Real-Power Computing: One Year Later

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Computing is Changing

References:
Challenges

- Trillions
- Diversity
- Productivity
- Energy, Autonomy & Intelligence
Real-Power Computing

**Hard real-power computing**
- No battery/no storage
- Extensive power-compute co-design needed

**Soft real-power computing**
- With energy storage
- Power-compute co-design
- + run-time adaptation

Energy autonomy requires awareness and robustness
Real-Power Challenges

• *Energy proportionality thru’ heterogeneity*

• **Robustness** under supply variations

• **Survivability** at zero cost
  – Automatic retention (like an instinct!)
**Case Study 1**

**Robust Perceptron Design**

Basic building block of neural networks
Used in classifiers, and supervised learning
Inverter, when fed with periodic rectangular pulses with a certain duty cycle produces output that is
- Proportional to $V_{dd}$
- Inversely proportion to $D$

$$V_{out}/V_{dd} = (1-D)$$
Case Study 1 – contd.

Robust Perceptron Design
Case Study 1 – contd.
Robust Perceptron Design

\[ V_{out} = (V_{dd} - GND) \cdot \frac{\sum_{i=1}^{k} DC_i \cdot W_i}{k \cdot (2^n - 1)} \]

<table>
<thead>
<tr>
<th>DC1</th>
<th>W1</th>
<th>DC2</th>
<th>W2</th>
<th>DC3</th>
<th>W3</th>
<th>( V_{out} ) theoretical</th>
<th>( V_{out} ) simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>70%</td>
<td>7</td>
<td>80%</td>
<td>7</td>
<td>90%</td>
<td>7</td>
<td>2.00V</td>
<td>1.99V</td>
</tr>
<tr>
<td>50%</td>
<td>1</td>
<td>50%</td>
<td>2</td>
<td>50%</td>
<td>4</td>
<td>0.42V</td>
<td>0.39V</td>
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<tr>
<td>20%</td>
<td>5</td>
<td>60%</td>
<td>6</td>
<td>80%</td>
<td>7</td>
<td>1.21V</td>
<td>1.17V</td>
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<tr>
<td>95%</td>
<td>7</td>
<td>90%</td>
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<td>2.00V</td>
<td>2.05V</td>
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<tr>
<td>30%</td>
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<td>40%</td>
<td>4</td>
<td>50%</td>
<td>2</td>
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<td>0.29V</td>
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<td>20%</td>
<td>3</td>
<td>50%</td>
<td>4</td>
<td>0.96V</td>
<td>0.89V</td>
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</table>

### Results

<table>
<thead>
<tr>
<th>( P_{\text{min}} )</th>
<th>( P_{\text{max}} )</th>
<th>( D )</th>
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</thead>
<tbody>
<tr>
<td>25uW</td>
<td>400mW</td>
<td>No change</td>
</tr>
</tbody>
</table>
• Design duty cycle *transcoding*, online learning and simplified power mgmt. circuit

• Implement a Neural Network
  – 100s of perceptrons

• Fabricate and validate for real-applications
Papers/Exemplars/Demos

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