ENERGY micro
LINEAR TECHNOLOGY
Farnell element14

WÜRTH ELEKTRONIK

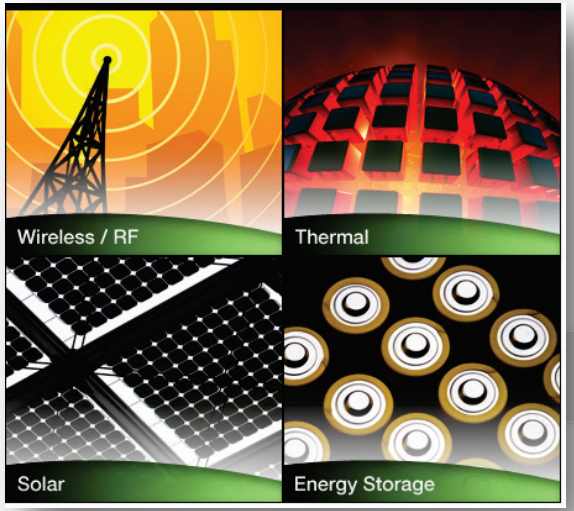
Energy Harvesting To Go

Lorandt Fölkel (M.ENG)
Field Application Engineer and
Product Development Manager

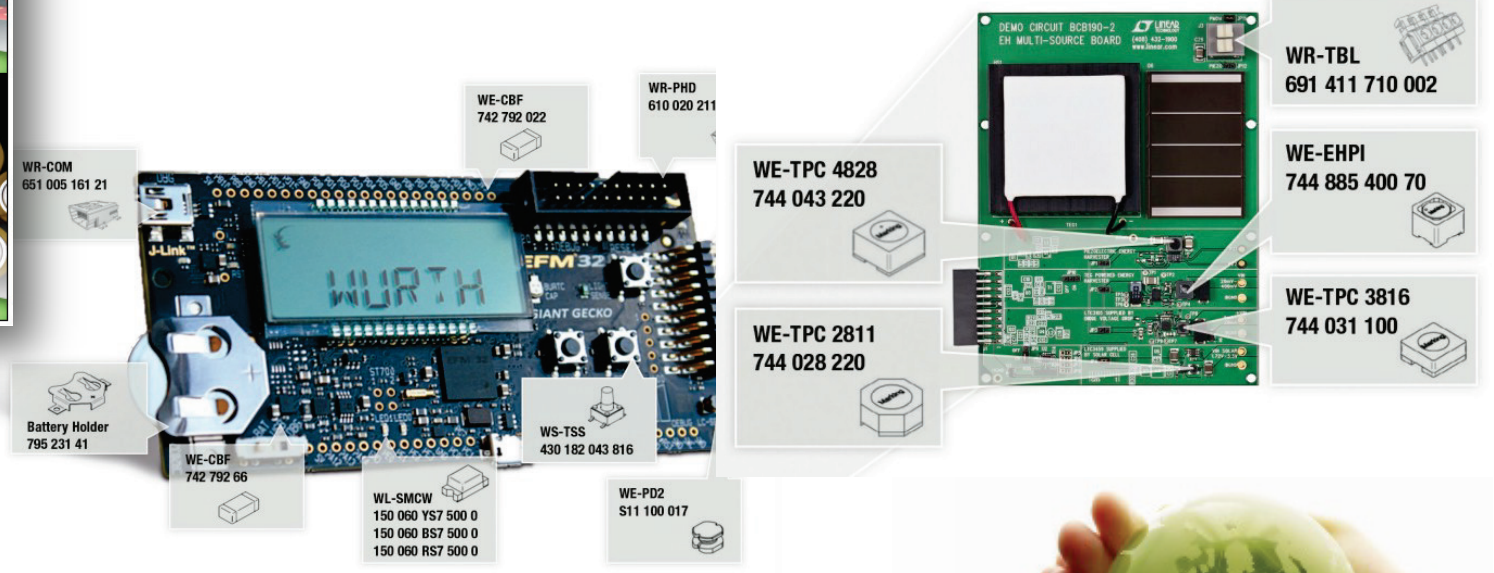
Würth Elektronik
eiSos GmbH & CO.KG

ENERGY HARVESTING TO GO

Energy Harvesting



- **Environment energy captured and converted into electricity for small autonomous devices making them self-sufficient.**



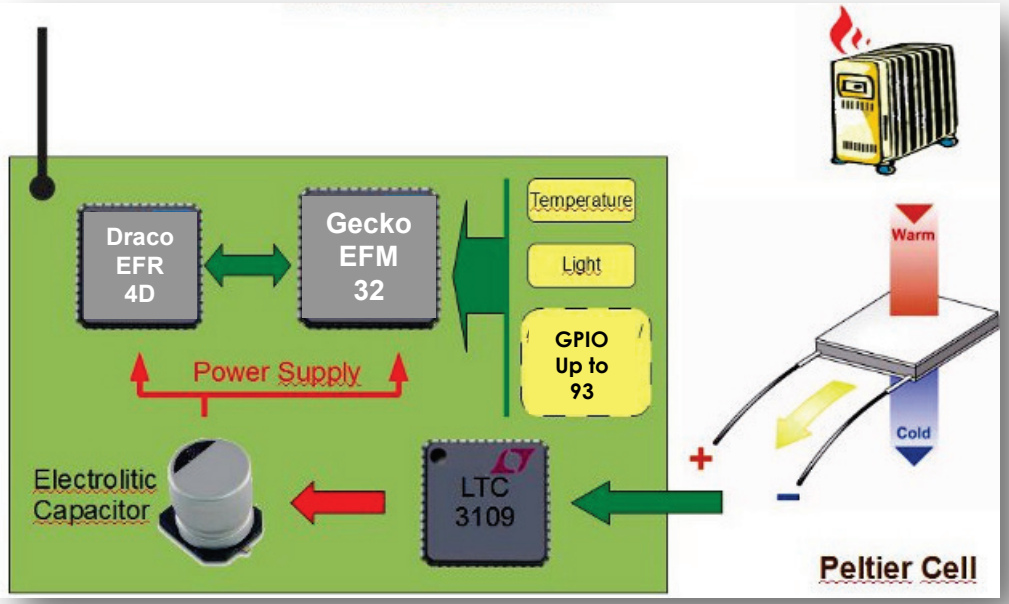
- Thermo Electric Generator (heat)
- Piezo Electric (vibration/strain)
- Photovoltaic (light)
- Galvanic (chemical)
- Induction (motion)

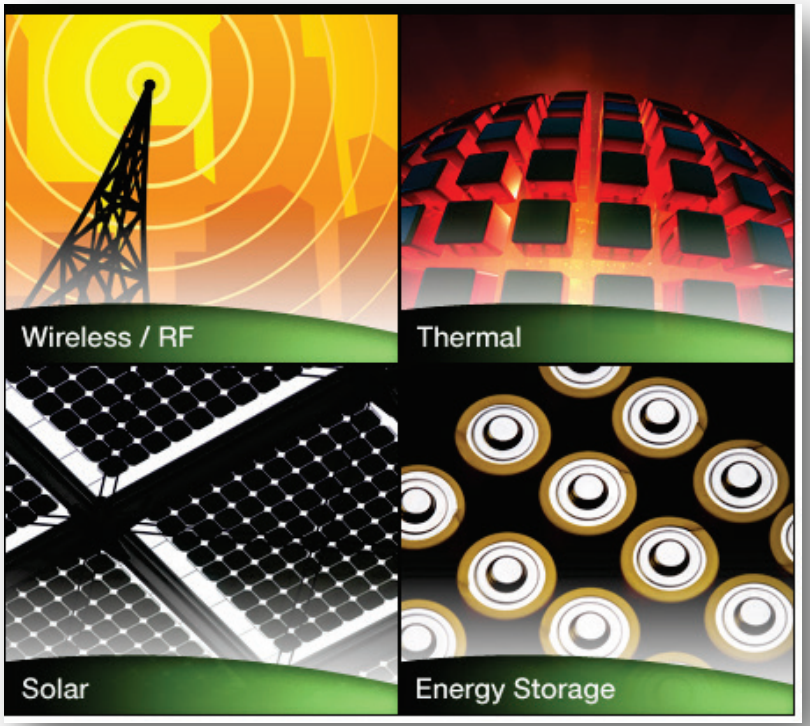
→ Energy Management & Storage → Regulated Voltage

What is Energy Harvesting

- **The process by which energy is derived from external sources, captured and stored for use in electronic systems**

- **Energy harvesting is the process by which ambient energy is captured and converted into electricity for small autonomous devices, such as satellites, laptops and nodes in sensor networks making them self-sufficient.**



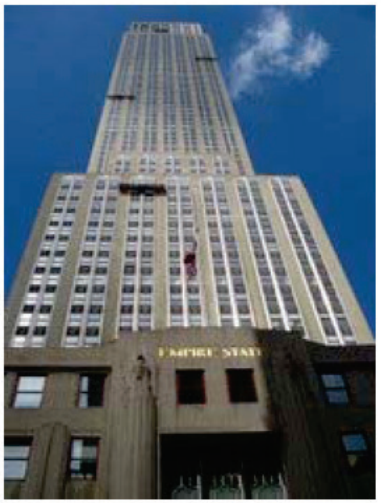


Where is it useful?

