Lecture 27: Gyro Minimum Detectable Signal

Announcements:
- HW#7 online and due Friday, 5/10, at 9 a.m.
- Module 17 is online (on Noise and MDS)
- Project outbrief scheduling done
  - Everyone has received a calendar invite
- Final Exam Info Sheet online
  - Will go through this in class
  - Also pass out some old Final Exam solutions
- Reading: Senturia Chpt. 16
- Lecture Topics:
  - Minimum Detectable Signal
  - Noise
    - Circuit Noise Calculations
    - Noise Sources
    - Equivalent Input-Referred Noise
  - Gyro MDS
    - Equivalent Noise Circuit
    - Example ARW Determination

Last Time:
- Did an example noise calculation and started into gyro MDS … now continue with this
Gyro Minimum Detectable Signal

1. Determine $\overline{N_0^2}$ (total output noise)
   - Use superposition, one source at a time

2. Find $N_0$ in terms of rotation rate $\omega$:
   - Find the rotation-to-noise transfer func:
     \[ \dot{x}_s = F_c \left( \frac{1}{r_x} \Theta (j \omega) \right) \cdot \dot{\omega} R_f \]

\[ \overline{N_{1x}} = \overline{N_0} \cdot \frac{r_f}{r_x} R_f \]
\[ \overline{N_{2x}} = \dot{\omega} R_f \]
\[ \overline{N_{3x}} = N_{1x} \]
\[ \overline{N_{4x}} = \dot{\omega} R_f \]

\[ \overline{N_0} = N_{10} \]
\[ \overline{N_{0x}} = \overline{N_0} \cdot \frac{r_f}{r_x} R_f \]

\[ \overline{N_{0y}} = \frac{r_f}{r_x} \overline{|\Theta(j \omega)|^2 \eta_e^2 R_f^2} \]

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\[ \frac{r_f}{r_x} |\Theta(j \omega)|^2 \eta_e^2 R_f^2 \]

\[ \overline{f_{rv}} = 4 k T R_f \Delta f \]

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\[ \overline{N_0} = \frac{1}{r_f} R_f + N_{10} + 4 k T R_f \left( \overline{1 + |\Theta(j \omega)|^2 \eta_e^2 R_f^2} \right) \Delta f \]

Total output
mean-square voltage value

\[ \overline{N_0} = \frac{1}{r_f} R_f + N_{10} + 4 k T R_f \left( \overline{1 + |\Theta(j \omega)|^2 \eta_e^2 R_f^2} \right) \Delta f \]

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Gyro Minimum Detectable Signal

\[ \Theta(\omega) = \frac{s(\omega \omega_0)}{s^2 + s(\omega \omega_0) + \omega^2} \]

\[ s(\omega) = 0 \]

\[ s^2 \omega_0^2 = \Theta(\omega) \]

\[ \omega_0 = \Theta(\omega) = 0 \]

\[ i_0 = n_e \Phi_s \]

\[ A = \text{scale factor} \]

\[ N_0 = n_e \Phi_s \]

\[ R_f = 2RF \]

\[ Q_s \times \Phi \Theta_f(j \omega) \]

\[ \Omega : \text{radius, from 0 to } \frac{\sqrt{N_0}}{R} \]

\[ \text{minimum detectable signal-to-noise ratio } = 1 \]

\[ n_0 = \sqrt{N_0} \]

\[ A \cdot n_{\text{min}} = \sqrt{N_0} \]

\[ n_{\text{min}} = \sqrt{N_0} \]

\[ \Omega_{\text{min}} = \sqrt{N_0} \]

\[ \text{tangent of out-of-plane} \]

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\[ \frac{\Omega_{\text{min}}}{\sqrt{\omega^2 + \omega_0^2}} \]

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\[ \text{tangent of out-of-plane} \]

Often most interested in spectral density:

\[ \Omega_{\text{min}} = \frac{1}{\sqrt{2}} \times \frac{360}{\text{hr}} \times \frac{10^6}{\text{hr}} \rightarrow \frac{(\Omega_\text{min})}{\sqrt{2} \times (\text{hr})} \]

Angle Random Walk = ARW = \frac{1}{10} \frac{\Omega_{\text{min}}}{\sqrt{\omega^2 + \omega_0^2}} \times \frac{\text{[\%]} \times \text{[hr]}}{\text{[\%]} \times \text{[hr]}}

Easier to determine direction or a function of elapsed time.