying.

Graphs 1997_1 and 1997_2. These two graphs include recordings going from the 1st January to the 30th June 1997 and from the 1st July to the 31st December 1997. In this case too all data were acquired through a PC.

Graph 1997_3. From the second half of November 1996 there had been a sudden voltage decrease of about 0.5 V in fifteen days. Since December 1996, a new phase, whose recordered signal can be seen more clearly distinguished. The second half of December shows a quick signal growth that terminates with an as quick decrease. Similar behaviours appear up to the end of March 1997.

It is important to observe that in most of these peaks the falling front is steeper than the rising front (see circles 1, 2, 3, 4 and 5). This means we are looking at the secondary peaks of the "fork". The primary peaks cannot be noticed, because, as they are lower than the secondary ones, they are hidden.

At first sight it seems circle 6 shows a "fork", which distance between the peaks is about 9 days but it is, very likely, a casual matching of the primary peak with the secondary peak of two different "forks".

Graph 1997_4. In this graph the voltage signal variations recordered by the sensor from June 1st 1997 up to October 31st 1997 are magnified.

After the series of peaks recorded in the first months of 1997, from the beginning of June 1997, there is a sudden increase of voltage which reaches a maximum value of about 1.3 V and, after that, the instrument starts recording a continuous series of voltage peaks.

When observing more carefully this graph, it is possible to identify two series of partially overlapped "forks". In particular, if is possible to notice "forks" having a 9 day distance between the peaks and "forks" whose distance between the peaks is of 11 days. Circle 1, instead, identifies a signal having apparently an oscillatory behaviour lasting a period of about $5 \div 6$ days that seems very similar to the one of January and February 1995.

Graphs 1998_1 and 1998_2. These two graphs show the recordings going from January 1st to june 30th 1998 and from July 1st to December 31st 1998.

In this period of time a series of overlapped signals was detected by the sensor. But, despide of 1997, in this case the overlapping is with signal having less intensity and longer time duration and it is more easy to identify "forks".

Graph 1998_3. This graph is a magnification of the recordings carried out from October the 1st 1997 to March 31st 1998.

During the second half of October, the graph marked with circle 1, indicates the beginning of a series of strong voltage oscillations, as indicated by circles 2, 3, and 4. It does not seem they are "forks". A "fork", insead, is marked with circle 5, even if it seems very disturbed by some still present voltage oscillations.

Graph 1998_4. This graph shows the recordings carried out from October 1st 1997 to September 30th 1998.

In this graph there is a series of "forks" that can be distinguished quite well (see circles 6, 7, 8 and 9). The secondary peaks of "forks" are all well visible notwithstanding the presence of some distortions while the primary peaks are less visible. The distance between the peaks is about 17 days.

In the same graph, from July to September 1998, one can also see very well another series of "forks" that overlapped the previous ones. Such signals have a shorter time duration and an higher intensity that makes them clearly emerge from the underlying voltage signals.

Graph 1998_5. In this graph the series of collapses occurred from July to September 1998 is indicated with more details.

Marked with circles 1 and 2, there are two well visible "forks" whose distance between the peaks is of 4.5 days.

Circle 3 marks another "fork" of the same series, while in circle 4 there are three peaks indicating a pair of "forks" whose intermediate much bigger one, is the overlap of a primary peak on a secondary one. Also in this case the distance between the peaks is of 4.5 days.

Circle 5 puts very well in evidence a "fork" with characteristics very similar to that recordered on September and October 1994.

Graphs 1999_1 and 1999_2. These graphs refer to recordings going from the 1st January to the 30th June 1999 and from the 1st July to the 31st December 1999. In this case too all data have been acquired through a PC.

The recordings of the first six months show a series of very irregular and overlapped signals, that always keep a rather high voltage at the ends of the sensor. During the second half of the year there is a single event of high intensity, where the well remarkable "fork" is followed by another peak of greater intensity, whose shape seems to be similar to the one of 1995. The voltage at the ends of the bridge has reached the highest value measured up to now, in overcoming 3 V.

Graph 1999_3. This graph compares the recordings carried out by the detector from October 1st 1998 up to June 30th 1999.

