Tech Brief

Evaluation of Smart Chip Technology

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HERE'S THE PROBLEM

Gas recognition technology has seen tremendous progress recently as a result of the wide spread utilization ranging from applications in the automotive industry to food processing to environmental engineering. Current instruments used for vehicle emission testing, to quantify the amount of unwanted gasses, although very sophisticated and able to reliably measure as low as a few parts per million, are very sensitive to environmental changes such as temperature, humidity, oxygen content, and sometimes non-gaseous content and particulates.

AND, HERE'S THE SOLUTION

By producing a type of signal processing technique, with an array of off-the-shelf sensors, called a reinforcement artificial neural network that will improve vehicle emission testing and reduce external environmental effect.
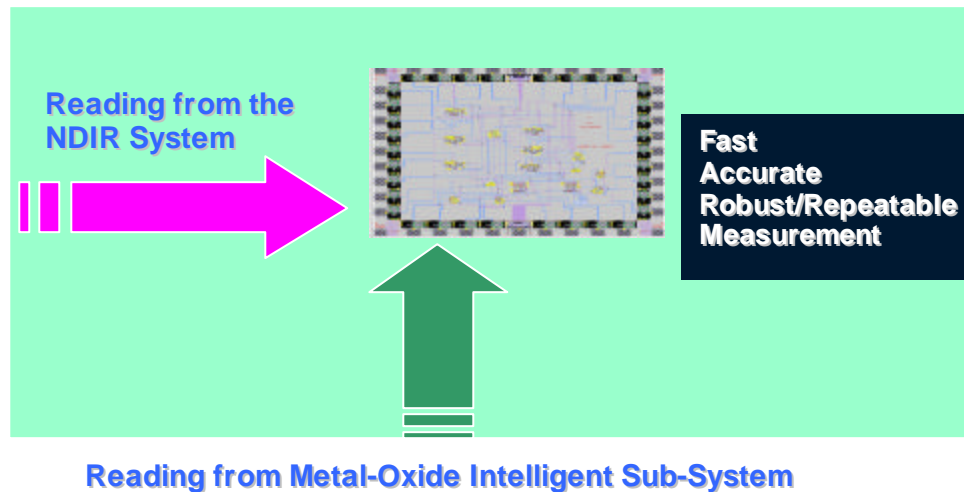
THESE ARE OBJECTIVES…

▪ To propose, build, and test a very large scale integration design and implementation of a Reinforcement Artificial Neural Network (RANN) that will improve emission testing.

▪ To obtain more accurate and more reliable emission testing results.

HERE IS WHAT WE DID…

Gas recognition technology currently includes signal processing techniques that take off-the–shelf sensor arrays as inputs and outputs. This results in a fast, accurate, highly sensitive and repeatable reading. Very Large Scale Integration Application Specific Integrated Circuit (VLSI ASIC) is used to provide a high quality gas recognition system. However, current methods are very sensitive to environmental changes such as

temperature, humidity, oxygen content, and sometimes non-gaseous content and particulates. This project explores the development and performance of a signal processing technique called reinforcement artificial neural networks with an array of off-the-shelf sensors used to enhance the output of vehicle emission instruments.

The project began with an introduction to the workings of Artificial Neural Networks (ANN), which represent collective, non-algorithmic, low-precision, nonlinear computing machines. The ANN learns through training from examples, and is data controlled. They consist of massively interconnected networks with simple computational units (neurons) as its nodes. ANN is inspired by the human brain and its ability to solve problems that do not have exact solutions, and the ability to learn from experience.

Reading from the NDIR System

**Fast
Accurate
Robust/Repeatable
Measurement**

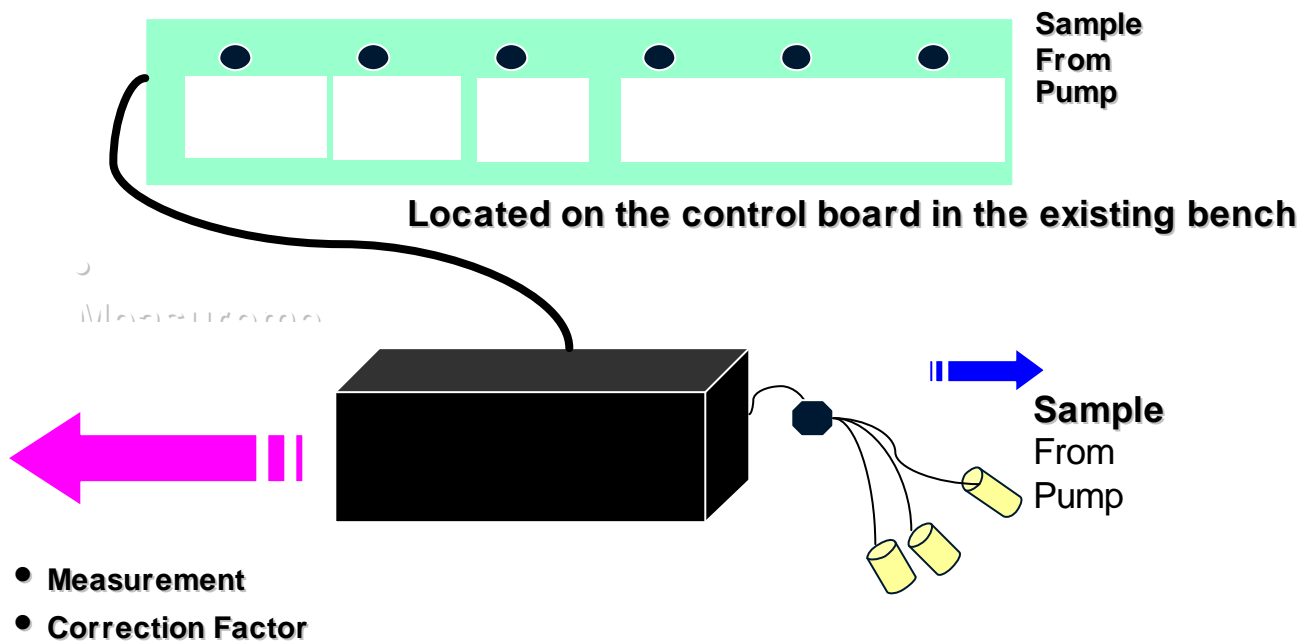**Reading from Metal-Oxide Intelligent Sub-System**

