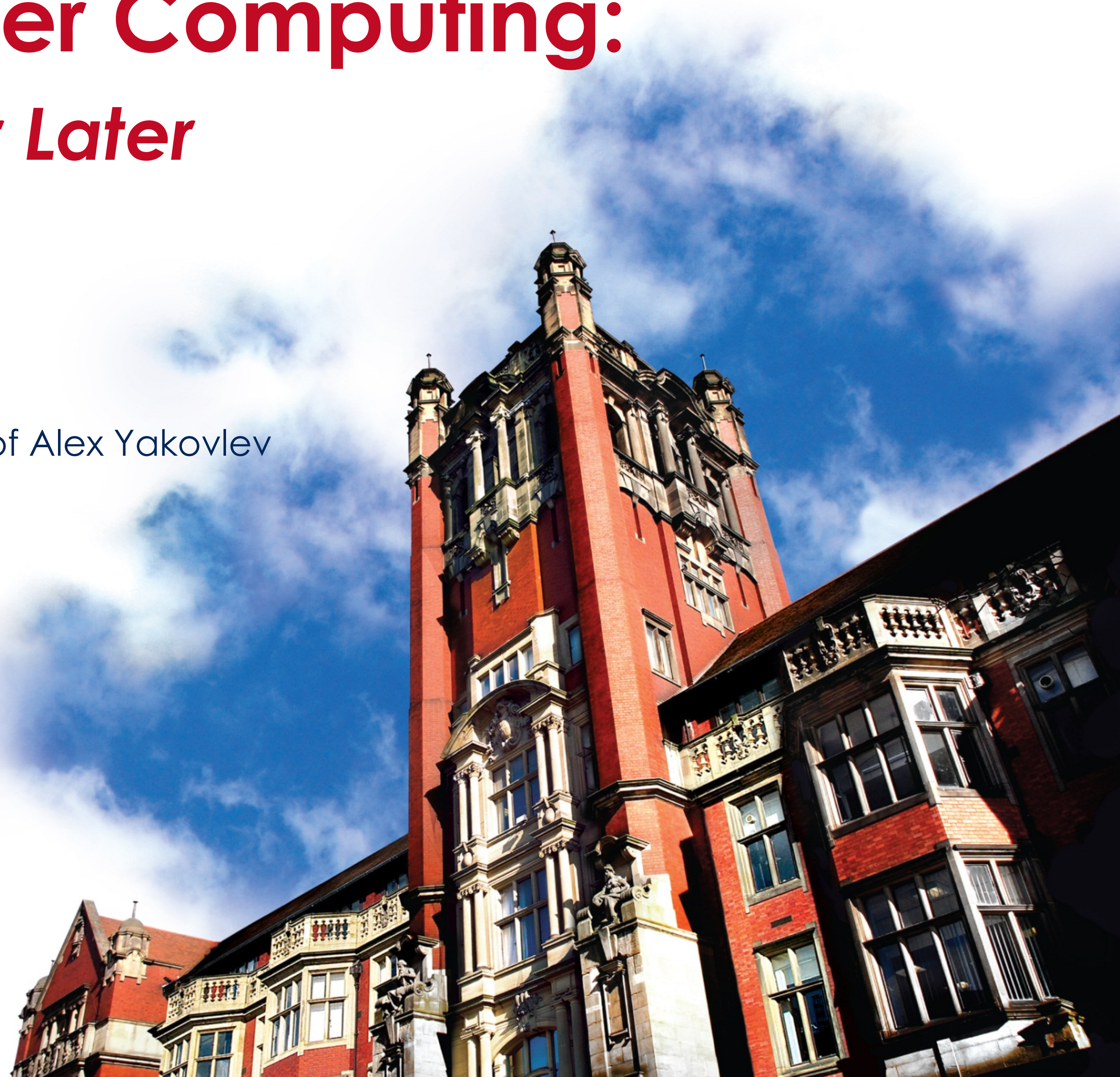
Real-Power Computing:
One Year Later



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