In October 1998 we notice (see circle 1) a "fork" followed by another two partially overlapped (see circles 2 and 3), after which there is a quick voltage decrease of about 0.5 V in fifteen days. The average distance of the peaks is about 11 days. The intensity of signals, because of the scale of ordinates used to draw this graph, seems to be low.

After these collapses, the voltage decreases by nearly 0.5 Volts in 15 days.

By mid November 1998 (see circle 4) a series of strong voltage oscillations began (see circle 5) which have lasted for about 2 months. In February 1999 we can notice very well the reversed "fork" (see circle 6), whose distance from the peaks is about 13 days. After this, during March 1999 there was a rather distorted "fork" (see circle 7) shows a distance from the peaks of about 13 days.

After that, a series of "forks" (see circles 8, 9 and 10), quite similar to that of previous year, was recordered, at the end of which voltage had rised to about 1.8 Volts.

Graph 1999_4. This graph shows recordings carried out in 1999.

In the graph other "forks", overlapping the previous series, are also very well visible during July and August 1999. Said signals have higher intensity and short duration, that makes them emerge very clearly from the underlying signals.

Very likely, the signals marked with circles 11, 12 and 13 still belong to previous series which started on February 1999.

Graph 1999_5. This graph shows a magnification of the recordings occurred in July, August and September 1999.

In the second half of July a "fork" is visible (see circle 1) whose distance peaks is of about 7 days.

By mid August there is another "fork" (see circle 2) with the same distance between peaks as the one recorded previous month was recordered. The second peak is not well visible as, at the same time, there had been another "fork", clearly emerging (see circle 3) was recordered whose distance of the two peaks that is of about 2.7 days. The amplitute of this last "fork", not considering the effect of the secondary peak of the previous one, should be around 0.75 V and 1.0 V.

In the last days of August the detector has recorded a signal of the same intensity as the previous one (see circle 4), where the first peak can be clearly distinguished but it seems there is no second peak. We can think about another event similar to the one observed in 1995 but it is not like this, as confirmed by the quick voltage decrease. Surely, it is the second peak occurred at the same time a sudden quick decreasing of the voltage signal (see circle 5).

Graph 1999_6. In this graph there is a magnification of the recordings made in August 1999. The knee, visible while the signal is rising, and marked with circle 6, is the evidence of its partial overlap with the previous "fork". Because of this overlap, the detector signal reached the highest value recorded up to now, which is of about 3.4 V.

Graph 2000_1. This graph represents recordings from Juanuary 2000 to June 2000.

After the strong variations recordered on August 1999 the voltage at the ends of the detector started decreasing again and, at the end of January 1999, reached a minimum value of about 1.8 V.

From the first days of March 2000, voltage started increasing again, even if very slowly reaching at the end of June 2000 a value of about 2.4 V.

Graph 2000_3. In this graph recordings from September 1999 to March 2000 are magnified.

In this graph small signal variations with short duration are still present (see circles 13 and 14), remarking the great precision of the signal recorded by the detector which indicates the high stability obtained in these years in controlling the external parameters that affect its operating.

7 Preliminary observations on the graphs

Upon a first analysis of the graphs it is possible to make the following remarks.

1. Voltage variations can be observed at the ends of the bridge lasts from about fifteen up to one hundred days and their intensity can reach up to a some Volts of voltage variation.
2. It seems said variations are due to specific events (or group of events) happening only few times a year.
3. *It seems there is a strong relationship between the intensity and the time the signals last.* There are high and narrow signals against low and rather width signals. This becomes evident when comparing the height of the ”forks” with the distance between the two peaks. Furthermore, the high and narrow signals are also very clear, while the low and width ones show remarkable distorsions.
4. If the signal at the sensor output is amplified 100 times, it is possible to observe less intensive variations having peculiar times varying from a few minutes up to a maximum of $1 \div 2$ hours. These variations can be recorded about ten times a day and their intensity is of a few mVolts [6].
5. There is no recording of events having intermediate characteristics other than those described.

8 Construction of different sensors

In these last years other detectors of different shapes have been built, always based on the measure a light source by a cadmium-sulphide photoresistor. Only some of them have proved to work properly.

Since 1997, there are another three sensors at work and the results they give are very similar to those recorded by the main sensor, as shown in the graphs illustrated in **Graphs A** and **B**. These three new sensors are placed in different environments than the main sensor, in a different temperature-controlled enclosure and they are power supplied autonomously.

