Stanford

Kwabena Boahen

Professor of Bioengineering and of Electrical Engineering

Bio

BIO

Kwabena Boahen is a Professor of Bioengineering and of Electrical Engineering at Stanford University, with a courtesy appointment in Computer Science, and an investigator in the Bio-X Institute, the System X Alliance, and the Wu Tsai Neurosciences Institute. He founded the Brains in Silicon Lab at Stanford to link neuronal biophysics to cognitive behavior through computational modeling and to emulate the brain with silicon chips through neuromorphic engineering. His interest in neural networks developed soon after he left his native Ghana to pursue undergraduate studies in Electrical and Computer Engineering at Johns Hopkins University, Baltimore, in 1985. He went on to earn a doctorate in Computation and Neural Systems at the California Institute of Technology in 1997. From 1997 to 2005 he was on the faculty of University of Pennsylvania, Philadelphia PA, where he was the inaugural holder of the Skirkanich Term Junior Chair. His research has resulted in over a hundred publications, including a cover story in Scientific American featuring his lab's work on a silicon retina and a silicon tectum that "wire together" automatically (May 2005). He has been invited to give over a hundred seminar, plenary, and keynote talks, including a 2007 TED talk, "A computer that works like the brain", with over seven hundred thousand views. He has received several distinguished honors, including a Packard Fellowship for Science and Engineering (1999) and a National Institutes of Health Director's Pioneer Award (2006). He was elected a fellow of the American Institute for Medical and Biological Engineering (2016) and of the Institute of Electrical and Electronic Engineers (2016) in recognition of his lab's work on Neurogrid, an iPad-size platform that emulates the cerebral cortex in biophysical detail and at functional scale, a combination that hitherto required a supercomputer. He has led several multi-university, multi-investigator research efforts, including one that raised the level of abstraction at which neuromorphic chips are 'programmed' by co-designing hardware and software (Brainstorm Project). A spin-out from his Stanford lab, Femtosense Inc (2018), is commercializing this breakthrough.

ACADEMIC APPOINTMENTS

- Professor, Bioengineering
- Professor, Electrical Engineering
- Member, Bio-X
- Member, Wu Tsai Neurosciences Institute

HONORS AND AWARDS

- Fellow, American Institute for Medical and Biological Engineering (2016)
- Fellow, Institute of Electrical and Electronic Engineers (2016)
- NIH Director's Pioneer Award, National Institute of Health (2006-2011)
- NIH Director's Transformative Research Award, National Institute of Health (2011-2016)
- Young Investigator Award, Office of Naval Research (2002-2005)

- Faculty Early Career Award, National Science Foundation (2001-2006)
- Fellowship in Science and Engineering, Packard Foundation (1999-2004)

PROFESSIONAL EDUCATION

- PhD, Caltech (1997)

LINKS

- Brains in Silicon: https://web.stanford.edu/group/brainsinsilicon/

Research & Scholarship

CURRENT RESEARCH AND SCHOLARLY INTERESTS

Boahen's group analyzes neural behavior computationally to elucidate principles of neural design at the cellular, circuit, and systems levels; and synthesizes neuromorphic electronic systems that scale energy-use with size as efficiently as the brain does. This interdisciplinary research program bridges neurobiology and medicine with electronics and computer science, bringing together these seemingly disparate fields.

Teaching

COURSES

2025-26

- Bioengineering Systems Prototyping Lab: BIOE 123 (Win)
- Neuromorphics: Brains in Silicon: BIOE 313, EE 207 (Spr)

2024-25

- Bioengineering Systems Prototyping Lab: BIOE 123 (Win)
- Neuromorphics: Brains in Silicon: BIOE 313, EE 207 (Spr)

2023-24

- Bioengineering Systems Prototyping Lab: BIOE 123 (Win)
- Neuromorphics: Brains in Silicon: BIOE 313, EE 207 (Spr)

2022-23

- Bioengineering Systems Prototyping Lab: BIOE 123 (Win)
- Neuromorphics: Brains in Silicon: BIOE 313, EE 207 (Spr)

STANFORD ADVISEES

Doctoral Dissertation Reader (AC)

Hugo Chen, Anna Kochnev Goldstein, Laura Moreno Carbonell, Shreyas Muralidharan, Ethan Trepka

Doctoral Dissertation Advisor (AC)