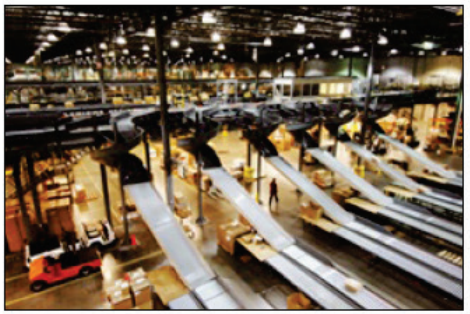
- Where line power is unavailable or costly
- Where batteries are costly or difficult to replace
- Where energy is needed only when ambient energy is present

Asset Tracking/Monitoring

Building Security, Lighting & Climate Control



Plant Automation



Remote Monitoring

TPMS

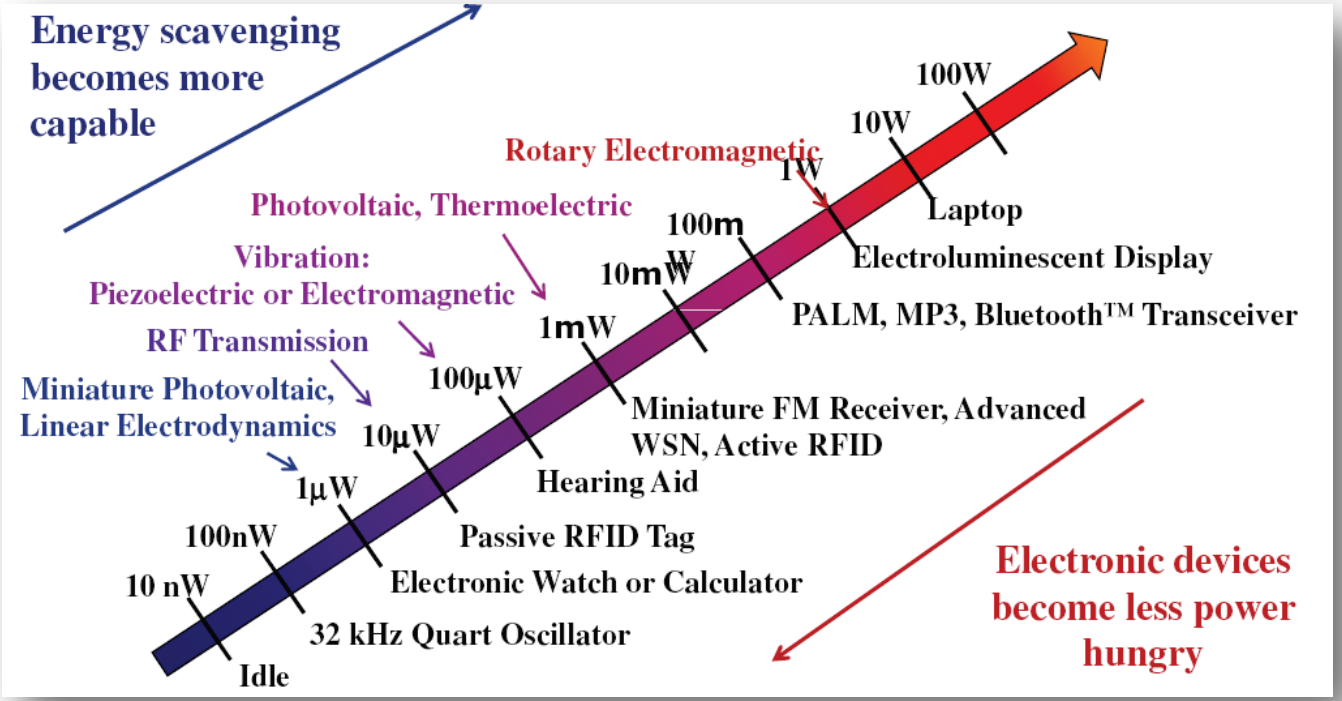
Source: LTC - Sam Nork – Energy Harvesting Presentation

Typical applications

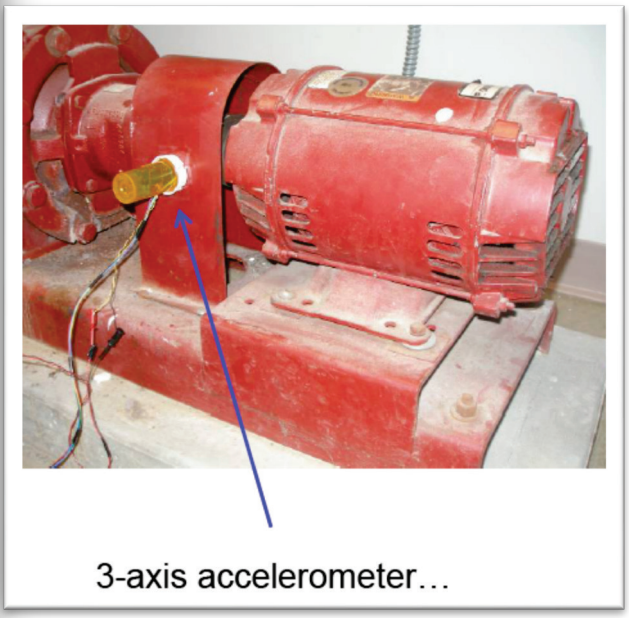
Energy, Gas, Water and Smart Meters	Home and Building Automation	Alarm and Security Systems	Health and Fitness	Smart Accessories
 Power Meters	 Access Control	 Fire and Safety	 Portable Medical	 Ultra low power add-ons and dongles
 Water Meters	 Light Control	 Burglar Alarms		
 Gas Meters	 Climate Control	 Motion Sensors	 Remote Diagnostics	
 Smart Meters	 Remote Control			

Where to find „free energy“

- **Typical energy harvester output power**
  - → RF: 0.1µW/cm²
  - → Vibration: 1mW/cm²
  - → Thermal: 10mW/cm²
  - → Photovoltaic: 100mW/cm²
- **Typical energy harvester voltages**
  - → RF: 0.01mV
  - → Vibration: 0.1 ~ 0.4 V
  - → Thermal: 0.02 ~ 1.0 V
  - → Photovoltaic: 0.5 ~ 0.7 V typ/cell

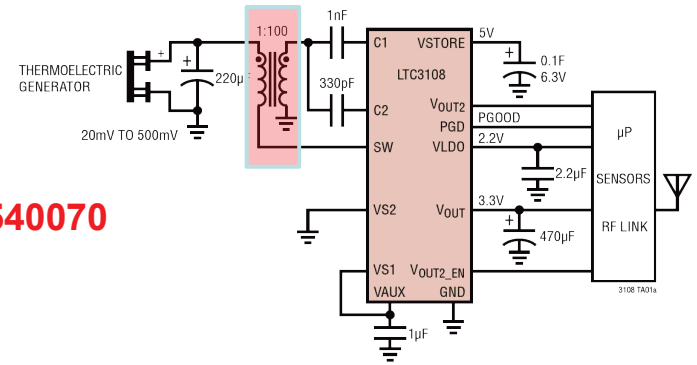


Source: Intel – Kamal Shah - Energy Harvesting Presentation



Linear Technology - Applications

Wireless Remote Sensor Application Powered from a Peltier Cell



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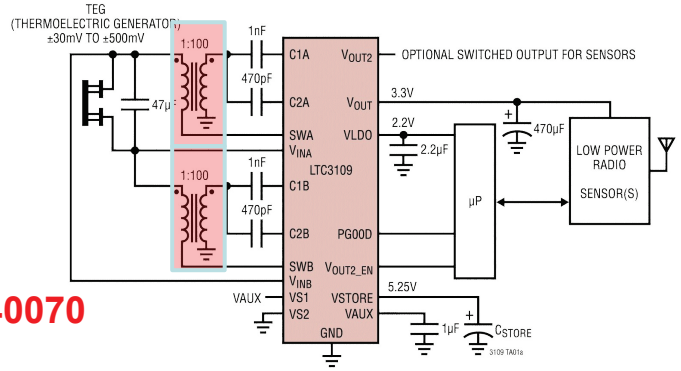
Energy Harvesting Operates from Small Differentials of Either Polarity