In these last years we have also assembled sensors using light emitted by a LED source. Such a sensors can record very well voltage variations lasting a short time,

---

[6] These phenomena could be clearly seen only after adding the second temperature-controlled enclosure on to the already operating one.

but are not very reliable when recording voltage variations lasting long time, as LED behaviour has not proved very stable [7].

9 Observations about detector behaviour

The sensor *should operate* as hereunder indicated. Inside the vacuum diode, the filament emits electrons which number is constant in time. They are accelerated by a constant voltage of about 12 V and subsequently hit the phosphorus screen (anode). This latter illuminates and the light intensity depends both on the current emitted by the filament (anode current) and on the acceleration voltage Va.

While the luminous energy E_ν the phosphoruses emit is, in its turn, directly proportional to the kinetic energy E_e of the electrons which hit the anode, that is directly depending on number n_e of electrons emitted by the filament, on the electron electric charge e and on the acceleration voltage V_a:

$$\dot{E}_\nu \propto \dot{E}_e = \dot{n}_e \; e \; V_a \tag{5}$$

If the current emitted by the filament and the acceleration voltage, as well as temperature, are kept constant, no resistance variations at the ends of the photoresistor should be recorded. It is not like that, instead!

According to the detector analyses observed during all these years, we have been able to verify the following facts:

Fact n. 1: *very high variations in voltage difference at the ends of the Wheatstone bridge, without any variation recording made by the instruments controlling the anode acceletation voltage and the current emitted by the filament, can be observed.*

Fact n. 2: *during the resistance variations of the photoresistor no similar variations can be noticed either for what concerns the light intensity (energy) or the light colour (frequency) emitted by the vacuum diode phosphoruses.*

Fact n. 3: *in performing the detector zero-adjusting, to set the voltage difference at the ends of the Wheatstone bridge back to zero, it is necessary to change the anode current according to the qudratic inverse law.*

As observed, further than the above facts, other peculiar behaviours of the sensor occured, when comparing the instrument with the other sensors operating. And more exactly:

- In order to become effective, a sensor needs working continuously for quite a long time (at least $12 \div 18$ months). While time is passing, this acquired

---

[7] After assembling and implementing similar sensors that use light emittted by a LED, it was possible to have a further improvement in resolution, in order to record also events of very low intensity, having times and characteristics varying from about one second up to half millisecond and with average intensity of 200 mVolts.

"memory" becomes higher. During that "formatting" period, the sensor sensitivity increases, and at the same time there is a decrease of signal recording delay. Such delay, which is of about one day at the beginning, gradually decreases to become only of few hours [8].

- In case the sensor is switched off, even for some minutes, when turned on, it will not work properly anymore for a period of time that depends on amount of interruption. It seems that, when is turned off, it loses part of the acquired "memory" acquired during "formatting". Also the periodic calibrations disturb it for some hours. For that reasons it is necessary to perform calibrations with anode current changes less than 1 %. In that cases 15÷20 minutes after calibration the instrument starts working again correctly as the small temperature excursion is quickly estinguished [9].
- As time goes on, the photo-resistance behaviour modifies. The initial resistance values of $80 \div 100$ $k\Omega$ gradually increases, until it stabilizes at a quite higher values. It is as if in working the photoresistor *depurates of the normal resistivity part and only keeps the photo-conductivity part* that is sensitive to the effective luminous energy emitted by the vacuum diode.

10 The detector "puzzle"

The questions arising in observing the sensor behaviour are the followng.

1. Why do the instruments controlling the anode current and the electron acceleration voltage record no variation?
2. Why do we, with our eyes detecting the light emitted by the vacuum diode phosphoruses, notice no luminous intensity variation, but the photoresistor only can record such variations?

   And above all (see **Figure 4**):
3. Why does an observer placed outside the enclosure (for example, a precision photometer) measure no variations in luminous energy emitted by the phosphoruses, while the internal obsever (the photoresistor), after $10 \div 15$ thousand hours continuous work, is in a position to detect and measure remarkable luminosity variations?

On addition to the above questions there are, also, the following points:

- it is a *very simple instrument*

---

[8] During the 1994 collapses, because of the strong variations recordered by the sensor, this one became "formatted" in less than 12 months.