Max Kanwal, Leo Liu, Kyrus Mama

Master's Program Advisor

Natasha Goenawan, Zara Jahan, Julia Kao-Sowa, Sawyer Lai, Diwen Shi, Madeline Smith, Vincent Thai, Kira Tran, Sydney Yan, Nico Zezza

Doctoral (Program)

Muhammad Abdulla, Vivek Chundru, Adam Dai, Mary Kate Gale, Madison George, Madeline Hays, Devrath Iyer, Max Kanwal, Zhaoyang Li, Yize Liu, Laura Moreno Carbonell, AJ Phillips, Sabrina Reguyal, Issah Samori, Hery Shin, James Skelly, Emily Steiner, Caelia Thomas, Selina Weber

GRADUATE AND FELLOWSHIP PROGRAM AFFILIATIONS

- Biomedical Data Science (Phd Program)
- Neurosciences (Phd Program)

Publications

PUBLICATIONS

- **A Low Thermal Sensitivity Subthreshold-Current to Pulse-Frequency Converter for Neuromorphic Chips** *IEEE JOURNAL ON EMERGING AND SELECTED TOPICS IN CIRCUITS AND SYSTEMS*
  Benjamin, B., Smith, R. L., Boahen, K. A.
  2023; 13 (4): 956-964
- **Catalyzing next-generation Artificial Intelligence through NeuroAI.** *Nature communications*
  Zador, A., Escola, S., Richards, B., Olveczky, B., Bengio, Y., Boahen, K., Botvinick, M., Chklovskii, D., Churchland, A., Clopath, C., DiCarlo, J., Ganguli, S., Hawkins, et al
  2023; 14 (1): 1597
- **Multi-gate FeFET Discriminates Spatiotemporal Pulse Sequences for Dendrocentric Learning** *2023 International Electron Devices Meeting (IEDM)*
  Chen, H., Beauchamp, M., Toprasertpong, K., Huang, F., Le Coeur, L., Nemec, T., Boahen, K.
  2023: pp. 1-4
- **Dendrocentric learning for synthetic intelligence.** *Nature*
  Boahen, K.
  2022; 612 (7938): 43-50
- **Optimal noise level for coding with tightly balanced networks of spiking neurons in the presence of transmission delays.** *PLoS computational biology*
  Timcheck, J., Kadmon, J., Boahen, K., Ganguli, S.
  2022; 18 (10): e1010593
- **Cortical state dynamics and selective attention define the spatial pattern of correlated variability in neocortex.** *Nature communications*
  Shi, Y., Steinmetz, N. A., Moore, T., Boahen, K., Engel, T. A.
  1800; 13 (1): 44
- **Neurogrid simulates cortical cell-types, active dendrites, and top-down attention** *NEUROMORPHIC COMPUTING AND ENGINEERING*
  Benjamin, B., Steinmetz, N. A., Oza, N. N., Aguayo, J. J., Boahen, K.
  2021; 1 (1)
- **Braindrop: A Mixed-Signal Neuromorphic Architecture With a Dynamical Systems-Based Programming Model** *PROCEEDINGS OF THE IEEE*
  Neckar, A., Fok, S., Benjamin, B., Stewart, T. C., Oza, N. N., Voelker, A. R., Eliasmith, C., Manohar, R., Boahen, K.
  2019; 107 (1): 144–64
- **A Neuromorph's Prospectus** *COMPUTING IN SCIENCE & ENGINEERING*
  Boahen, K.
  2017; 19 (2): 14-15
- **Selective modulation of cortical state during spatial attention** *SCIENCE*
  Engel, T. A., Steinmetz, N. A., Gieselmann, M. A., Thiele, A., Moore, T., Boahen, K.
  2016; 354 (6316): 1140-1144
- **Neurogrid: A Mixed-Analog-Digital Multichip System for Large-Scale Neural Simulations** *PROCEEDINGS OF THE IEEE*
  Benjamin, B. V., Gao, P., Mcquinn, E., Choudhary, S., Chandrasekaran, A. R., Bussat, J., Alvarez-Icaza, R., Arthur, J. V., Merolla, P. A., Boahen, K.
  2014; 102 (5): 699-716
- **A silicon retina that reproduces signals in the optic nerve** *JOURNAL OF NEURAL ENGINEERING*
  Zaghloul, K. A., Boahen, K.