Analog circuit implementation was the approach considered in this project due to its advantages of being area efficient, truly real-time, simple, and highly interconnected. The ANN learns through reinforcement learning. The system uses stochastic methods to explore the environment, and tries to maximize the reward reinforcement signal.

A compact four quadrant P-type Metal Oxide Semiconductor (PMOS) Anaglog Multiplier was designed. The circuit consists of twelve P-type Metal Oxide Semiconductor and two N-type Metal Oxide Semiconductor transistors. The signal output of this multiplier is voltage, which makes it easy to interface with other analog circuits.

The next step was the design of a novel multi-input Metal Oxide Semiconductor (MOS) analog adder, consisting of $2n + 2$ NMOS transistors. The characteristics of this circuit made it perfect for being the adder cell to the neural network applications. A 3-input analog adder was designed, and a Very Large Scale Integration Circuit (VLSIC) implemented as part of a Reinforcement Artificial Neural Network (RANN).

Two analog comparators are required in the RANN because the reference values can be adjusted externally. These reference values are what determine the lower/upper levels of neuron output, which indicate the existence of the targeted gas. The output has two distinct values as the neuron output is either higher or lower than the reference value.

The circuits were then utilized in design and build of a Reinforcement Neural Network (RNN) to be used as a signal processing unit for vehicle emission evaluation. It was necessary that the VLSI system be able to recognize a number of organic/non-organic volatile chemicals and quantify them. A simple approach of using a set of elements of relatively broad, overlapping selectivity profiles was used. The set of sensors provides a pattern that can be interpreted as an indication of the existence of certain chemicals in the environment.

Sample From Pump

Located on the control board in the existing bench

Sample From Pump

- **Measurement**
- **Correction Factor**

The wide response sensors were interfaced to an electronic system that conditions the input signals, improves signal-to-noise ratio, and employs a pattern recognition algorithm to determine to which volatile chemical the set of sensors are exposed.

The Artificial Neural Networks were found to be advantageous because they learn by example, rather than using a modeled environment and then having to account for noise and sensor fluctuations. The ANN contains a database consisting of the olfactory system response and chemical names. Once it is exposed to an unknown volatile chemical, it selects from a gas on this list, and the environment provides a simple "right" or "wrong" feedback.

The ANN learns by examples or experience and is data controlled. In concluding the project, a set of examples was prepared. The following procedure was established to describe the data collection:

A. Power the system up with TGS813, TGS203, and TGS2620 and wait for the steady state condition by monitoring the output voltage of the sensors to reach its steady state voltage.
B. Inject the standard low gas levels (corresponds to low vehicle emission) into the box.
C. Wait for the system to reach steady stage voltages.
D. Read the output voltages of the sensors.
E. Flush the system using pure nitrogen (zero gas).
F. Repeat steps A-E with target gas concentrations mid1, mid2, and high.
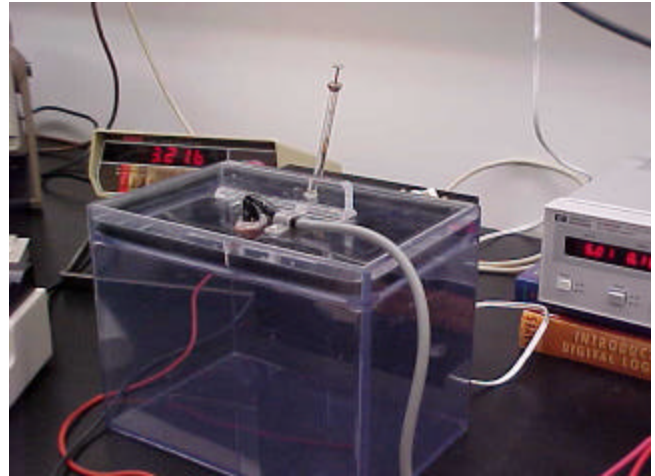
CONCLUSION:

Voltage mode, all-MOS, compact, and analog computational standard cells for neural network applications have been utilized to design an analog RANN. The RANN has been designed and VLSI implemented using 1.5um technology. The interfacing between these circuits has displayed compatibility and thus eliminates the need for additional matching circuitry, reduces the silicon area, and improves the system performance, accuracy, and repeatability.

The implemented analog RANN was used in this gas recognition application successfully, and the number of pads limited the number of neurons in the Tiny Chip to two.

The proposed RANN was successfully trained and is able to positively recognize three volatile organic compounds, namely Propane, Carbon monoxide, and Nitric oxide.

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A final report is available online at http://www.state.nj.us/transportation/research/research.html

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