ELECTRICALENGINEERING

What kind of inductor for DC-DC converter module's EMC filter?

Asked 4 years, 1 month ago Modified 4 years ago Viewed 2k times

5

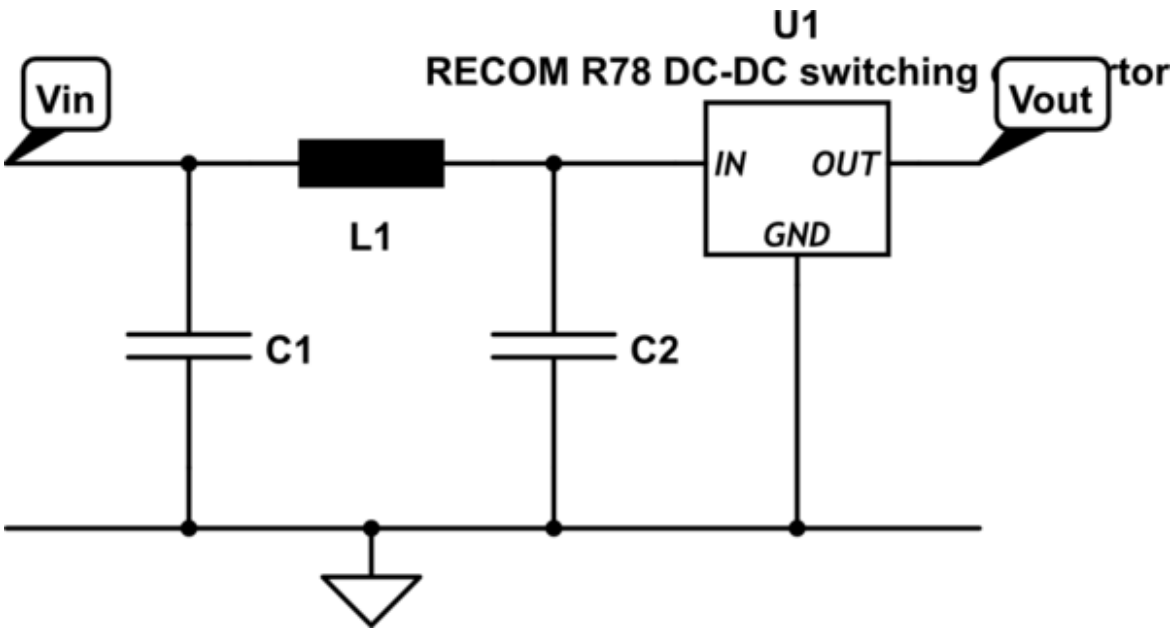
I'm looking at the datasheets for a number of switching DC-DC converters. They suggest for EMC filtering to add an inductor and a capacitor or two on the input side of the converter.

The question: what kind of inductors are required? How critical are the values?

I'm not after product recommendation, I'm after clarification of the type of component.

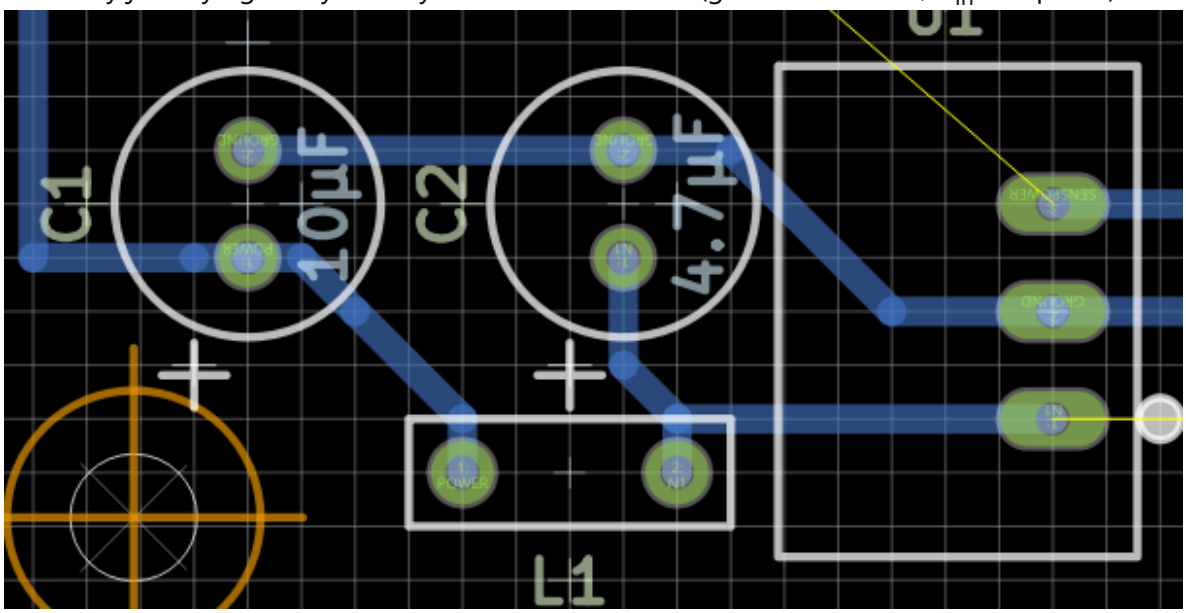
Are they "axial-leaded high-frequency inductors", in a resistor-like package? Open coils? I've been looking at Epcos BC+ (datasheet), Bourns 78F (datasheet), Wurth WE-TI (datasheet).

