OAK RIDGE NATIONAL LABORATORY

Operated by
UNION CARBIDE NUCLEAR COMPANY
Division of Union Carbide Corporation

Post Office Box X
Oak Ridge, Tennessee

EXTERNAL DISTRIBUTION AUTHORIZED

ORNL
CENTRAL FILES NUMBER

58-12-121

DATE: December 31, 1958
SUBJECT: STABILITY TESTS ON THE TYPES IN430A AND IN430B
AVALANCHE DIODE REGULATORS
TO: Distribution
FROM: J. L. Blankenship

COPY NO. 127

MASTERABSTRACT

The manufacturers' specifications for temperature coefficient of voltage and internal impedance of the compensated avalanche diode types IN430A and IN430B appear quite promising. These devices could be used as shunt regulators in high stability power supplies if the noise and drift rate were sufficiently small. One investigator reported the voltage did not drift more than ± 0.002 per cent over a 7,000 hour period. Stability tests were performed on two diode samples under reasonable laboratory conditions. The measured drift rate did not exceed 0.005 per cent per month, and short term noise was less than ± 0.002 per cent. The actual diode drift rate may be even lower than the measured rate.

NOTICE

This document contains information of a preliminary nature and was prepared primarily for internal use at the Oak Ridge National Laboratory. It is subject to revision or correction and therefore does not represent a final report. The information is not to be abstracted, reprinted or otherwise given public dissemination without the approval of the ORNL patent branch, Legal and Information Control Department.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

- A. Makes any warranty or representation, express or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or
- B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission to the extent that such employee or contractor prepares, handles or distributes, or provides access to, any information pursuant to his employment or contract with the Commission.

Introduction

A stable voltage source is necessary for many measurement and control problems. Unsaturated cadmium cells of the Weston type are frequently used as voltage references. However, these cells have several limitations. The internal impedance is approximately 500 ohms, and the load current must not exceed 100 microamperes at any time. The voltage decreases 10 microvolts per °C temperature rise. The voltage decreases at the rate of 100 microvolts per year.

Avalanche diodes of the JETEC type 1N430 are useful not only as voltage references but also as sources of power when used in properly designed circuits. These diodes are temperature compensated over a range which far exceeds the usable limits of the unsaturated standard cell, the temperature coefficient is smaller than that of the standard cell, and the internal impedance is less than 15 ohms. The diodes are designed for a current of 10 ma and may be operated as shunt regulators.

The purpose of this investigation was to determine the noise and the short- and long-term stability of the diode regulator voltage at operating current. The short- and long-term stability was measured by comparison with an unsaturated standard cell, the most stable voltage reference available at ORNL. Only one standard cell was used, and this cell was thermally insulated from room air. Stability measurements on two samples compare well with those of Enslein (see Appendix). After an ageing period of about a month, the samples tested showed drift rates of less than ± 5 parts in 10^5 (0.005 per cent) per month.

Experimental Methods

Two tests were run; the first test employed a laboratory-type high stability power supply and many precision wire wound resistors as the source of current for the diode. The circuit diagram is shown in Figure 1. A fraction of the avalanche diode operating voltage was obtained from a resistor divider and bucked against a 1.019V standard cell. The voltage difference was applied to a one millivolt recorder. The Helipot was adjusted to produce mid-scale deflection at the start of the test. The half-scale deflection is then 0.0005 volts compared to 1.019 volts, or 0.05 per cent. Voltage variations of 5 microvolts or 0.0005 per cent were easily detectable. The recorder chart speed was two inches per hour, and the experiment was run for more than two months. The results are shown in the graph of Figure 2 (ORNL-IR-Dwg. 31171), which was obtained from the original chart by sampling points at four-hour intervals. This graph demonstrates the feasibility of an avalanche-diode voltage regulator for an 11 milliamperes constant-current supply.

An all-solid-state regulated power supply of simple design was then constructed. The circuit diagram is shown in Figure 3 (ORNL-IR-Dwg. 31170). The Sola transformer and three stages of avalanche diode regulators stabilize the output against line voltage changes. The temperature coefficients of the avalanche diode regulators are consistent with the improvement factor of each regulator stage. The last two stages and the manganin resistors were immersed in an oil bath to minimize rapid temperature changes.

The stability test on this power supply constituted the second avalanche diode stability test. Figure 4 is a block diagram of the experimental setup. The working-current supply furnished the current to the battery terminals of

the Rubicon potentiometer, and the strip chart recorder was connected to the galvanometer terminals. The standard cell was connected to the standard cell terminals. The function switch was turned to "S.C." (standard cell) and the galvanometer switch was depressed and locked down. The series resistors were adjusted until the strip chart recorder indicated mid-scale.

The equipment was run continuously without adjustment for more than fourteen weeks. The results are shown in Table 1.

Discussion of Results

The first experiment demonstrated that the avalanche diode did not exhibit drift and noise greater than ± 0.002 per cent over the span of one week. In fact, the noise and drift from the fifteenth through the fortieth day did not exceed ± 0.002 per cent. Enslein observed comparable stabilities in four samples of this type of diode regulator (see Appendix).

The potentiometer working current supply demonstrated an ageing effect which seemed to stabilize after the third week. The peak deviation from the average drift was probably a temperature effect due to the non-zero temperature coefficients of both the standard cell and the reference diode. The variations are periodic, and a daily and weekly pattern are apparent. The random drift as observed in this power supply test is much greater than the random drift in the first diode test. The standard cell in the first experiment was immersed in a large oil bath, along with the most of the other components. It is believed that the heat-lagging in the second experiment was insufficient to assure thermal isolation.

