PERFORMANCE OF THE AD590 TEMPERATURE TRANSDUCER AT LOW TEMPERATURE

Test Report

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Device Description

The AD590 is a two-terminal integrated circuit (voltage in/current out) temperature transducer that produces an output current proportional to absolute temperature. In addition to temperature measurement, this device can be used in applications that include flow rate measurements, correction of discrete components, temperature compensation, biasing proportional to absolute temperature, level detection of fluids and anemometry.

Effort Objective

Temperature transducers are commonly used in electronic systems in almost all of NASA missions. The simple design of the AD590, which requires no support circuitry, makes it particularly useful in remote sensing applications [1]. Unlike other conventional transducers, the AD590 does not require any linearization circuitry, precision voltage amplifiers, resistance measurement circuit, or cold junction compensation. Its simple design and high accuracy render it a good candidate for use in many of NASA space exploration missions.

Device Specifications

The AD590 temperature transducer is made by Analog Devices, Inc. and Harris Corporation. The device comes in different grades with ceramic package or metal can options. The specifications of some of these packages are listed in Table I.

Table I. Some of the manufacturer specifications of the devices tested [2,3].

	AD590LF	**AD590JF**	**AD590JH**
Input Voltage (V)	+4 to +30	+4 to +30	+4 to +30
Linear Current Output (μA/K)	1	1	1
Temperature Range (°C)	-55 to +150	-55 to +150	-55 to +150
Maximum Nonlinearity (°C)	±0.4	±1.5	±1.5
Maximum Absolute Error (°C)	±3	±10	±10
Maximum Calibration Error @R.T. (°C)	±1	±5	±5
Maximum Repeatability (°C)	±0.1	±0.1	±0.1
Package	Ceramic	Ceramic	Metal

Test Procedure

Three different versions of the AD590 were evaluated in terms of output response and linearity as a function of temperature. A total of 61 devices were characterized in the temperature range of 293K (+20 °C) to 80K (-193 °C). The data were initially gathered at room temperature, then at successive test temperatures down to 80K, and again at room temperature after low temperature was completed. At a given test temperature, the device under test was allowed to soak for 20 minutes so that thermal equilibrium was reached before any measurement was made. To investigate the effect of low temperature exposure on the packaging, devices with ceramic packaging and metal cans were used in this work. Each device was characterized in its output current, which is proportional to absolute temperature, as a function of temperature and its input or supply voltage. After the last measurement was taken at the lowest temperature, i.e. -190 °C, data was then obtained at room temperature.

Test Results

A total of 61 devices were evaluated in this work. These comprised of ceramic-packaged (LF and JF versions) and metal-canned (JH version) units. While the first batch (six) of the LF-series was about seven years old, the rest of the devices (55) were recently acquired. An overall summary on the performance of the devices tested is shown in Table II.

Table II. Summary of performance of the various AD590 devices.

Version	Package	Quantity	Manufacturer	Performance with Temperature
LF	Ceramic	6	Analog Devices (old)	5 devices showed good performance down to 90 - 80K 1 device had good performance down to only 144K
		6	Analog Devices	5 devices showed good performance down to 170 - 140K 1 device exhibited deviation in performance below 220K
JF	Ceramic	30	Analog Devices	9 devices exhibited good performance down to 120 - 80K 19 devices showed good performance down to ~130K 2 devices started to drift in performance below 170K
JH	Metal	10	Analog Devices	All devices performed well down to only 120K
		9	Harris	All devices exhibited poor performance between 220-170K

It can be clearly seen from Table II that a wide variation in performance was exhibited by the various versions of the AD590 temperature transducer. In fact, discrepancies in output behavior with temperature were even observed for devices from the same series. For example, the first batch (old six) of the ceramic LF-series exhibited, in general, much better performance with temperature than those acquired recently. It is not readily clear why such unexpected outcome is observed. However, it can be postulated that different production lots and possibly new manufacturing processes or design modifications might have contributed to this behavior.

Most of the JF-series devices exhibited good performance down to about 140 to 130K. While nine of the remaining devices performed relatively well with temperature down to about 120 to 80K, two devices exhibited good operation only down to 170K. It is important to note that all of the devices were able to generate some output beyond the aforementioned good low temperature cut-offs. The produced output, however, did not reflect an accurate representation of the temperature to be measured.

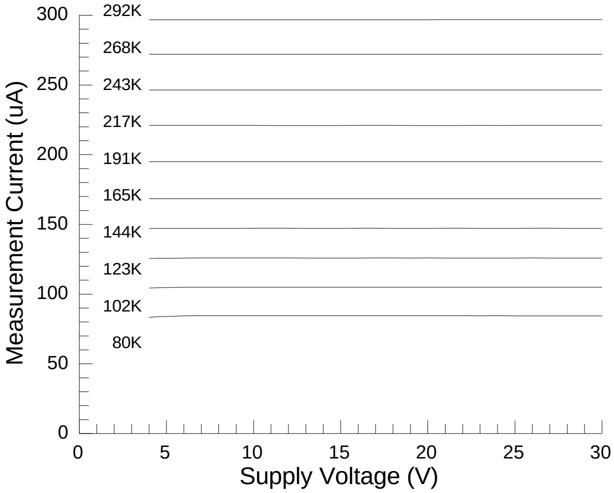
The metal-can packaged devices were obtained from two manufacturers. The ten Analog Devices units displayed good and consistent behavior from room temperature down to 120K. The Harris devices, nine of them, however, exhibited behavior that was different from one device to another from the same batch. While some of these devices operated quite well down to 170K, others exhibited irregularity in their output at temperatures as low as 220K.

A detailed listing of the devices tested along with their corresponding good low temperature limit, below which deviation in the output was observed, is given in Table III.

Table III. Approximate working low temperature of devices tested.

Device Type	Device #.	Temp. (K)	Device Type	Device #.	Temp. (K)
AD590LF(old)	1	80	AD590JF	4	123
	2	80		5	123
	3	144		6	102
	29	80		7	144
	30	80		8	144
	31	90		9	123
AD590LF(new)	56	170		32	100
	57	220		33	110
	58	150		34	170
	59	140		35	140
	60	150		36	130
	61	140		37	130
AD590JH Analog	10	120		38	130
	11	120		39	140
	12	120		40	80
	13	120		41	140
	14	130		42	130
	15	120		43	130
	16	120		44	130
	17	120		45	120
	18	120		46	130
	19	120		47	130
AD590JH Harris	20	220		48	130
	21	220		49	120
	22	170		50	170
	23	220		51	140
	24	220		52	130
	25	170		53	130
	26	220		54	140
	27	170		55	130
	28	220			

Graphical representations of the data obtained on each device are followed in the same sequence as were presented in Table II. The parameters depicted in each figure include the supply input voltage (a test variable) and the specific test temperatures at which measurements were made. The corresponding output current, which was measured at various temperatures, is plotted along the coordinate. This measurement can also be read as temperature in Kelvins since the AD590 temperature transducer provides an output of 1µA/K.



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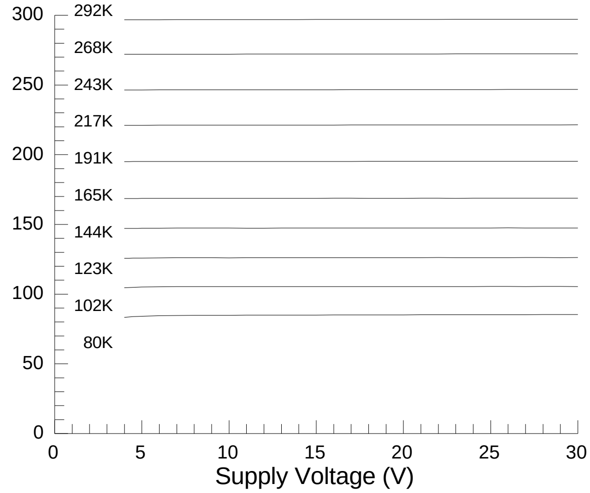

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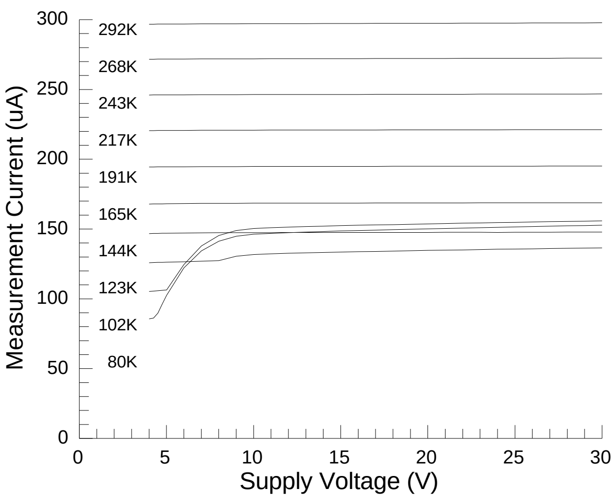