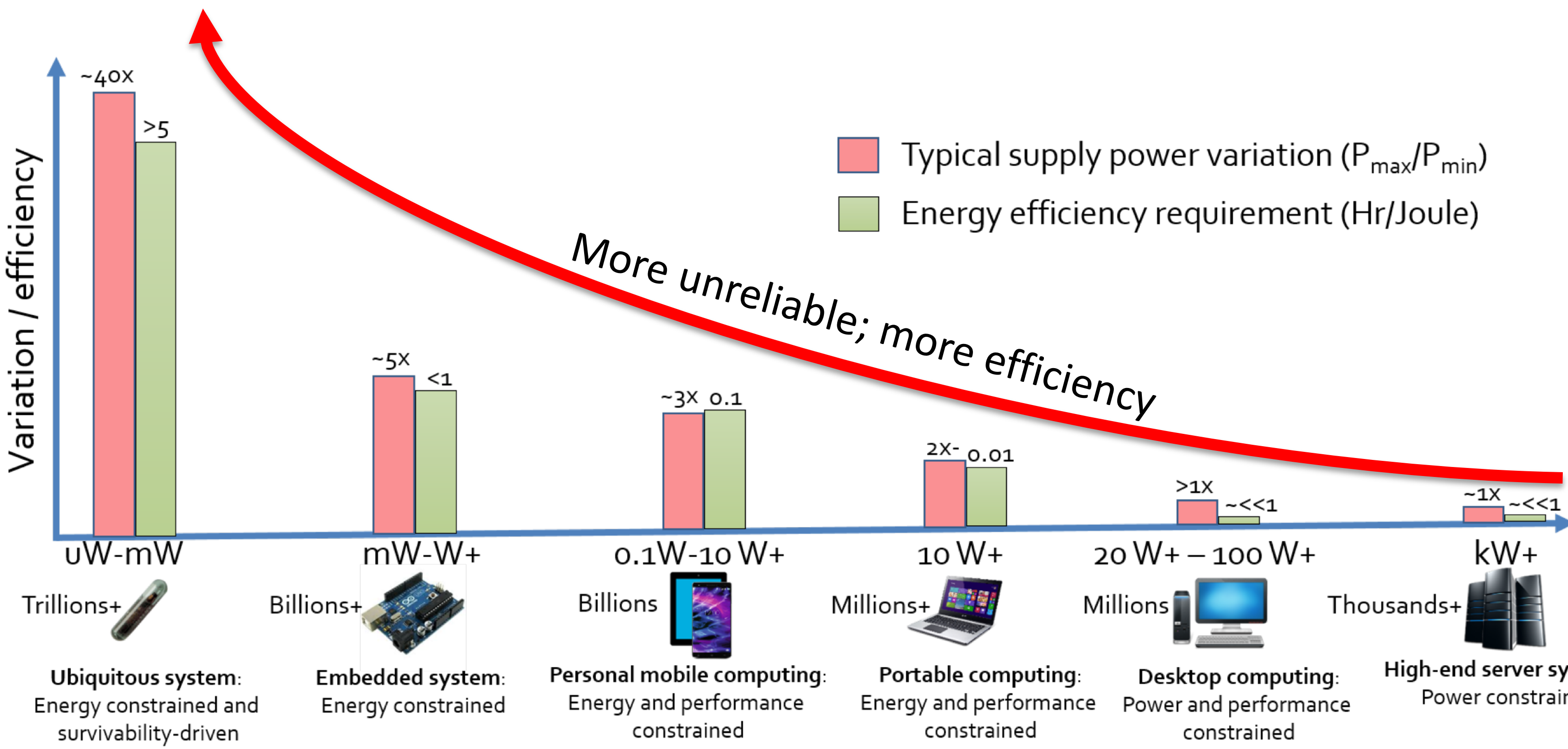
Energy drives logic
μSystems Research Group

