DESIGN NOTES

Lower Power Op Amp: Low Noise Reference, Utility Sine Wave

Design Note 1042

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Introduction

Our op amp family has expanded with industry-leading speed versus supply current. The LTC®6258/LTC6259/LTC6260 family (single, dual, quad) provides 1.3MHz at a super low 20µA supply current, with 400µV maximum offset voltage and rail-to-rail input and output. In combination with a 1.8V to 5.25V supply, this op amp enables countless applications requiring uncompromised performance with low power and low voltage at reasonable cost.

Low Noise Reference

The LT6656 is a precision series voltage reference with a low 1µA supply current. In combination with a simple filter, the LTC6258 can lower the LT6656's effective noise and enhance its output current drive capability while maintaining low total power consumption.

Figure 1 shows such a configuration. First, a very low cutoff frequency follows the LT6656 output (R_{IN1} and C_{IN1}, lower than 5Hz cutoff). Large values of R_{IN1} can develop significant offset voltage due to the LTC6258's input bias current. Setting R_{IN1} to 2.7kΩ produces an offset that is lower than the nominal input offset voltage of the op amp. C_{IN1} can be larger or smaller, with more or less filtering accordingly. The voltage withstanding requirement of C_{IN1} is low, resulting in relatively large capacitance in a small volume.

This circuit takes advantage of the ability of the LTC6258 to drive large capacitive loads. Use of a large output capacitor bank attached to the LTC6258 enables significant bypassing of follow-on circuits that use the reference voltage. In total, the combination of LT6656 and LTC6258, in this configuration, develops a reference voltage with low noise, at low power, and with appreciably large bypass capacitance.

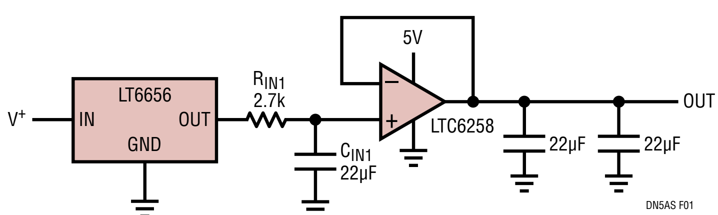

Figure 1. Low Noise Reference

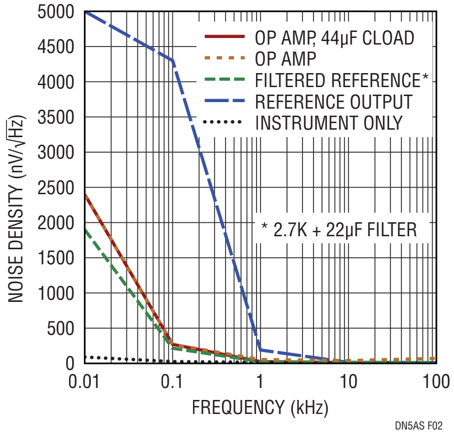

Figure 2. Buffer Noise Density

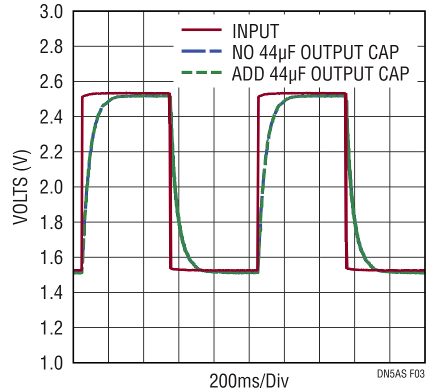

Figure 3. Reference Buffer Transient Response

Voltage spectral noise densities are shown in Figure 2. Greater noise from the reference below 10kHz noticeably drops down once a filter (R_{IN1} and C_{IN1}) follows the reference. The op amp, configured in unity gain, with or without a large 44µF load, remains stable and contributes only a small amount of low frequency noise. Figure 3 shows the transient response of the combination of R_{IN1} – C_{IN1} filter and op amp circuit, with and without the 44µF output capacitor.

Importantly, there is no appreciable degradation in the output voltage accuracy with the introduction of the LTC6258 into the reference circuit. The LT6656 A-grade accuracy is 0.05%. At 1.25V, the error is ±625µV; the B-grade with 0.1% the error is ±1.25mV. Use of the LTC6258 with 400µV offset max will add some nominal output voltage uncertainty, but well within the order of magnitude of the LT6656's initial error.