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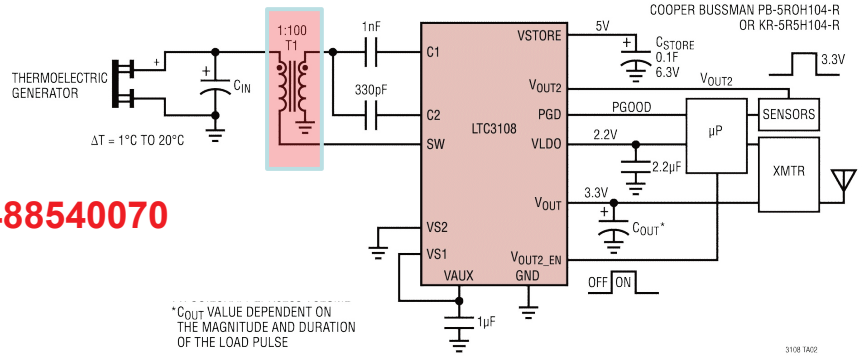
Peltier-Powered Energy Harvester for Remote Sensor Applications



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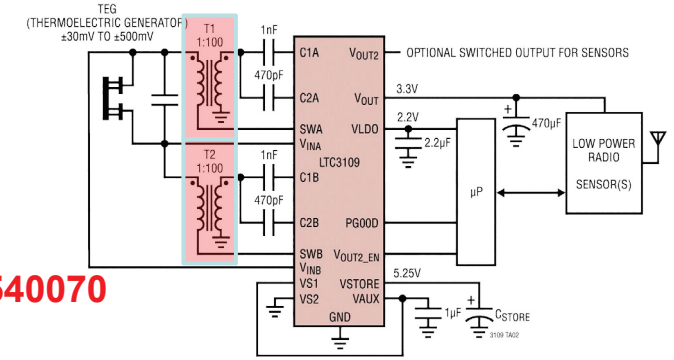
Energy Harvesting Operates from Small Temperature Differentials of Either Polarity



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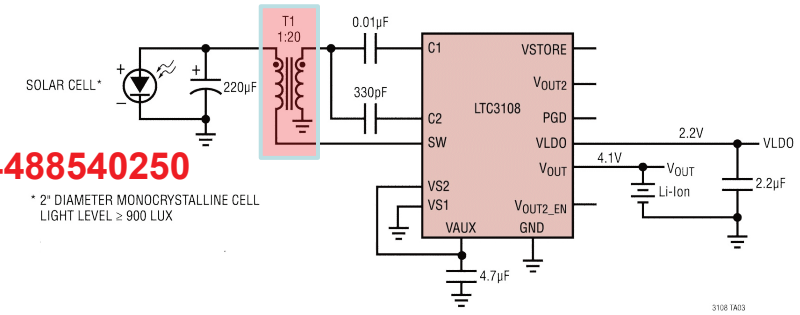
Linear Technology - Applications

Li-Ion Battery Charger and LDO Powered by a Solar Cell



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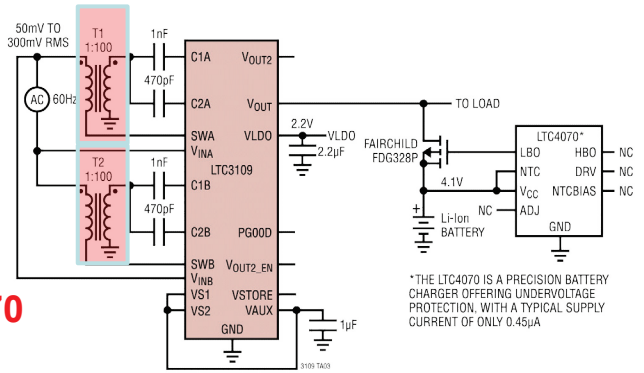
* 2" DIAMETER MONOCRYSTALLINE CELL
LIGHT LEVEL ≥ 900 LUX

Li-Ion Battery Charger and LDO Operates from a Low Level AC Input



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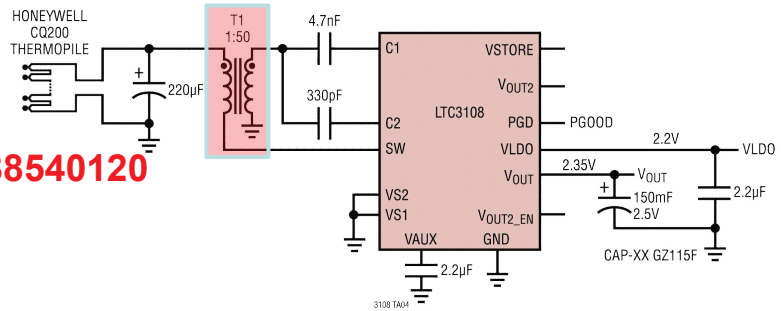
Supercapacitor Charger and LDO Powered by a Thermopile Generator



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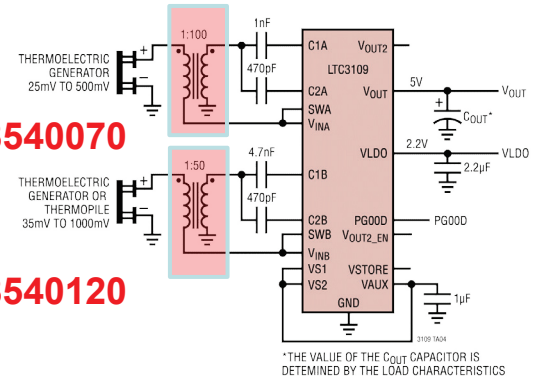
Dual-Input Energy Harvester Generates 5V and 2.2V from Either or Both TEGs, Operating at Different Temperatures of Fixed Polarity



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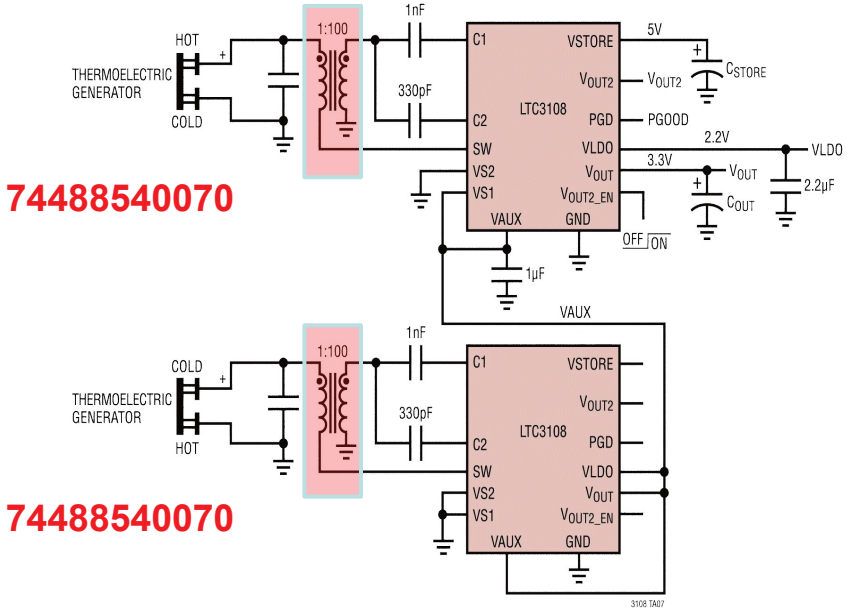
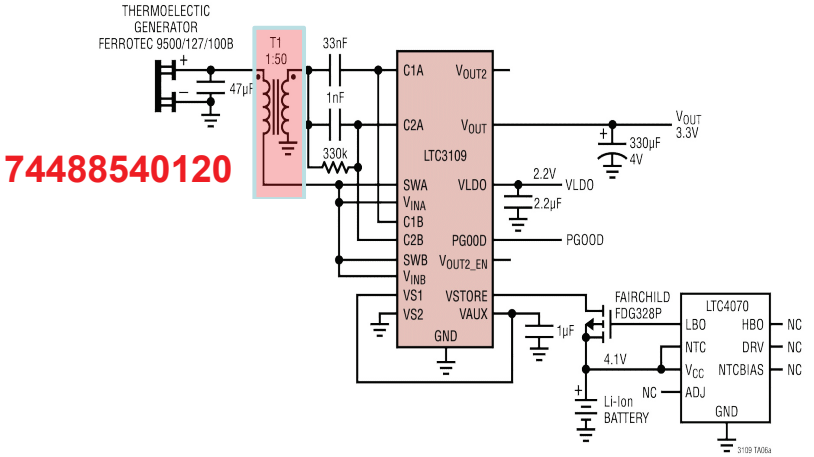
*THE VALUE OF THE C_{OUT} CAPACITOR IS
DETEMINED BY THE LOAD CHARACTERISTICS

