ELL-i:
Build an internet for your (fixed) things

Cyber Physical Systems, TUCS

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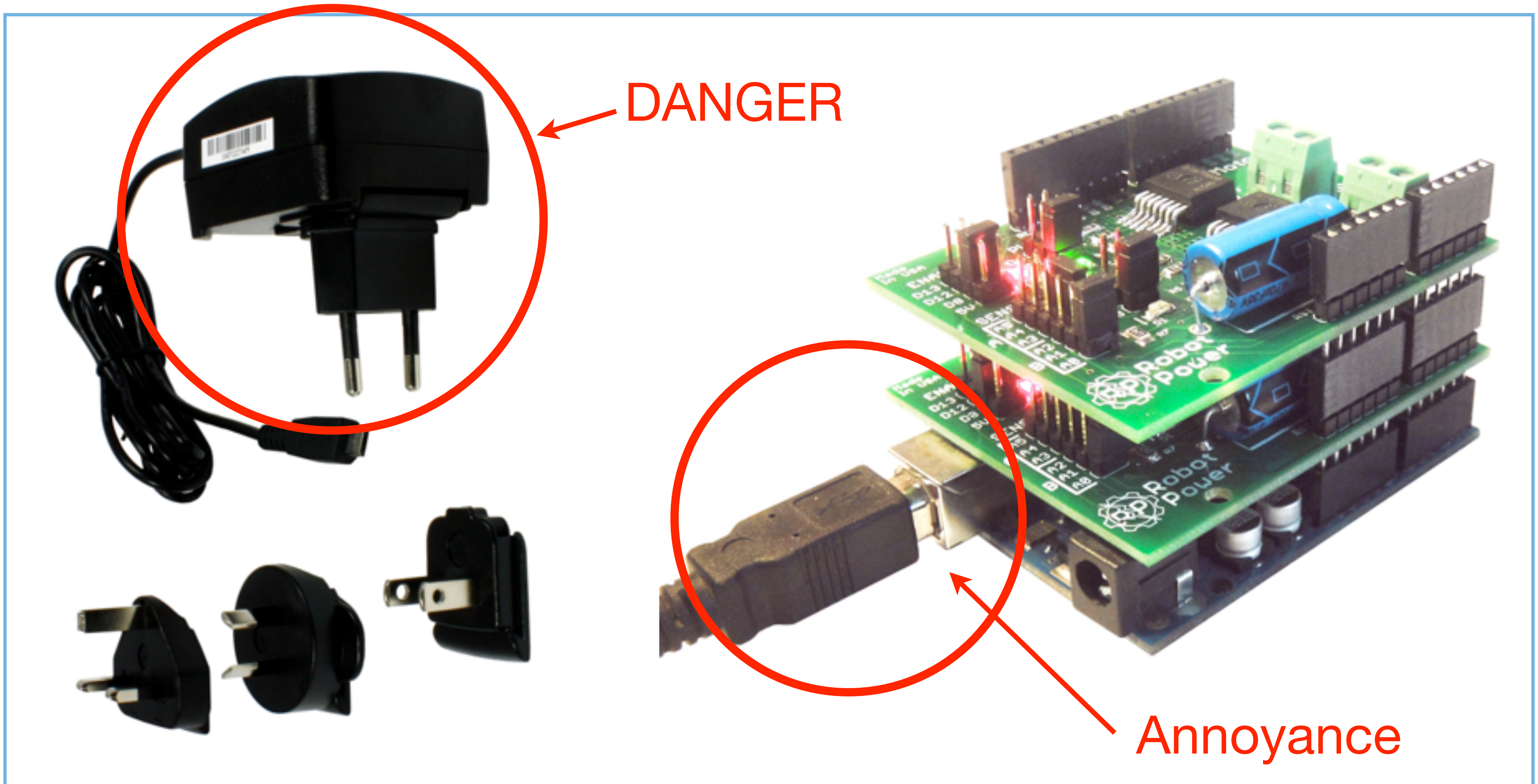
Presentation contents

- Motivation
- ELL-i background
  - The ELL-i story, co-op, and ecosystem
  - ELL-i as a technical platform
  - ELL-i vs. Arduino
- Basics of DC/DC SMPS power supplies
- Different electrical loads
- Building a simple “buckish” converter

The ignored secret: the power supply



Cool power — not hot!

- Electricity is **not only** mains power
  - 110 / 230 VAC is a deadly artefact of the past
- ELV (extra low voltage) is a **free domain**
  - not dangerous to humans; fire still an issue
  - anybody can design & install
- Power-over-Ethernet 48 VDC is ELV
  - Both power and data via a **single** CAT **cable**
  - 13W, 25W, or even more, at **our hands**

