Technical Article

Find the "Goldilocks" Voltage Reference for Your Application

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So you know you need a voltage reference, but you are not sure how to pick the best one for your application. You have come to the right place! In this post, I will discuss some of the key voltage-reference parameters and help you weigh them based on your application needs in your search for a “Goldilocks” voltage reference that’s “just right.”

First, think about your application and whether you are going to need a shunt reference or a series reference. You don’t have to settle on a topology right away, but it will be helpful to know the best use cases for each. If you are not familiar with the difference between a shunt reference and a series reference, I have written a white paper “Shunt versus series: How to select a voltage-reference topology” on this topic, so check it out.

Second, define the system boundaries of your application. Understanding the physical environment, ambient temperature changes and whether any system calibration will take place are important considerations when looking for a voltage reference. I have outlined a few key parameters below, with some corresponding calculations and questions. At the end of each section are example devices and applications where those devices are often used.

Initial Accuracy

- Relevant questions:
  - “How accurate do I need my reference to be?”
  - “Do I need to perform system calibration?”
- Description:
  - “Initial accuracy” is a specification of how close the actual reference voltage will be to the listed voltage at room temperature. Initial accuracy is typically specified as a percentage of the target voltage. For example, a 2.5V reference with an initial accuracy of +/-1% will have an initial room-temperature voltage between 2.475V and 2.525V, or +/-2.5mV. Keep in mind that this initial accuracy specification may not a high priority if you are performing system calibration.
- Examples:
  - LM4132 series reference: 0.05% accuracy.
  - LM4030 shunt reference: 0.05% accuracy.
- Applications:
  - The LM4030 is popular in factory automation and test/measurement applications because of its high initial accuracy.

Temperature Coefficient

- Relevant question:
  - “Will the system experience high or low temperatures?”
- Description:
  - “Temperature coefficient,” also known as TempCo or temperature drift, is a measure of the change in the reference voltage due to a change in ambient temperature. This delta is typically listed in parts per million/degrees Celsius, which may be a little confusing at first. To calculate the change in the reference voltage, multiply the temperature coefficient by the tested temperature range. For example, the LM4132 has a temperature coefficient of 20ppm/°C over a temperature range of -40°C to 125°C, so the maximum deviation due to temperature is 3,300ppm, or 8.25mV for a 2.5V reference. Even if the application

temperature range is less than the tested temperature range, you must use the full tested temperature range in your calculations because the deviation is not necessarily linear with temperature.

- Examples:
  - LM4132 series reference: 20ppm/°C.
  - REF50xx series reference: 3ppm/°C.
  - LM4050 shunt reference: 50ppm/°C.
- Applications:
  - The LM4132's low temperature coefficient makes it popular in factory automation and control applications, where the environment can stray from a comfortable room-temperature setting.

Thermal Hysteresis

- Relevant question:
  - "Will the system cycle hot and cold temperatures?"
- Description:
  - "Thermal hysteresis" is the difference in reference voltage at room temperature after a full cycle of ambient temperature. A full ambient temperature cycle starts at room temperature and ramps the ambient temperature to the device's minimum and maximum before returning to room temperature. The reference voltage is measured at a temperature of 25°C before and after the temperature cycle, and the difference is recorded as thermal hysteresis. Thermal hysteresis is caused by stresses imposed on the package and the die from thermal effects such as thermal expansion. If your application will be in a fixed temperature environment, thermal hysteresis is less of a concern.
- Example:
  - LM4140 series reference: 20ppm.
- Applications:
  - The LM4140 has very low thermal hysteresis, making it great for factory automation applications such as sensor transmitters.

Long-term Stability

- Relevant question:
  - "How stable will the reference voltage be in the long run?"
- Description:
  - "Long-term stability" is an estimate of the reference voltage deviation over time. This parameter is characterized during product development, where several parts are tested under normal operating conditions for 1,000 hours. The reference voltage is measured before and after the 1,000-hour test, and the difference is recorded in parts per million as the long-term stability. Placing the part on an area of the board where mechanical stresses are minimal can reduce the factors affecting long-term stability. The edges of a typical printed circuit board will see the least deformation for a given stress, while the center will see the most deformation.
- Examples:
  - LM4030 shunt reference: 40ppm.
  - REF50xx series reference: 45ppm.
- Applications:
  - The LM4030 is popular in factory automation and test/measurement applications because of its low long-term drift, where voltage references need to last a long time.

Low-frequency Noise

- Relevant question:
  - "How much noise should I expect to see on the reference voltage?"
- Description:
  - "Low-frequency noise," characterized as a peak-to-peak value between 0.1Hz and 10Hz, is typically not filtered out due to its low-frequency nature. On the other hand, wideband noise is often characterized between 10Hz and 10kHz, and is easier to filter out with a properly sized output capacitor. Low-frequency noise is therefore typically the dominant source of noise for a voltage reference.
- Examples:

  - LM4140 series reference: 2.2µVpp.
  - REF50xx series reference: 3µVpp/V (3µVpp per volt on V_{OUT}; for the REF5025, 3µVpp per volt on V_{OUT} = 7.5µVpp).
- Applications:
  - The low noise of the LM4140 makes it a popular series reference in medical, server and factory-automation applications.

Now that you have a basic understanding of some of the most important voltage-reference parameters, you can more confidently browse the library of voltage references available from Texas Instruments. If you are interested in more detail about topics discussed in this blog, read the white paper, "Voltage Reference Selection Basics."

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