DCDC noise measurement board

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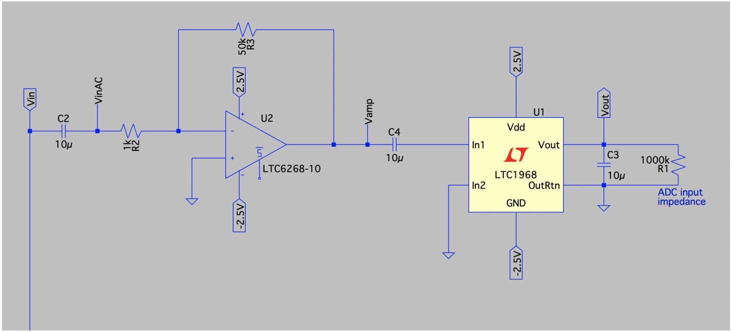
Introduction: measurement of DC noise RMS

- As part of the powerboard QC, we need to measure the noise of the DCDC converter (bPOL) output (1.5V) and identify any outlier that has large noise
  - Previous FFT studies showed the noise spectrum peaks at around 2MHz
  - We need a fast and cheap way to measure the noise (measure $\mathcal{O}(10)$ boards at the same time)
- Options:
  - Fast ADC: expensive, requires many peripherals (clock, FPGA, etc.)
  - Scope: need too many scopes (expensive)
  - Commercial RMS to DC converter chips: focus of today

RMS to DC converter

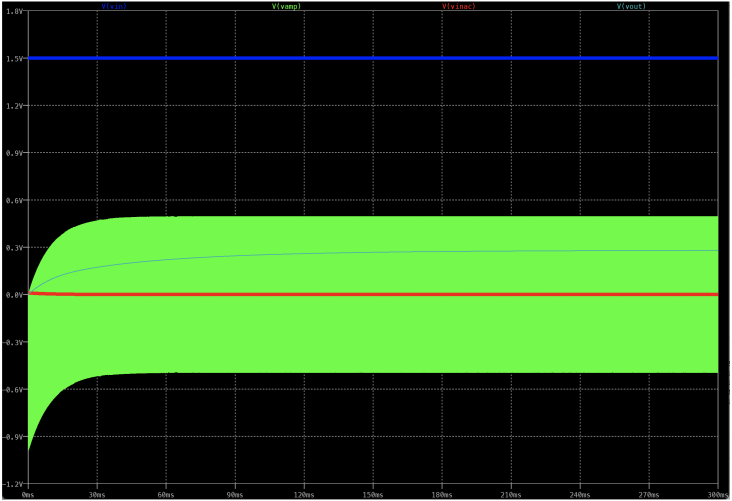
- A device that produces a DC output proportional to the RMS of an input signal
- Some methods:
  - Explicit: squarer + integrator (average) + square root ($V_o = \sqrt{\mathrm{Ave}[V_{in}^2]}$)
  - Implicit: output being fed back to average input as the divisor ($V_o = \mathrm{Ave}[\frac{V_{in}^2}{V_o}]$)
  - $\Delta\Sigma$ method: use a $\Delta\Sigma$ modulator as the divider
- Will use a converter based on $\Delta\Sigma$ method: highest bandwidth among the three methods. The chip we'll use is LTC1968 (-3dB Bandwidth: 15MHz)

Circuit design



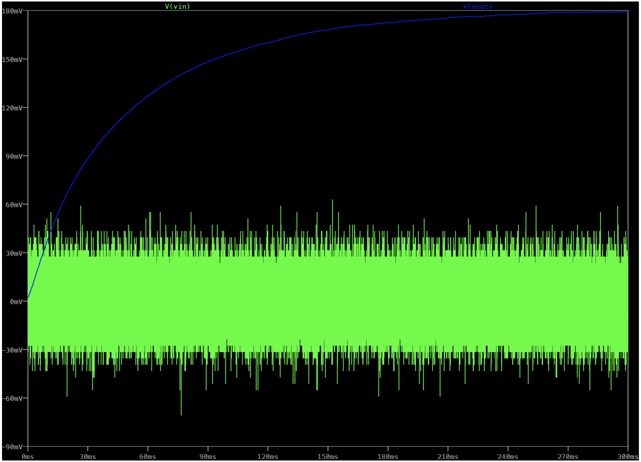
- LTC6268-10: fast op-amp (GBP: 4GHz)
- Amplifier gain: $R_3/R_2 = 50$
- AC input range (peak-to-peak): $\pm$50mV
- Average capacitor (C_3): large capacitance gives better precision, but also takes longer time to settle down the output signal

Circuit output (triangular input)



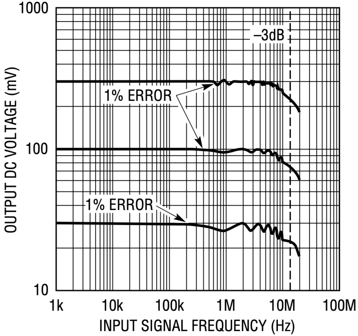
- Input: 1.5V DC with 10mV (Vp) triangular noise
- Output DC value: 280mV (measured RMS = 280/50 = 5.6mV)

