

Absolute Phase Measurements with the PicoPak Module

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• Introduction

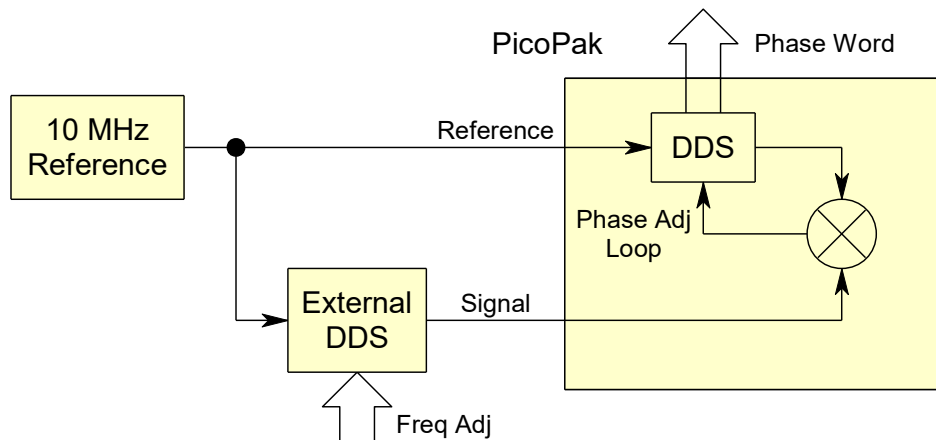
Although intended primarily for making relative phase or frequency measurements from incremental phase data, the PicoPak clock measurement module can be configured to make high-resolution absolute phase measurements by using a frequency source that exactly matches its internal DDS synthesizer.

• PicoPak Operation

The PicoPak operates by adjusting the phase control word of an externally-referenced DDS synthesizer for quadrature with respect to the applied signal being measured. If the phase word is read initially with coherent reference and signal inputs, subsequent phase word readings will indicate absolute phase differences. But the finite tuning resolution of the PicoPak's internal DDS synthesizer generally causes a small frequency offset that produces a phase slew with respect to the initial phase calibration. Because this DDS phase error is a function of time, it is hard to correct for, making absolute phase difference measurements difficult since they cannot simply use the current value of the DDS phase control word.

• PicoPak Setup for Absolute Phase Measurements

The most practical way to make absolute phase measurements with the PicoPak is to use another external DDS synthesizer as the signal source, adjusting it to generate exactly the same frequency as the internal DDS. The PicoPak uses a 32-bit DDS clocked at 120 MHz from a 10 MHz reference. If an equivalent external DDS is used with the same reference and tuning word, the PicoPak's phase slew can be eliminated and absolute signal phase measurements then become practical. The external DDS can be either a DDS per se or an RF signal generator having the same functionality. This setup is shown in the figure below.



After an initial reading, the phase word will directly indicate absolute phase differences in the signal path. The phase word can be read with the "P" command using a simple terminal program. The signal and/or reference leads can be broken and restored while maintaining the same phase reference. Note that the phase word has 14 bits and each count is $360^\circ/2^{14} \approx 0.0220^\circ$ or ≈ 6.10 ps at 10 MHz. It will retrace modulo its MSB which represents the 180° ambiguity of the PicoPak phase control loop.

- **Examples of PicoPak Absolute Phase Measurements**

The simplest way to obtain PicoPak phase data of this type is to manually capture the DDS phase word with a terminal program such as TeraTerm. The DDS phase word is read with the letter “P” command followed by ↵ (Enter) or by the #5 data stream.

For example, one can insert a short length of coax into the signal path to make a phase change. The resulting hex values returned by the “P” command with and without the extra cable length are converted to modulo 2^{14} decimal values, averaged over a few back-and-forth measurements, and converted to a phase difference in picoseconds. A value of 1.63 ns was obtained in this way for a 1-foot length (plus BNC connectors) of RG-58 coax (VP=66%), which certainly seems like a reasonable value. The phase readings had a variation of a few counts and retraced quite well.

A more elaborate version of that test was to use a DPDT switch to insert or remove a 6” length of RG-174 coax. The phase words were captured by the TeraTerm terminal program after activating the #5 data stream with the “S=05” command, and imported into Excel for HEX2DEC conversion, averaging, conversion to time delay and analysis. The average phase change was 835 ps with a standard deviation of about 10 ps, and it retraced to about ± 5 ps. No outliers or discontinuities were seen, and no modulo reductions were needed, but there were intermediate values immediately after the transitions that were excluded from the analysis.

Another simple test was to switch in and out 3 dB of attenuation in the signal line with an ordinary step attenuator. No large phase word changes were observed, and the average phase word hex values were 35D4 and 35C7, a difference of 13 counts or about 79 ps. The phase readings had a variation of only several counts and retraced almost perfectly. The phase change is caused by the slight change in signal path length (equivalent to ≈ 1 inch) and perhaps some PicoPak sensitivity to signal amplitude.

As another example of this phase measurement technique, one can pass the signal through a 2-way RF power splitter and measure the effect of terminating the other port. We measured hex phase readings of B849 and B857 when the 2nd output port was open or terminated into 50Ω , a phase difference of 0E hex = 14 decimal corresponding to 85.4 ps or 0.308° at 10 MHz. There was essentially no phase difference between the two outputs, an average of only 2 counts or about 12 ps (0.04°). Care must be taken with the cables, connectors and connector torque when making measurements like that.

- **Absolute Phase Measurement Software**

PicoPak absolute phase measurements could be supported with a dedicated software application if there was sufficient need to justify the effort. The scale factor of the phase control word is determined by the signal frequency and requires no calibration. Each count corresponds to a phase increment equal to the period of the signal frequency divided by 16,384.

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