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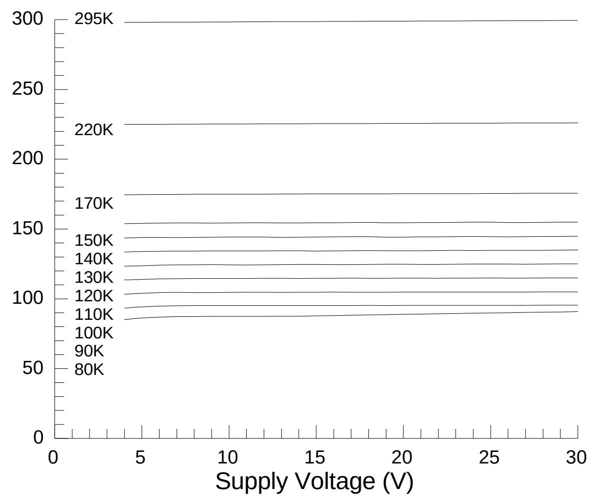

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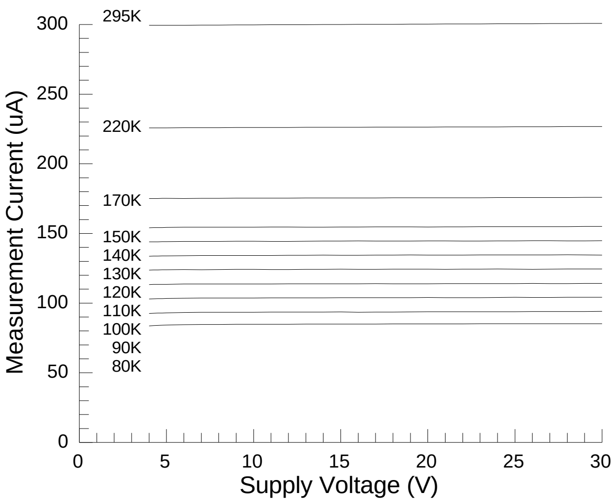

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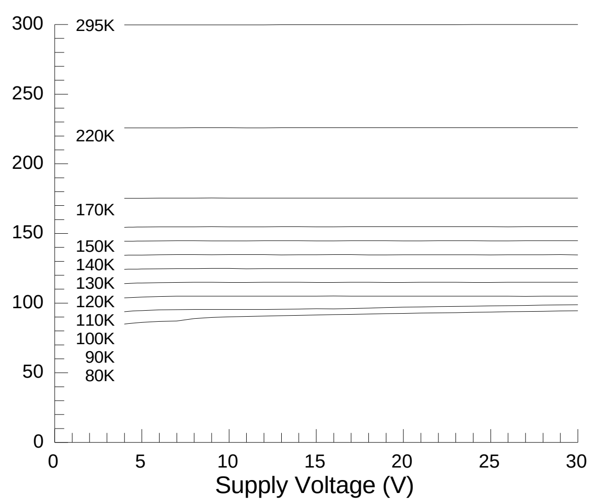

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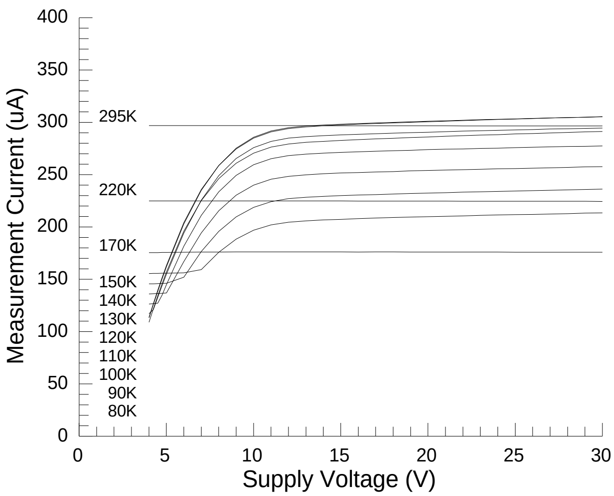

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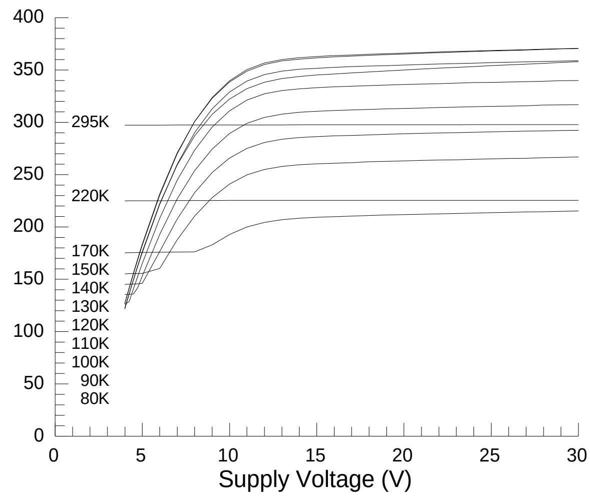

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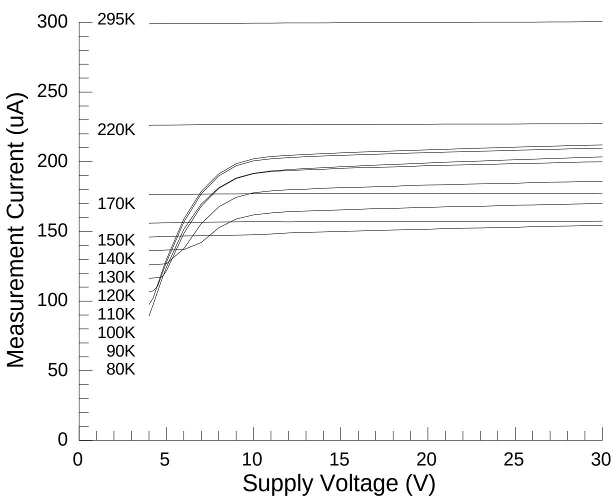

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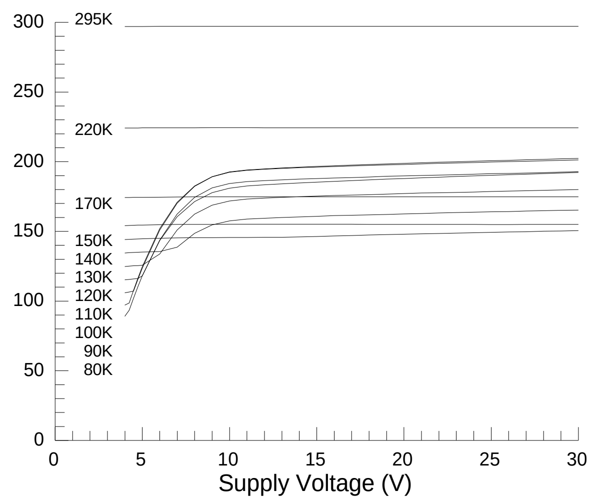

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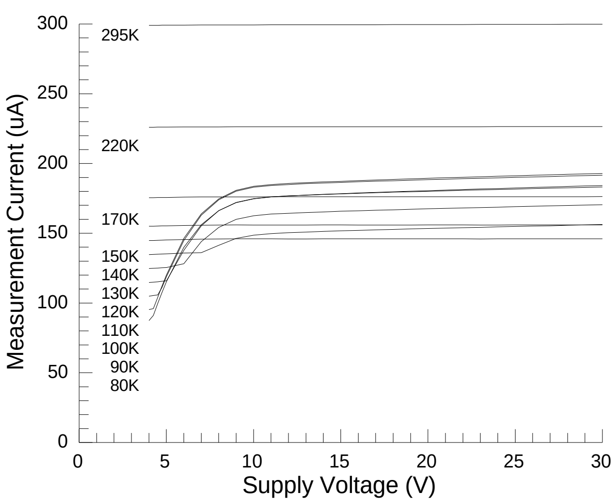

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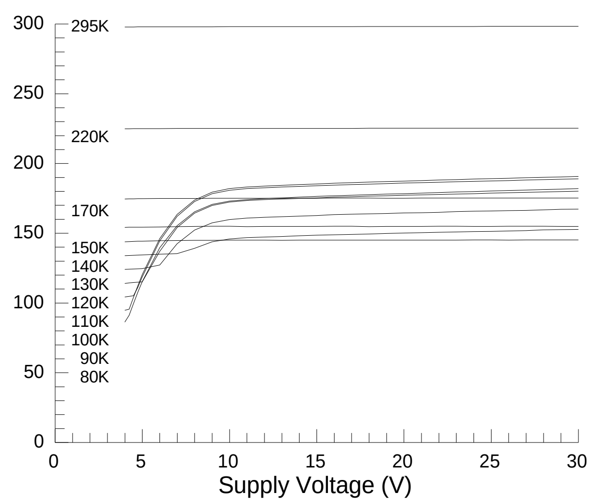

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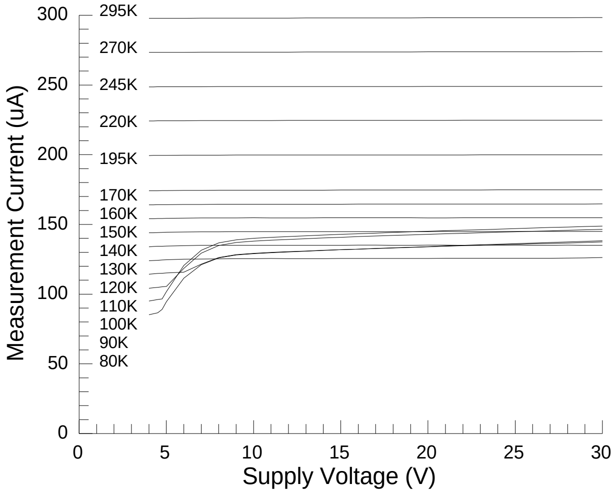