The converter datasheets show a filter circuit as follows:



simulate this circuit – Schematic created using CircuitLab

I'm really just trying to lay out my PCB at the moment (grid is 0.127 mm, V_{in} is top left.)



For reference, these are the values from the DC-DC converter datasheets:

Recom R78E-0.5 series (datasheet) suggests EN 55032 EMC filtering: Class A filter L1 3.9µH, C1 4.7µF/50V, no C2; Class B filter L1 12µH, C1 10µF/100V, C2 4.7µF/50V.
Traco power TSR-1 series (datasheet) suggests Class A filter L1 5.6µH/3.5A, C1 10µF/50V, C2 10µF/50V.

inductor emc component-selection

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edited May 21, 2020 at 17:24

asked May 6, 2020 at 19:07
jonathanjo
14.4k 3 34 67

If you plan on adding a front-end LC filter, make sure it does not degrade the overall stability considering the negative incremental resistance of the dc-dc module. You will probably need to damp the filter otherwise the performance may be worse than without a filter. I have explained the details in an APEC seminar I taught in 2017. – Verbal Kint May 15, 2020 at 14:08

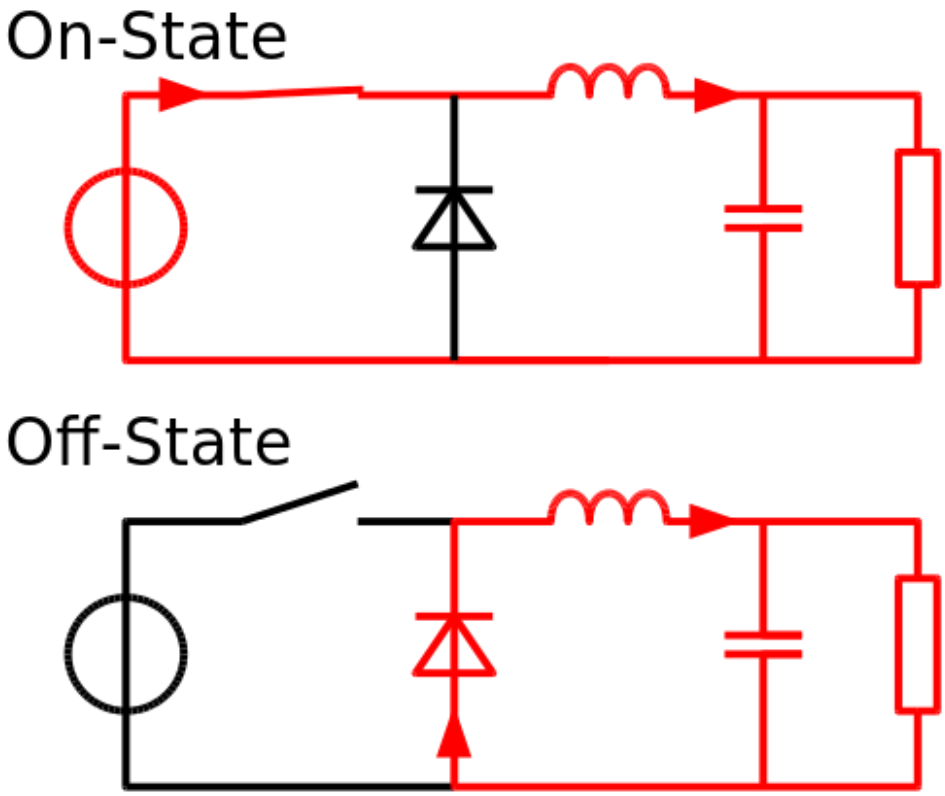
Hi @VerbalKint thanks very much for this, but all the answers I'm getting are about the design of the filter, whether it's necessary/good etc. What I'm actually after is a sentence about the inductors, perhaps modelled on this one about a transistor: "The 2N3904 is a common NPN bipolar junction transistor used for general-purpose low-power amplifying or switching applications. It is considered low current and power, medium voltage, and moderately fast." (wikipedia). – jonathanjo May 15, 2020 at 17:26

