Stable Low Noise Voltage Source

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Hum and noise on power sources can have a significant effect on system noise, and because it is predominately low frequency, 60 or 120 Hz, it is extremely difficult to reduce to levels in the order of 1 $\mu V/\sqrt{H_z}$, particularly at high current levels. Filtering to achieve low hum and noise is best accomplished at low current levels and should therefore be done locally. The diode regulator circuit described in this article is nearly ideal for this type of local filtering.

I. Introduction

A stable low noise voltage source has been designed for use in the Very Long Baseline Interferometry (VLBI) phase calibrator in order to reduce the hum and noise associated with typical power supplies to a level that results in a sufficiently small contribution to the phase noise on the output signal.

II. Effect of Hum and Noise

The hum and noise on the power supplies used in the phase calibrator is specified at 250 μV and is predominately at 60 Hz and 120 Hz. This noise is translated by the circuitry to phase noise on the output signal. The voltage-controlled oscillator (VCO), voltage-controlled phase shifter (VCS) and related circuitry are most susceptible to power supply hum and noise. The rest of the circuitry contributes relatively little phase noise.

If the 15-volt power supply voltage is applied to the bias input to the voltage variable capacitance diode in the VCO through a 3:1 voltage divider to provide 5 V bias, the hum and noise on the power supply is translated to sidebands at "X" band equal in amplitude to the desired calibration signal.

It is necessary to have at least a 40-dB ratio between the calibration signal and the hum and noise sidebands at X-band. To achieve this ratio, hum and noise on the power supply must be reduced by more than 50 dB before it is applied to the critical circuitry.

III. Method Used

A voltage source to supply the critical circuitry was needed with the following requirements.

(1) Low noise down to dc.

(2) Low temperature coefficient.

(3) Physically small.

(4) Low cost.

(5) Reliable.

(6) High rejection of power supply hum and noise.

Circuits were designed using constant current diodes in series with low-voltage avalanche diodes, taking advantage of the large difference in dynamic impedance of the two types of diodes to obtain a very high rejection ratio to power supply hum and noise. The rejection ratio is essentially the ratio of dynamic impedances of the two diodes.

IV. Example

An example of a practical circuit is shown in Fig. 1. It consists of a 1N5314 (4.7-mA) constant current diode in series with an LVA 347A (4.7-V) low-voltage avalanche diode. A general-purpose rectifier is placed in series with the constant current diode to protect the circuit from an inadvertent application of a negative voltage, in which case the circuit would probably be damaged.

This circuit will supply about 2 mA to a load at 4.7 V and meet the following specifications:

(1)	Output noise	$< 1\ \mu V/\sqrt{Hz}$
(2)	Temperature coefficient	$\pm 0.01\%/^\circ C$
(3)	Size	$0.01\ in.^3$
(4)	Cost	< $10
(5)	Reliability	> 50,000 h MTBF
(6)	Hum and noise rejection	> 85 dB

The power to the VCO in the calibration generator was conditioned as shown in Fig. 2 with a primary regulator supplying power to the VCO and a secondary regulator in series with it to supply the varactor bias.

V. Tradeoffs

It is possible to make tradeoffs between hum and noise rejection, desired output current and temperature coefficient. If maximum hum and noise rejection is desirable it can be achieved by maximizing the impedance ratio between the constant current diodes and the LVA. The diode impedance curves show that for a given current, higher dynamic impedance with constant current diodes may be obtained by paralleling lower current diodes and that LVA diodes with about a 6-V avalanche voltage have the lowest impedance for a given current. Hum and noise rejection > 110 dB can be achieved.

The best temperature coefficient will be achieved using an LVA 347A (4.7-V) avalanche diode. Any constant current diode which supplies 470 μA or more when used with an LVA 347A, which has a nearly zero temperature coefficient, should result in a temperature coefficient $< 0.015\%/^\circ C$. An order-of-magnitude improvement over this should be possible by selecting diodes.

Available output current can be increased by paralleling constant current diodes. This will result in less hum and noise rejection provided the current through the avalanche diode is not increased.

See Figs. 3 through 6 for typical parameter curves for constant current diodes and low-voltage avalanche diodes.

VI. Conclusion

Extremely low noise voltages are difficult to achieve at the level of a systems primary power supply. The large currents at this level would necessitate the use of large and expensive components.

Even if low noise voltages were achieved at this level, great care would be required in the form of careful shielding and grounding techniques to prevent excessive degradation of these voltages. Local filtering of the supply to critical circuits is a more practical approach.

The diode regulator circuit described herein works very well in this application. It achieves excellent hum and noise rejection, with good output voltage stability in a small, low-cost, reliable circuit.