[9] At the beginning, when it was necessary to make some modifications to improve the instrument, these had to be performed while it was operating. The changes, were made when the diagram showed rather flat.

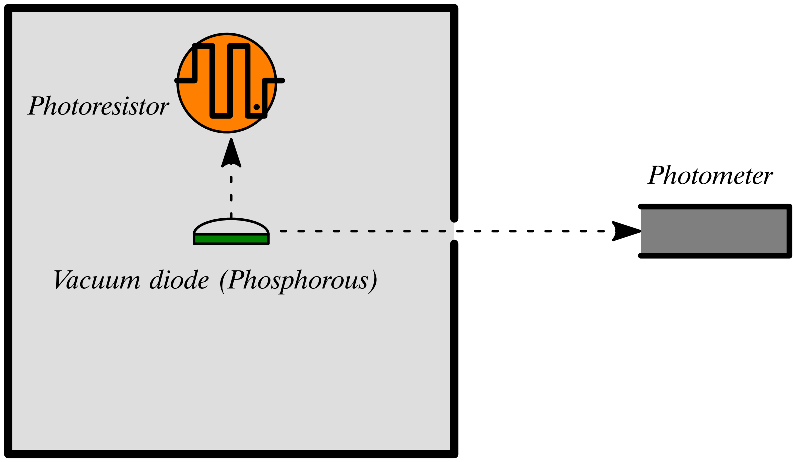


Figure 4: The detector "puzzle"

- the measured voltage variations are quite high
- the high quality characteristics of the Wheatstone bridge as measurement apparatus

To give a solution to this "puzzle" has taken some years. During this work we realized *the detector behaviour cannot find any explanation in the present Laws of Physics*. It is possible to give a *simple* and *satisfactory* explanation of its operation only if we reject some of the present basic ideas of Physics.

Furthermore, we want to remark that this is not an *electromagnetic* instrument but an *electric* one!

11 A detector for Gravitational Waves

What does this instrument record? What do the graphs it generates represent? What is the physical meaning of the calibration constant k

After six years from its construction we feel sure that this instrument is in a position to detect *gravitational waves* emitted by events as collapses or explosions of celestial bodies.

It is a very sensitive instrument which is *capable to record nearly all highly energetic phenomena occurring in the Visible Universe*.