5 Answers

Sorted by: Highest score (default)

2

Your Traco bricks are buck converters which means the output current waveform is a sawtooth, and the input current waveform is a high-frequency square wave. Thus the highest amount of HF current harmonics is on the **input**, hence the filter.



Here's a neat image that shows current waveforms (source):

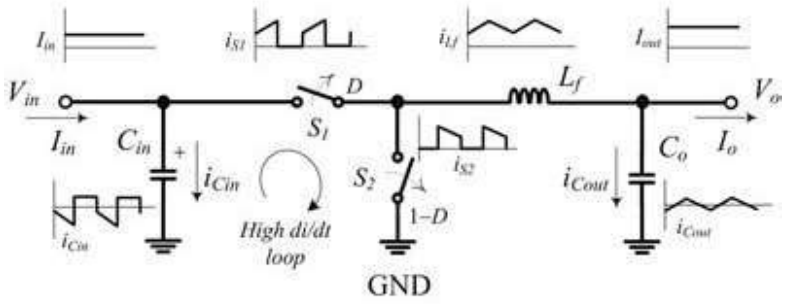


Figure 1: Buck Converter Power Stage

These are 0.5A and 1A DC-DC converters so max input current will be a bit above 1A peak square wave, say 1.5A accounting for inductor current ripple. Frequency around 500kHz. It will be somewhat smoothed by the internal ceramic caps, but short of actually measuring it, there is no way to know how choppy it will be.

Capacitor type:

Caps should withstand 1A ripple current at 500kHz.

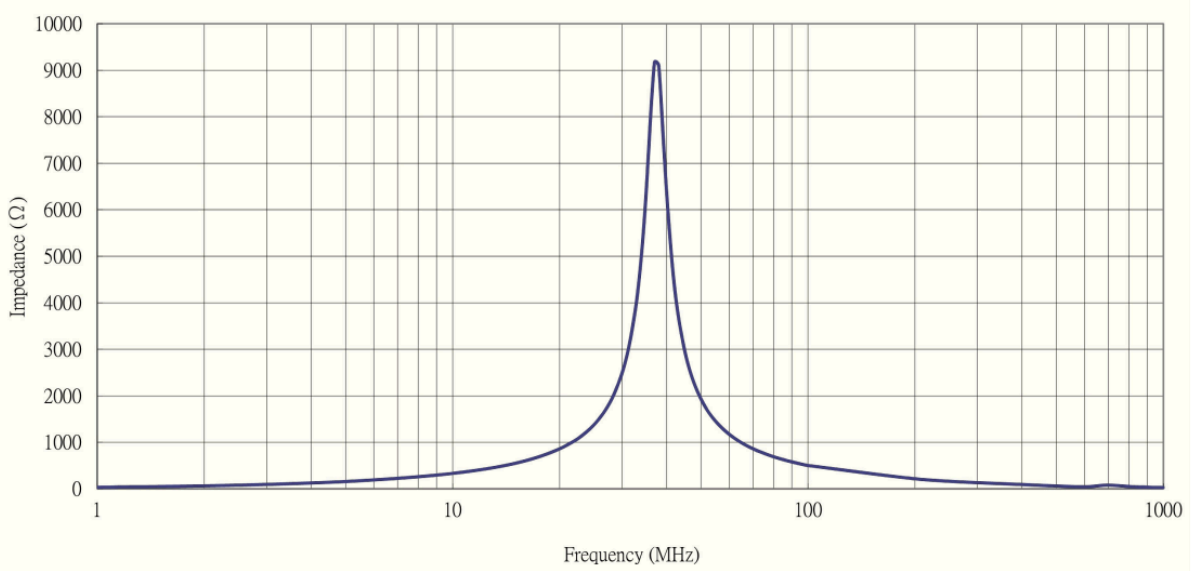
Noise voltage on the input caps will depend on their ESR and ESL (Equivalent Series Resistance and Inductance). When input current jumps from 0A to 1A this will cause a voltage drop on the cap which is: $Rdi + L\frac{di}{dt}$.