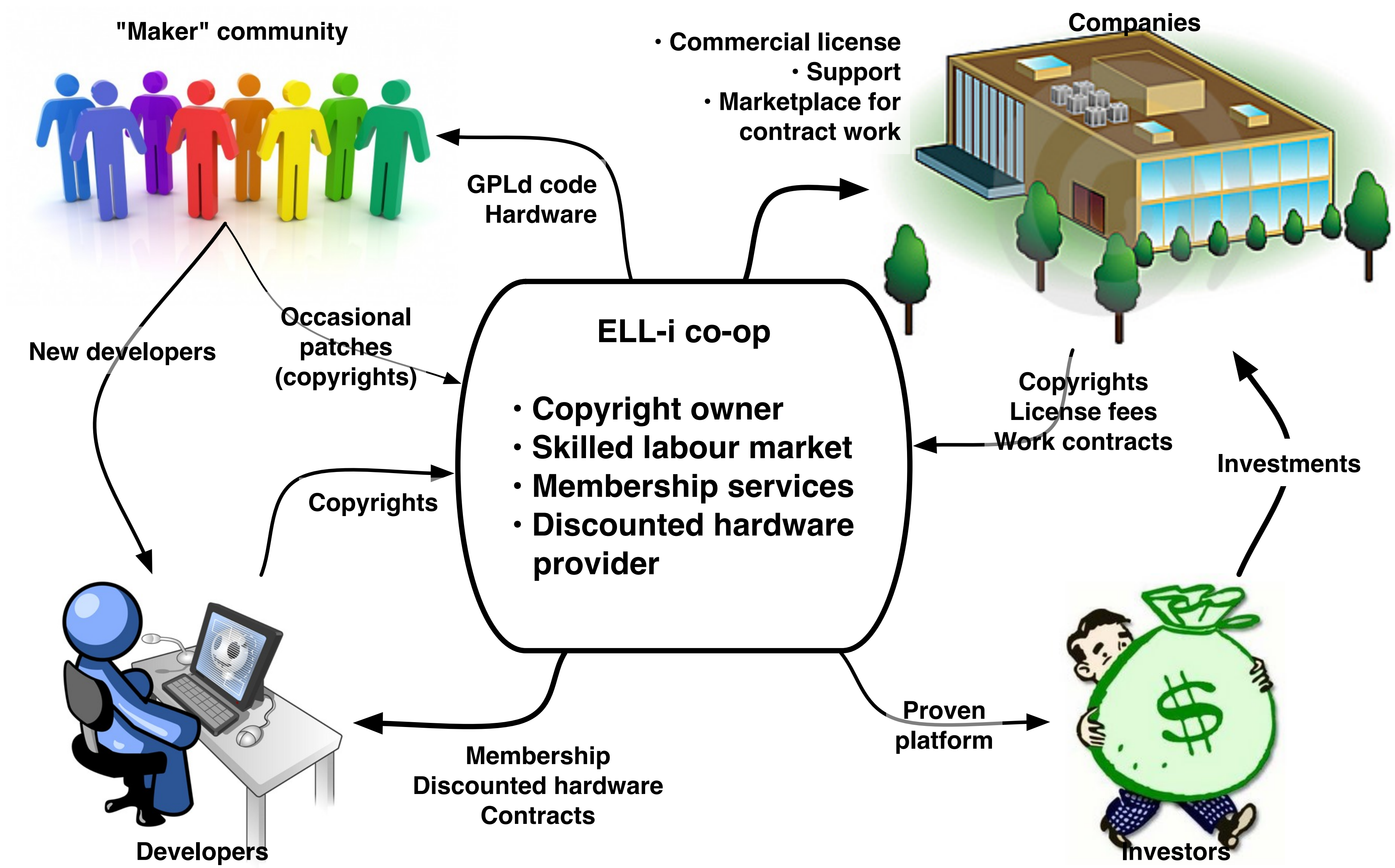
The ELL-i story

- Started by
  Pekka Nikander & Teemu Hakala in Summer 2012
  - Pekka has had home automation since 2005
    - Sauna not integrated; actuator & sensor issues
  - Teemu wants to automate lights, car warming, …
- Power-over-Ethernet looked good
  - Power and control in a single cable
  - Uses existing CAT5 cabling (from the 2005 system)
  - Clearly growing towards higher power levels
- And the whole story grew from there …

ELL-i co-operative

- An organisational bases for forming an ecosystem
- **Co-own the software and hardware copyrights**
  - A pool of open source HW & SW
  - Anyone may donate copyrights & join the co-op
- Strengthen the community
  - Provide development hardware
  - Form a model for licensing the IPR
- Create a market place for skilled labour

The ecosystem



Part II: ELL-i technical platform

http://www.ell-i.org

ELL-i: Democratising power

- Internet democratised *information*
- 3D printers are democratising *manufacturing*

- ELL-i wants to democratise *power*
  - Regulated as ELV — anyone may install
    - No electrician needed
  - DC — easy to understand, convert, and store
  - Safe — has automatic circuit breakers

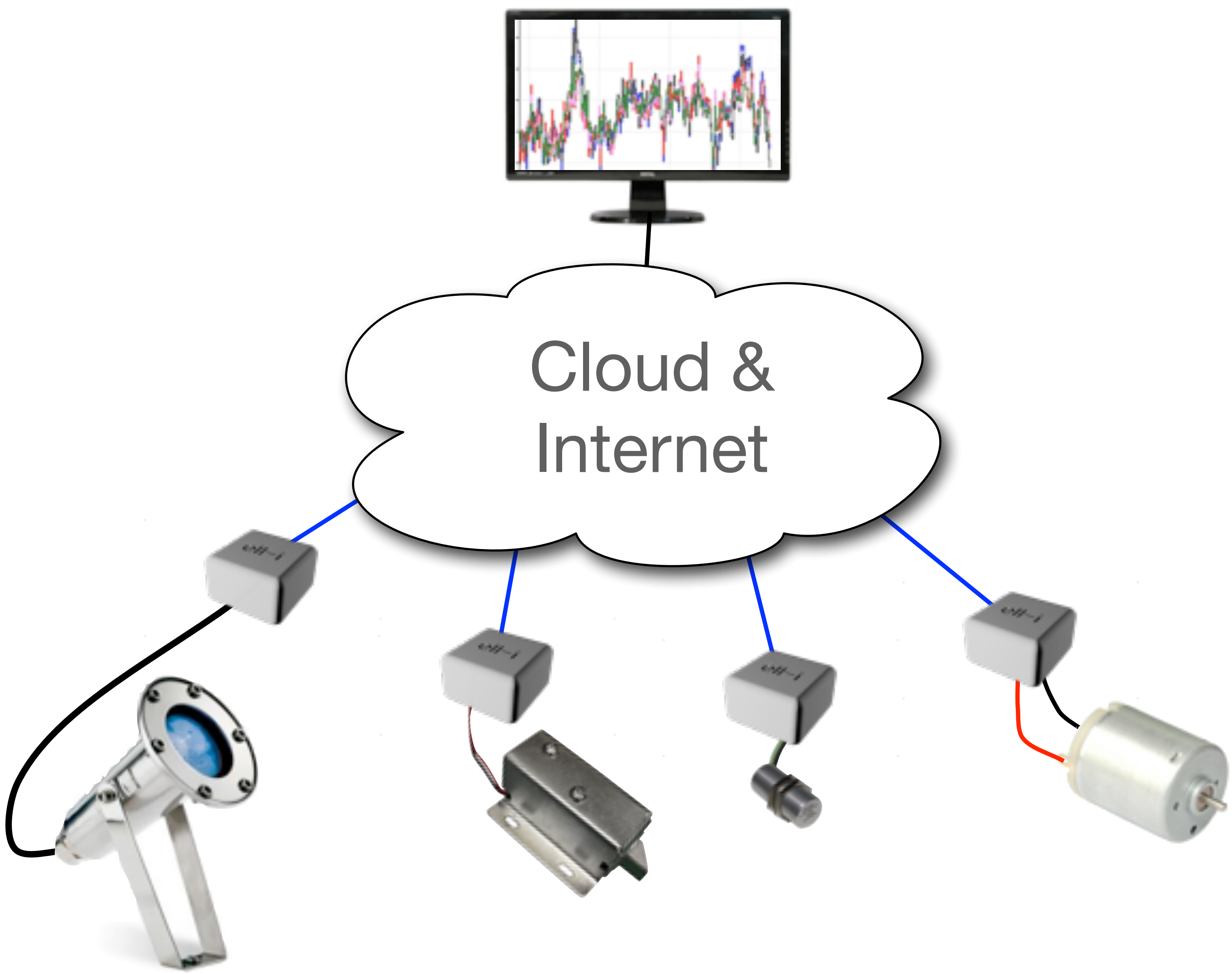
ell-i

Platform goals

- **Intelligence** and **power** to everywhere
  - Inexpensive and flexible
  - Installable by anyone; no electrician needed
  - Easy to start with; Arduino compatible
  - Powerful, cloud connected, upgradeable