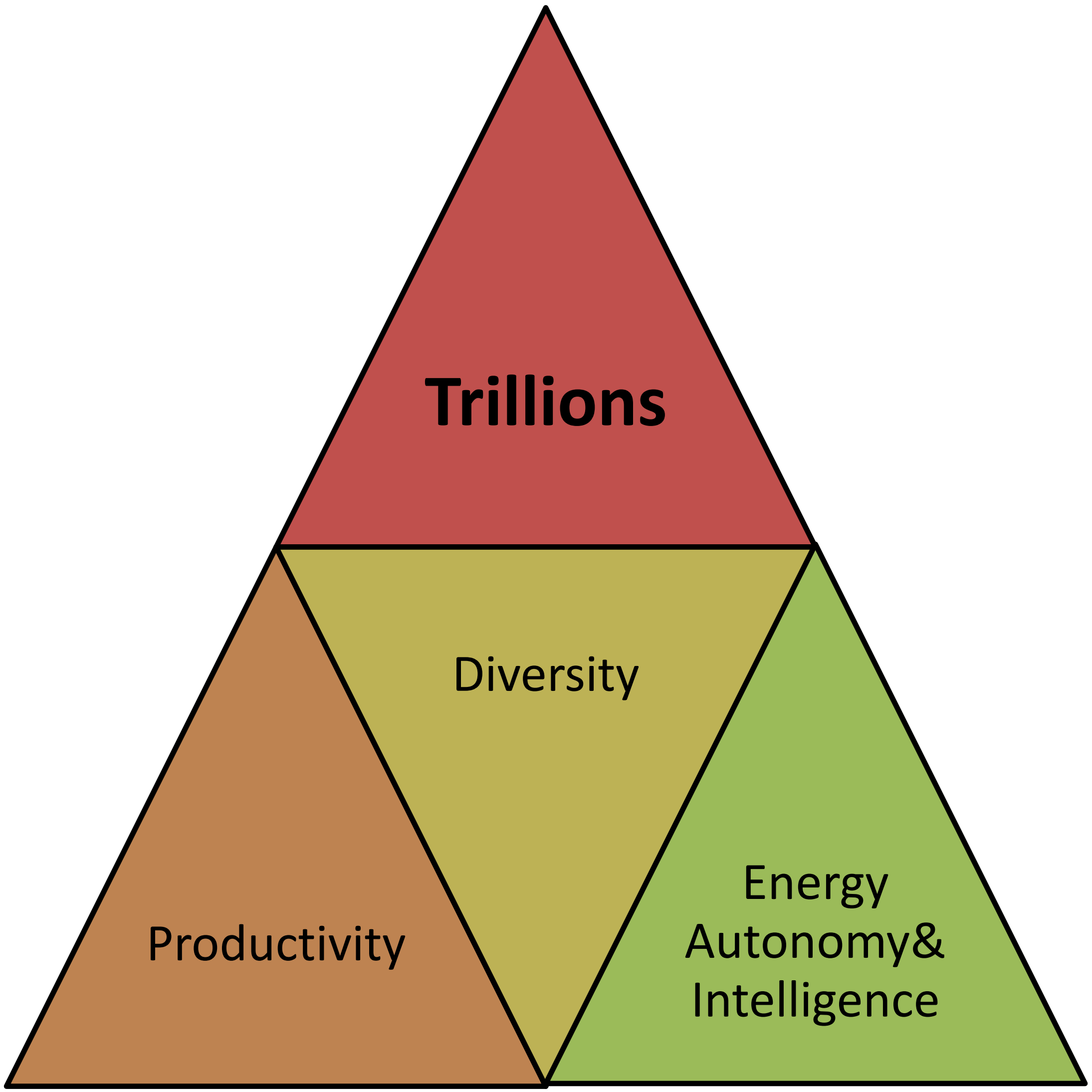
Newcastle University

Computing is Changing



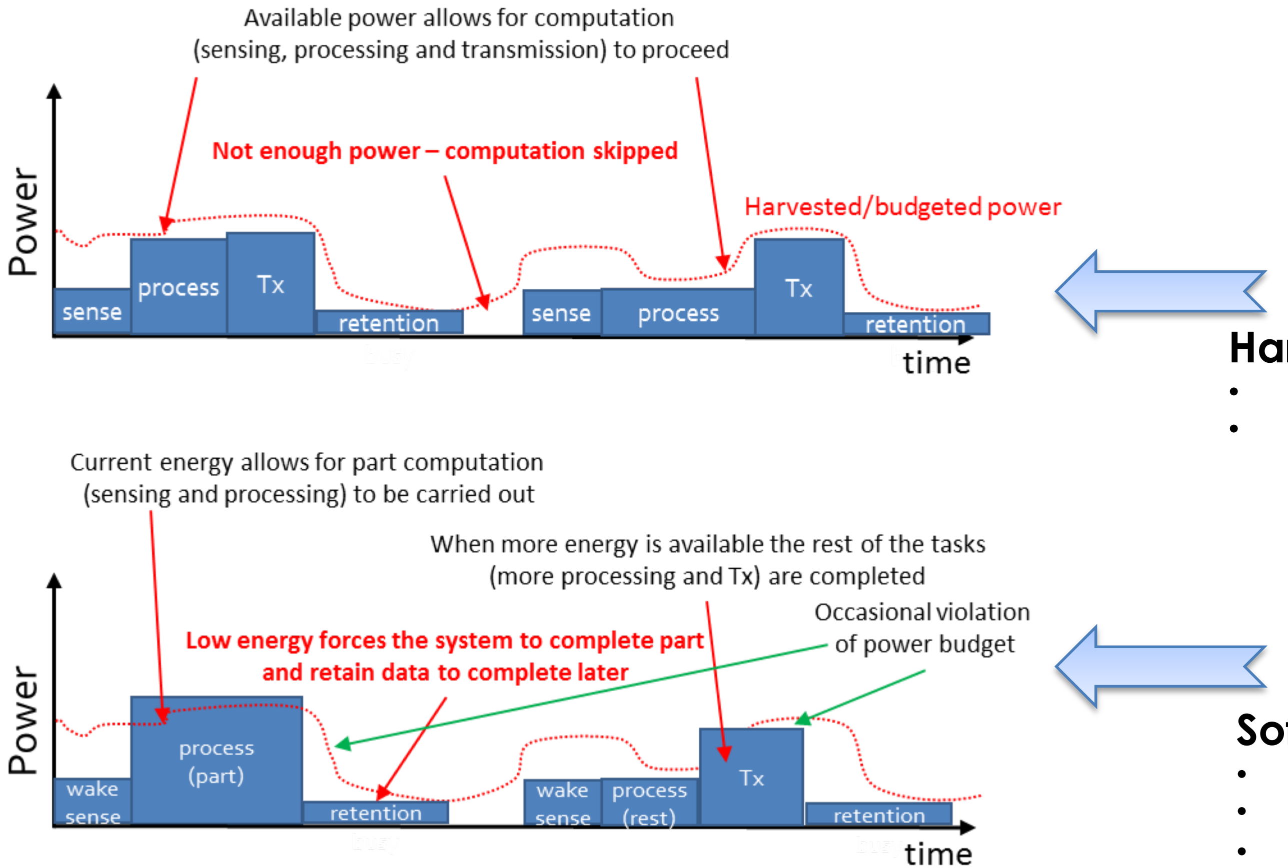
References:
Shafik *et al.*, "Real-Power Computing," in *IEEE Trans. on Comp.*, 67(10), 1445-1461, 2018.