The small electrolytics you selected will have ESR above 10 ohms, and they can't take the ripple current, so they're out. Besides leaded caps of this size have ESL above 3 nH which is unnecessarily high.

The proper cap type is X7R SMD ceramic, as per datasheet. There is no need to buy 4.7µF and 10µF caps, it will probably be cheaper to just get 10x 1206 10µF X7R caps in whatever voltage you use at the input like 25V, that buying several different values. These will have ESR of a few milliohms and low ESL too.

Inductor type

Traco specs the inductor ; important parameters are saturation current, value, and self-resonant frequency (SRF). The latter is the resonant frequency of the parallel LC circuit formed by the inductor and its own capacitance.



Here SRF is about 35 MHz. Note above SRF, impedance decreases, but it still stays pretty high up to 100MHz, so the inductor will still be effective above the SRF. It doesn't abruptly stop working above the SRF.

So if you want to pick another inductor, make sure to select 5.6µH (or more), saturation current above about 2A, SRF above about 20 MHz, and series resistance depending on how much losses you deem acceptable. Also a shielded inductor is less headache. Sort by price, and pick a winner.

If this is for a one-off personal project it makes more sense to invest 50c in a LC filter rather than mulling it over 2 hours and testing it to see if you can save 50c in parts.

Layout

Caps have series inductance, which includes trace inductance. Using a ground plane ensures lowest possible inductance, which means your caps will be better at shorting HF noise to ground.

This filter is simply a current divider. You want to keep HF current out of the supply cable, so you add a high impedance in series with the cable (the inductor) and a low impedance to ground (the capacitor). This is why it is important to have low inductance capacitors.

If you don't know where to put the input cap, put it as close as possible to the DC-DC pins. It's OK to put it below the board very close to the pins if you solder this by hand.

Since there is only one layer used on your board screenshot, please use a ground plane on the other layer. Also, copper is free, so you can fatten power traces and use copper pours.

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answered May 17, 2020 at 12:00

bobflux
79k ● 3 ● 93 ● 228

Thanks for such a complete answer. Perhaps you could move the direct answer ("Inductor type") to the top; and do you have anything to say about shielding and Q for this type of application? – jonathanjo May 18, 2020 at 10:27

I'm a little confused when you say "invest 50c in a LC filter": you mean something other than the LC filter gvien on the datasheets? – jonathanjo May 18, 2020 at 10:34

I mean the LC filter specified in the datasheet, they already did the time-consuming work for you, so you don't have to. – bobflux May 18, 2020 at 10:36

The parts suggested on the datasheets are SMD, we want a a through-hole board. I'm not trying to redesign the filter, I'm trying to understand what they are suggesting in a deeper way than "use our matching product". – jonathanjo May 18, 2020 at 10:42

Well, component choice is about the parameters I explained in the answer. Extra inductance of thru-hole parts doesn't matter for an inductor, so it can be thru hole or SMD. However thru-hole caps will have higher inductance, so worse filtering. Use ceramics not electrolytics. – bobflux May 18, 2020 at 12:29

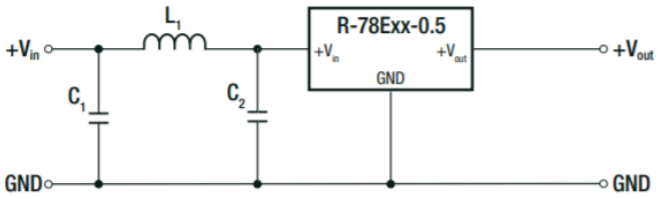
4

> *The question: what kind of inductors are required? How critical are the values?*

