ANALOG DEVICES

AN-1154
APPLICATION NOTE

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Optimizing Phase Noise and Spur Performance of the ADF4157 and ADF4158 PLLs Using Constant Negative Bleed

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INTRODUCTION

The phase noise (PN) and integer boundary spur (IBS) performance of the ADF4157 and the ADF4158 can be improved by activating a constant negative bleed current. The biggest improvement is achieved at frequencies at, or close to, integer multiples of the phase frequency detector (PFD) frequency. It is more visible for loop bandwidths greater than 60 kHz; however, it is recommended to use constant negative bleed for all PLL loop bandwidths.

Constant negative bleed current works by adding a constant offset to the charge pump (equivalent to a phase offset in the PLL loop). This has the effect of linearizing the charge pump by moving away from the nonlinear area near the origin (sometimes referred to as the charge pump dead zone). Figure 1 illustrates this phenomenon.

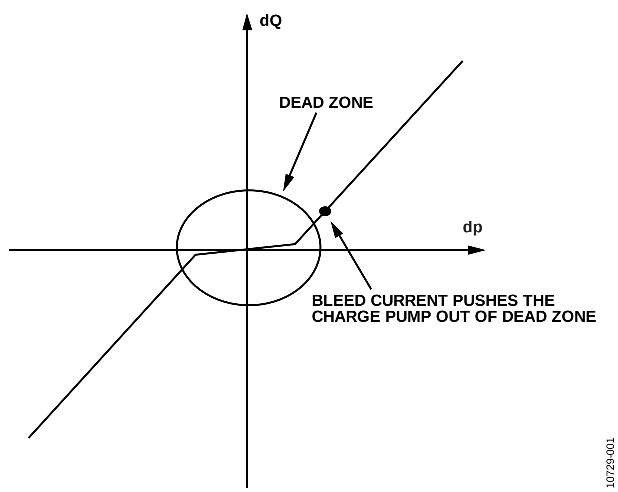

Figure 1. The Effect of Bleed Current on Charge Pump

Without this constant current offset, sigma-delta quantization (dQ) noise can fold back in-band and cause excessive noise or spurs. This aliasing of sigma-delta noise in-band only happens for high resolution sigma-delta modulators (equivalent to high value of modulus) as used on the ADF4157 and ADF4158. These parts require activation of a constant negative bleed current to achieve optimal phase noise and spur performance. This current is not needed for other Fractional-N PLLs with lower value of modulus or Integer-N PLLs.

The constant negative bleed on the ADF4157 and ADF4158 is activated by setting bits DB[24:23] in Register 4 to 0b11.

THE EFFECT OF BLEED CURRENT ON PHASE NOISE AND SPURS

The use of a constant negative bleed only improves phase noise and integer boundary spurs for a certain range of charge pump currents (I_{CP}). For some values of I_{CP}, phase noise and spurs can degrade. This phenomenon was measured for two PFD frequencies, 12.5 MHz and 25 MHz. Each PFD frequency was tested near two consecutive integer channels. The loop filter configuration for each PFD frequency is show in the Appendix.

HOW MEASUREMENTS WERE RECORDED

The measurements were recorded on an EV-ADF4157SD1Z evaluation board. The loop filter was modified for each PFD frequency.

1. The loop was locked at 5800.001 MHz using a PFD frequency of 25 MHz.
2. The charge pump current was set to the minimum value (0.31 mA).
3. Negative bleed was disabled.
4. The phase noise at a 5 kHz offset and the integer boundary spur at 1 kHz were recorded.
5. Negative bleed was enabled.
6. The phase noise at a 5 kHz offset and the integer boundary spur at 1 kHz were recorded.
7. Step 3 to Step 6 were repeated for every charge pump current setting up to 5 mA.
8. Step 2 to Step 7 were repeated with the loop locked at 5825.001 MHz.
9. The loop filter was modified for a PFD frequency of 12.5 MHz, the loop was locked at 5800.001 MHz using a PFD frequency of 12.5 MHz. Step 2 to Step 8 were repeated.