2006; 3 (4): 257-267

- **Hierarchical Event Readout with Asynchronous Pipelined Opportunistic Merges**
  Liu, L., Boahen, K., IEEE COMPUTER SOC
  IEEE COMPUTER SOC.2025: 108-117
- **An Analytical MOS Device Model With Mismatch and Temperature Variation for Subthreshold Circuits** *IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS II-EXPRESS BRIEFS*
  Benjamin, B., Smith, R. L. L., Boahen, K. A. A.
  2023; 70 (6): 1826-1830
- **PinT: Polynomial in Temperature Decode Weights in a Neuromorphic Architecture**
  Reid, S., Montoya, A., Boahen, K., IEEE
  IEEE.2019: 60–65
- **Optimizing an Analog Neuron Circuit Design for Nonlinear Function Approximation**
  Neckar, A., Stewart, T. C., Benjamin, B. V., Boahen, K., IEEE
  IEEE.2018
- **A Serial H-Tree Router for Two-Dimensional Arrays**
  Fok, S., Boahen, K., IEEE
  IEEE.2018: 78–85
- **Live Demonstration: Optimizing an Analog Neuron Circuit Design for Nonlinear Function Approximation**
  Neckar, A., Stewart, T., Benjamin, B., Boahen, K., IEEE
  IEEE.2018
- **A Population-Level Approach to Temperature Robustness in Neuromorphic Systems**
  Kauderer-Abrams, E., Gilbert, A., Voelker, A., Benjamin, B., Stewart, T. C., Boahen, K., IEEE
  IEEE.2017: 2723–26
- **Stochastic and Adversarial Online Learning without Hyperparameters**
  Cutkosky, A., Boahen, K.
  edited by Guyon, Luxburg, U. V., Bengio, S., Wallach, H., Fergus, R., Vishwanathan, S., Garnett, R.
  NEURAL INFORMATION PROCESSING SYSTEMS (NIPS).2017
- **Extending the Neural Engineering Framework for Nonideal Silicon Synapses**
  Voelker, A. R., Benjamin, B. V., Stewart, T. C., Boahen, K., Eliasmith, C., IEEE
  IEEE.2017: 2086–89
- **Calibrating Silicon-Synapse Dynamics using Time-Encoding and Decoding Machines**
  Kauderer-Abrams, E., Boahen, K., IEEE
  IEEE.2017: 2525–28
- **A Multicast Tree Router for Multichip Neuromorphic Systems** *IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS I-REGULAR PAPERS*
  Merolla, P., Arthur, J., Alvarez, R., Bussat, J., Boahen, K.
  2014; 61 (3): 820-833
- **Potassium conductance dynamics confer robust spike-time precision in a neuromorphic model of the auditory brain stem** *JOURNAL OF NEUROPHYSIOLOGY*
  Wittig, J. H., Boahen, K.
  2013; 110 (2): 307-321
- **Design and validation of a real-time spiking-neural-network decoder for brain-machine interfaces.** *Journal of neural engineering*
  Dethier, J., Nuyujukian, P., Ryu, S. I., Shenoy, K. V., Boahen, K.
  2013; 10 (3): 036008-?
- **Dynamical System Guided Mapping of Quantitative Neuronal Models Onto Neuromorphic Hardware** *IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS I-REGULAR PAPERS*
  Gao, P., Benjamin, B. V., Boahen, K.
  2012; 59 (10): 2383-2394

- **Inferior olive mirrors joint dynamics to implement an inverse controller** *BIOLOGICAL CYBERNETICS*
  Alvarez-Icaza, R., Boahen, K.
  2012; 106 (8-9): 429-439

- **A Superposable Silicon Synapse with Programmable Reversal Potential** *34th Annual International Conference of the IEEE Engineering-in-Medicine-and-Biology-Society (EMBS)*
  Benjamin, B. V., Arthur, J. V., Gao, P., Merolla, P., Boahen, K.
  IEEE.2012: 771–774

- **Deep cerebellar neurons mirror the spinal cord's gain to implement an inverse controller** *BIOLOGICAL CYBERNETICS*
  Alvarez-Icaza, R., Boahen, K.
  2011; 105 (1): 29-40

- **Silicon-Neuron Design: A Dynamical Systems Approach.** *IEEE transactions on circuits and systems. I, Regular papers : a publication of the IEEE Circuits and Systems Society*
  Arthur, J. V., Boahen, K.
  2011; 58 (5): 1034-1043