Challenges



Trillions
Diversity
Productivity
Energy
Autonomy&
Intelligence

Real-Power Computing



Hard real-power computing

- No battery/no storage
- Extensive power-compute co-design needed

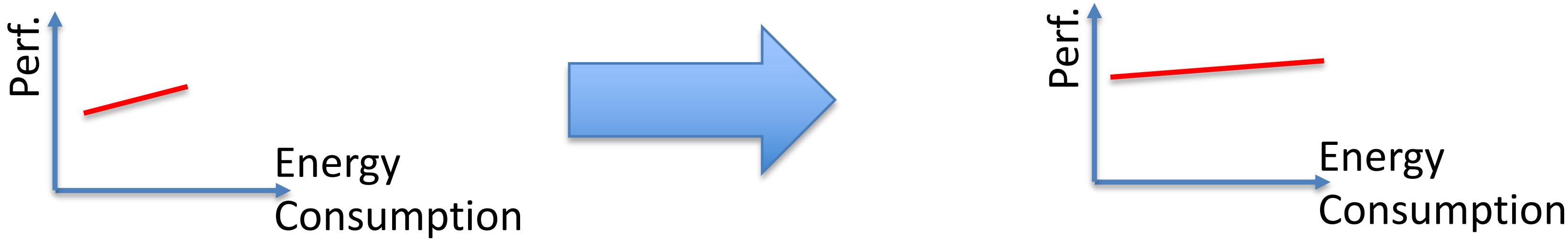
Soft real-power computing

- With energy storage
- Power-compute co-design
- + run-time adaptation

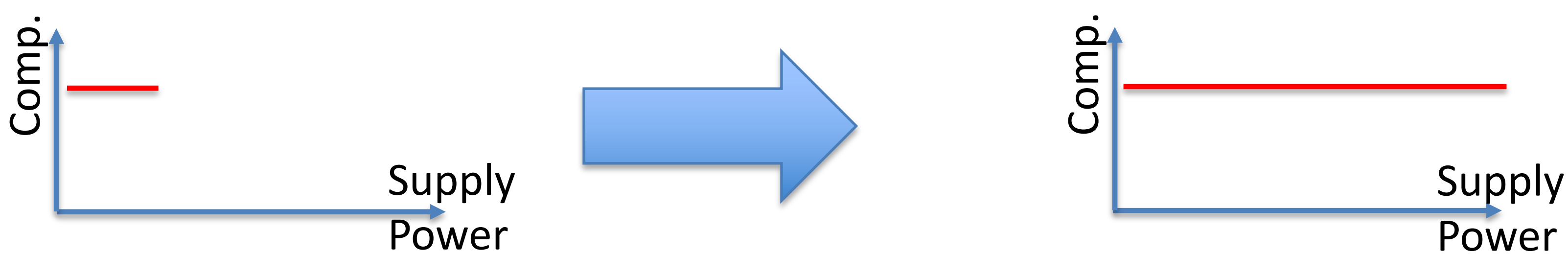
Energy autonomy requires awareness and robustness

Real-Power Challenges

- ***Energy proportionality*** *thru'* ***heterogeneity***

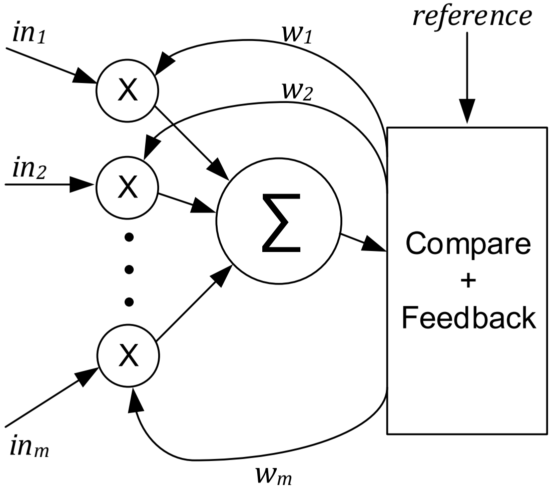


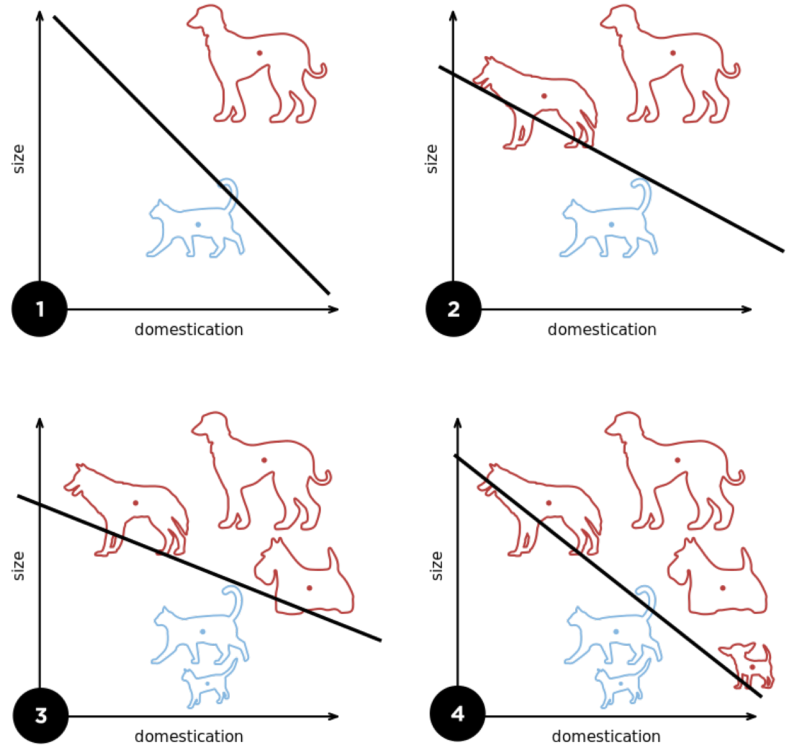
- ***Robustness*** under supply variations



- ***Survivability*** at zero cost
  - Automatic retention (like an instinct!)