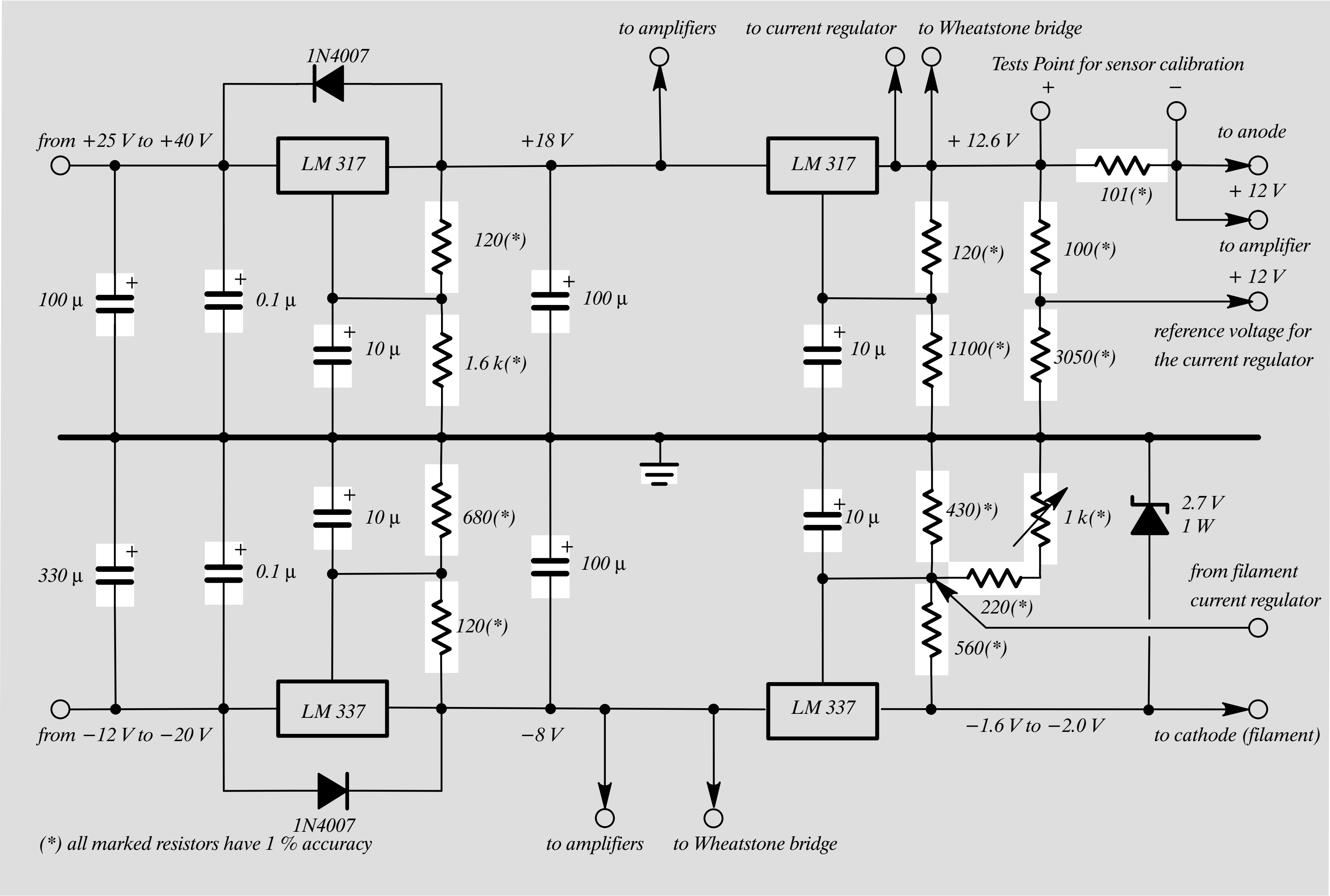


Figure 5: Electric diagram of the power supply

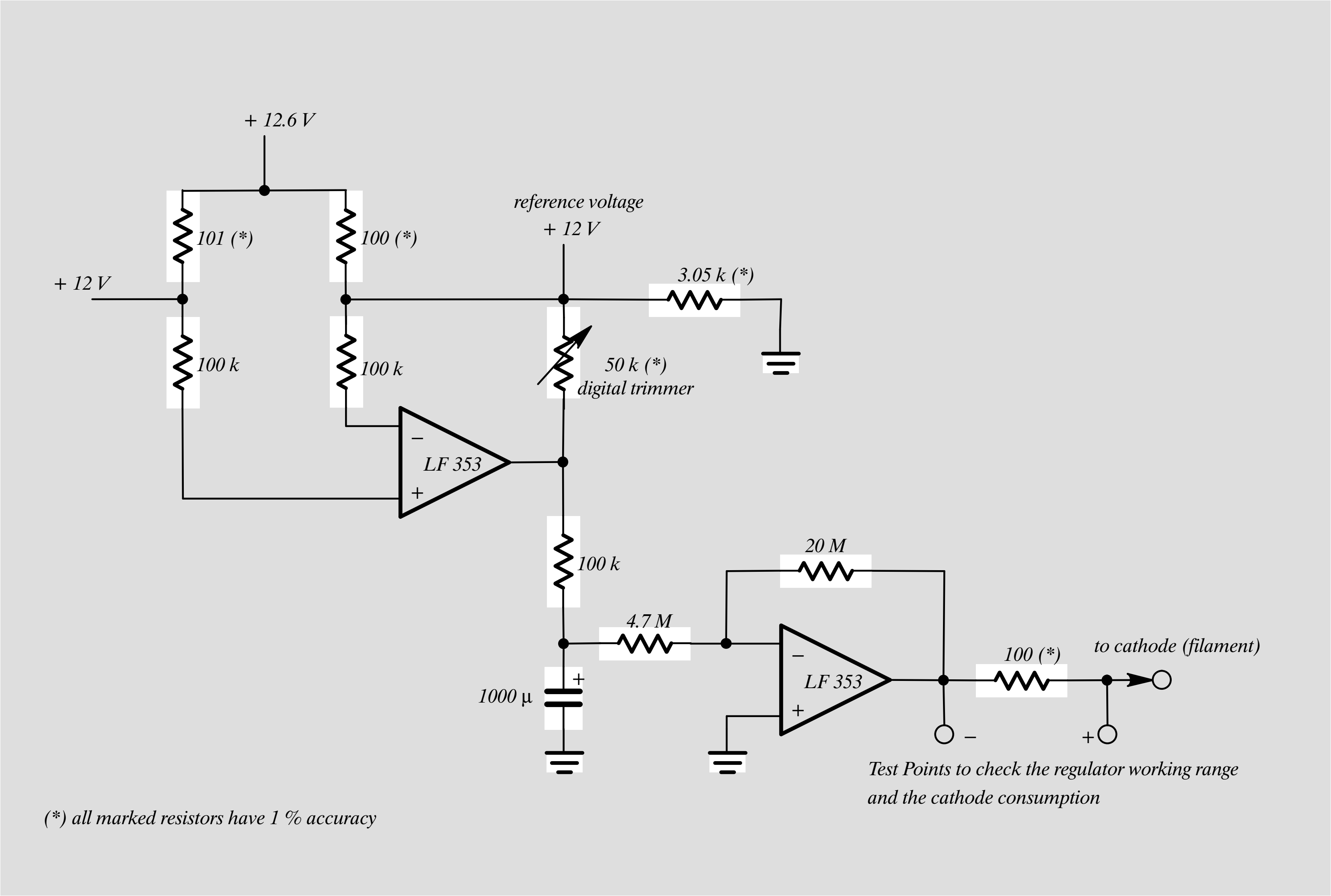
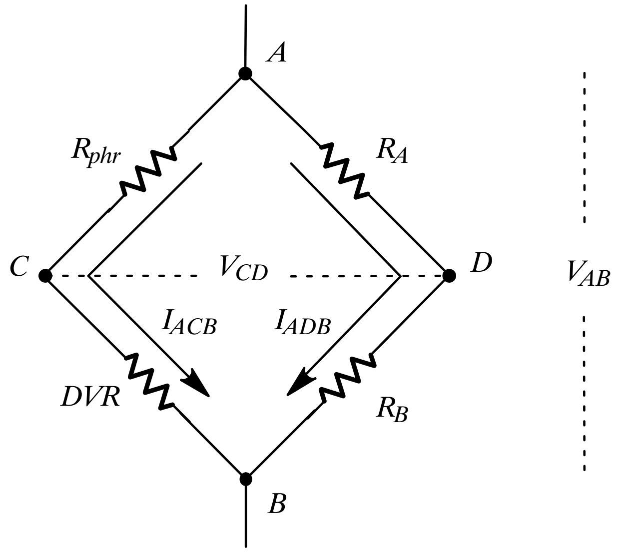


Figure 6: Electric diagram of the anode current regulator

A APPENDICES

A.1 The Wheatstone bridge

Figure 7 shows the Wheathstone bridge scheme used for the detector.



$R_A = R_B = 10\ k\Omega$

$R_{phr} = Cadmium - Sulphide\ photoresistor$ $(80 \div 100\ k\Omega)$

$DVR = Digital\ Variabile\ Resistor$ $(5\ digits)$

Figure 7: The Wheatstone bridge

The voltage difference between C and D is given by:

$$V_{CD} = \left(V_{AB} - V_{AC}\right) - \left(V_{AB} - V_{AD}\right) \equiv V_{AD} - V_{AC} \tag{6}$$

from which using Ohm's Law one can obtain,

$$V_{CD} = V_{AB}\ \frac{R_A}{R_A + R_B} - V_{AB}\ \frac{R_{phr}}{R_{phr} + DVR} \tag{7}$$

When the bridge is balanced (V_{CD} set to zero) we must have,

$$0 = V_{AB}\ \frac{R_A}{R_A + R_B} - V_{AB}\ \frac{\left(R_{phr}\right)_{zero}}{\left(R_{phr}\right)_{zero} + \left(DVR\right)_{zero}} \tag{8}$$

and simplifying it, we obtain:

$$\left(DVR\right)_{zero} = \frac{R_A}{R_B}\ \left(R_{phr}\right)_{zero} \tag{9}$$