Linear Technology - Applications

Dual TEG Energy Harvester Operates from Temperature Differentials of Either Polarity



Unipolar Energy Harvester Charges Battery Backup

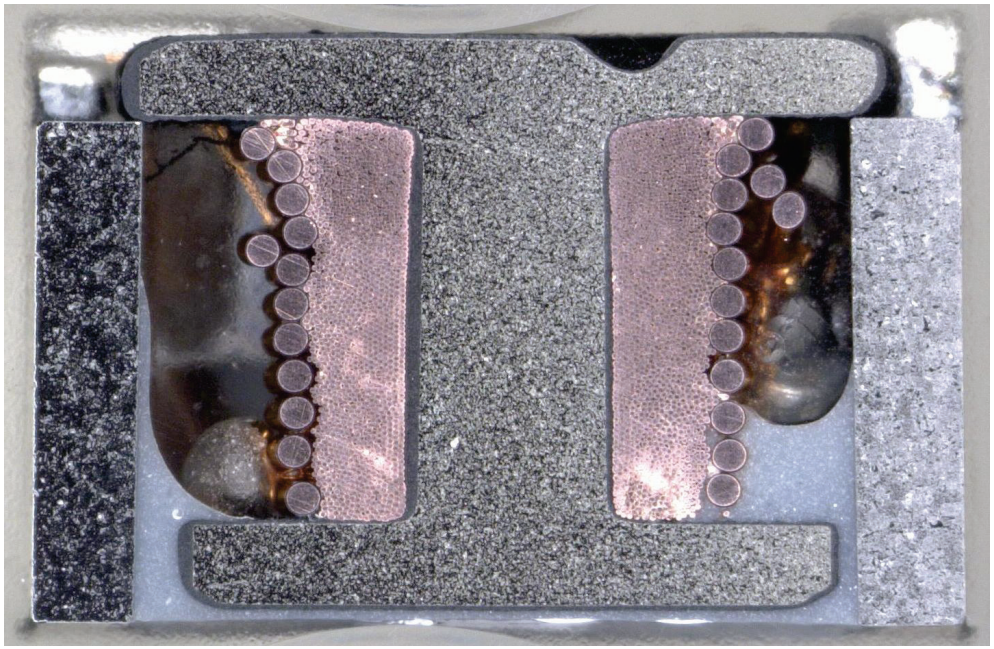


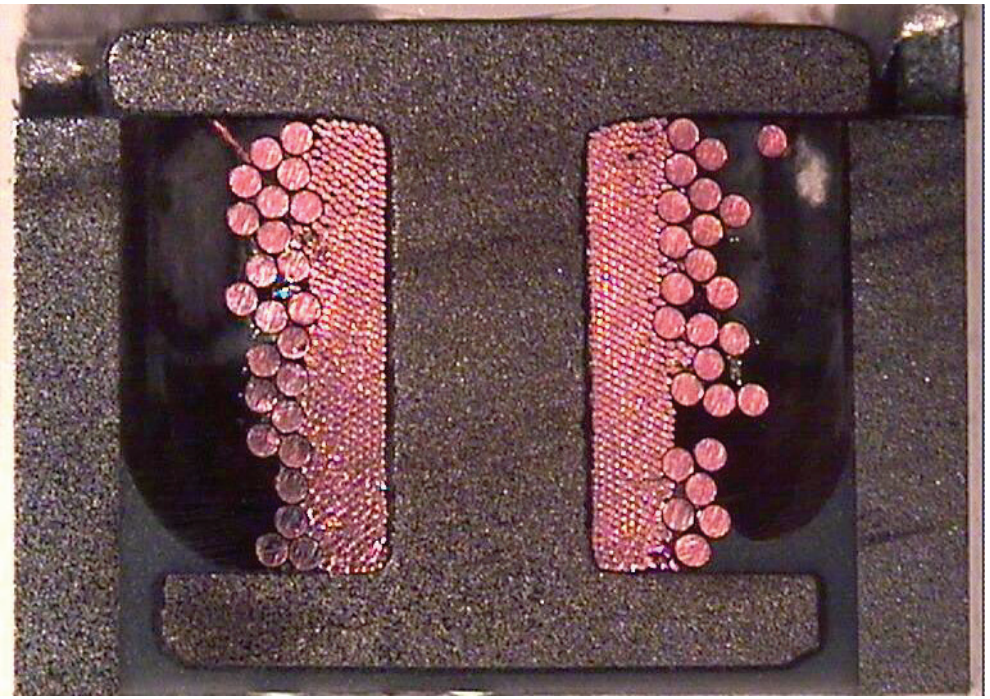
- **Linear Technology Preferred Partner for Magnetics**

http://cds.linear.com/docs/Product%20Info/EnergyHarvestingPartners.pdf

What is behind the WE-EHP transformer?

- **winding style**





Würth Elektronik eiSos components

WE-EHPI
Energy Harvesting Power Inductor

NEW!

Optimized for LTC3108/LTC3109 and more

Characteristics

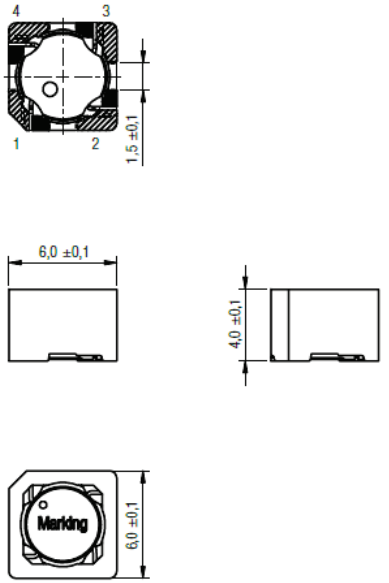
- Low profile: 4 mm
- Small footprint 6 x 6 mm
- Very low secondary R_{DC}
- Different turn ratios available
- Separated welding/soldering pad for a high reliable component
- Optimized, high reliable winding style

Applications

- Wireless fire, alarm, gas and metering remote sensors driven by environmental energies based on energy harvesting voltage transformers like LTC3108/LTC3109
- Sensors with predictive battery replacements in applications which are difficult to access
- Energy self-sufficient supply using subsequent installed sensors for energy harvesting

QR-Code

Dimensions (in mm)

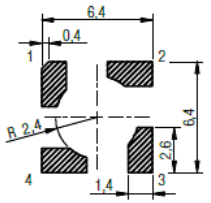


Electrical properties

Order Code	L_1 ±20% (µH)	L_2 ±20% (µH)	n	I_{R1} (A)	I_{sat1} (A)	R_{DC1} (Ω)	R_{DC2} (Ω)
744 885 400 70	7.5	75000	1:100	1.9	1.3	0.085	205
744 885 401 20	13.0	33000	1:50	1.7	1.0	0.090	135
744 885 402 50	25.0	10000	1:20	1.5	0.7	0.200	42