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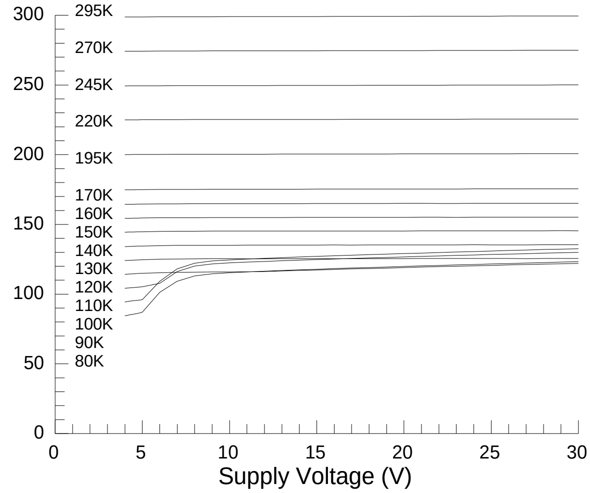

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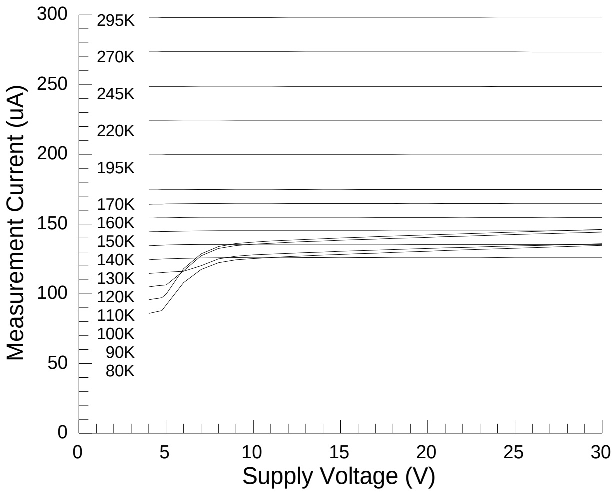

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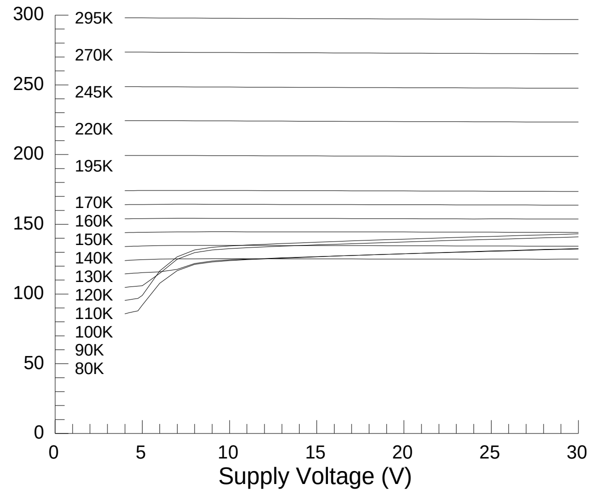

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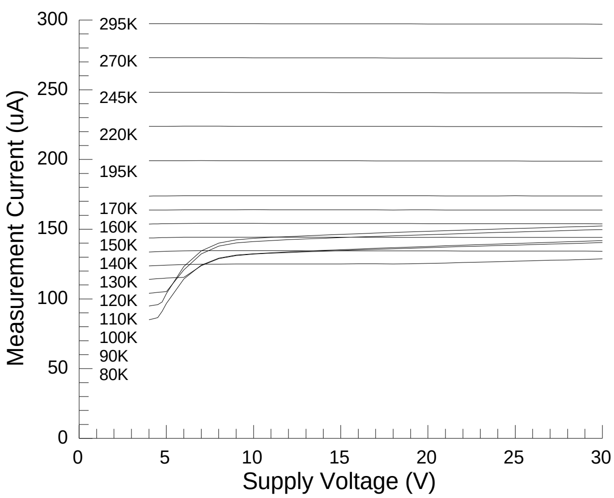

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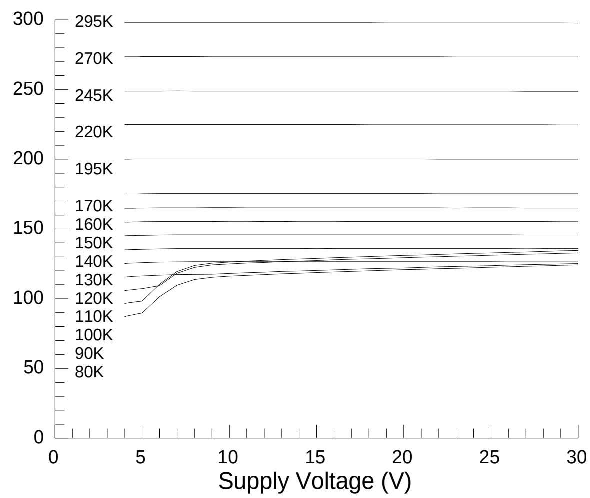

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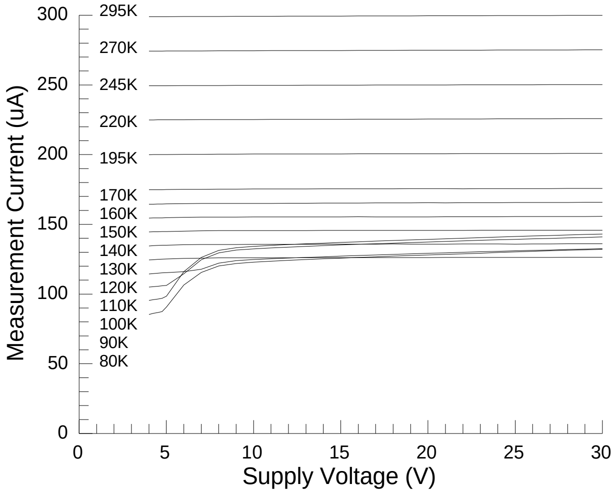

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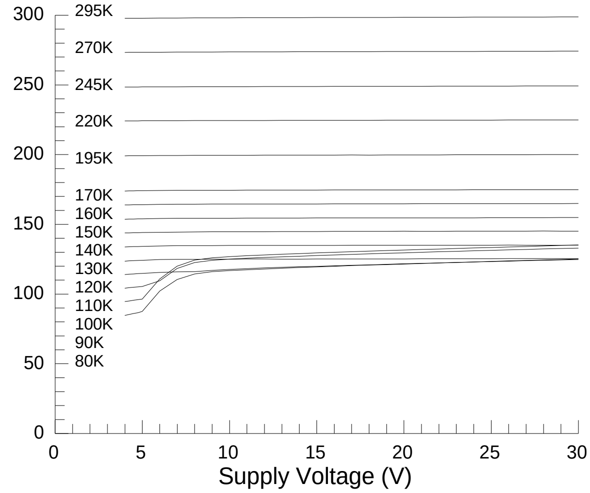

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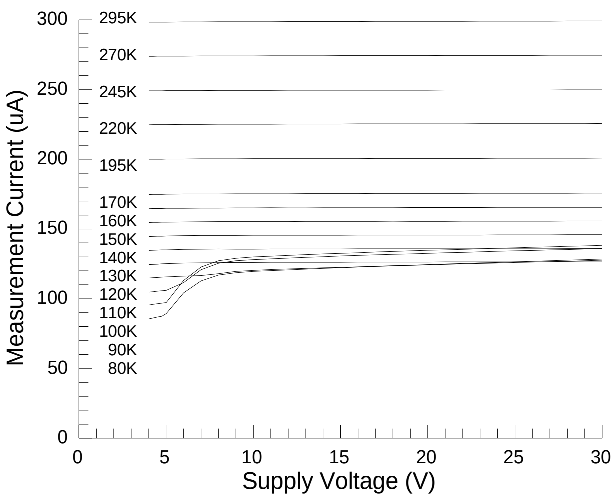

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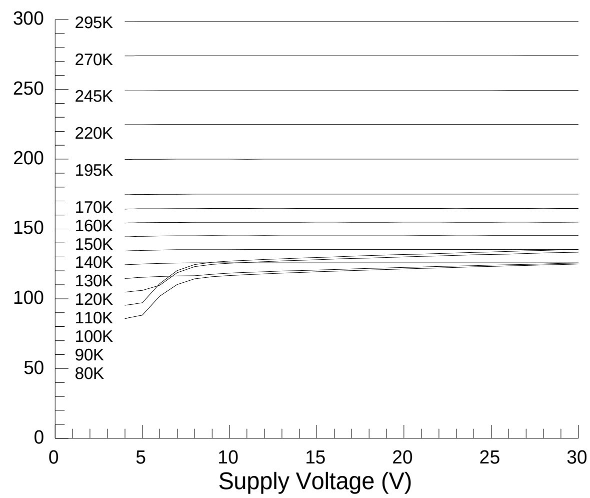

