Absolute Pull Range (APR)

When specifying the frequency adjustment range for a VCXO, designers often encounter confusion due to inconsistent terminology across manufacturers' datasheets. This stems from differing methodologies used to describe voltage-controlled frequency tuning. Some manufacturers specify Absolute Pull Range (APR), while others refer to Total Pull Range or Total Pullability. Although these terms are related, they measure different aspects of VCXO performance. Misinterpreting them can lead to incorrect assumptions about the oscillator's tuning capability in each application. This Tech Brief defines Absolute Pull Range (APR) and explains how it differs from Total Pull Range, helping designers make informed decisions when selecting VCXOs for PLL-based systems.

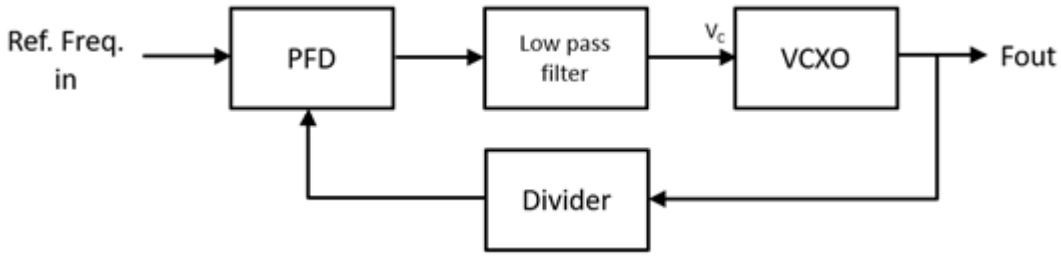
VCXO

A VCXO (Voltage-Controlled Crystal Oscillator) is a type of oscillator that uses a quartz crystal to generate a highly stable output frequency. What differentiates a VCXO from a standard clock oscillator is its ability to finely adjust its frequency through the application of a control voltage to its voltage control pin (VC).

This control voltage is applied to a varactor diode[1] within the oscillator circuit. As the voltage changes, the capacitance of the varactor diode varies, which in turn causes a slight shift in the crystal's resonant frequency. This mechanism allows the oscillator's output frequency to be "pulled", or adjusted, slightly higher or lower within a limited range.

VCXOs are commonly used in Phase-Locked Loop (PLL) applications, where they must lock to and track a reference frequency input. Maintaining lock is critical, and the VCXO's ability to precisely adjust its frequency is essential for reliable operation in such systems.

PLL:



ABSOLUTE PULL RANGE (APR)

Absolute Pull Range (APR) refers to the minimum guaranteed frequency deviation a VCXO can achieve from its nominal frequency across its full control voltage range. Unlike total pull range, APR accounts for all internal sources of frequency variation within the VCXO, including:

- Initial frequency tolerance
- Temperature drift
- Aging effects
- Power supply fluctuations
- Load changes

1. A varactor diode is a specialized semiconductor device that functions as a voltage-dependent variable capacitor. When a voltage is applied across its terminals, its capacitance changes, enabling precise tuning in frequency-sensitive circuits such as oscillators and filters.

APR represents the usable tuning range that remains after compensating for these worst-case frequency errors. It ensures that the VCXO can reliably adjust its frequency to track an external reference under all operating conditions.
The relationship can be expressed as:

APR = Total Pull Range – (Combined Worst-Case Frequency Errors)
By specifying APR, manufacturers provide a more application-relevant metric, allowing designers to confidently assess whether the VCXO can meet the frequency tracking requirements of the reference input source.

EXAMPLE

To illustrate the benefit of specifying APR over total pull range, consider an application where a VCXO must track an input reference with a ±40 ppm variation. If the VCXO datasheet specifies only the Total Pull Range, it must also detail the individual sources of frequency error, and might look like this:

Stability:	Spec (max):
vs. initial tolerance	±20 ppm
vs. temperature	±30 ppm
vs. time (aging)	±10 ppm
vs. input voltage change	±5 ppm
vs. load change	±5 ppm
Specified Pull Range	±100 ppm

In this case, the ±100 ppm Total Pull Range is sufficient to retune the oscillator back to its nominal frequency, compensating for the cumulative internal frequency errors (±70 ppm total). However, this range does not guarantee that the VCXO can also track the ±40 ppm variation of the input reference.

After accounting for internal errors, only ±30 ppm of tuning range remains:

±100 ppm (total pull range) - ±70 ppm (internal errors) = ±30 ppm

This "leftover" range is insufficient to meet the ±40 ppm tracking requirement. To ensure lock across the full reference range, the VCXO would need a Total Pull Range of at least ±110 ppm:

±70 ppm (internal errors) + ±40 ppm (reference tracking) = ±110 ppm

By contrast, if the VCXO's pull range is simply specified as APR = ±40 ppm, this tells the designer that all internal sources of frequency variation have been accounted for, and that the VCXO is guaranteed to have at least ±40 ppm of usable tuning range available to track the reference under all conditions.

In this case, the oscillator's Total Pull Range would be ≥ ±110 ppm, but the APR specification simplifies the design analysis by directly stating the usable range for reference tracking.

CONCLUSION

Defining a VCXO by its Absolute Pull Range (APR) streamlines the design process for PLL engineers. By specifying APR, all internal sources of frequency variation—such as temperature drift, aging, and load changes—are already accounted for.
This eliminates the need for designers to manually calculate the impact of these variations on the oscillator's center frequency.

The only remaining requirement is to ensure that the VCXO's APR meets or exceeds the expected frequency variation of the PLL's input reference. This approach simplifies specification review and product selection for the designer and ensures reliable lock performance under all operating conditions.