- Open sourced for Open Innovation

An ELL-i network



http://www.ell-i.org

ELL-i project: The platform vision

LED lighting

Intelligent home

Industrial automation

Your own fixed, powered IoT vision

An open source platform

mW power

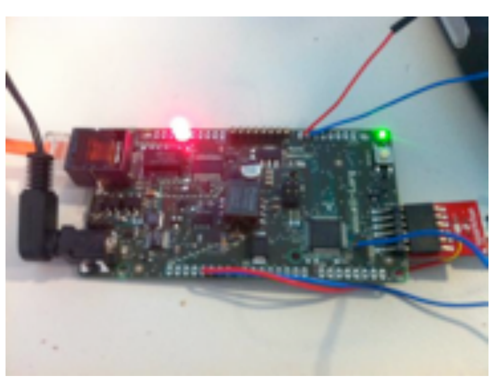
1–100 W = PoE

kW Power

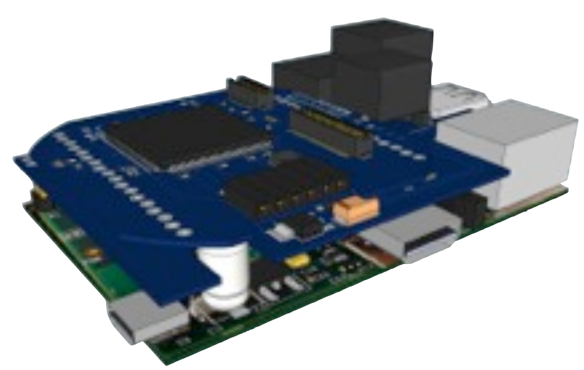
http://www.ell-i.org

ELL-i technical roadmap

v1.0 prototype
- Arduino compatible!
- 32-bit CPU
- 48 MIPS
- 16 kb RAM
- 64 kb FLASH
- 10 Mb/s Ethernet
- 13W of power

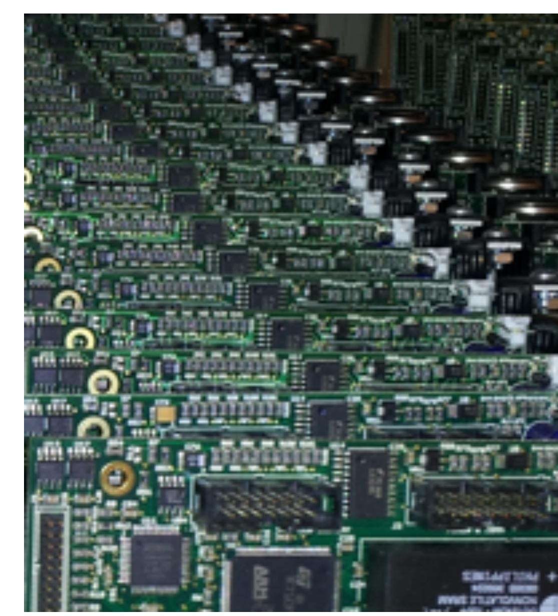


v2.0 design
- JS compatible?
- Two alternatives
- 48 or 180 MIPS
- 16 or 256 kb RAM
- 64 kB or 1 Mb FLASH
- 100 Mb/s Ethernet
- 13 or 25W of power



KICKSTARTER

v2.0 production run



May 2013 | Dec 2013–Jan 2014 | Apr–May 2014 | Aug-Sep 2014

ELL-i vs. Arduino: 1/2

	Arduino (excl. Due)	ELL-i 1.0
MCU	Atmel AVR	ARM Cortex-M
CPU speed	8 or 16 MHz	48 MHz
RAM	1–8 kB	16 kB
Flash	16–256 kB	64 kB
GPIO	~20	~40
Connectivity	UART, USB	UART, Ethernet
Power	USB	PoE, (USB)

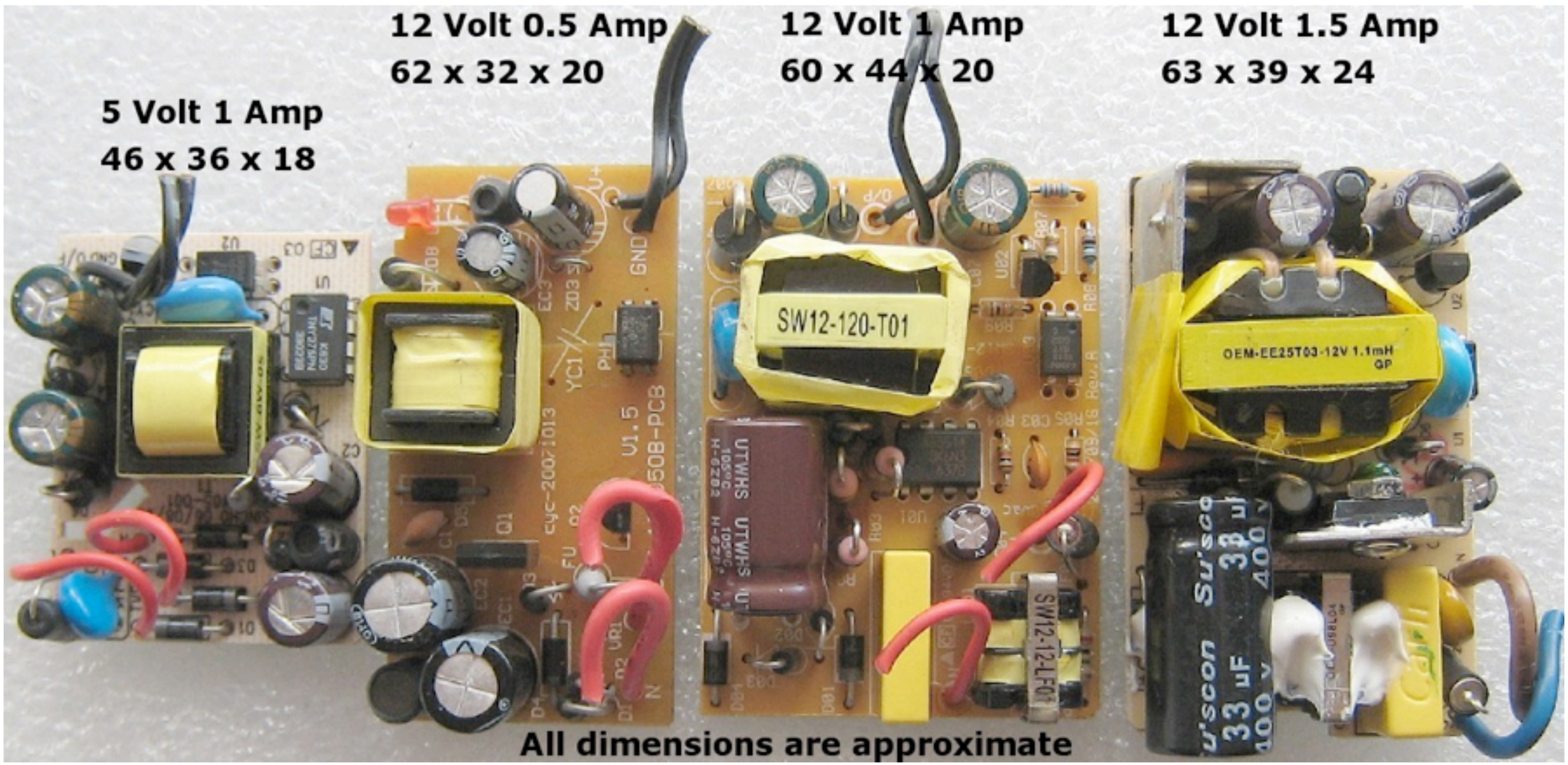
ELL-i vs. Arduino: 2/2

- Power-over-Ethernet
  - Both data and power over a single cable
  - Ability to build your own power supplies
    - Enabling, safe, unregulated, …
    - Interesting amount of power (13W now, more later)
- ELL-i 2.0: FPGA
  - Reaction speed beyond an MCU
    - MCU “latency” ~10 μs, FPGA ~100 ns