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REVISION HISTORY

5/12—Revision 0: Initial Version

RESULTS

PFD Frequency = 25 MHz

Output frequency = 5800.001 MHz

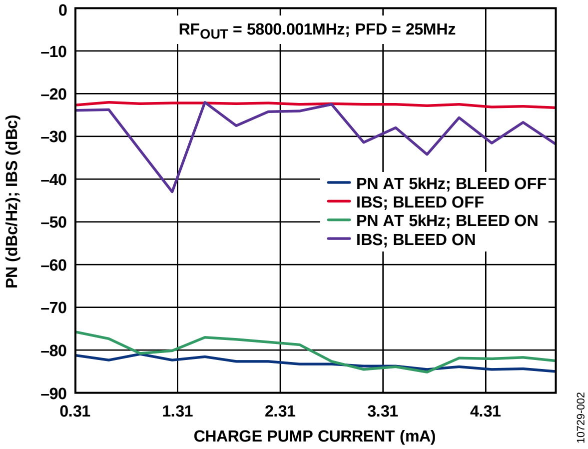

Figure 2. Phase Noise and IBS at 5800.001 MHz with a PFD Frequency = 25 MHz

Output frequency = 5825.001 MHz

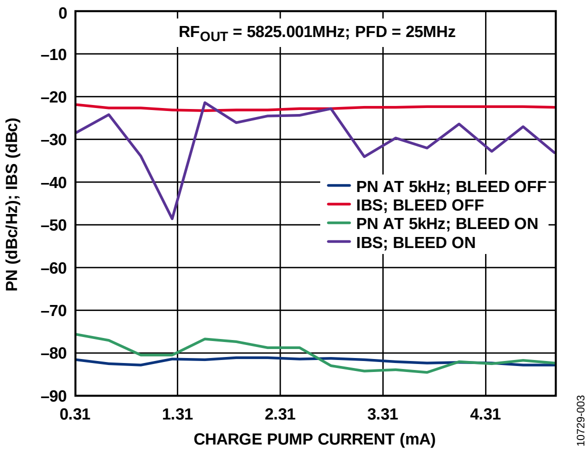

Figure 3. Phase Noise and IBS at 5825.001 MHz with a PFD Frequency = 25 MHz

PFD Frequency = 12.5 MHz

Output frequency = 5800.001 MHz

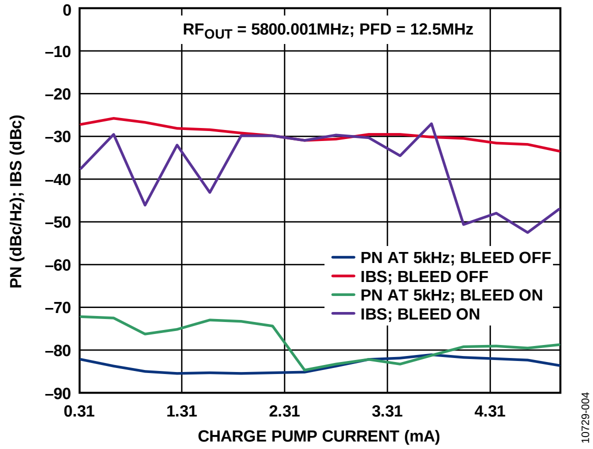

Figure 4. Phase Noise and IBS at 5800.001 MHz with a PFD Frequency = 12.5 MHz

Output frequency = 5825.001 MHz

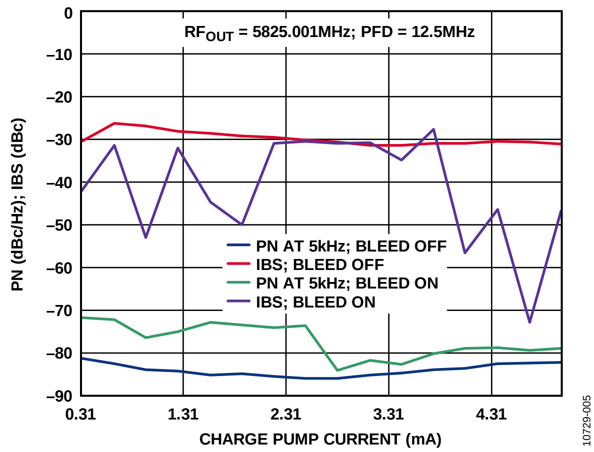

Figure 5. Phase Noise and IBS at 5825.001 MHz with a PFD Frequency = 12.5 MHz

ANALYSIS OF RESULTS

In Figure 2, it can be seen that, for a PFD frequency of 25 MHz, using a charge pump current between 3.13 and 3.75, is the best option for optimum PN and IBS. This is consistent with Figure 3, which shows the values between 3.13 and 3.75 are optimum for both frequencies.

From Figure 4 and Figure 5, it is clear that, for a PFD frequency of 12.5 MHz, no value of charge pump current improves PN, but using a charge pump current of 4.06, and higher, results in a considerable improvement of IBS without too much degradation of PN.

CONCLUSION

For some PFD frequencies, using negative bleed with a particular charge pump current results in improved integer boundary spurs and phase noise.

At other PFD frequencies, using negative bleed does not result in any improvement to phase noise, but can give significant improvement in integer boundary spurs. In this situation, the tradeoff between optimum integer boundary spurs or optimum phase noise depends on the application.

It may be necessary to repeat the measurement in this application note with a specific application's PFD frequency, to find the optimum charge pump current.

APPENDIX

Table 1. Constant Negative Bleed vs. Charge Pump Current Scaling

CP	Current (mA)	Bleed (µA)	% Bleed
0	0.3125	100	32
1	0.625	200	32
2	0.9375	200	21
3	1.25	300	24
4	1.5625	600	38
5	1.875	700	37
6	2.1875	700	32
7	2.5	800	32
8	2.8125	100	4
9	3.125	200	6
10	3.4375	200	6
11	3.75	300	8
12	4.0625	600	15
13	4.375	700	16
14	4.6875	700	15
15	5.00	700	14

Loop Filters

Loop filter configuration for PFD frequency = 25 MHz. Charge pump current = 2.5 mA.

Loop bandwidth	107 kHz
Phase margin	45°
C1	560 pF
R1	680 Ω
C2	6.8 nF
R2	1.2 kΩ
C3	220 pF

Loop filter configuration for PFD frequency = 12.5 MHz. Charge pump current = 2.5 mA.

Loop bandwidth	101 kHz
Phase margin	47°
C1	220 pF
R1	1.2 kΩ
C2	3.3 nF
R2	2.7 kΩ
C3	100 pF

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