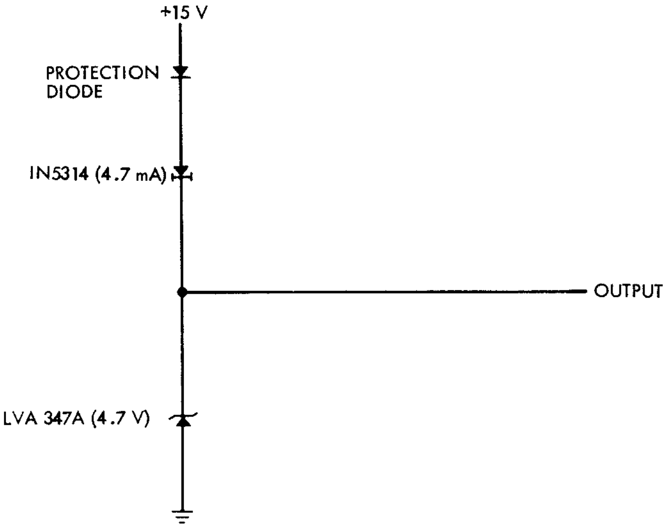

Fig. 1. Example of a practical circuit

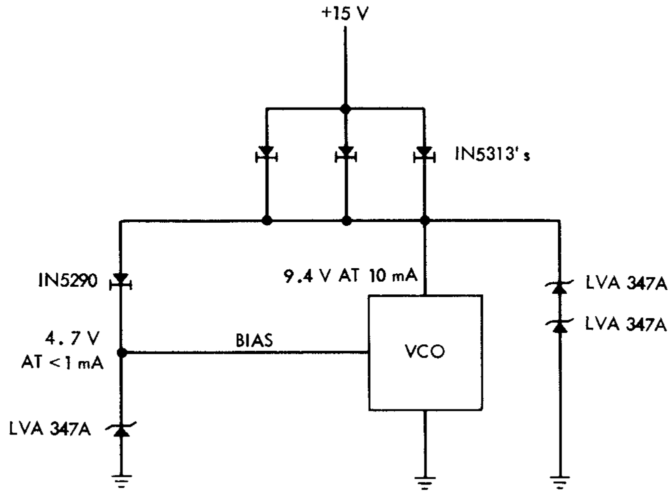

Fig. 2. Circuit used to supply power and bias to the VCO

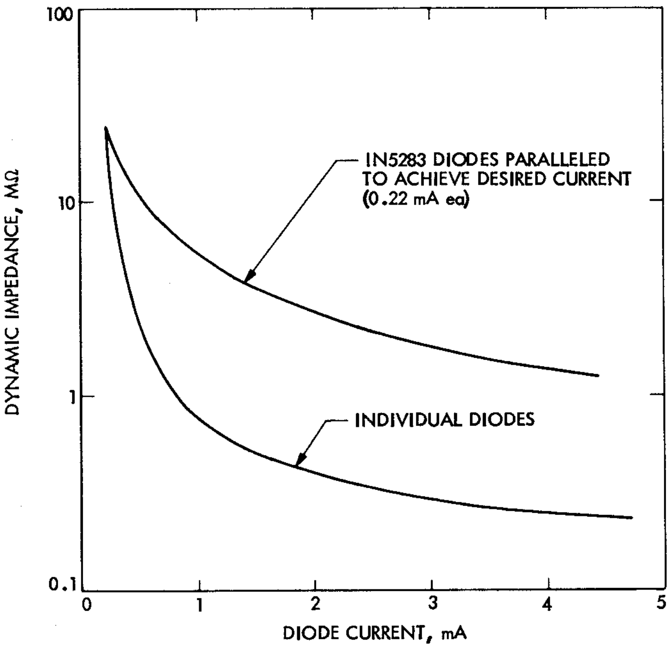

Fig. 3. Constant current diodes dynamic impedance vs current