Presentation contents

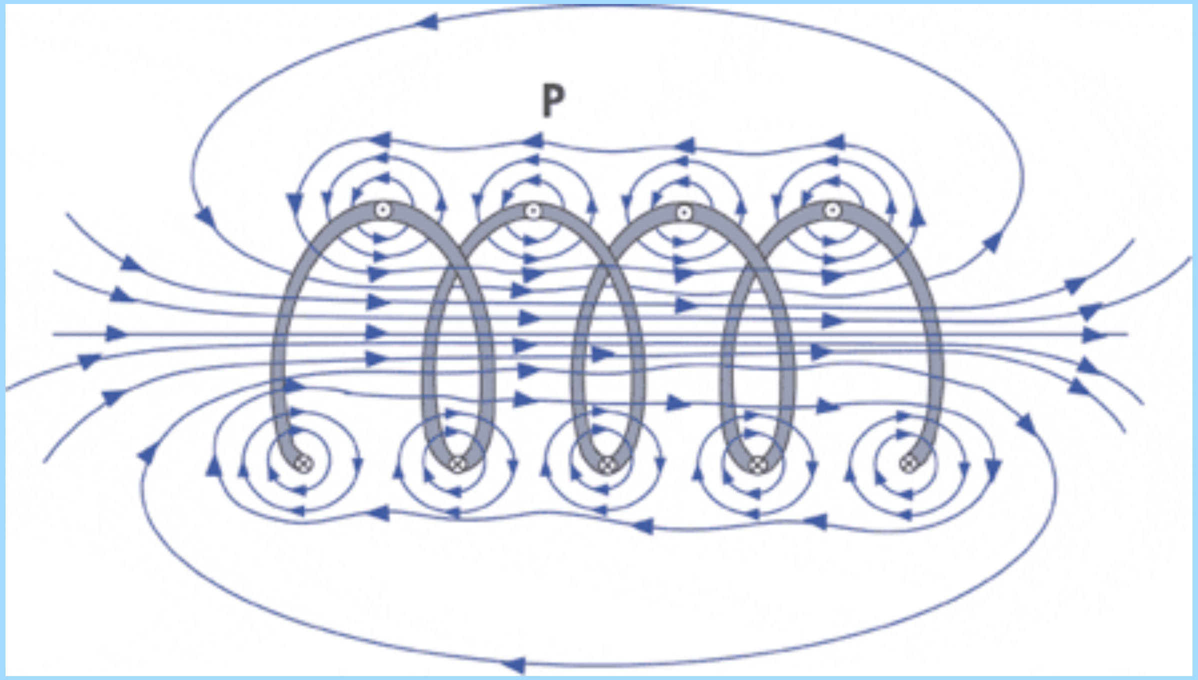
- Motivation
- ELL-i background
- Basics of DC/DC SMPS power supplies
  - Storing energy in a coil or capacitor
- Understanding different electrical loads
  - Resistive, constant voltage drop, inductive
- Building a simple “buckish” converter
  - Intro to the afternoon lab

DC/DC power supplies



Storing and releasing electromagnetic energy

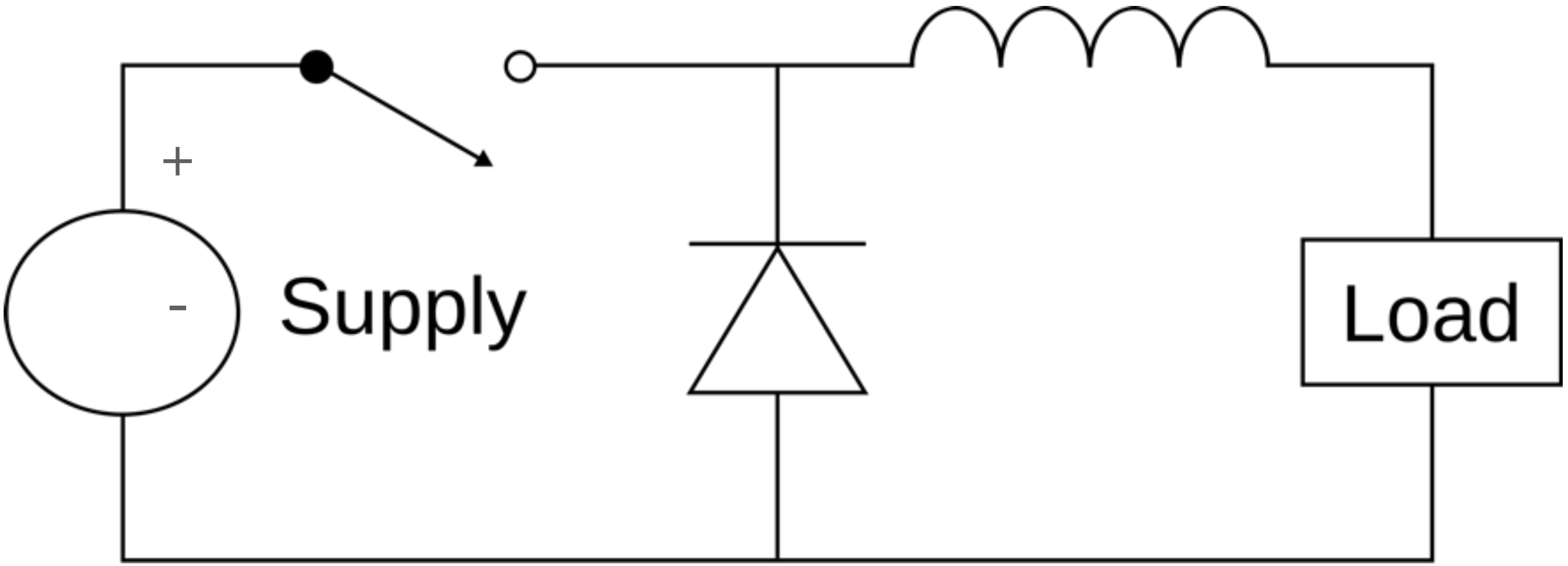
- An inductor stores energy into a magnetic field
  - Resists current growth (until saturates)
- Stored energy is released when voltage is removed
  - Generates a current
- Similar storage possible with a capacitor
  - Harder in practise