Circuit output ("white" noise)

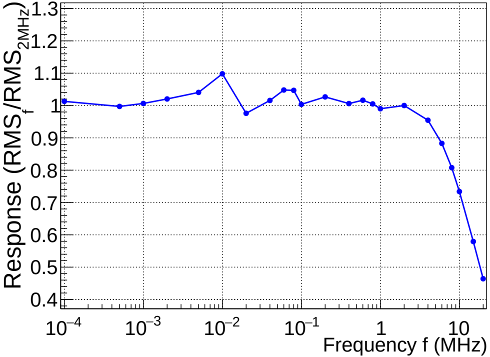


- Input: "white" noise taken with scope on DCDC output with DCDC off (sampling rate: $15.6 \times 10^6 \mathrm{s}^{-1}$)
- Output DC value: 180mV (measured RMS $= 180/50 = 3.6$mV)

Output vs. Frequency

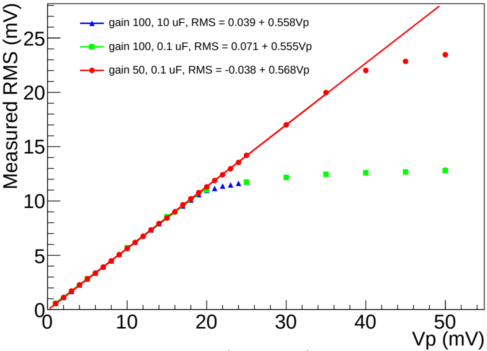


LTC1968 datasheet



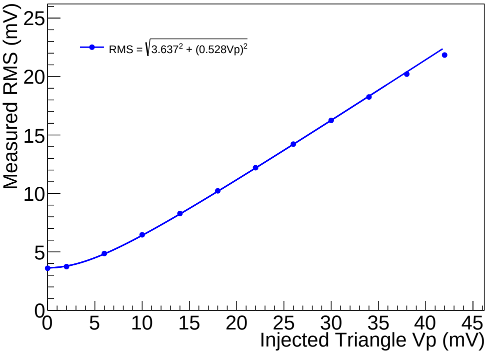
LTspice simulation
(input: 10mV (x50 gain) triangular)

Output RMS vs. input Vp (triangular)



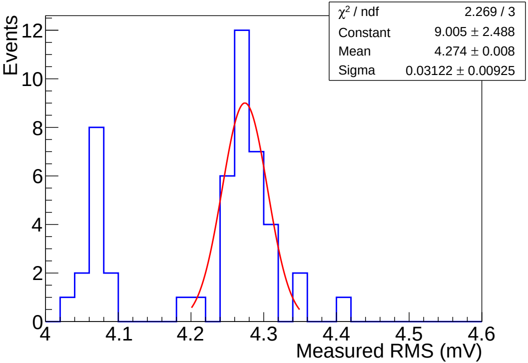
- Input: pure triangular signal (2MHz)
- Gain affects the input range. Will choose gain 50 since the maximum Vp of the "white" noise is around 40mV.
- Average capacitor does not affect the output RMS at 2MHz. To reduce simulation time, will use small capacitance (2uF) in the simulations on next slides.

Output RMS vs. input (triangular + "white" noise)



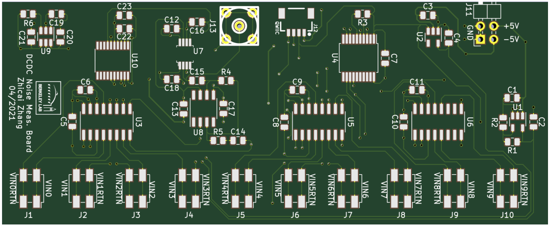
- Input: "white" noise taken by scope + triangular signal (2MHz)
- The output RMS is a good representation of quadrature sum of the RMS of "white" noise and triangular signal
- If we know the distribution of the RMS of the "white" noise, we can know the minimum detectable triangular signal RMS

"White" noise RMS distribution



- Data on two peaks are taken at different times
- For data taken in one time window ($\mathcal{O}(\mathrm{seconds})$), the "white" noise RMS has a spread of less than 1%
- If we perform "white" noise subtraction every time we measure the noise of DCDC converter, we should be able to detect noise with RMS smaller than $\mathcal{O}(1)$ mV.

PCB design



- Auxillary PCB designed to be connected to the powerboard active board
- Measure the output noise of 10 DCDC converters with multiplexers (ADG1309)
- Output of RMS to DC converter measured with a 10-bit ADC (AD7997) and a 1.8V reference voltage (output for 50mV triangular signal: 1.4V)
- Also placed a connector to the amplifier output to allow scope debug

Backup slides

What if input RMS changes with time?