Schematic

Land pattern (in mm)

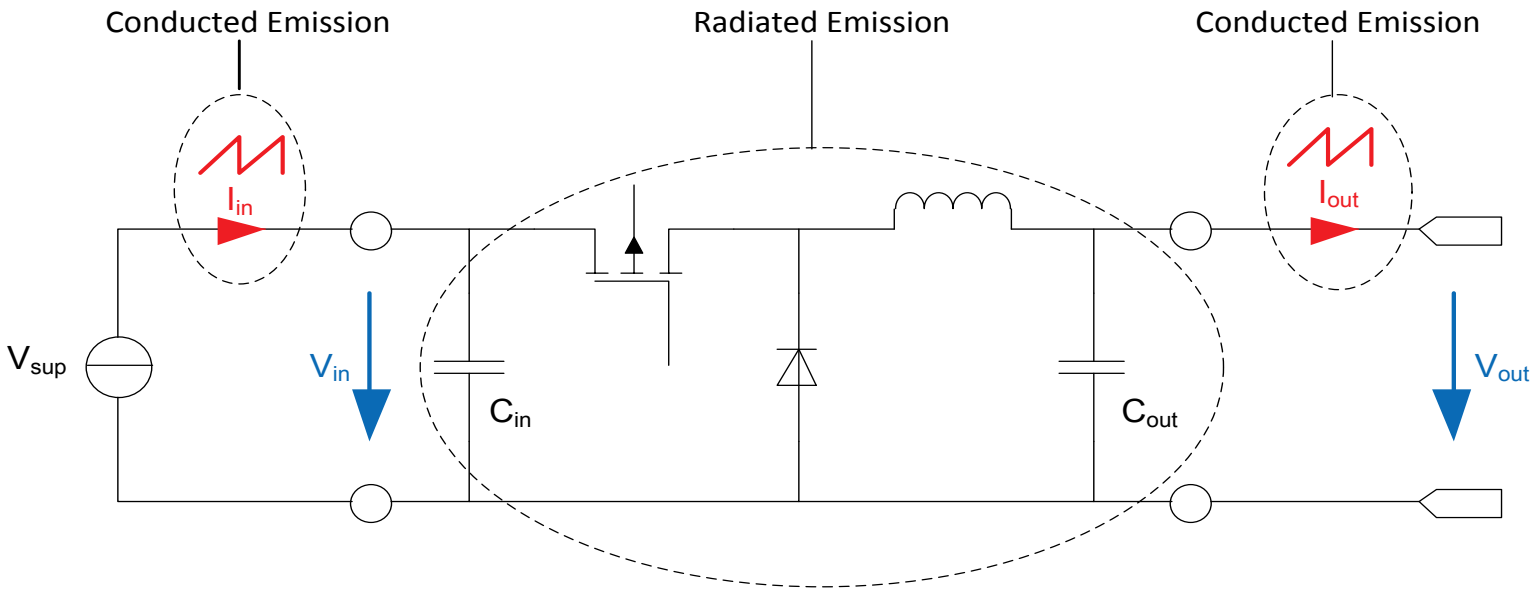


Transformer designed on EP7 cores are available on request – Order code: 760370096, 760370097, 760370098

During design stage of this series, we used S11100032, S11100033 & S11100034.
With our standard series we have replaced these order codes.

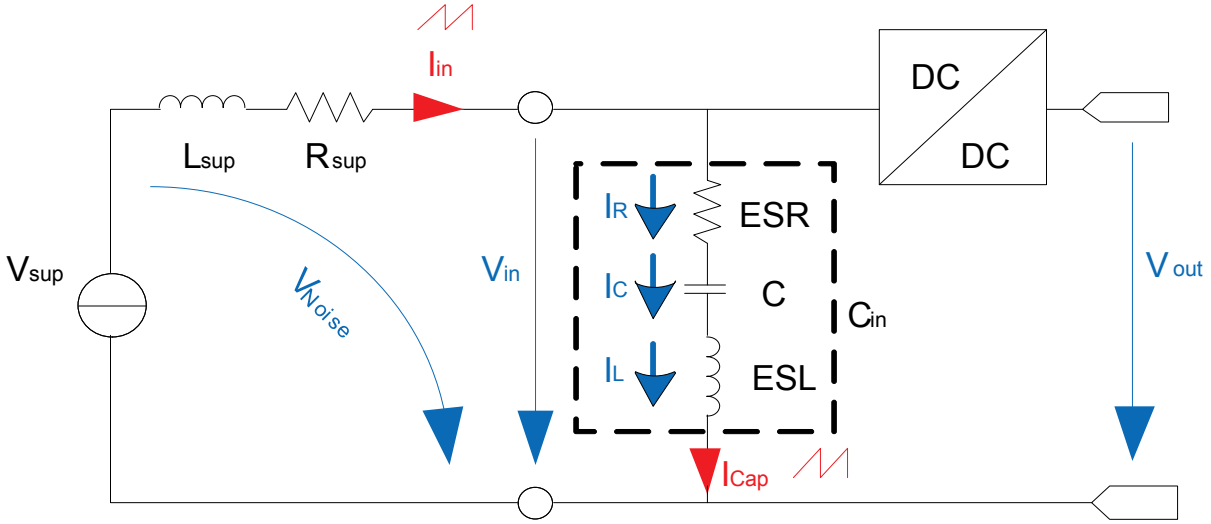
EMC / EMI NOISE SOURCES

Representative noise sources



- **Input current caused by voltage ripple → *„Conducted Emission“***
- **Power traces and choke radiate EMI → *„Radiated Emission“***
- **Output current caused by voltage ripple → *„Conducted Emission“***
- **Radiated emission will increase by using long input / output lines(cables)**

Conducted noise at converter input



- **Conducted Emission is generated by voltage drop across R_{Sup} and ESR_L**

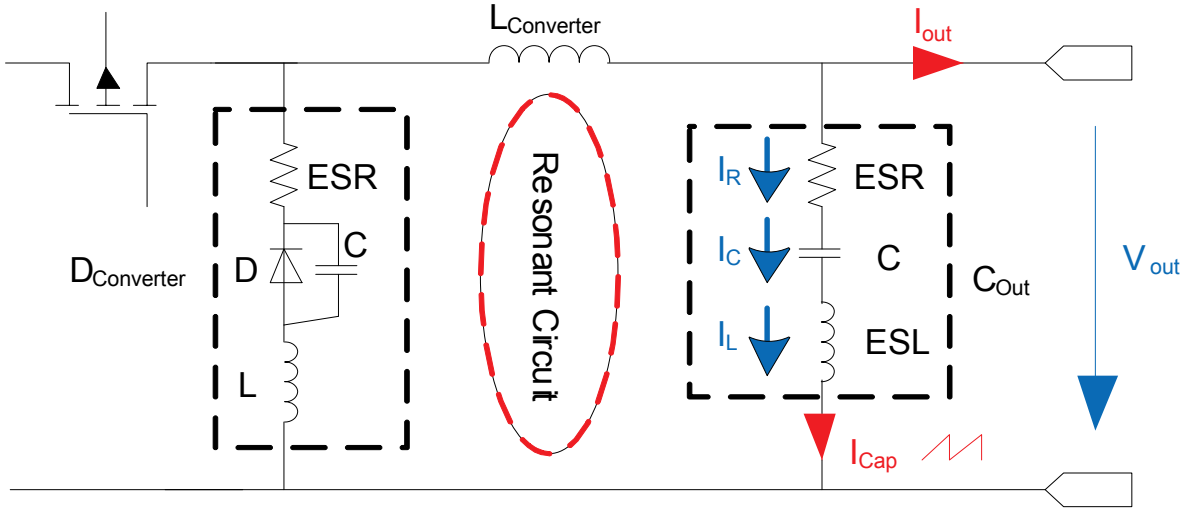
$$V_{Noise} = Rsup * Iin + ESR * ICap$$

- **V_{Noise} = Rsup * Iin + ESR*I_{Cap}**
- **Resonance circuit is formed by L_{sup}, C_{in} and ESL_{Cin}**

$$f_0 = 1 / 2\Pi\sqrt{(Lsup-ESL)*Cin}$$

- **Different harmonics due to fundamental frequency from $f_{DC/DC}$ and $f_{Resonance\ Circuit}$**