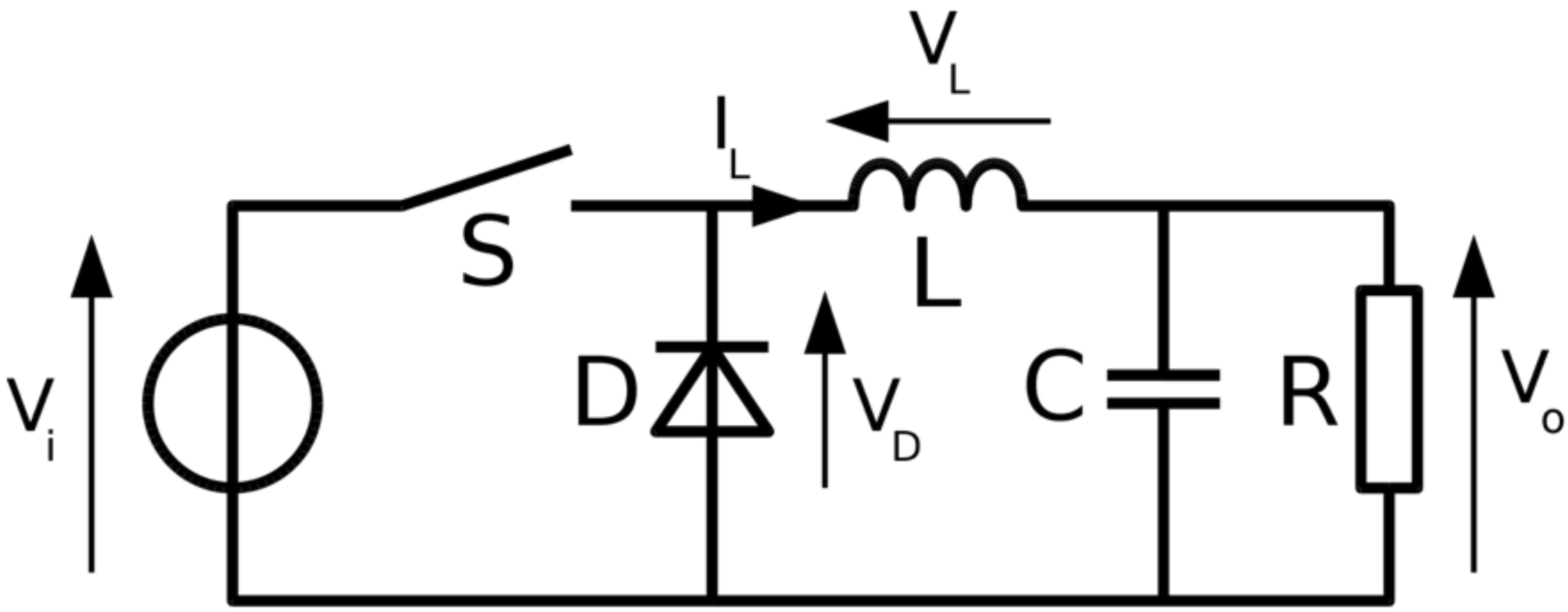
SMPS basics

- Different design topologies:
  - Non-isolated: Buck, boost, buck–boost
  - Isolated: Forward, flyback, half-bridge, full bridge
- Basic operations very easy to understand
  - Store energy in a coil, then release it
- Basic component calculations quite easy
- Handling parasitics & EMI hard
- Buck is the easiest one — our focus today