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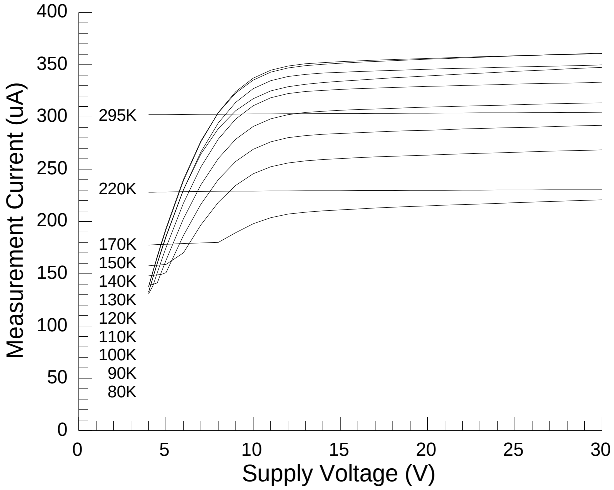

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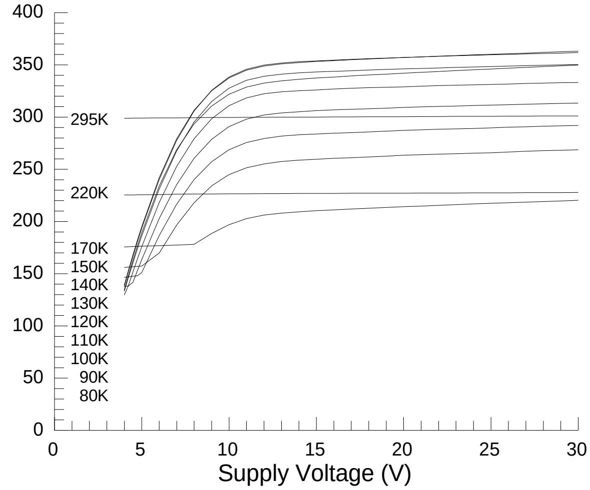

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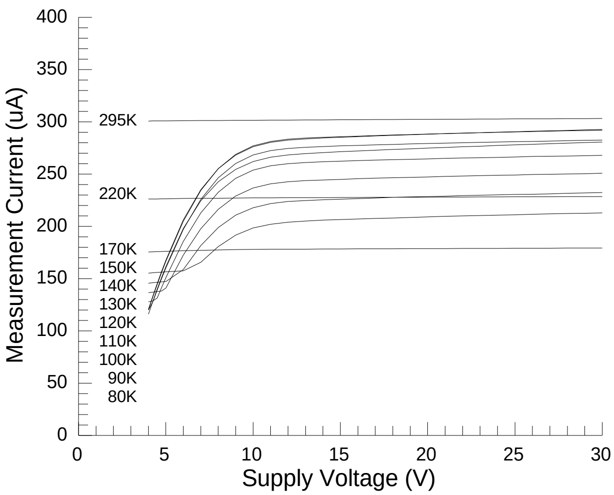

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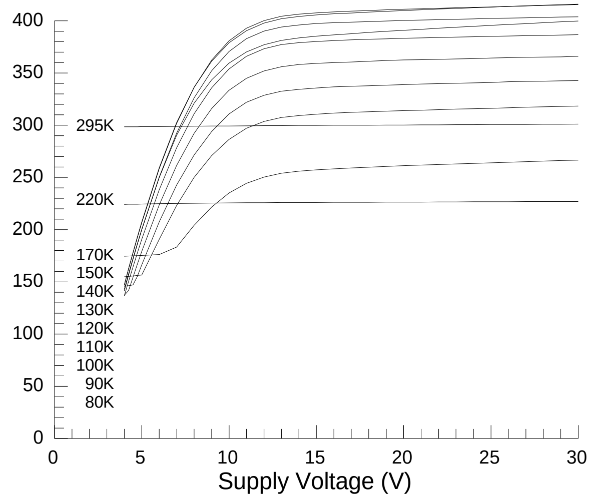

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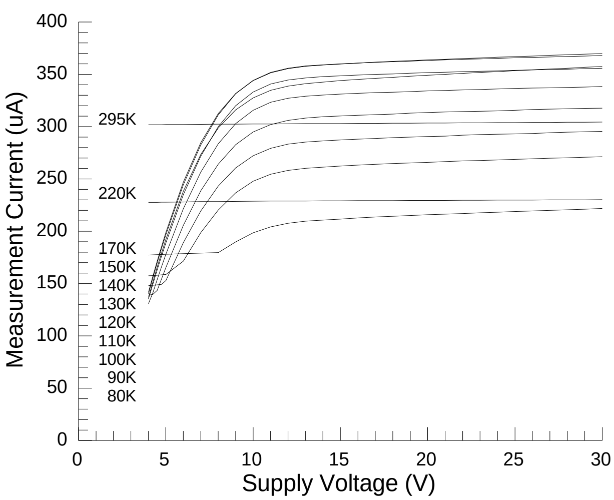

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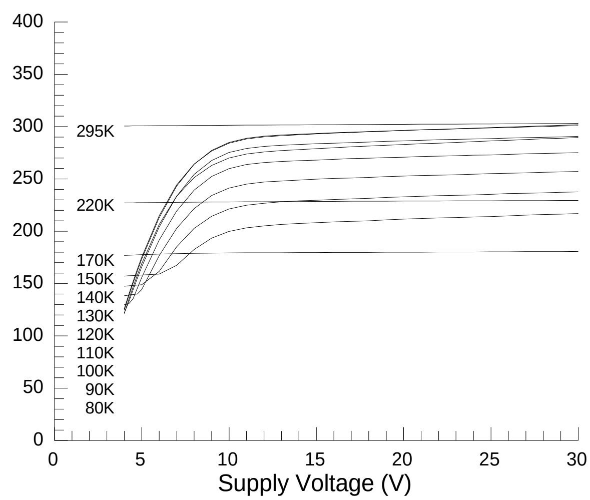

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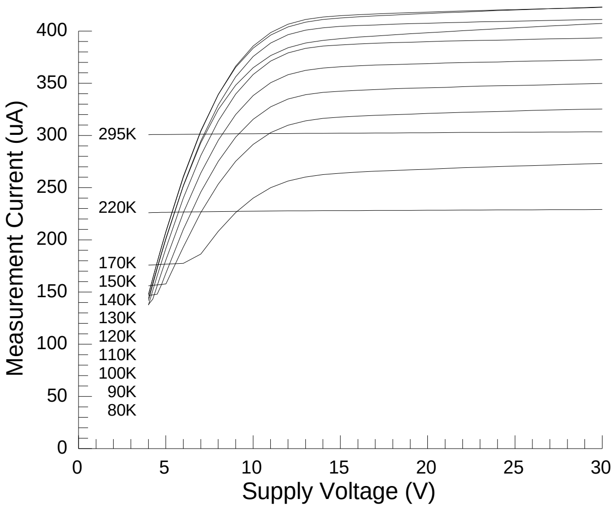

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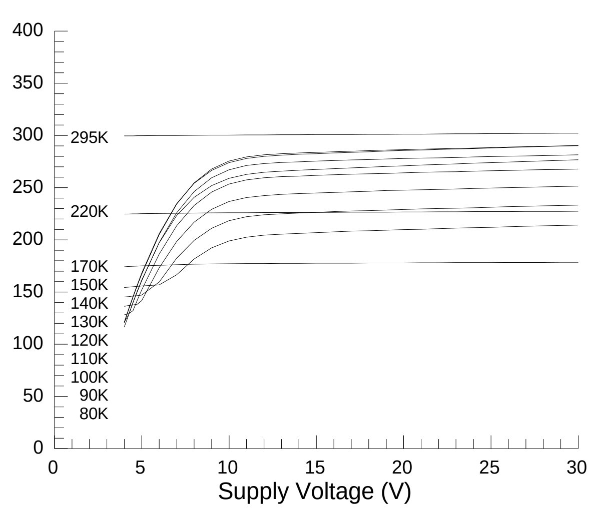

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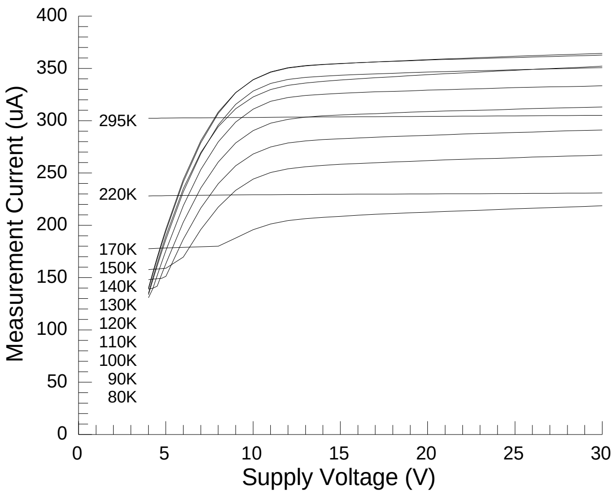