Conducted noise at converter output



- **Conducted emission is generated by voltage drop at ESR_C**

$$U_{Noise} = ESR_{Cout} * ICout$$

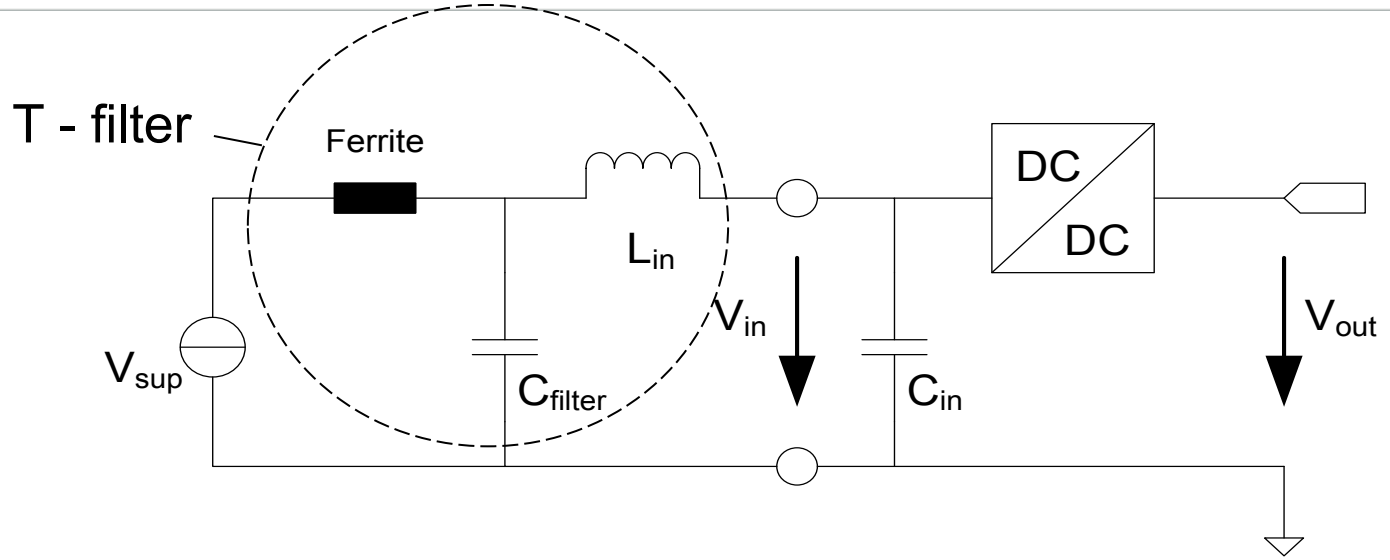
- **Resonance circuit is formed by $C_{Dconverter}$, C_{Out}, $L_{Converter}$, and ESL_{Cout}**

$$f_0 = \frac{1}{2\pi\sqrt{(ESL_{Cout})*COut}}$$

- **Different harmonics due to fundamental frequency from $f_{DC/DC}$ and $f_{Resonance\ Circuit}$**

Wideband input filter

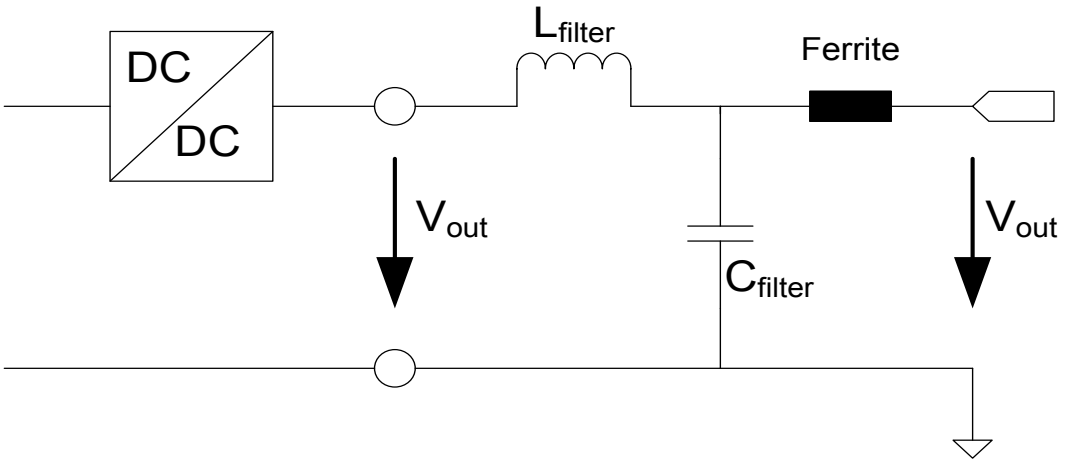
(recommended filter solution)



- **T-filter recommend for wideband filtering**
  - **L_{in} for low frequency filtering (DC/DC converter switching frequency)**
  - **Ferrite for high frequency filtering**
  - **C_{filter} shorting ACnoise to GND (220pF < C_{filter} < 1nF, low ESR)**

Attention!!! This filter is not efficient to reduce common mode noise on input lines

„T“ - output filter
(recommended filter solution)

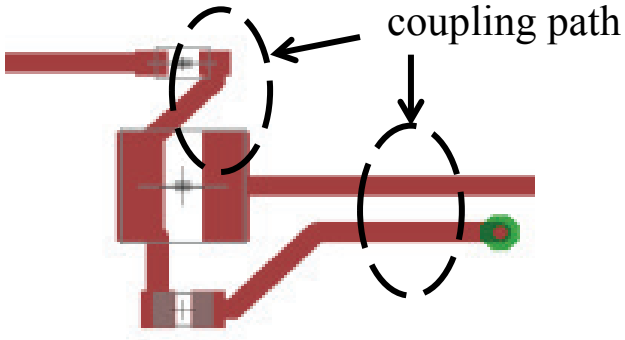


- **T-filter recommend for wide bandwidth filtering**
  - **L_{filter} for low frequency filtering (DC/DC converter switching frequency)**
  - **Ferrite for high frequency filtering**
  - **This kind of output filter is for powering radio devices high recommended**

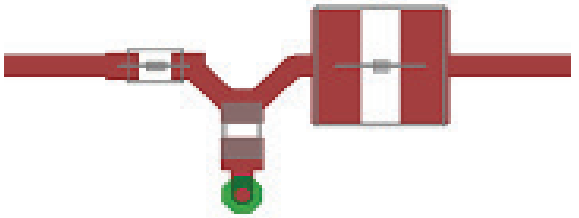
Attention!!! This filter is not efficient to reduce common mode noise on output line