Basic buck topology

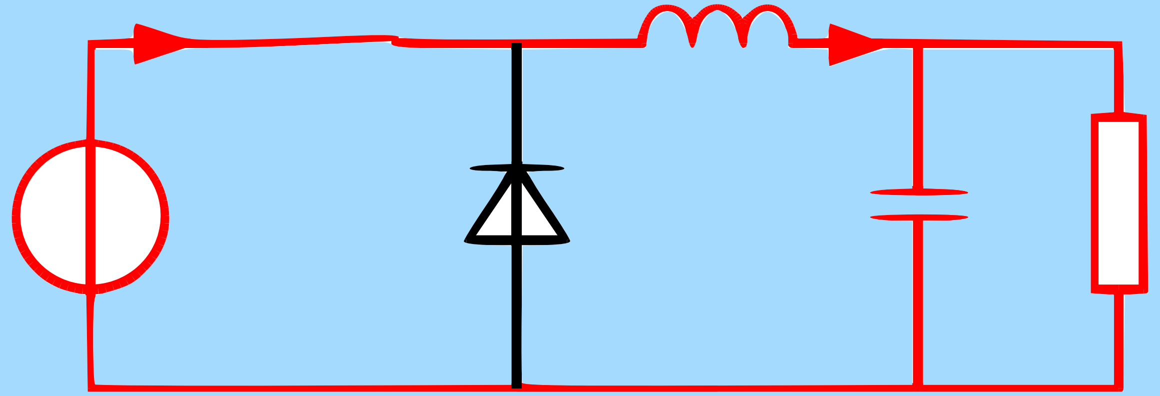


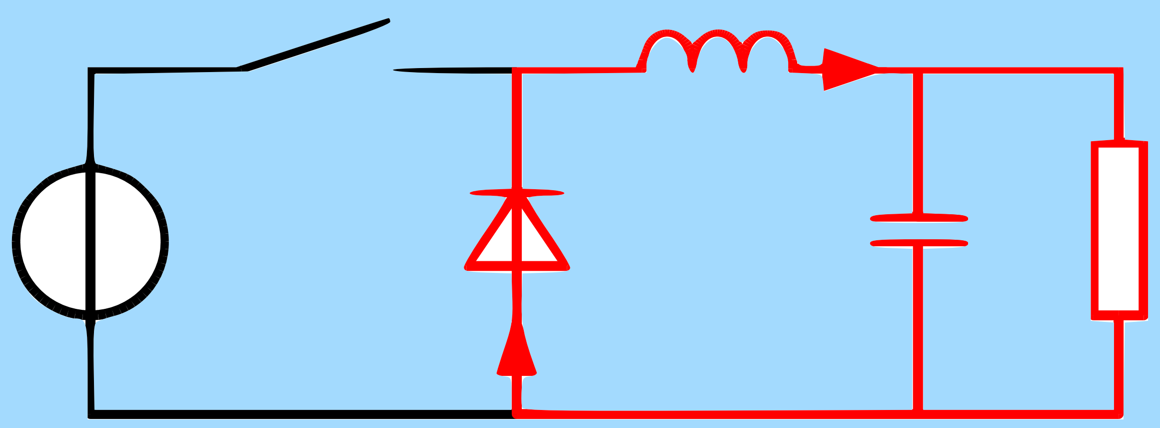
Naming conventions



Switching on and off

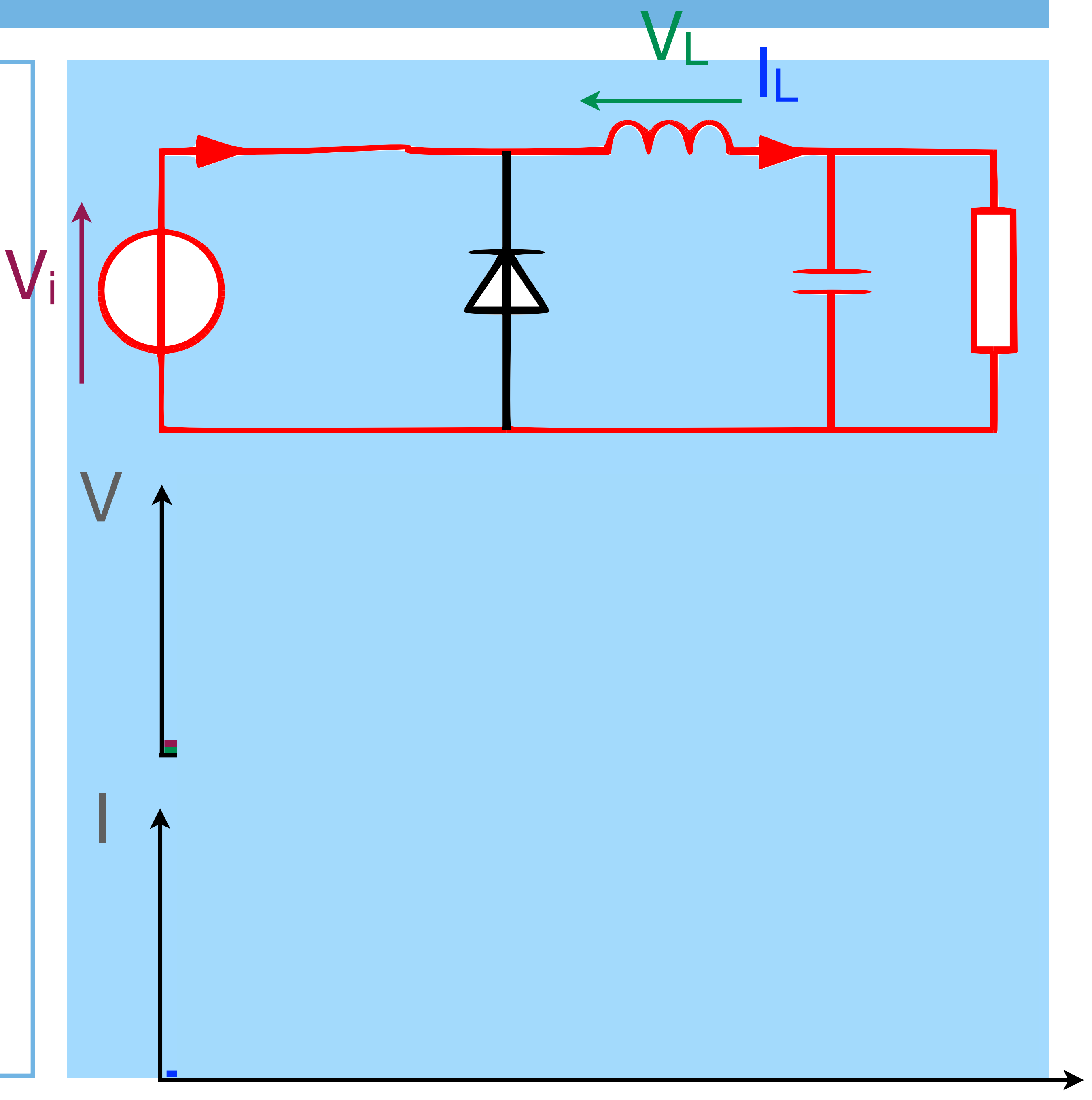
- Input voltage applied
  - Current grows and energy gets stored
- Input voltage off
  - Energy is released, current falls