Measured supply current consumption is 21µA.

Utility Sine Wave

One does not expect to generate a sine wave with –100dBc distortion using a 5V low power op amp. All the same, a bandpass filter using the LTC6258 can combine with an easy-to-use low power oscillator to create a sine wave at low cost, low voltage, and extremely low dissipation.

Active Filter

The bandpass filter of Figure 4 is AC coupled to an input. As a result, the LTC6258 input does not place a burden on the previous stage to develop a particular absolute common mode voltage. A simple resistor divider with RA1 and RA2 provides biasing for the LTC6258 bandpass filter. Pegging the op amp inputs to a fixed voltage helps to reduce distortion that might arise with moving common mode.

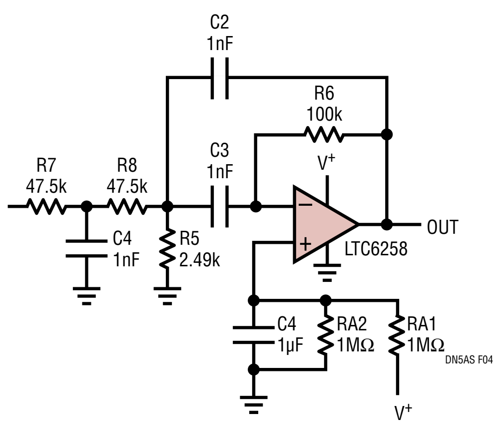

Figure 4. 10kHz Bandpass Filter

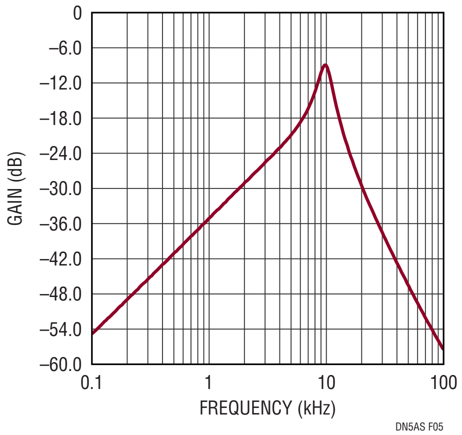

Figure 5. Bandpass Filter Gain/Phase vs Frequency

This filter is centered at 10kHz. The exact resistance and capacitance values can be tweaked upward or downward, depending on whether lowest resistor noise or lowest total supply current is most important. This implementation was optimized for low dissipation by reducing current in the feedback loop. The capacitors C2 and C3 had initially been 4.7nF or higher, with lower resistor values. In the end, 1nF with higher resistors optimized for lower dissipation.

Besides power dissipation, a secondary but no less important aspect of feedback impedance is loading of the op amp rail-to-rail output stage. Heavier loading, such as between 1K and 10K impedance, significantly lowers open loop gain, which in turn affects the accuracy of the bandpass filter. The data sheet suggests A_{VOL} reduces by a factor of 5 from 100kΩ to 10kΩ. Lower C2 and C3 might be feasible, but then R6 becomes even larger, introducing more noise at the output.

The target Q of this bandpass filter is moderate – approximately 3. A moderate Q, rather than a high Q, allows for use of 5% capacitors. Higher Q will demand more accurate capacitors, and very likely higher open loop gain at 10kHz than is available with the feedback impedance load. Naturally, moderate Q results in less attenuation of harmonics than a higher Q.

Adding The Oscillator

A low power sine wave generator can be derived by driving a square wave into the bandpass filter. A complete schematic is shown in Figure 6. The LTC6906 micropower resistor set oscillator easily configures as a 10kHz square wave, and can drive the relatively benign loading seen in the bandpass filter input resistors. Supply current of the LTC6906 at 10kHz is 32.4μA.