Case Study 1
Robust Perceptron Design



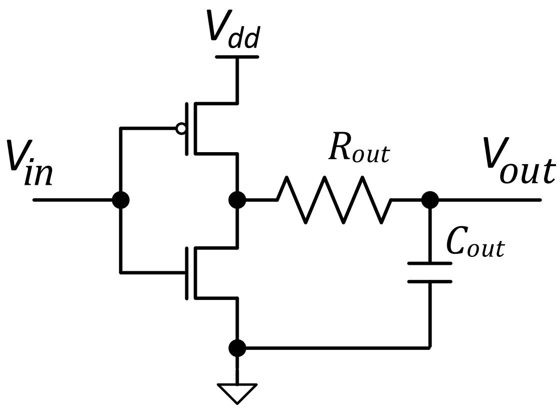


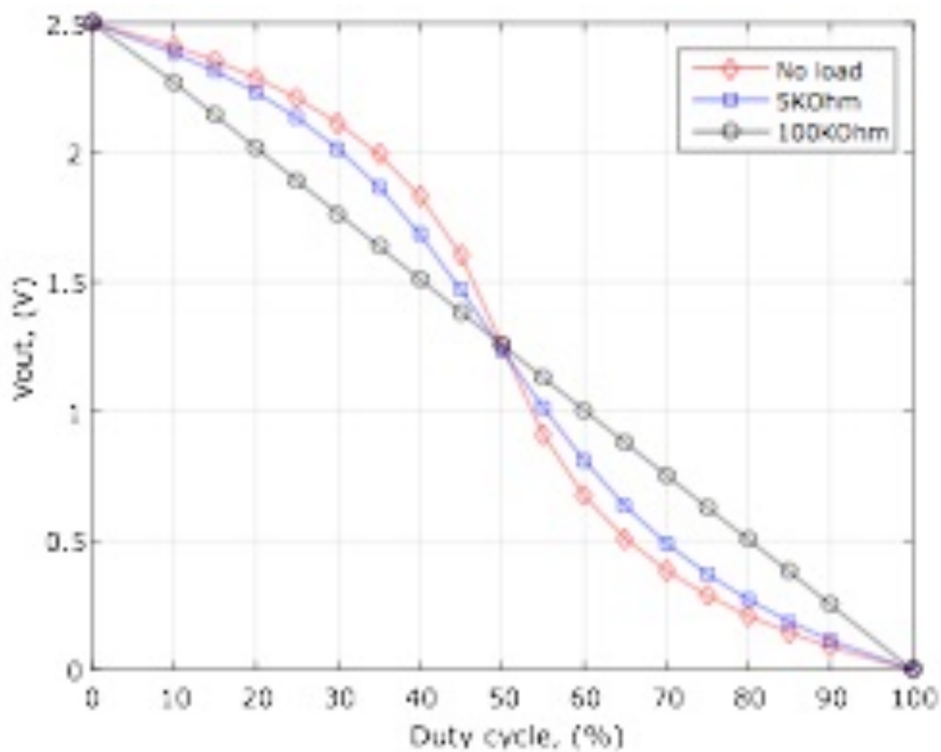
Basic building block of neural networks
Used in classifiers, and supervised learning

Case Study 1 – *contd.*

Robust **Perceptron Design**

V_{in}=2.5V
$NMOS_{width}$ = 320nm
$PMOS_{width}$ = 865nm
$NMOS_{length}$ = 1.2um
$PMOS_{length}$ = 1.2um
C_{out} = 1pF