PCB-Layout recommendations

T-filter



not recommended

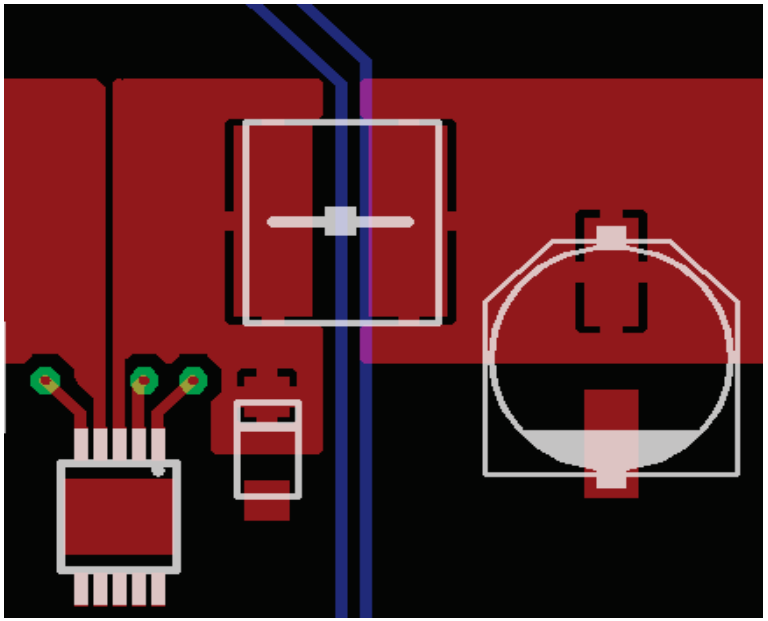


recommended

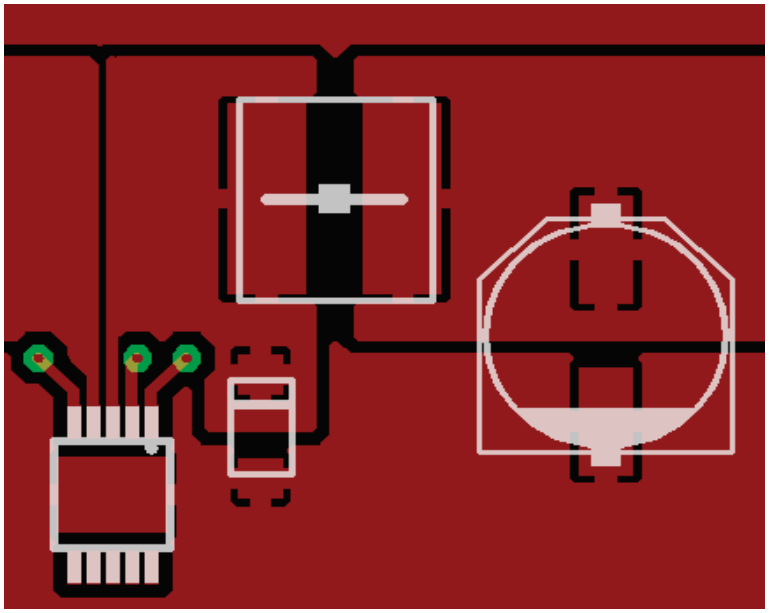
- **Keep PCB traces as short as possible**
- **Avoid indirect trace routing**
- **Avoid any kind couplings → "*capacitive*", "*inductive*"**
- **AC-current should flow across capacitor**
- **Short way for AC-current direct to GND (place double vias to GND)**

PCB-Layout recommendations

DC/DC buck converter



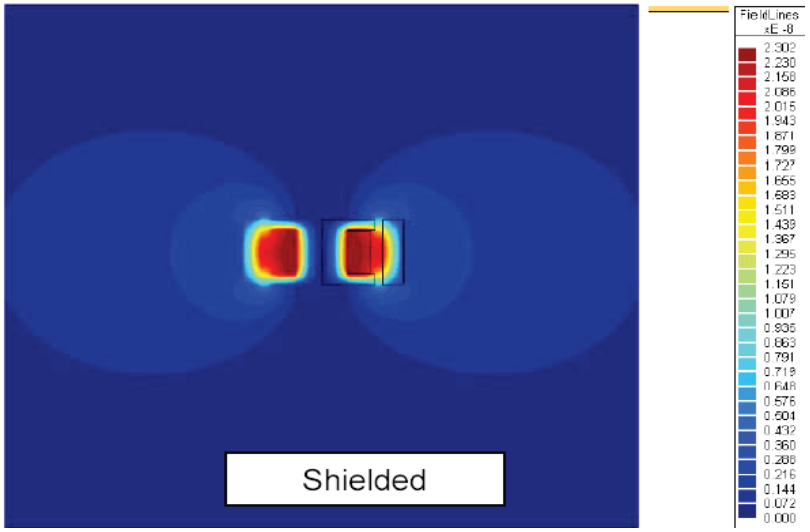
not recommended

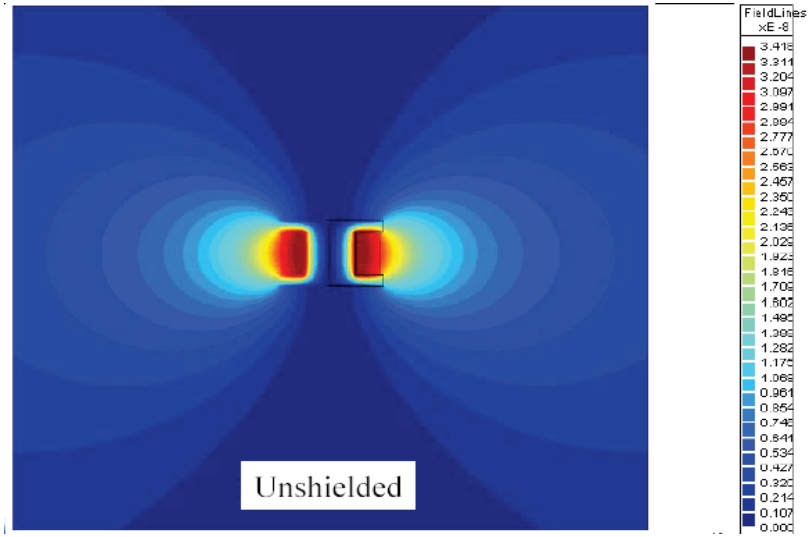


recommended

- **Avoid GND planes under inductor (between inductor pads)**
- **Don’t route any kind of signals (analog, clock) under the inductor**
- **Fill out unused space on PCB with GND (flood)**

