

# FlexWatts: A Power- and Workload-Aware Hybrid Power Delivery Network for Energy-Efficient Microprocessors

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# The Power Delivery Network (PDN) Debate



## 2013 Intel Haswell Uses **IVR** PDN (FIVR)

The Haswell Review: Intel Core i7-4770K & i5-4670K Tested

With FIVR, it's easy to implement tons of voltage rails

on-package and efficiently distribute power to all areas of the chip. Voltage ramps are 5 - 10x quicker with FIVR than with a traditional on-board voltage regulator implementation.

FIVR also comes with a reduction in board area and component cost.

## 2015 Intel Skylake Uses **MBVR** PDN

The Intel Skylake Mobile and Desktop Launch, with Architecture Analysis

CPU Power Delivery – Moving the FIVR

For Skylake, the voltage regulation is moved back into the hands of the motherboard manufacturers. This should allow for cooler processors depending on how the silicon works, but it will result in slightly more expensive motherboards.

## 2017 AMD Ryzen Uses **LDO** PDN

Ryzen Mobile is Launched: AMD APUs for Laptops, with Vega and Updated Zen

When Intel introduced their FIVR implementation, they said that they found better efficiency using their big inductors and decided against the linear LDO regulators because they were inefficient at low power. We put that to Sam Naffziger, AMD's top guy on power, and he responded that yes, as a percentage, the power efficiency at idle might be lower than expected – but the power consumption of an idle core while another is loaded is still a very tiny proportion. Sam stated that when the LDO is in complete power gate mode, it can be

they still worked hard on the LDO implementation for power efficiency anyway, to make sure everything still worked. Overall, total current requirements were down 36%, which reduces the motherboard-side power regulation, leading to smaller, lighter, and potentially cooler designs.

## 2019 Intel Icelake Uses **IVR** PDN (FIVR)

Examining Intel's Ice Lake Processors: Taking a Bite of the Sunny Cove Microarchitecture

Intel is keen to promote that one of the new features of Ice Lake is its Thin Magnetic Inductor Array, which helps the FIVR achieve better power conversion efficiencies and waste less power. The main issue with a FIVR is at low power consumption states that have a lot of inefficiency – some other processor designs have



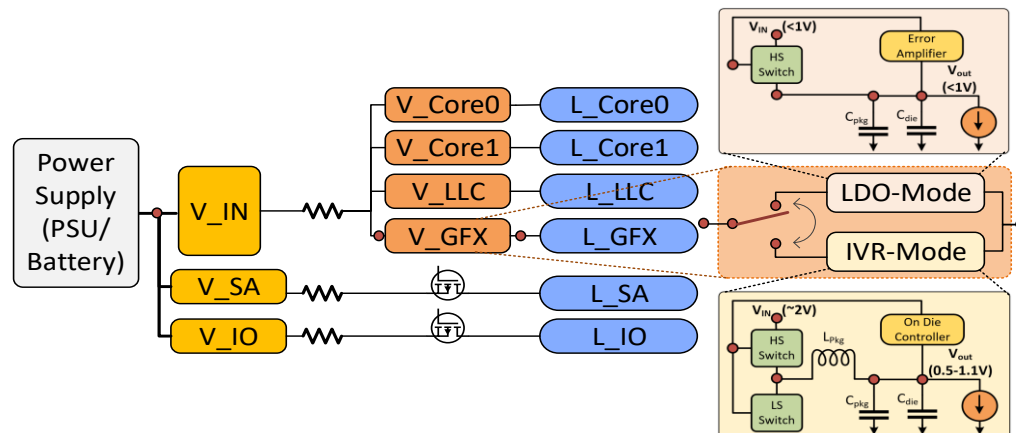
## Power Delivery Affecting Performance At 7nm

One particularly troublesome area involves the power delivery network (PDN). To distill it to its simplest form, resistance is going up because of decreasing dimensions. That causes more IR drop, which in turn affects timing, sometimes in unexpected ways. Chips are coming back that are not able to run at intended clock speed.

<https://semiengineering.com/power-delivery-affecting-performance-at-7nm/>

# Our Goal: A Hybrid and Adaptive PDN

- A **client processor** operates across a wide range of **power consumption** and executes a wide **variety of workloads**
- We find that there is **no single PDN** for modern client processors that **provides a high energy-efficiency** across the wide range of **power consumption** and wide **variety of workloads**
- **Our Goal is to propose a new PDN architecture that overcomes the inefficiencies of prior PDN architectures**
- To this end, we propose **a hybrid and adaptive PDN** that provides the **advantages of** each one of the **three commonly-used PDNs**
  - by dynamically adapting the hybrid PDN based on **processor power consumption** and **workload characteristics**



# FlexWatts: Key Results

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- FlexWatts is the **first** hybrid PDN to use two types of on-chip voltage regulators (**IVR** and **LDO**) to leverage the **advantages** of both
- FlexWatts efficiently **chooses the processor PDN** based on the **power demands** and **workload characteristics**
- We evaluate FlexWatts using our **new open-sourced PDNspot model**
  - FlexWatts **improves the performance** of CPU and graphics workloads (by up to 22% and 25%, respectively, for 4W thermal design power (TDP))
  - FlexWatts **reduces the average power consumption** of battery life workloads (by up to 11%) across all TDPs
- We **show** that FlexWatts is an effective approach:
  - To **provide high efficiency and high performance** in metrics of interest
  - In client processors across a wide spectrum of TDPs and workloads with **minimal overhead**

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