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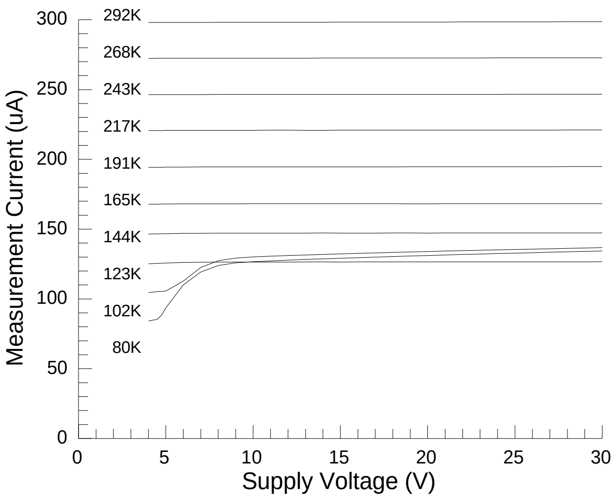

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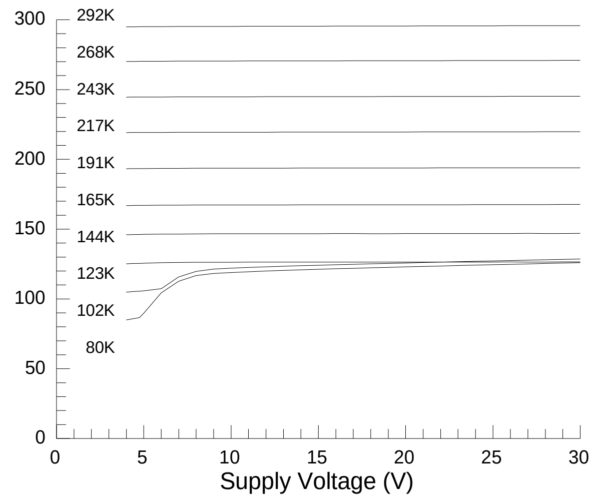

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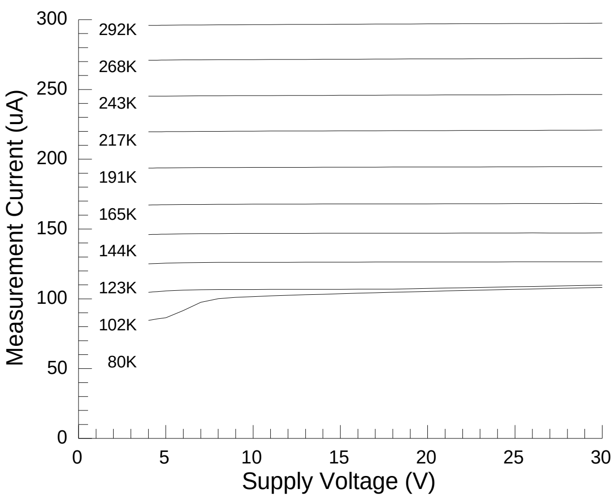

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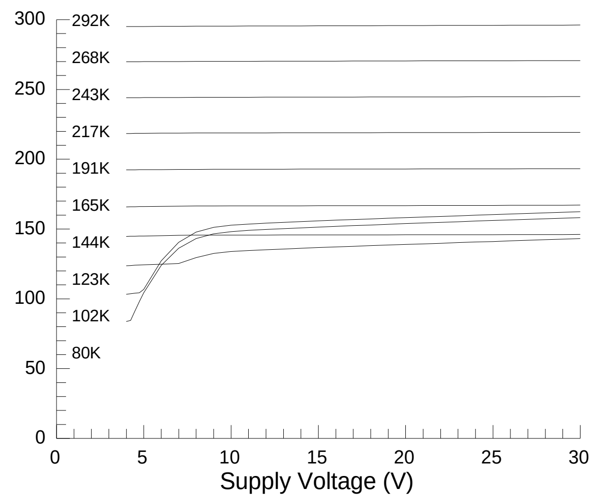

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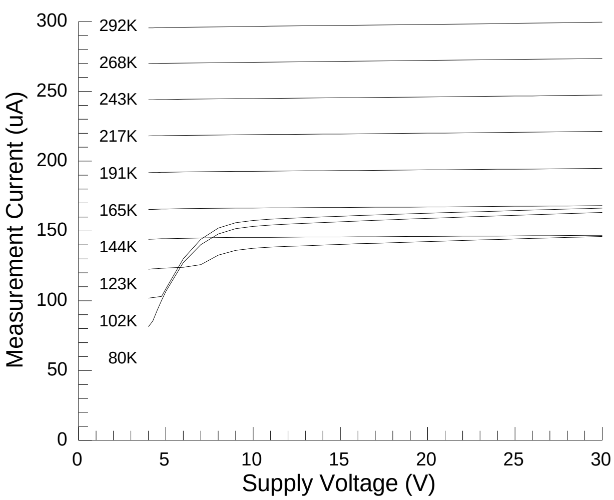

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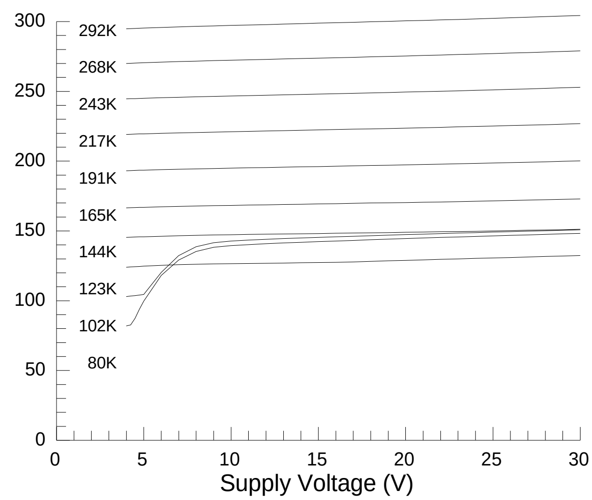

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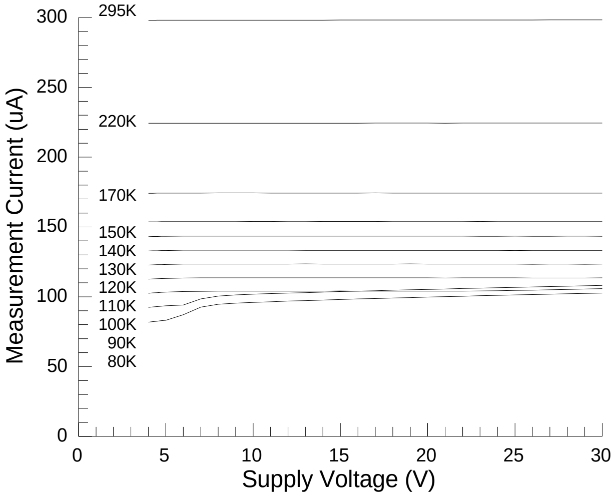

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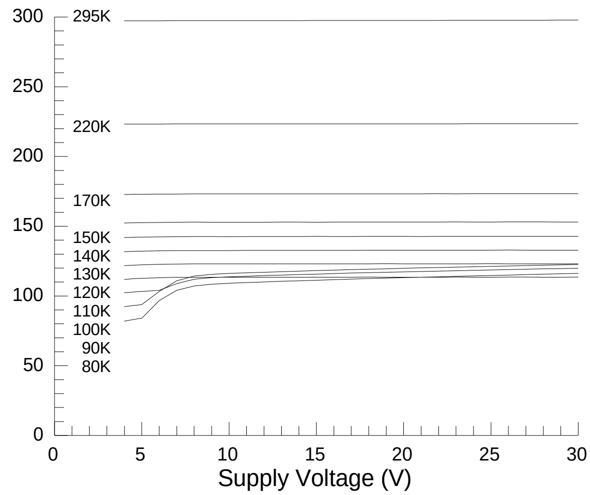

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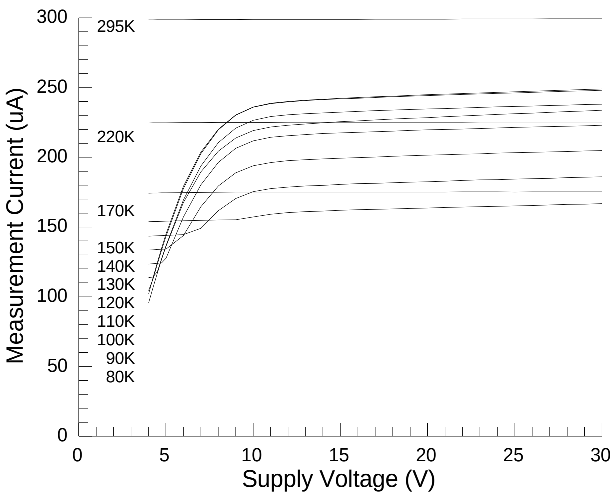

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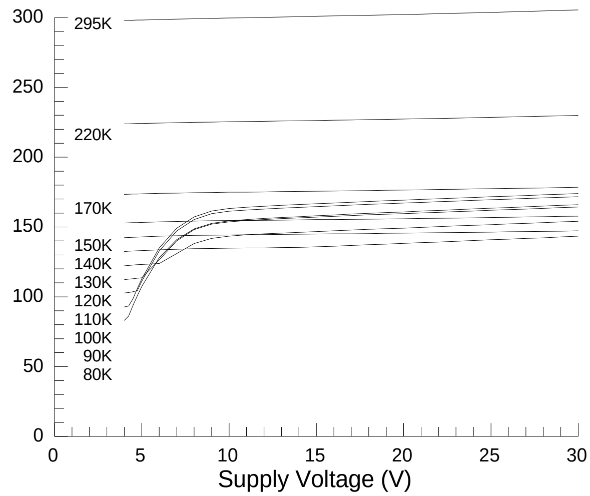