Just take a careful look at the data sheet for the RECOM model: -

EMC Compliance	Condition	Standard / Criterion
Electromagnetic compatibility of multimedia equipment - Emission requirements	with external filter (see filter suggestion below)	EN55032, Class A and B

EMC Filter Suggestion according to EN55032



Component List Class A

MODEL	C1	L1
R-78E3.3-0.5	4.7µF 50V MLCC	3.9µH choke RLS-397
R-78E15-0.5		

Component List Class B

MODEL	C1	C2	L1
R-78E3.3-0.5	10µF 100V MLCC	4.7µF 50V MLCC	12µH choke RLS-126
R-78E15-0.5			

Notes:

Note5: Filter suggestions are valid for indicated part numbers only. For other part numbers, please contact RECOM tech support for advice

Notice the part numbers inside the red boxes?

RLS-126

Features

- Tested and proved in RECOM filter design
- RoHS2+ compliant
- SMD

Line Inductors

RECOM Accessory

RLS-126

Line Inductors for RECOM Power Supply

3 YEAR Warranty

Model Numbering

RLS-126-R

Inductance — Packaging [1]

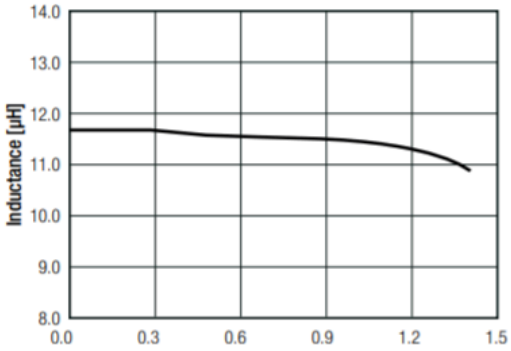
Notes:

Note1: with suffix „-R", standard packaging tape and reel
without suffix optional airbag packaging

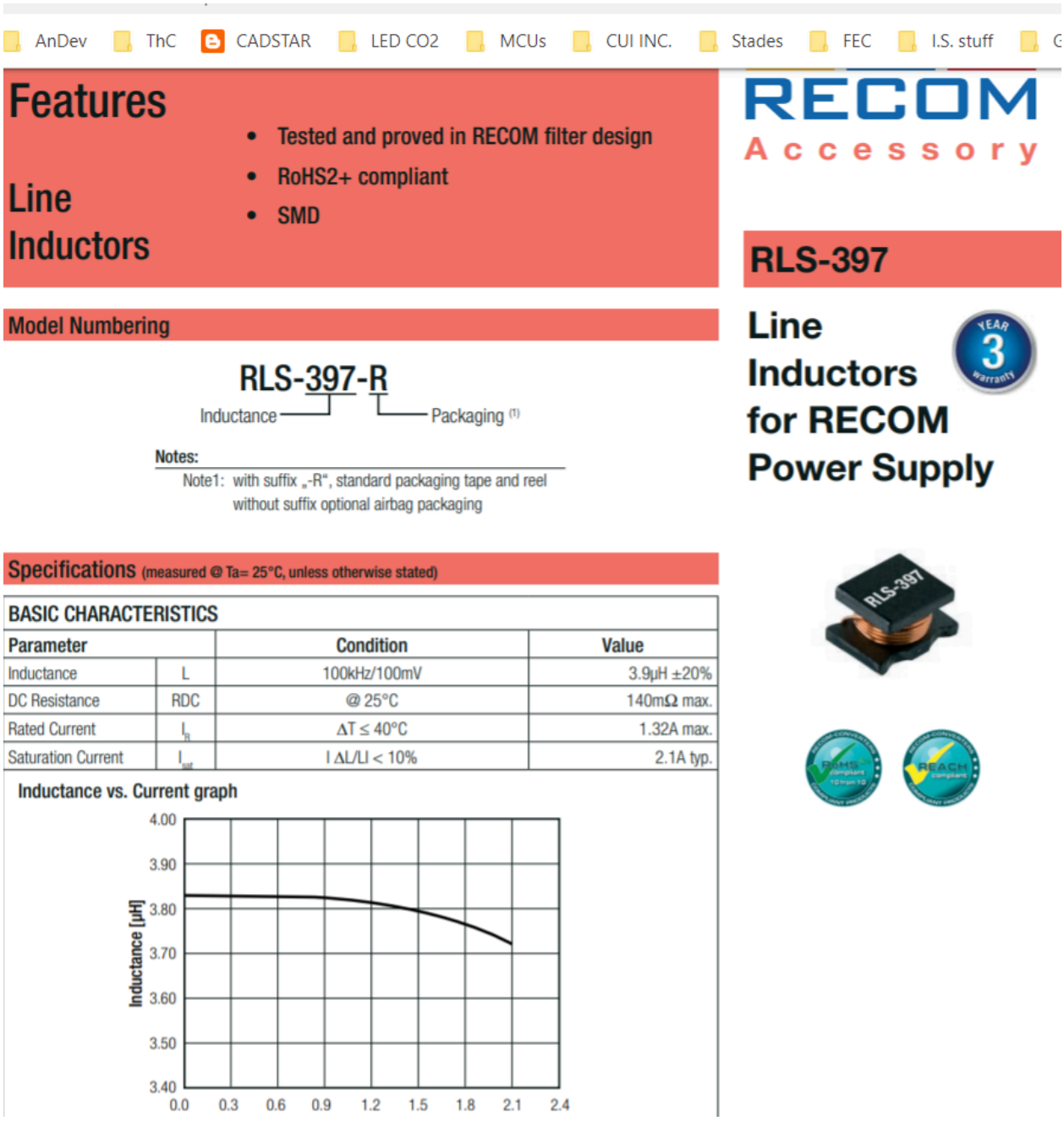
Specifications (measured @ Ta= 25°C, unless otherwise stated)