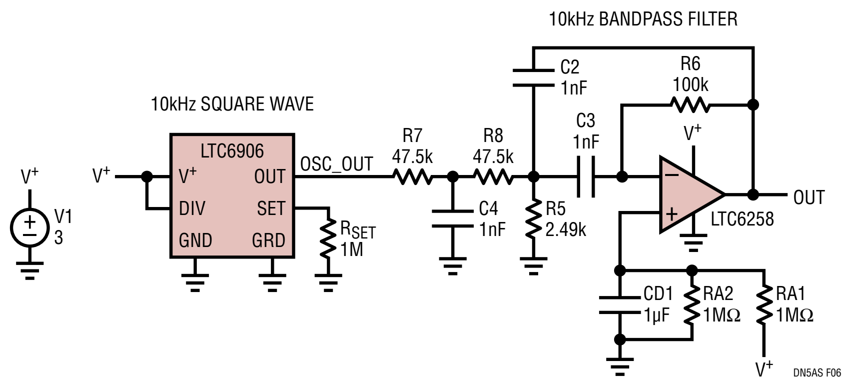

Figure 6. 10kHz Oscillator Circuit Using LTC6906 TimerBlox® Input

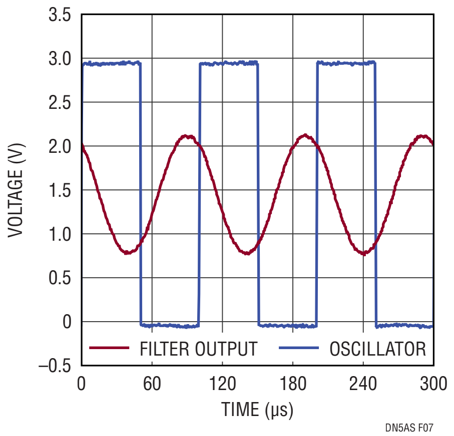

Figure 7. Voltage Waveforms Oscillator and Filter Output

Figure 7 shows the LTC6906 output and bandpass filter output. HD2 of the sine wave is –46.1dBc, and HD3 –32.6dBc. The output was $1.34V_{P-P}$ to $1.44V_{P-P}$ with exact level varying slightly due to finite op amp open loop gain at 10kHz. Total current consumption is below 55µA on a 3V rail.

Other Enhancements

Figure 8 shows optional enhancements. A low power reference takes advantage of the ability of the LTC6906 and LTC6258 to operate on a very low supply. The reference provides 2.5V from a battery input. The fixed 2.5V supply stabilizes the output voltage swing in the presence of varying input voltage. In addition, even lower filter capacitor values with higher resistances reduce LTC6258 loading further, lowering dissipation and improving filter accuracy.

Conclusion

The LTC6258/LTC6259/LTC6260 family (single, dual, quad) provides 1.3MHz gain bandwidth at a low 20µA supply current, with 400µV maximum offset voltage and rail-to-rail input and output. In combination with 1.8V to 5.25V supply, this op amp enables applications requiring excellent performance with low power and low voltage at low cost.

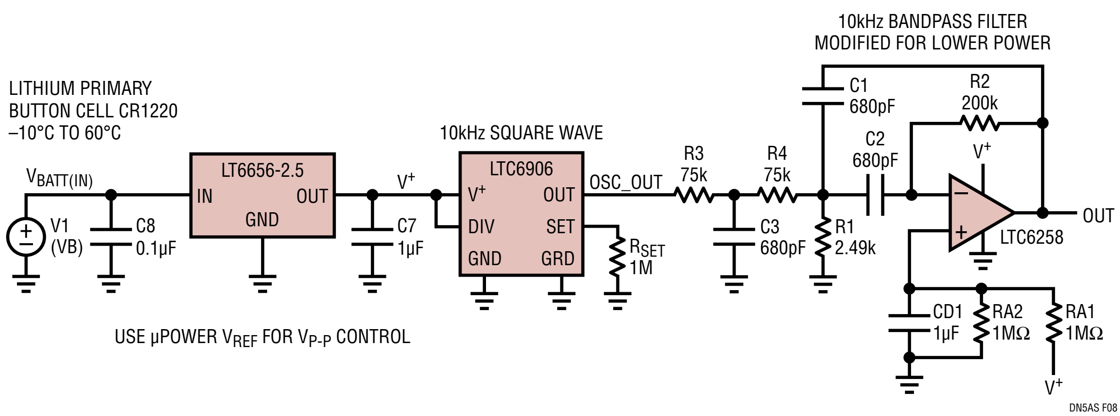

Figure 8. Oscillator and Filter with a Regulated Supply

Data Sheet Download

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