With V_{CD} different from zero, the current I_{ACB} is:

$$I_{ABC} = \frac{V_{CB}}{\big(DVR\big)_{zero}} = \frac{V_{DB} + V_{CD}}{\big(DVR\big)_{zero}} \tag{10}$$

therefore, the photoresistor resistance R_{phr} becomes:

$$R_{phr} = \frac{V_{AC}}{I_{ABC}} = \big(DVR\big)_{zero} \, \frac{V_{AD} - V_{CD}}{V_{AD} + V_{CD}} \tag{11}$$

Example. In case we have:

$$V_{AB} = 20 \ Volt$$

$$V_{CD} = 1 \ Volt$$

$$R_A = R_B = 10 \ k\Omega$$

$$\big(DVR\big)_{zero} \equiv \big(R_{phr}\big)_{zero} = 80 \ k\Omega$$

the current I_{ACB} is,

$$I_{ABC} = \frac{V_{CB}}{\big(DVR\big)_{zero}} = \frac{10+1}{80} = 0.1375 \ mA$$

thererfore, the photoresistor resistance R_{phr} becomes:

$$R_{phr} = \big(DVR\big)_{zero} \, \frac{10-1}{10+1} = 80 \ \frac{9}{11} = 65.4545 \ k\Omega$$

then, we obtain a relative variation of:

$$\frac{\Delta R_{phr}}{R_{phr}} = \frac{80 - 65.4545}{80} = 0.1818... \ (= 18.18 \ \%)$$

Thus, a 10 % decrease of voltage through the photoresistor gives a resistance variation of 18 %. On the contrary, a 10 % increase of voltage through the photoresistor gives:

$$R_{phr} = \frac{V_{AC}}{I_{ABC}} = \big(DVR\big)_{zero} \, \frac{10+1}{10-1} = 80 \ \frac{11}{9} = 97.7777 \ k\Omega$$

then, we obtain:

$$\frac{\Delta R_{phr}}{R_{phr}} = \frac{97.7777 - 80}{80} = 0.2222... \ (= 22.22 \ \%)$$

that is a 22 % increase of the photoresistor resistance.

So that, for small variations, an increase/decrease of voltage V_{CD} is corresponding to a double decrease/increase for the photoresistor resistance.

A.2 Detector calibration

With the bridge balanced, to simulate a 1 luminous energy emitted by the vacuum diode phosphoruses, that is to say,

$$\dot{E}_\nu = \left(\dot{E}_\nu\right)_{zero}(1 + 0.01)$$

it is necessary to perform a 1 % increase of kinetic energy of the electrons hitting the anode. Namely, it is necessary to perform at the same time the following variations:

- a 1 % increase of the anode current I_a:

$$I_a = \left(I_a\right)_{zero}(1 + 0.01)$$

- a 1 % increase of the anode voltage V_a:

$$V_a = \left(V_a\right)_{zero}(1 + 0.01)$$

As it is difficult to perform these variations without disturbing the detector, we preferred to perform a *quadratic* variation of the anode current I_a only. That is to say:

$$I_a = \left(I_a\right)_{zero}(1 + 0.01)^2$$

To compensate the error we carried out two variations: one with increased I_a and the other with diminuished I_a performing then the average of the two measures.

To make clearer how to calculate the k constant, we indicate hereunder a calibration carried out on 29th January 2001, on one of the sensors of the second detector. The anode current at start was:

$$\left(I_a\right)_{zero} = 3770\ \mu A$$

After the 1 % quadratic increase, the new value of the anodic current has changed to:

$$I_a = 3770\ (1 + 0.01)^2 = 3845.8\ \mu A$$

On the voltmeter placed at the ends of the bridge, voltage has changed from 50.3 mV to 132.4 mV, with an increase of 82.1 mV.

The anode current has subsequently been carried back to the start value of 3770 mA. After this, we waited for a while, in order to let voltage at the ends of the bridge return to its start value of 50.3 mV.

At that moment, we performed a 1 % quadratic decrease and the anode current has changed to:

$$I_a = \frac{3770}{(1 + 0.01)^2} = 3695.7\ \mu A$$

The voltage at the ends of the bridge, has varied, changing from 50.3 mV, to -35.3 mV, with a decrease of 85.6 mV. By calculating the average between the two voltage values we obtain:

$$V_{CD} = \frac{82.1 + 85.6}{2} = 83.85\ mV$$

Thus, for the k constant one obtains the following value:

$$k = \frac{1\ \%}{85.85\ mV} = 0.012\ \%\ per\ mV$$