BASIC CHARACTERISTICS			
Parameter		**Condition**	**Value**
Inductance	L	100kHz/10mV	12.0µH ±20%
DC Resistance	RDC	@ 25°C	420mΩ max.
Rated Current	I_R	ΔT ≤ 40°C	0.80A max.
Saturation Current	I_{sat}	I ΔL/LI < 10%	1.4A typ.

Inductance vs. Current graph



RLS-397



AnDev ThC CADSTAR LED CO2 MCUs CUI INC. Stades FEC I.S. stuff

Features

- Tested and proved in RECOM filter design
- RoHS2+ compliant
- SMD

Line Inductors

RECOM Accessory

RLS-397

Line Inductors for RECOM Power Supply

3 YEAR warranty

Model Numbering

RLS-397-R

Inductance — Packaging (1)

Notes:

Note1: with suffix „-R", standard packaging tape and reel
without suffix optional airbag packaging

Specifications (measured @ Ta= 25°C, unless otherwise stated)

BASIC CHARACTERISTICS

Parameter		Condition	Value
Inductance	L	100kHz/100mV	3.9µH ±20%
DC Resistance	RDC	@ 25°C	140mΩ max.
Rated Current	I_R	ΔT ≤ 40°C	1.32A max.
Saturation Current	I_{sat}	I ΔL/LI < 10%	2.1A typ.

Inductance vs. Current graph

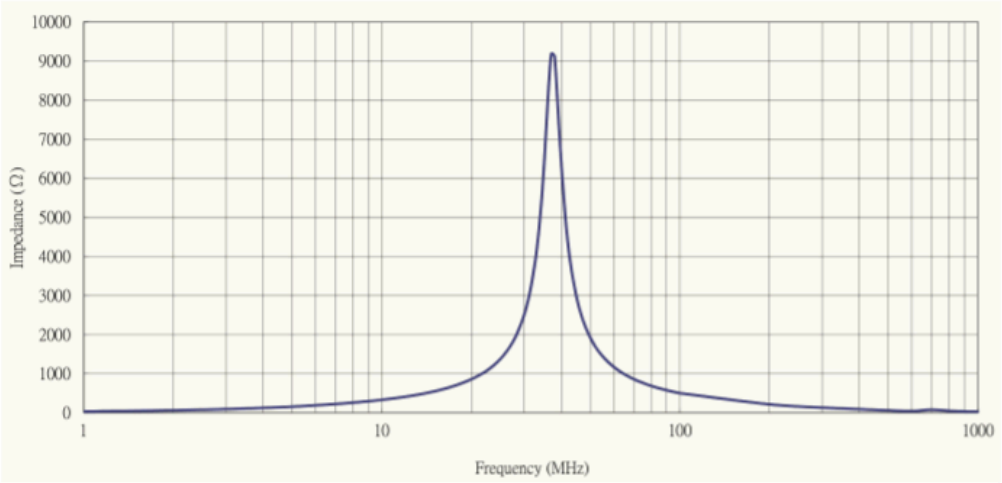
And, for the Traco supply, they recommend this part: -