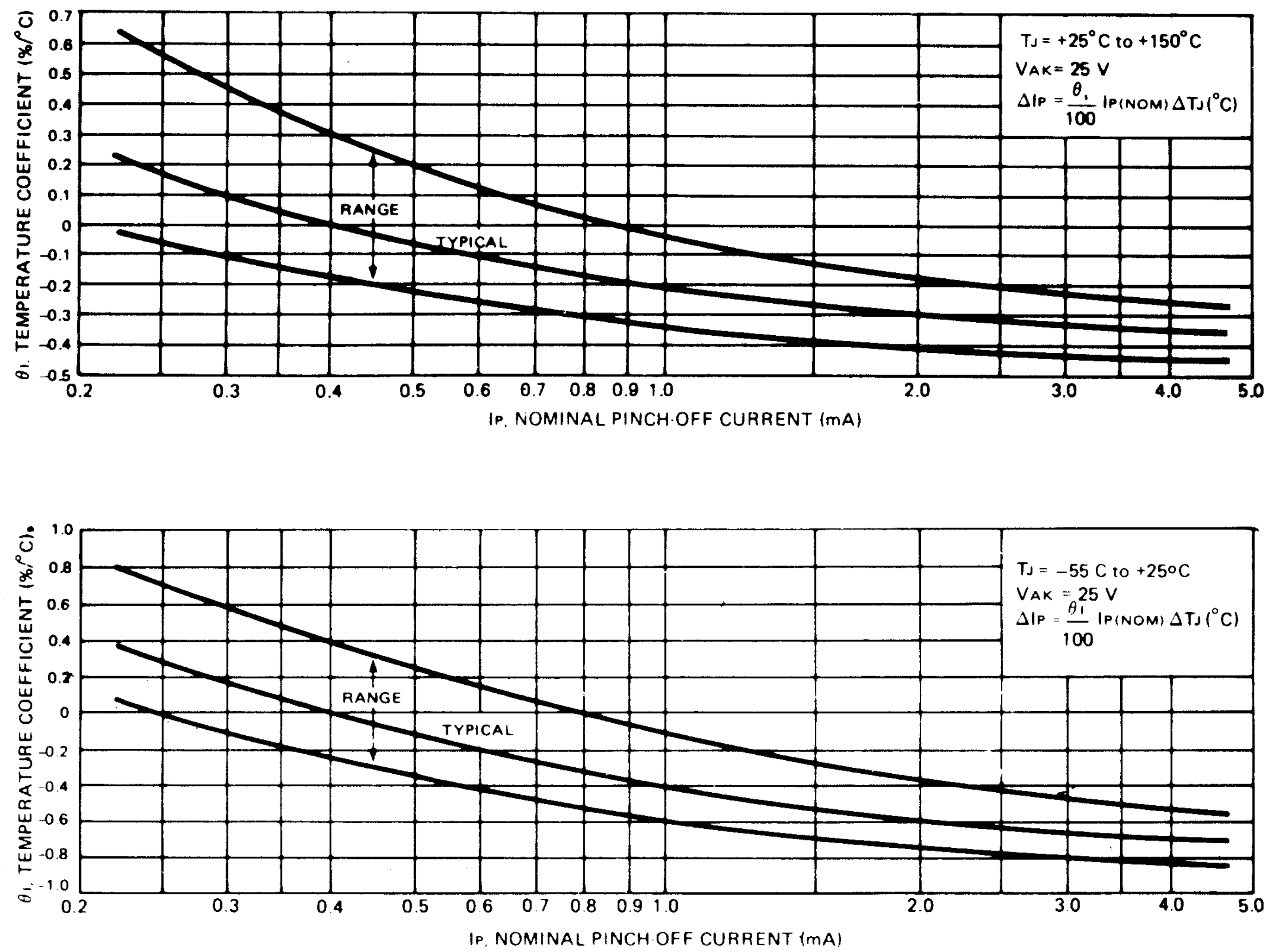

Fig. 4. Constant current diode temperature coefficient

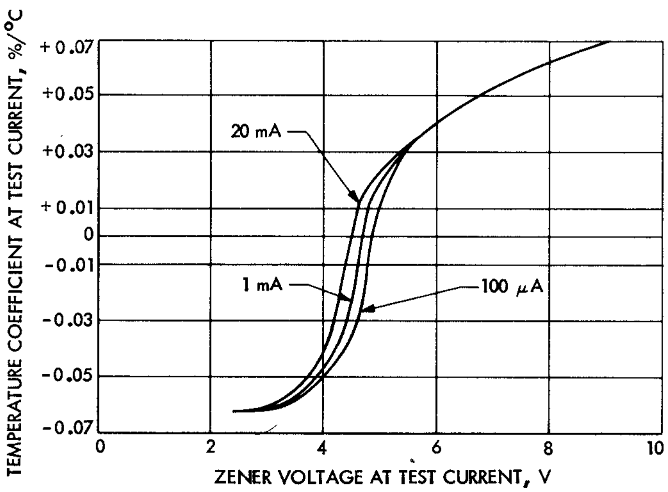

Fig. 5. LVA diode typical temperature coefficient (25 to 100°C)

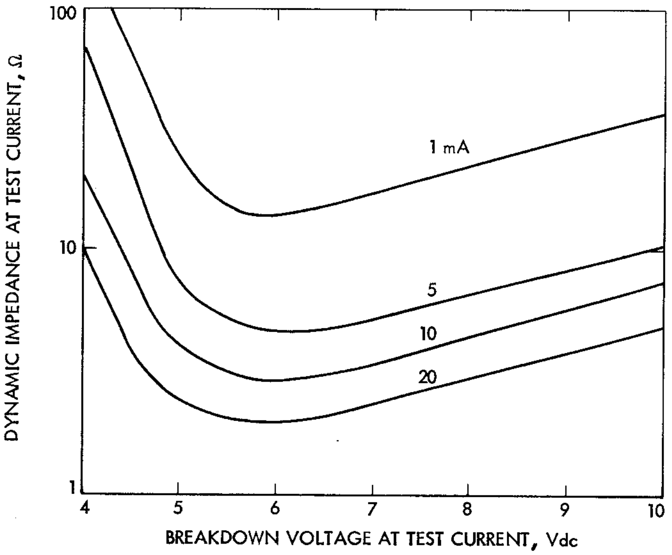

Fig. 6. LVA diode typical dynamic impedances