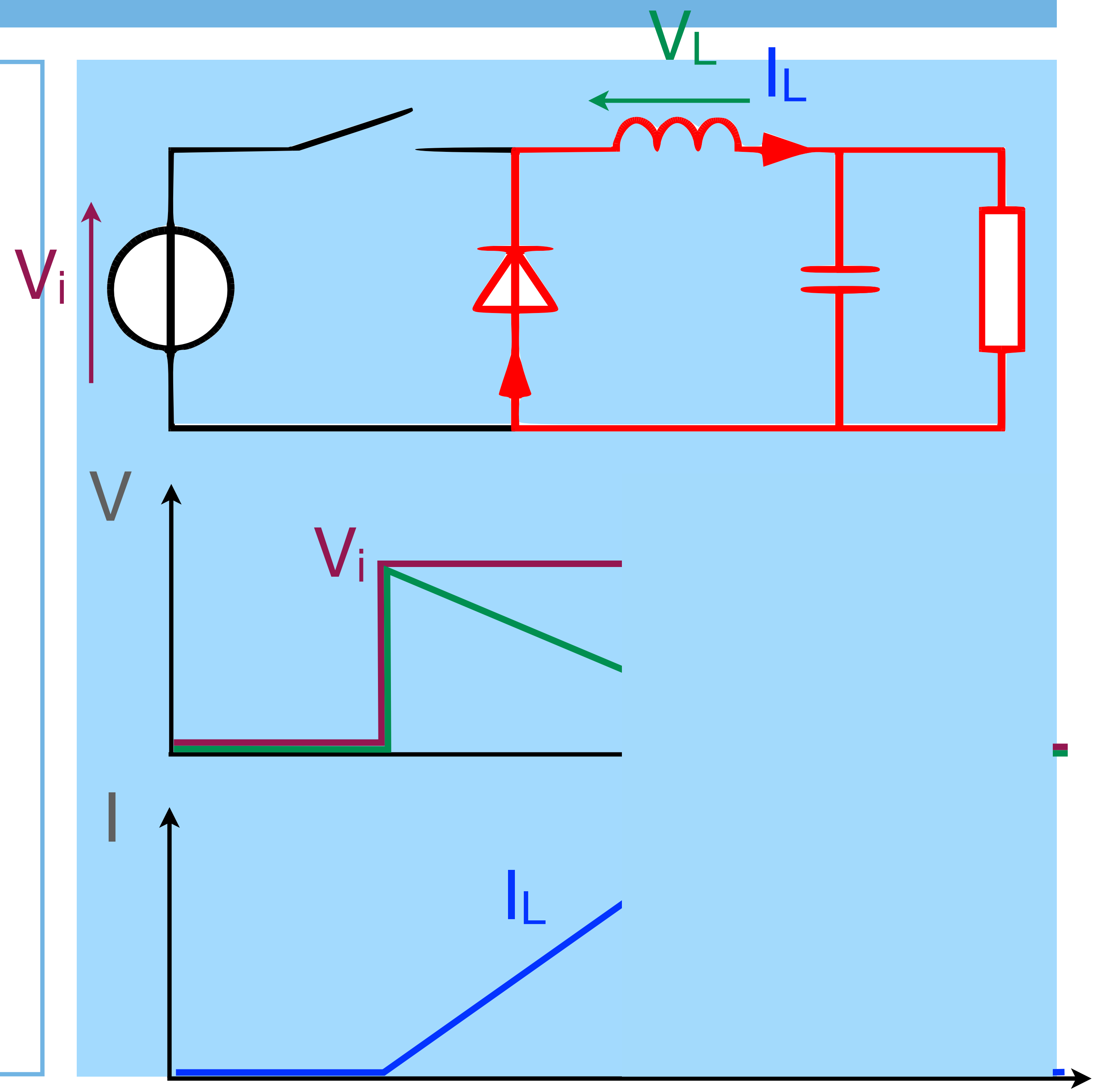
Voltage applied

- Input voltage applied
- Current flows through the coil, growing
- Magnetic field builds up
- Energy gets stored into the magnetic field



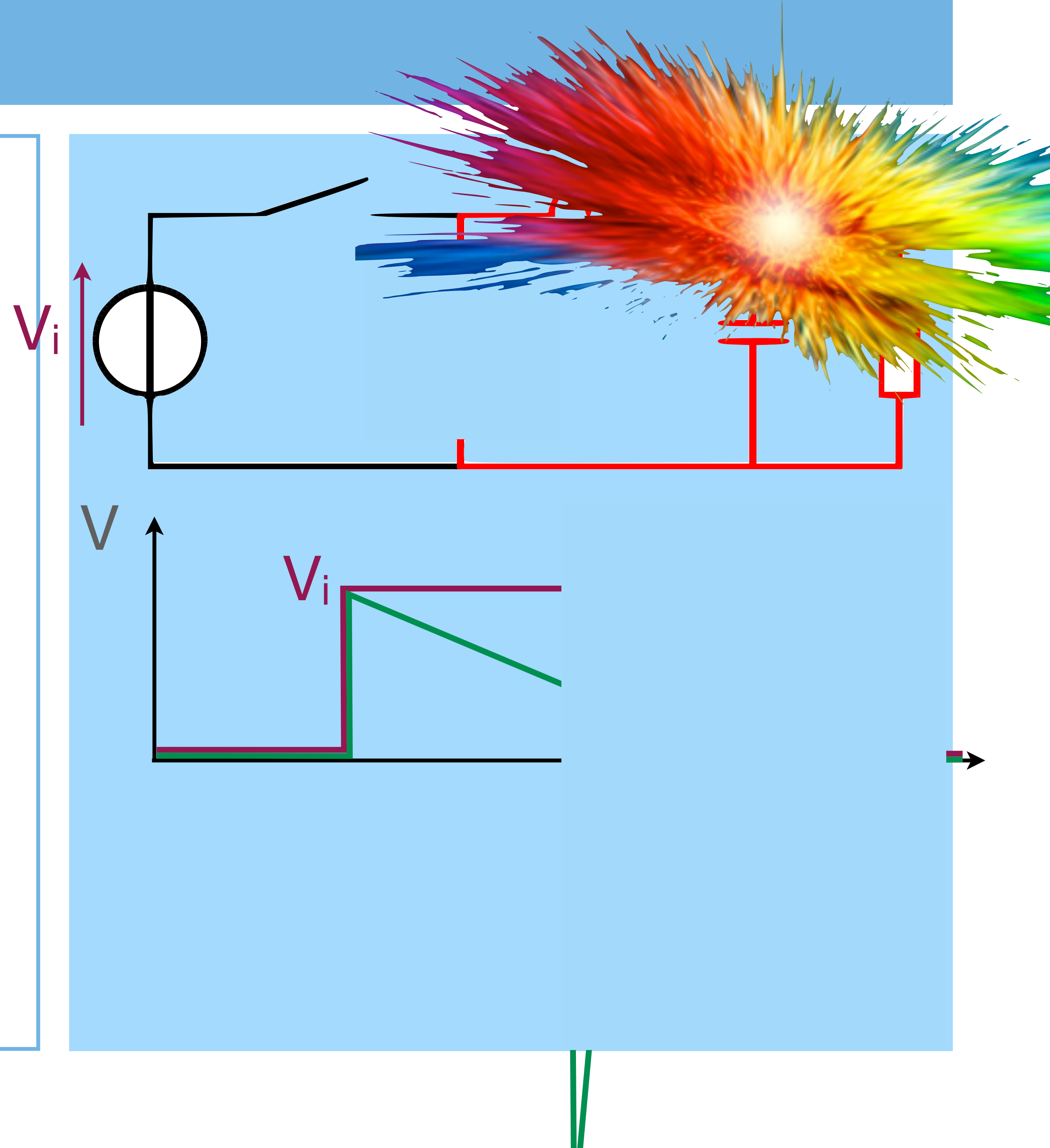
Voltage dropped

- Energy gets released from the magnetic field
- The magnetic field induces a current
- A reverse voltage gets built up to sustain the current
  - As large as it takes to sustain the current!