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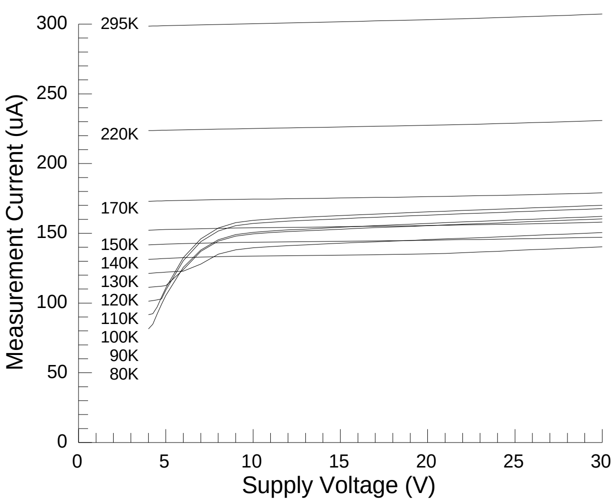

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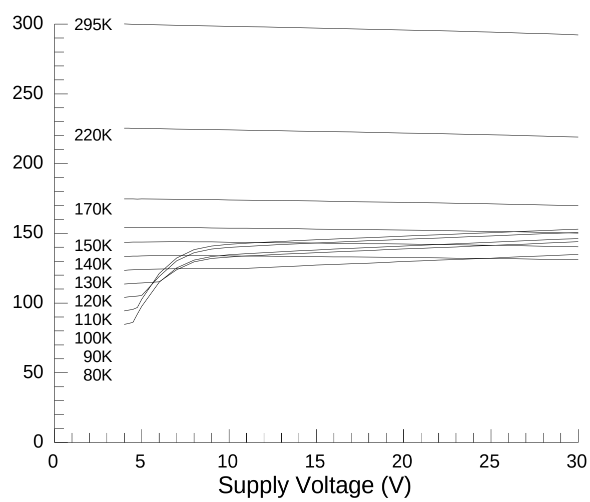

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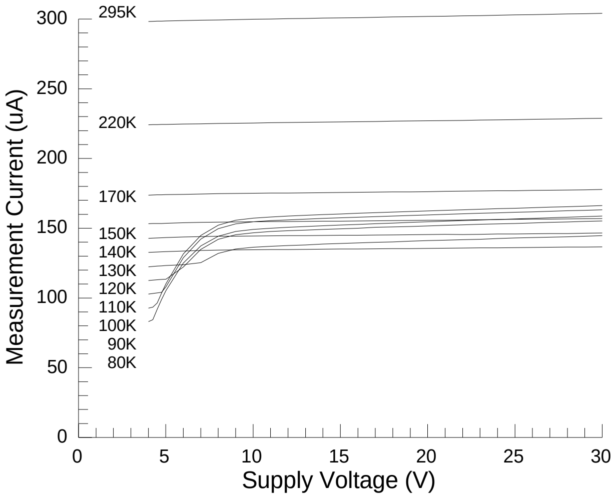

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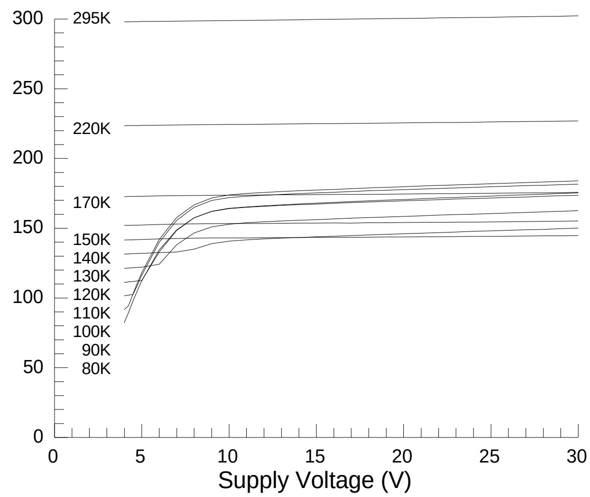

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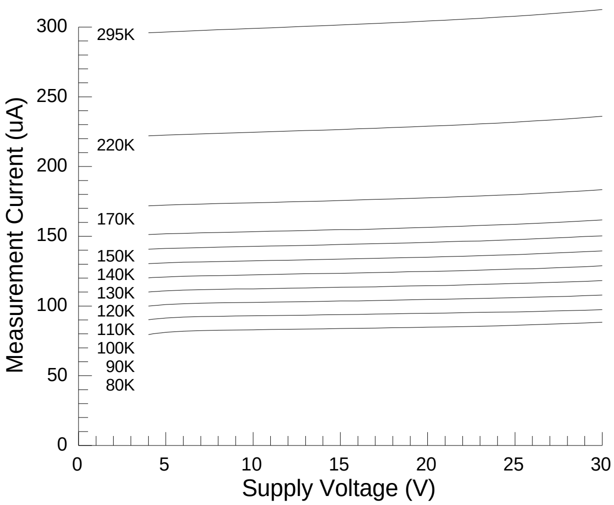

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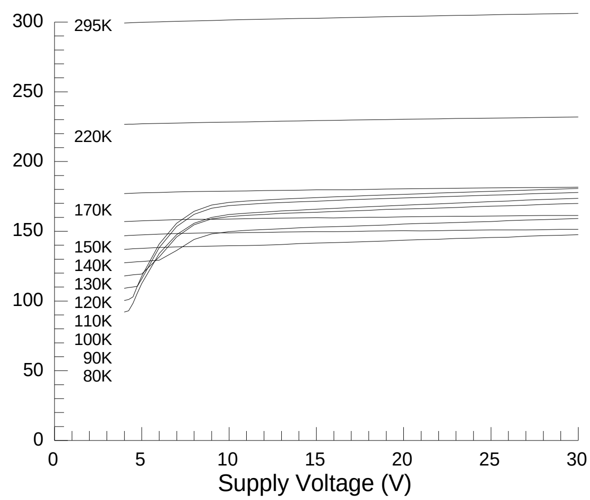

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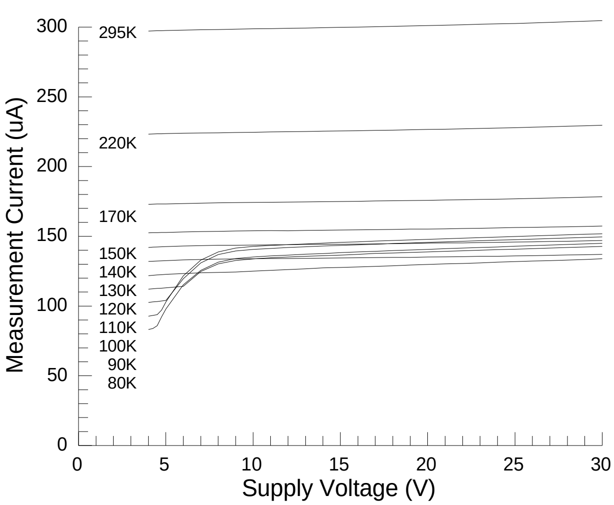

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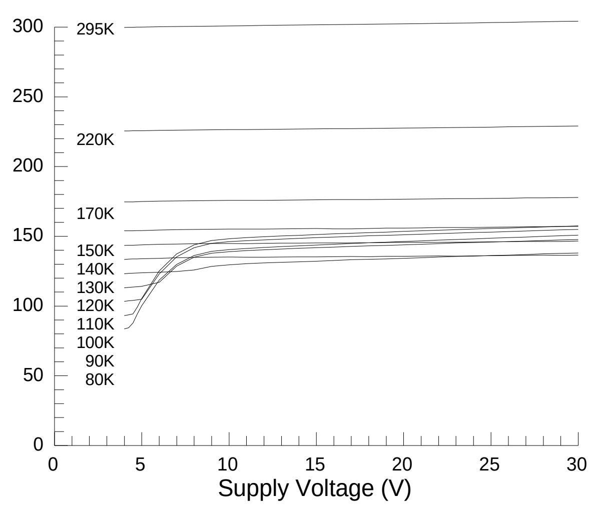

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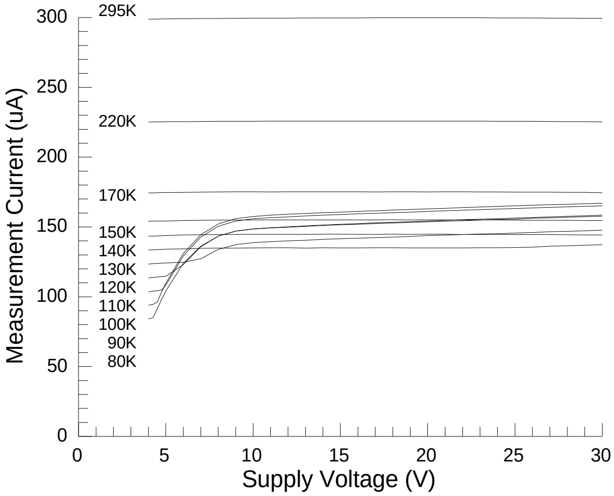