- **Space coding by gamma oscillations in the barn owl optic tectum** *JOURNAL OF NEUROPHYSIOLOGY*
  Sridharan, D., Boahen, K., Knudsen, E. I.
  2011; 105 (5): 2005-2017

- **A Brain-Machine Interface Operating with a Real-Time Spiking Neural Network Control Algorithm.** *Advances in neural information processing systems*
  Dethier, J., Nuyujukian, P., Eliasmith, C., Stewart, T., Elassaad, S. A., Shenoy, K. V., Boahen, K.
  2011; 2011: 2213-2221

- **Spiking Neural Network Decoder for Brain-Machine Interfaces.** *International IEEE/EMBS Conference on Neural Engineering : [proceedings]. International IEEE EMBS Conference on Neural Engineering*
  Dethier, J., Gilja, V., Nuyujukian, P., Elassaad, S. A., Shenoy, K. V., Boahen, K.
  2011

- **Neuromorphic silicon neuron circuits** *FRONTIERS IN NEUROSCIENCE*
  Indiveri, G., Linares-Barranco, B., Hamilton, T. J., van Schaik, A., Etienne-Cummings, R., Delbruck, T., Liu, S., Dudek, P., Hafliger, P., Renaud, S., Schemmel, J., Cauwenberghs, G., Arthur, et al
  2011; 5

- **Spiking Neural Network Decoder for Brain-Machine Interfaces** *5th International IEEE Engineering-in-Medicine-and-Biology-Society (EMBS) Conference on Neural Engineering (NER)*
  Dethier, J., Gilja, V., Nuyujukian, P., Elassaad, S. A., Shenoy, K. V., Boahen, K.
  IEEE.2011: 396–399

- **A 1-change-in-4 Delay-Insensitive Interchip Link** *International Symposium on Circuits and Systems Nano-Bio Circuit Fabrics and Systems (ISCAS 2010)*
  Chandrasekaran, A., Boahen, K.
  IEEE.2010: 3216–3219

- **A Silicon Cochlea With Active Coupling** *IEEE TRANSACTIONS ON BIOMEDICAL CIRCUITS AND SYSTEMS*
  Wen, B., Boahen, K.
  2009; 3 (6): 444-455

- **Nonlinear Influence of T-Channels in an in silico Relay Neuron** *IEEE TRANSACTIONS ON BIOMEDICAL ENGINEERING*
  Hynna, K. M., Boahen, K. A.
  2009; 56 (6): 1734-1743

- **A Delay-Insensitive Address-Event Link** *15th IEEE International Symposium on Asynchronous Circuits and Systems*
  Lin, J., Boahen, K.
  IEEE.2009: 50–57

- **Synchrony in silicon: The gamma rhythm** *IEEE TRANSACTIONS ON NEURAL NETWORKS*
  Arthur, J. V., Boahen, K. A.

2007; 18 (6): 1815-1825

- **Neurotech for neuroscience: Unifying concepts, organizing principles, and emerging tools** *JOURNAL OF NEUROSCIENCE*
  Silver, R., Boahen, K., Grillner, S., Kopell, N., Olsen, K. L.
  2007; 27 (44): 11807-11819
- **Expandable networks for neuromorpbic chips (vol 54, pg 301, 2007)** *IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS I-REGULAR PAPERS*
  Merolla, P. A., Arthur, J. V., Shi, B. E., Boahen, K. A.
  2007; 54 (4): 925-926
- **Thermodynamically equivalent silicon models of voltage-dependent ion channels** *NEURAL COMPUTATION*
  Hynna, K. M., Boahen, K.
  2007; 19 (2): 327-350
- **Silicon neurons that burst when primed** *IEEE International Symposium on Circuits and Systems*
  Hynna, K. M., Boahen, K.
  IEEE.2007: 3363–3366
- **Silicon neurons that inhibit to synchronize** *IEEE International Symposium on Circuits and Systems*
  Arthur, J. V., Boahen, K.
  IEEE.2007: 1186–1186
- **Silicon neurons that inhibit to synchronize** *2006 IEEE INTERNATIONAL SYMPOSIUM ON CIRCUITS AND SYSTEMS, VOLS 1-11, PROCEEDINGS*
  Arthur, J. V., Boahen, K.
  2006: 4807-?