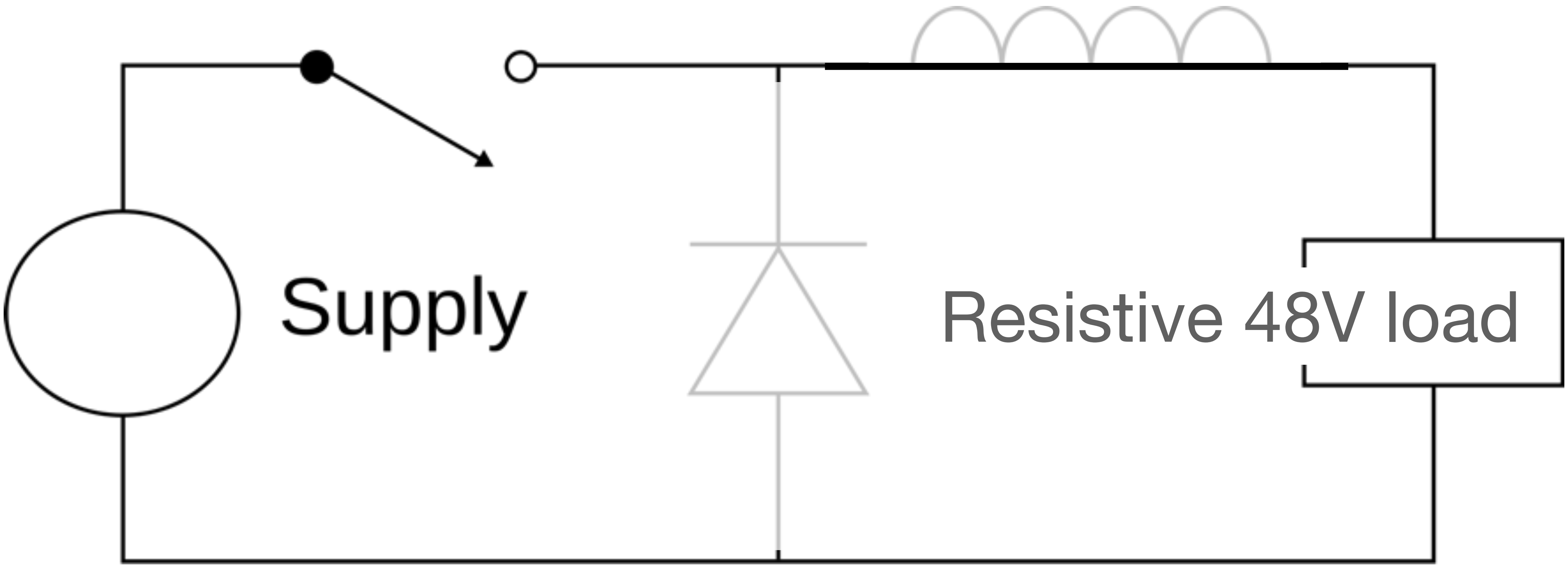


Diode missing

- Energy is stored in the magnetic field
- The magnetic field induces a current
- A reverse voltage spike gets built up!
  - It may be hundreds of volts, beware!



A simplified "buck"



Understanding loads

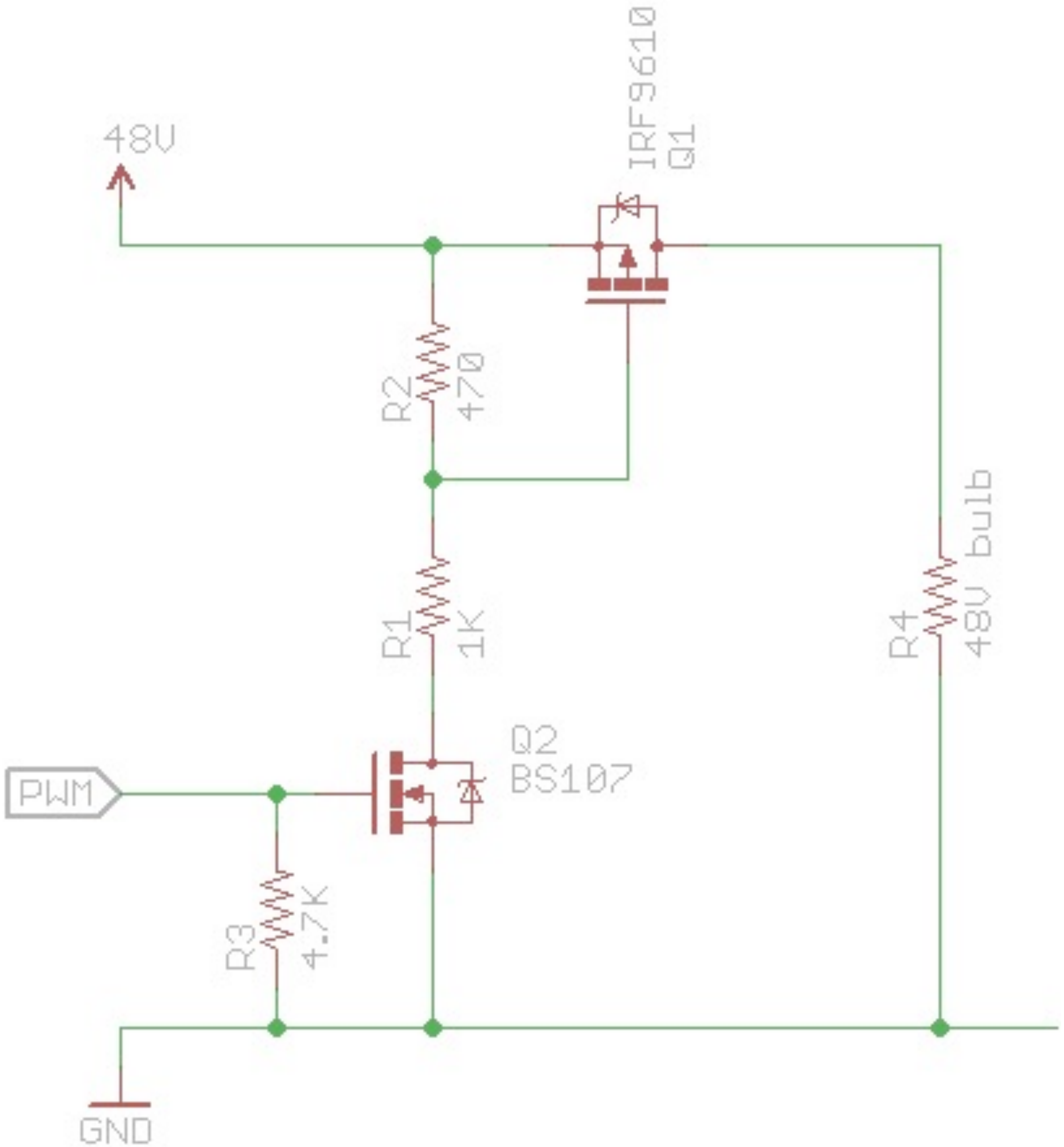
- Different loads require different design
  - Voltage/current dynamics are different
- Resistive: $V = R \cdot I$ $P = V \cdot I = I^2R$
- LED: $V \approx \text{constant}$ $P = V \cdot I = a\, I$
- Coil: $dI/dt \approx \pm\text{constant}$ $P = V \int I(t)\, dt$
  - Only a rough approximation,
    but good enough for us today
- (We ignore capacitors, for simplicity)

SMPS summary so far

- Buck stores energy in a coil during duty
- Energy gets released at off-duty period
- Generates a “constant” current
  - The average is constant
  - The “constant” depends on freq. & duty
- Too high current burns components
  - Your software mistakes may do that :-)
  - That’s completely ok!

Today's lab exercise

- Purely resistive load
  - 48V light bulb
- First a simple PWM circuit
  - Switches 48V on/off
- More advanced may continue to a real buck
  - Add coil & diode
  - Try with some other load



Practicalities

- Lab at 1–4 pm
- Instructions in a Wiki for following
  - Instructions are for a full buck converter
    - Building a full buck converter takes 5–7 hours
      - But YMMV, maybe you are quick
  - Initially leave out the coil and diode
- Don’t be (too) scared about burning things
  - Burning components in normal, like having bugs in your code is normal

Summary

- ELL-i aims to democratise electrical power
  - PoE is “cool” power, 48VDC ELV
  - You can build your own DC/DC converter
- ELL-i co-op owns the open source designs
  - Build an ecosystem around the platform
- ELL-i 1.0 is Arduino compatible, PoE enabled
  - ELL-i 2.0 is being designed, adding FPGA
- Control your things — build your own DC/DC