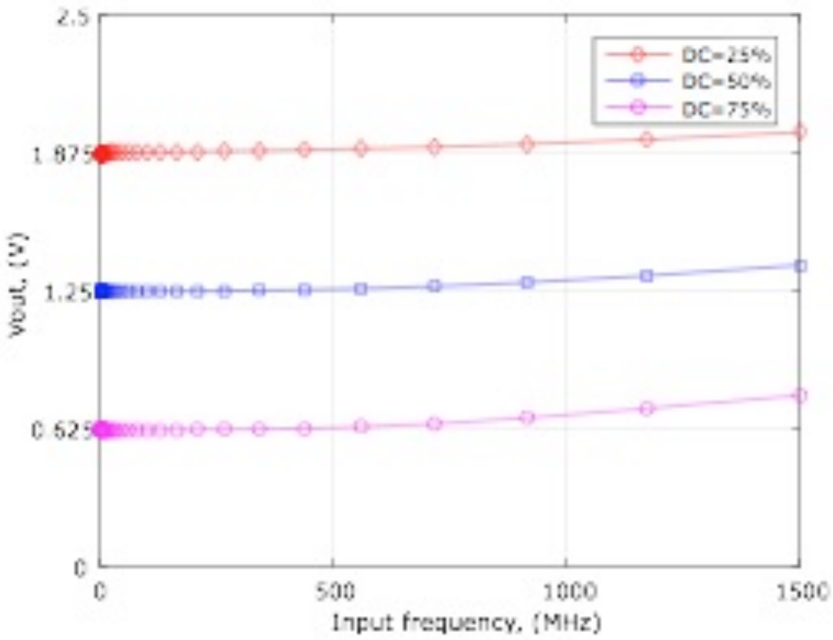


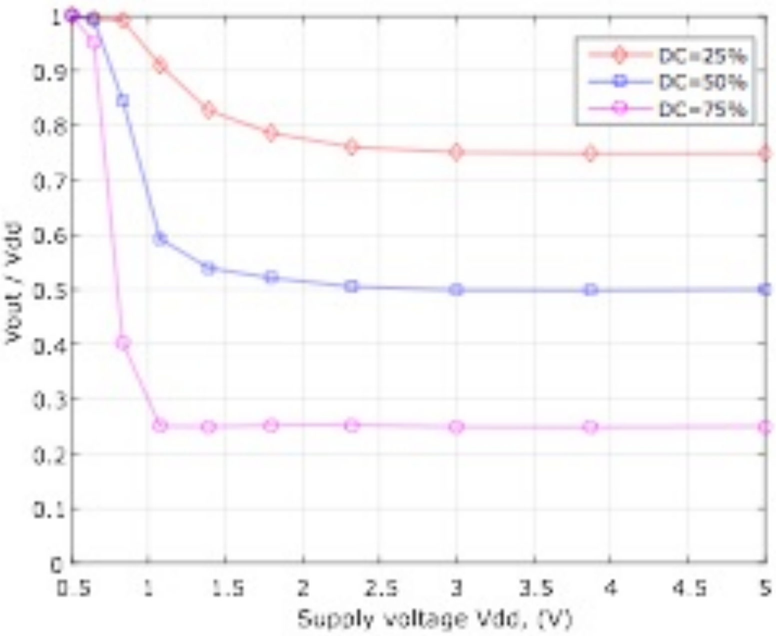
Inverter, when fed with periodic rectangular pulses with a certain duty cycle produces output that is

- Proportional to V_{dd}
- Inversely proportion to *D*

$V_{out}/V_{dd} = (1-D)$

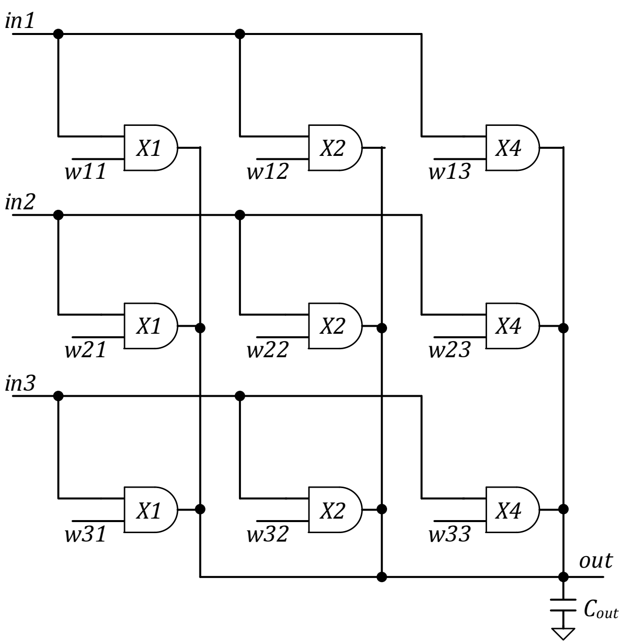
Case Study 1 – *contd.*
Robust Perceptron Design





Case Study 1 – *contd.*

Robust Perceptron Design



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

DC1	W1	DC2	W2	DC3	W3	V_{out} theoretical	V_{out} simulation
70%	7	80%	7	90%	7	2.00V	1.99V
50%	1	50%	2	50%	4	0.42V	0.39V
20%	5	60%	6	80%	7	1.21V	1.17V
95%	7	90%	6	80%	6	2.00V	2.05V
30%	1	40%	4	50%	2	0.34V	0.29V
80%	7	20%	3	50%	4	0.96V	0.89V

P_{min}	P_{max}	D
25uW	400mW	No change

Case Study 1 – *contd.*
Robust Perceptron Design

- 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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Energy drives logic

μSystems Research Group

Credits

Jonathan Edwards, Temporal Computing

Serhil Mileiko, Microsystems

Alex Yakovlev, Microsystems

Thank you!