Edson W A. Noise in oscillators. *Proc. IRE* **48**:1454-66, 1960.
[General Electric Microwave Lab., Palo Alto, CA]

Electronic oscillators generate waveforms in which successive cycles are not identical either in magnitude or duration. These irregularities are referred to as noise and degrade the performance of communication and radar systems. The paper develops statistical equations that relate the magnitude of these effects to the circuit parameters. [The *SCI*® indicates that this paper has been cited in over 100 publications since 1961.]

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"This paper had its roots in a conversation with my brother, J.O. Edson, around 1938, when I was helping him build his house on Staten Island, New York. He suggested that an oscillator should be regarded as a regenerative amplifier in which the gain was increased so much that noise caused saturation of the output. I reflected on this idea, liked it, and later used it to obtain analytic expressions for noise bandwidth in Chapter 15 of my book, *Vacuum Tube Oscillators*.[1]

"Because I was never fully satisfied with the results from this approach or with results obtained by a few other workers in this field, I continued to seek a better analytic approach. Progress was slow because I had to increase my understanding of statistics and correlation. The breakthrough, if there was one, was use of the noise impulse method suggested by L.C. Hale in a personal conversation (about 1955). It was a difficult paper to write and the manuscript did not reach the Institute of Radio Engineers (IRE) until June 9, 1959.

"At this point a remarkable thing happened: two days later the IRE received a somewhat shorter manuscript from J.A. Mullen[2] and three months later it received another manuscript from M.J.E. Golay,[3] both addressing the same topic. Faced

with this situation the IRE editor asked each of us to review and comment on the other two papers. Although addressing the same problem, the other two papers took different approaches and used different mathematical methods. Finally, after revisions resulting from these and independent reviews, the three papers were published in successive pages of the *Proceedings of the IRE*.

"Publication of these papers led to a flurry of activity, exemplified by a two-day symposium[4] that featured 26 technical papers and four panel discussions. A recent computer search coded to noise in oscillators[5] identified more than 50 publications during the last four years.

"My work was motivated by a long-term interest in oscillators which extends back to 1934 when for a bachelor's degree thesis I built a thyratron inverter to convert DC into AC. A year later, my master's thesis was on an electromechanical system to control the drive of an astronomical telescope by impulses from a pendulum clock. Only much later did I realize that these were, respectively, a relaxation oscillator and a phase-locked loop. The pattern continued with my doctoral thesis, *A Theoretical and Experimental Investigation of the Frequency Stability of Vacuum Tube Oscillators*.[6]

"At least as early as World War II, it was recognized that oscillator noise limits the performance of microwave systems. However, measurement techniques were crude, and there was no adequate theory to guide system design. My paper and those published with it furnished a solid foundation for further work, both analytic and experimental.

"I believe this paper has been widely cited because it was very timely and because it emphasizes the physical basis of oscillator noise, using mathematics only where needed. The results are expressed in simple equations that are easy to apply, and the writing is clear. It probably would not have been published and if published would probably have received little attention had the manuscript been delivered a year later.

"I am pleasantly surprised to learn that this paper is regarded as a classic. The only honor traceable to it that I have received was chairmanship of the session on theory at the 1964 IEEE-NASA Symposium."[4]

1. **Edson W A.** *Vacuum tube oscillators.* New York: Wiley, 1953. p. 367-83.
2. **Mullen I A.** Background noise in nonlinear oscillators. *Proc. IRE* **48**:1467-73, 1960.
   [The *SCI* indicates that this paper has been cited in over 50 publications since 1961.]
3. **Golay M J E.** Monochromaticity and noise in a regenerative electrical oscillator.
   Proc. IRE **48**:1473-7, 1960.
   [The *SCI* indicates that this paper has been cited in over 20 publications since 1961.]
4. **Goddard Space Flight Center.** *Short-term frequency stability: proceedings of the IEEE-NASA Symposium on the Definition and Measurement of Short-Term Frequency Stability, Goddard Space Flight Center, 1964.*
   Washington, DC: US Government Printing Office, 1965. 317 p.
5. **Howe D A, Allan D W & Barnes J A.** Properties of signal sources and measurement methods.
   Proceedings of the Thirty-Fifth Annual Frequency Control Symposium, 28-29 May 1981, Philadelphia, PA.
   Washington, DC: Electronics Industries Association, 1981. p. 667-715.
6. **Edson W A.** *A theoretical and experimental investigation of the frequency stability of vacuum tube oscillators.*
   PhD dissertation. Cambridge, MA: Graduate School of Engineering, Harvard University, 1937.