A gradual drift of about 0.005 per cent per month was observed in the power supply test. Since most standard cells exhibit a voltage decrease of

approximately 0.001 per cent per month, the drift was probably a real effect in the avalanche diode. No such drift was observed by Enslein over a period of 7,000 hours (almost a year).

Appendix

Enslein, Kurt, I.R.E. Trans. on Instrumentation I-6 (June 1957) 105-118.

"There is shown in Figure 27 a recording of E_d vs. time for the regulator circuit....An analysis of many such hours of recording shows that the maximum deviation of the output voltage is less than $\pm 0.002\%$.

"The voltage regulator output has been measured daily for approximately 7,000 hours at this writing. There has been no detectable long-term drift of the voltage up to this time. However, there have been fluctuations of the order of $\pm 0.015\%$, attributable to temperature variations of the early curves. Late data shows less than $\pm 0.002\%$ fluctuations.

"An attempt was made to measure high frequency noise present across the terminals of the regulator. This value is approximately 10 microvolts, peak-to-peak. The bandwidth of measurement was 10 cycles to 60 thousand cycles per second....An analysis of the end values of many....ignition curves shows that the maximum deviation for the regulator circuit is $\pm 0.002\%$."

NOTE: All parts except the power supply and recorder are in an oil bath.

FIGURE 1. CIRCUIT DIAGRAM OF STABILITY TEST OF A TYPE IN430B AVALANCHE DIODE.

Fig. 2. Stability Test for Type 1N430B Hoffman Avalanche Diode.

UNCLASSIFIED
ORNL-LR-DWG. 31170

Fig. 3. Avalanche Diode Regulated Power Supply Q-1931-4.

FIGURE 4. BLOCK DIAGRAM OF STABILITY TEST OF AVALANCHE DIODE REGULATED POTENTIOMETER CURRENT SUPPLY (Q-1931-4).

<u>Week</u>	<u>Average Drift During Week</u> <u>x 10⁻⁵</u>	<u>Peak Deviation</u> <u>From Average Drift</u> <u>x 10⁻⁵</u>	<u>Total Drift</u> <u>Over Four Weeks</u> <u>x 10⁻⁵</u>
1	+8	±3-1/4	
2	2-1/2	3-1/2	
3	4	3	
4	0	2-3/4	+14-1/2
5	1-1/2	2-1/2	
6	2	2-1/4	
7	0	2-1/4	
8	2-1/4	2-3/4	5-3/4
9	2	2-1/2	
10	2-1/4	2-1/2	
11	0	2-1/2	
12	0	1-1/2	4-1/4

TABLE 1. DRIFT CHARACTERISTICS OF AN AVALANCHE DIODE POTENTIOMETER CURRENT SUPPLY.

DISTRIBUTION

1. R. K. Abele	57. W. W. Johnston, Jr.
2. R. K. Adams	58. J. P. Judish
3. R. G. Affel	59. M. J. Kelly
4. J. L. Anderson	60. R. F. King
5. S. J. Ball	61. R. J. Klein, Jr.
6. H. E. Banta	62. D. J. Knowles
7. A. E. G. Bates	63. P. D. Koster
8. M. C. Becker	64. J. W. Krewson, Jr.
9. E. H. Bell	65. A. M. Leppert
10. B. C. Behr	66. B. Lieberman
11. E. S. Bettis	67. C. S. Lissner
12. A. M. Billingson	68. J. L. Lovvorn
13. T. M. Blalock	69. E. R. Mann
14-23. J. L. Blankenship	70-74. F. W. Manning
24. C. J. Borkowski	75. J. E. Marks
25. G. A. Bradley	76. H. J. Metz
26. J. R. Brown	77. R. L. Moore
27. E. W. Burdette	78. C. A. Mossman
28. G. H. Burger	79. W. F. Mruk
29. C. M. Burton	80. L. C. Oakes
30. L. H. Chase	81. F. M. Porter
31. H. E. Cochran	82. J. F. Potts, Jr.
32. T. E. Cole	83. J. W. Reynolds
33. C. C. Courtney	84. J. B. Ruble
34. R. A. Dandl	85. J. A. Russell, Jr.
35. J. B. Davidson	86. C. H. Schalbe
36. J. DeLorenzo	87. H. W. Schmitt
37. R. H. Dilworth	88. R. S. Stone
38. S. Ditto	89. J. R. Tallackson
39. J. K. East	90. J. R. Tarrant
40. J. D. Eddlemon	91. H. A. Todd
41. T. L. Emmer	92. D. S. Toomb, Jr.
42. E. P. Epler	93. R. Toucey
43. E. Fairstein	94. E. Vincens
44. T. M. Gayle	95. C. S. Walker
45. F. M. Glass	96. D. D. Walker
46. F. P. Green	97. K. W. West
47. G. W. Greene	98. P. P. Williams
48. W. J. Greter	99. H. N. Wilson
49. J. D. Gundlach	100. J. W. Woody, Jr.
50. S. H. Hanauer	101-120. Laboratory Records
51. C. S. Harrill	121. Laboratory Records, ORNL-RC
52. P. G. Herndon, Jr.	122. Central Research Library
53. N. W. Hill	123. Biology Library
54. G. A. Holt	124. Health Physics Library
55. J. L. Horton	125. REED Library
56. R. F. Hyland	126. ORNL - Y-12 Document Reference Library
	127-141. TISE, AEC