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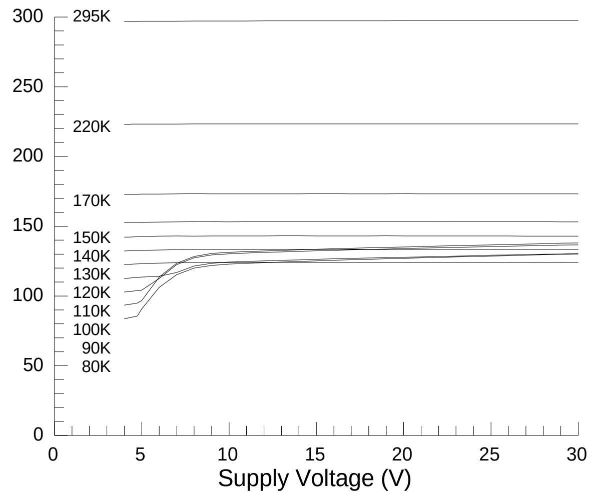

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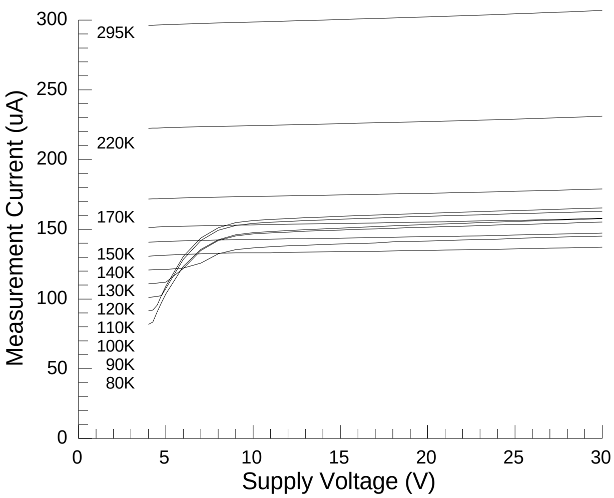

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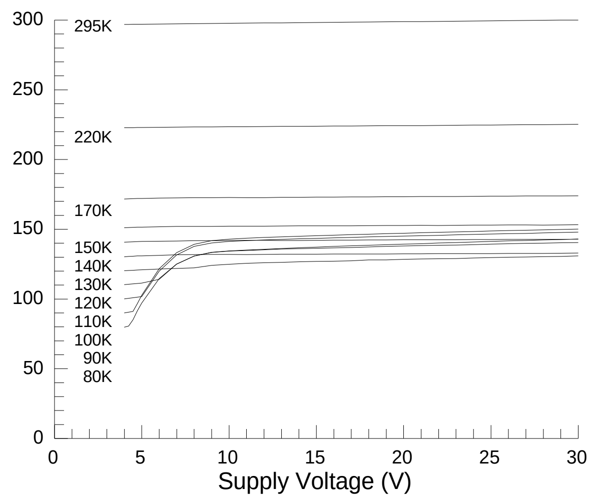

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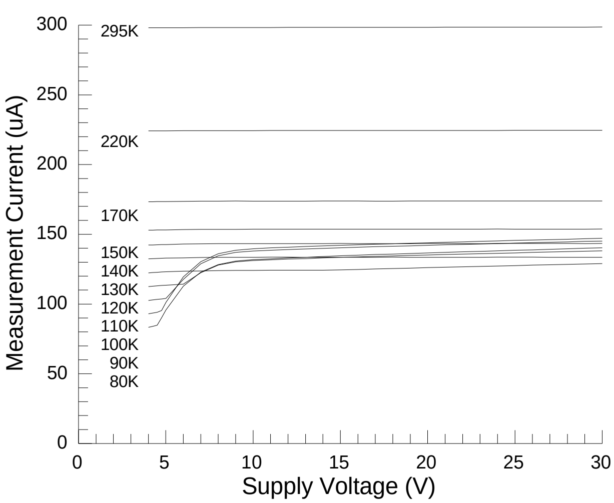

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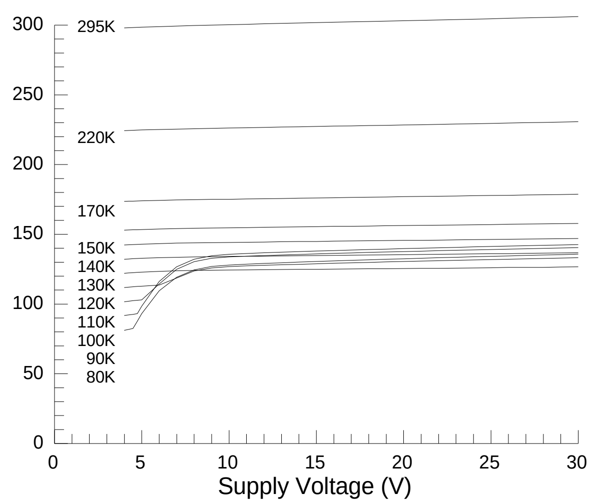

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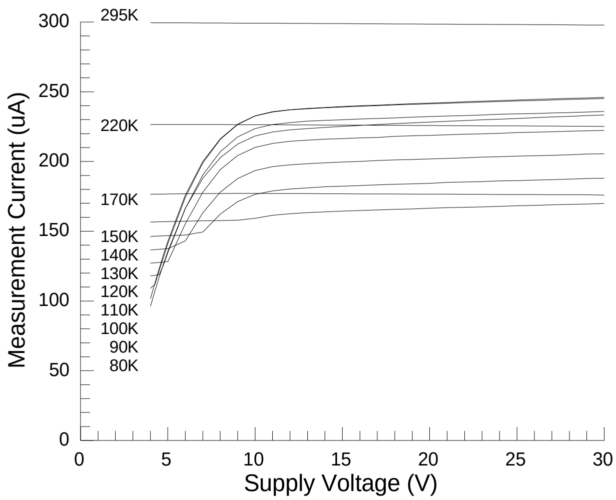
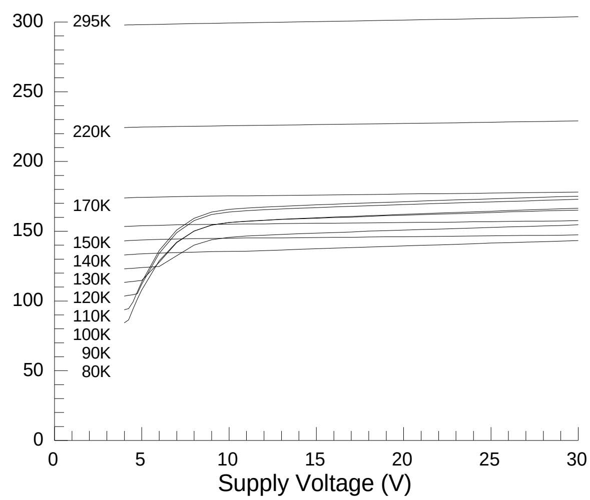
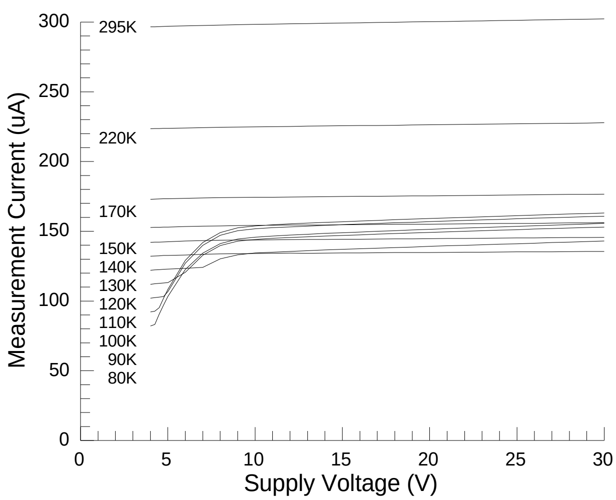


AD590JF Dev #50



AD590JF Dev #51



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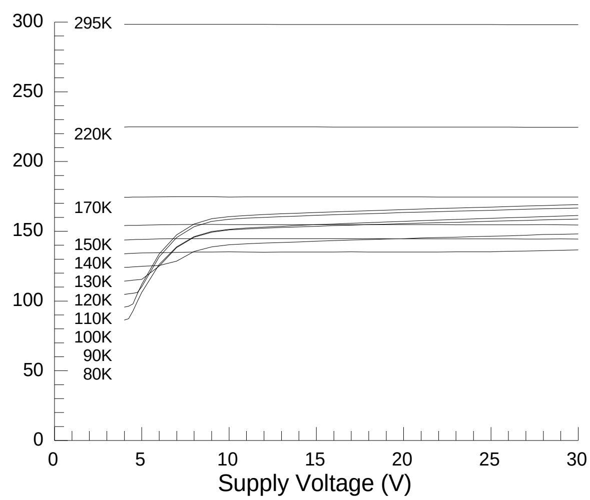