Magnetic field leakage



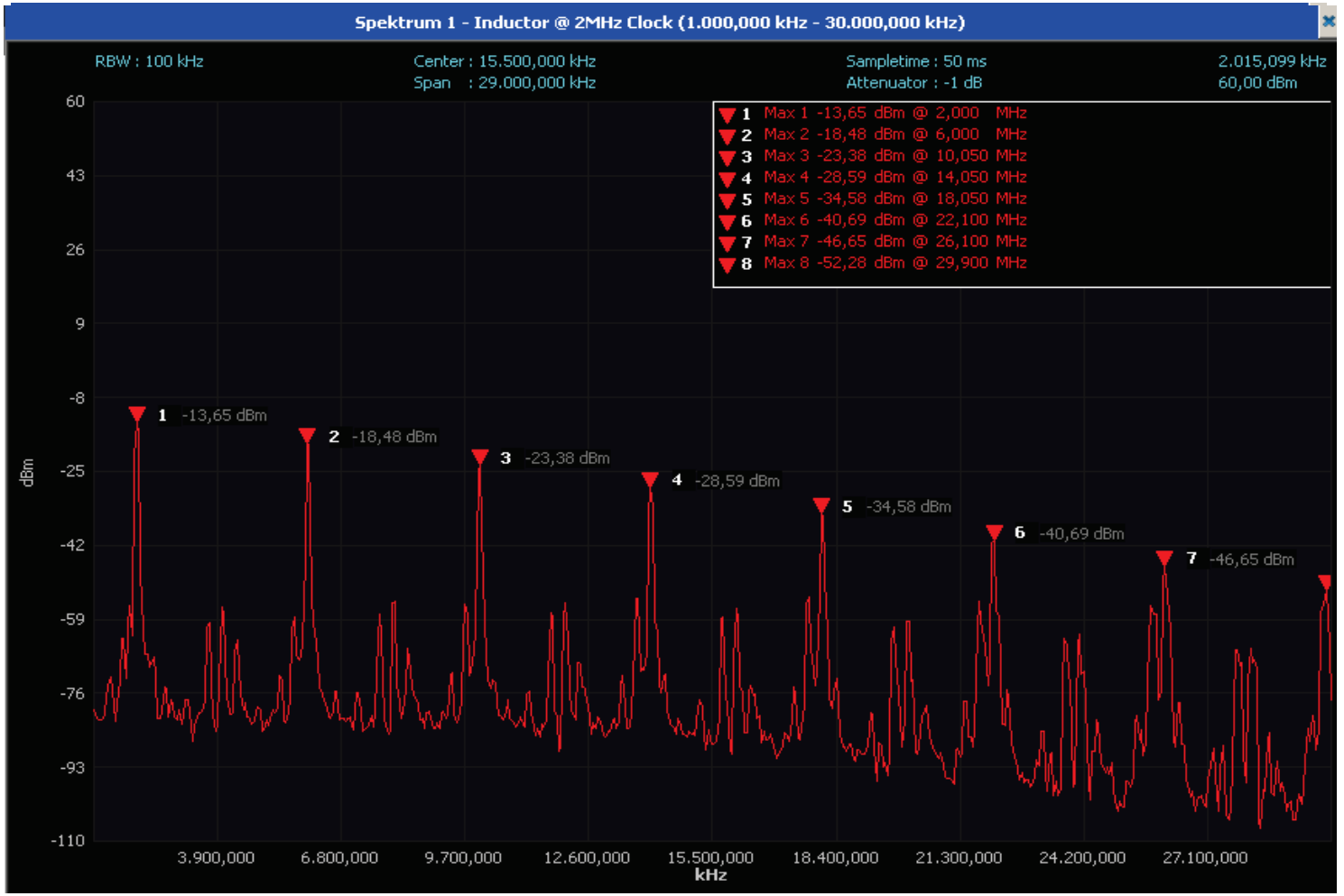


Radiation by inductor

WE - PD2 unshielded
10µH, 2MHz Clock, 1A

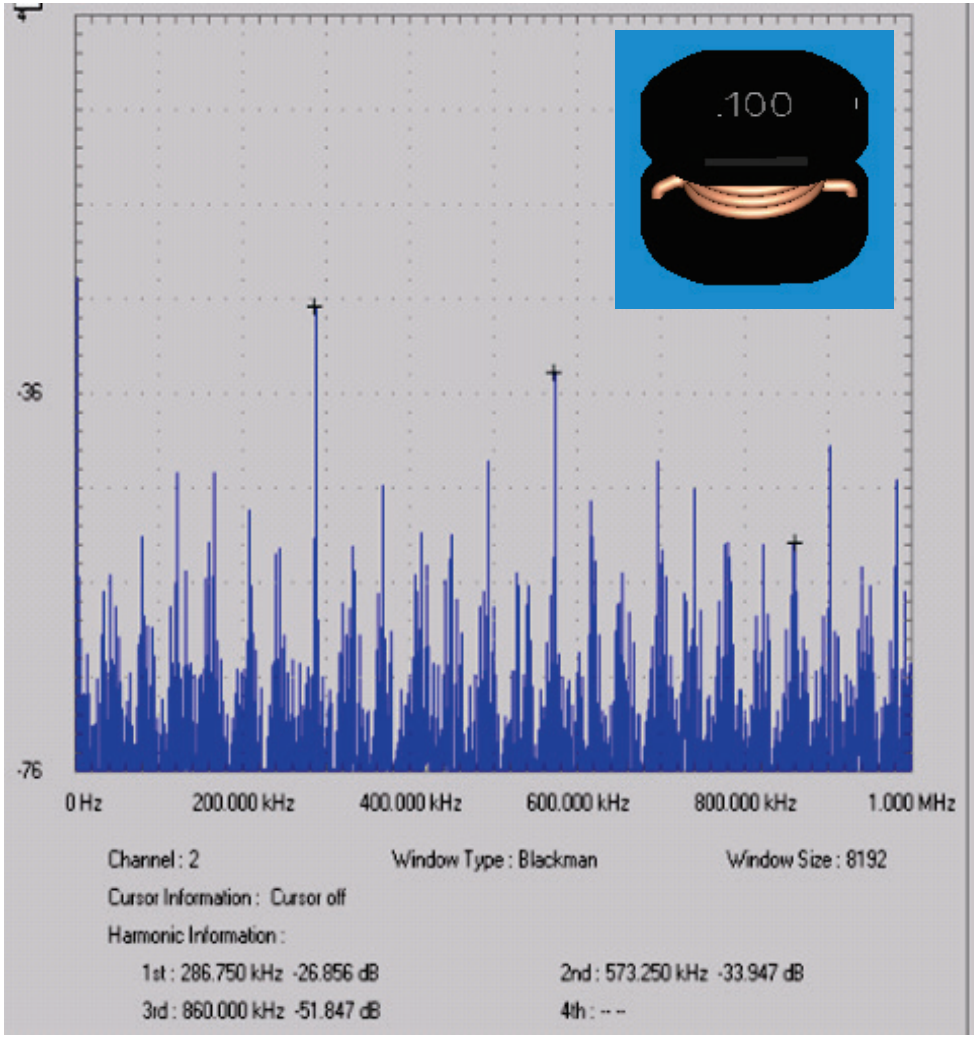
WE – PD shielded
10µH, 2MHz Clock, 1A

19dBm difference

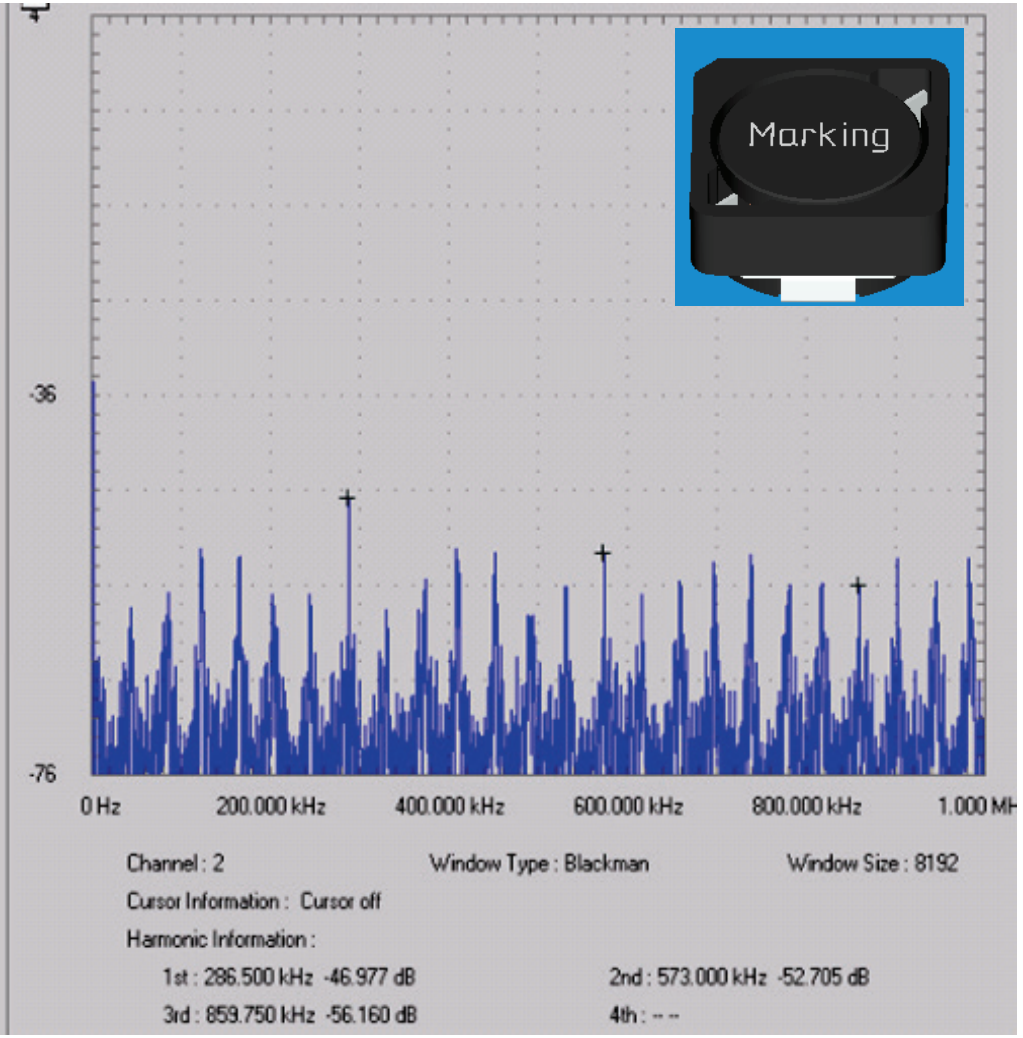


Magnetic leakage shielded vs. unshielded

unshielded



shielded



Let us work together!

Technical Support

- Design Guide “Trilogy of Magnetics”, “Trilogy of Connectors” & „Simulation in LTspice IV“
- Local support

Design-In Support

- EMC test lab racks
- Reference designs of IC manufacturers
- Toolbox for engineers & purchasers
- Free design program Component Selector

Delivery

- All products available ex stock
- Within 24 hours
- No MOQ
- Service degree: 98.5 %
- Samples free of charge

Service

- Free technical seminars
- Design Kits with lifelong free refill
- EMC Test lab search engine

Helpful tools for engineers & purchasers: www.we-online.com/toolbox

Energy Harvesting To Go Kit

More information at:

www.we-online.com

and at our local distributor:

www.farnell.com

www.element14.com