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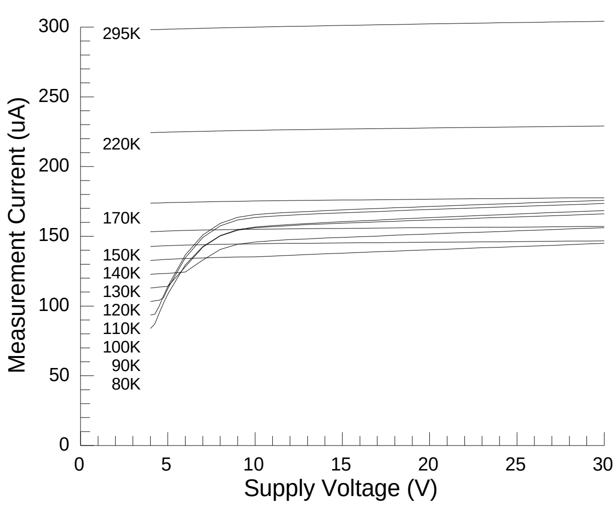
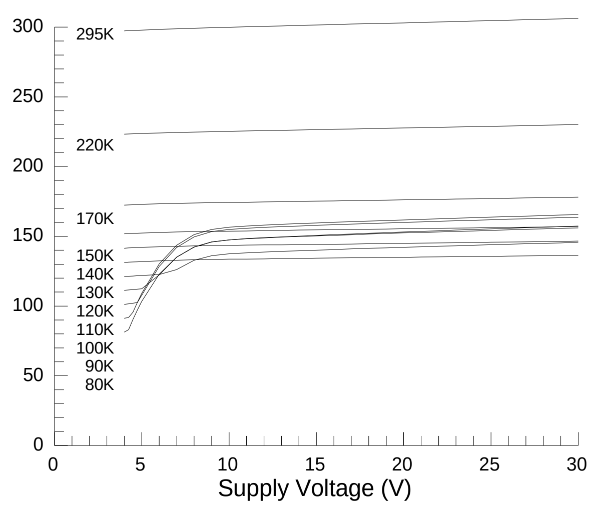
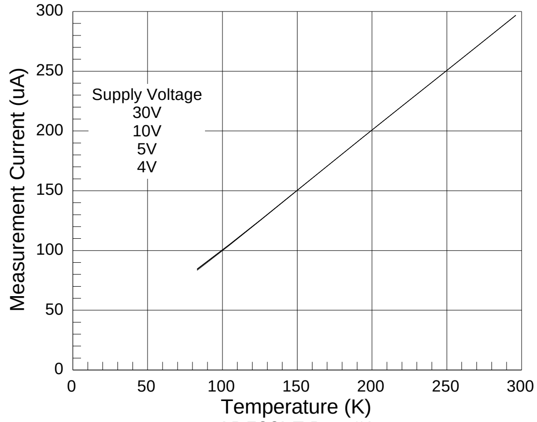


AD590JF Dev #54

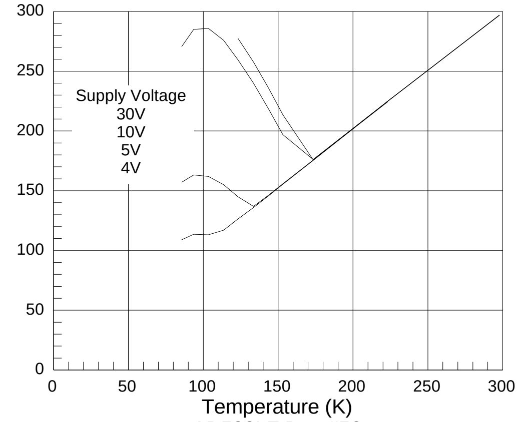


AD590JF Dev #55

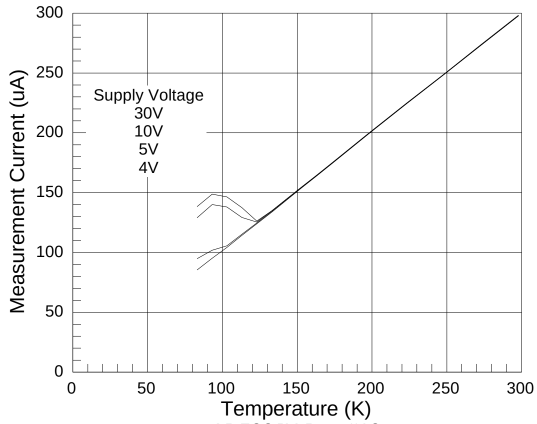
To illustrate the effect of low temperature exposure on the linearity of these temperature transducers, data pertaining to six selected devices are plotted in the following figures. The data shows the linearity curves for devices 1 and 56 of the LF-series, 10 and 22 of the JH-series, and 6 and 52 of the JF-series. For a given device, the figure depicts the output current corresponding to a certain temperature at various supply voltage levels. It can be clearly seen that all devices exhibit some non-linearity as the temperature is decreased. These effects become more apparent at extreme low temperatures and at high supply voltage levels. The severity of these changes are, however, dependent on the series-type of the device, its manufacturer as well as production lot.



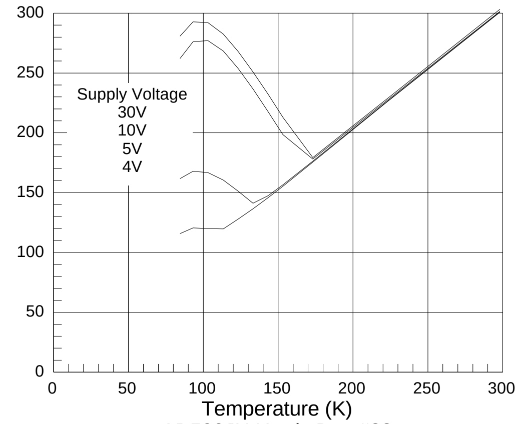
AD590LF Dev #1



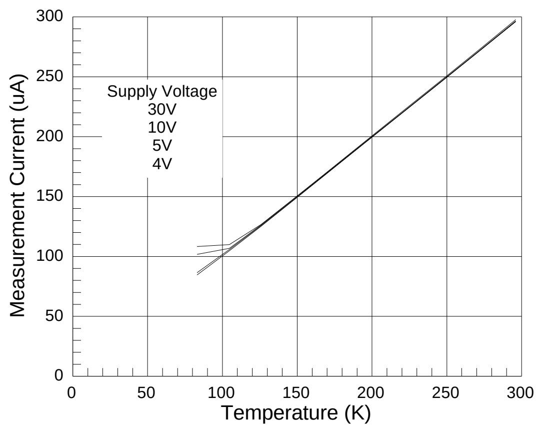
AD590LF Dev #56



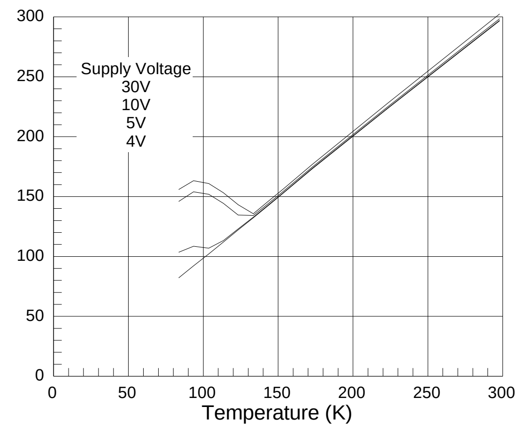
AD590JH Dev #10



AD590JH Harris Dev #22



AD590JF Dev #6



AD590JF Dev #52

Conclusion

Temperature transducers are widely used in electronic systems for remote sensing applications. Design simplicity of the AD590 device, which does not require any supporting circuitry, makes it an attractive candidate for use in NASA missions. A large number of these devices were investigated in this work for suitability for use in low temperature environment. Ceramic-packaged and metal-canned devices, with different accuracy ratings, were included in this investigation to determine if the low temperature exposure has any effect on the packaging material of these components.

Although these devices are rated for only -55 °C (218K), this effort was undertaken to determine their operation limit at low temperature. All devices exhibited variation in their operational behavior with temperature. While some of these devices displayed good performance with temperature all the way down to 80K (around liquid nitrogen temperature), others started to deviate in their output response at temperatures below 220K (manufacturer rating). It is important to note that although the majority of the devices exhibited changes, with varying degrees, in their output linearity with decreasing temperature, none underwent any catastrophic failure due to exposure to the low temperature environment. This is evident from the full recovery in performance exhibited by all the devices tested upon their thermal stabilization back to room temperature. As far as the packaging material is concerned, the results of this preliminary work preclude any decisive assessment of the effects induced by the low temperature exposure. More comprehensive testing is, therefore, required to fully characterize the behavior of these devices and to determine their suitability for use and limitation in low temperature environments. Issues such as thermal cycling, non-linearity, and low temperature operation capability need to be addressed for designing efficient and reliable electronic systems for space and terrestrial applications.

Acknowledgment

This work has been performed at the NASA Glenn Research Center under SETAR and GESS Tasks. Support was also provided by the Jet Propulsion Laboratory through the NASA Electronic Parts and Packaging (NEPP) Program.

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[3]. Harris/Intersil Corporation product data sheet.