TRACO POWER

Inductor **TCK-141**

Order Code	TCK-141
Inductance	5.6 µH ±20% (at 100 kHz / 250 mV)
Impedance (DCR)	90 mΩ max.
Rated Current	3.5 A max.
Operating Temperature	-55°C to +125°C

Impedance Curve



> *I'm not after* product recommendation*, I'm after clarification of the type of component.*

It's fairly difficult to answer this question without giving a product recommendation because the data sheets for the Traco and Recom actually give specific product recommendations. However, just because they do, it doesn't mean you can't locate similarly specified components at possibly a lower price. But this takes a little more care.

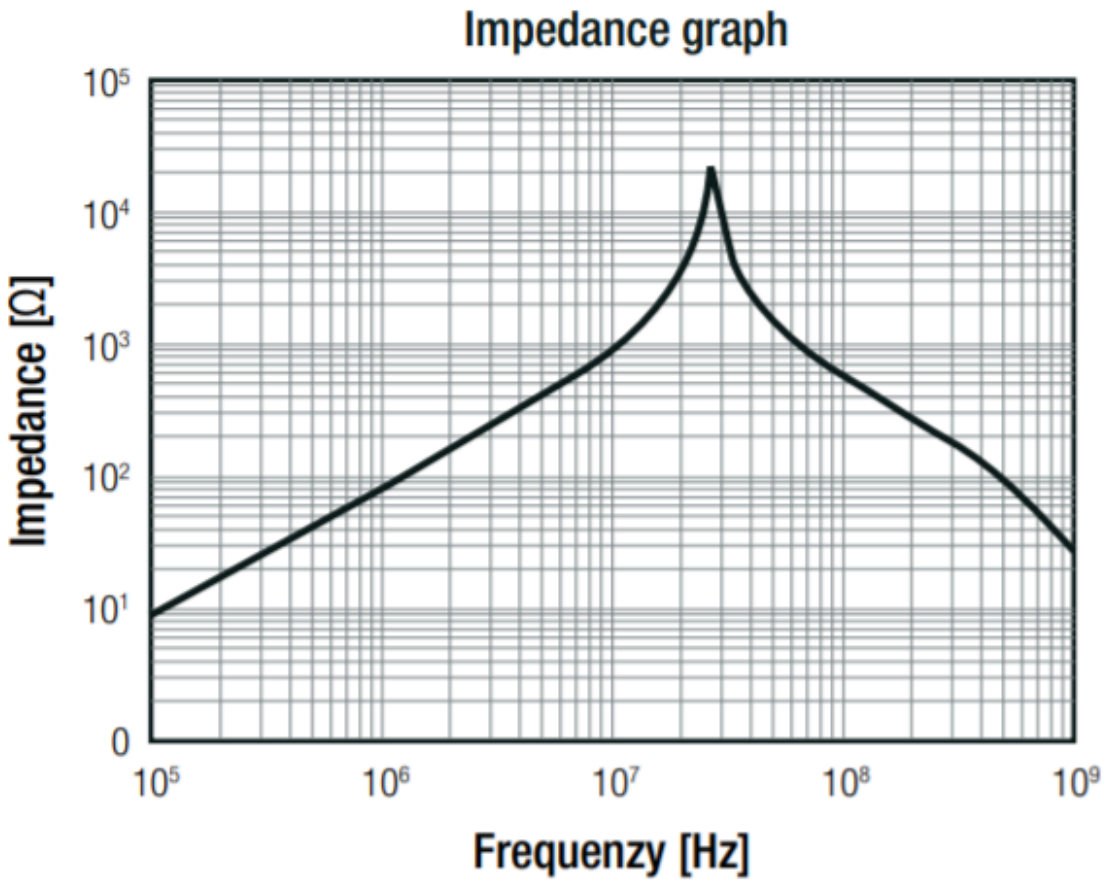
> *Are they "axial-leaded high-frequency inductors", in a resistor-like package? Open coils?*

The pictures (above) taken from the data sheets tell you and, if you need any more help, just leave a comment.

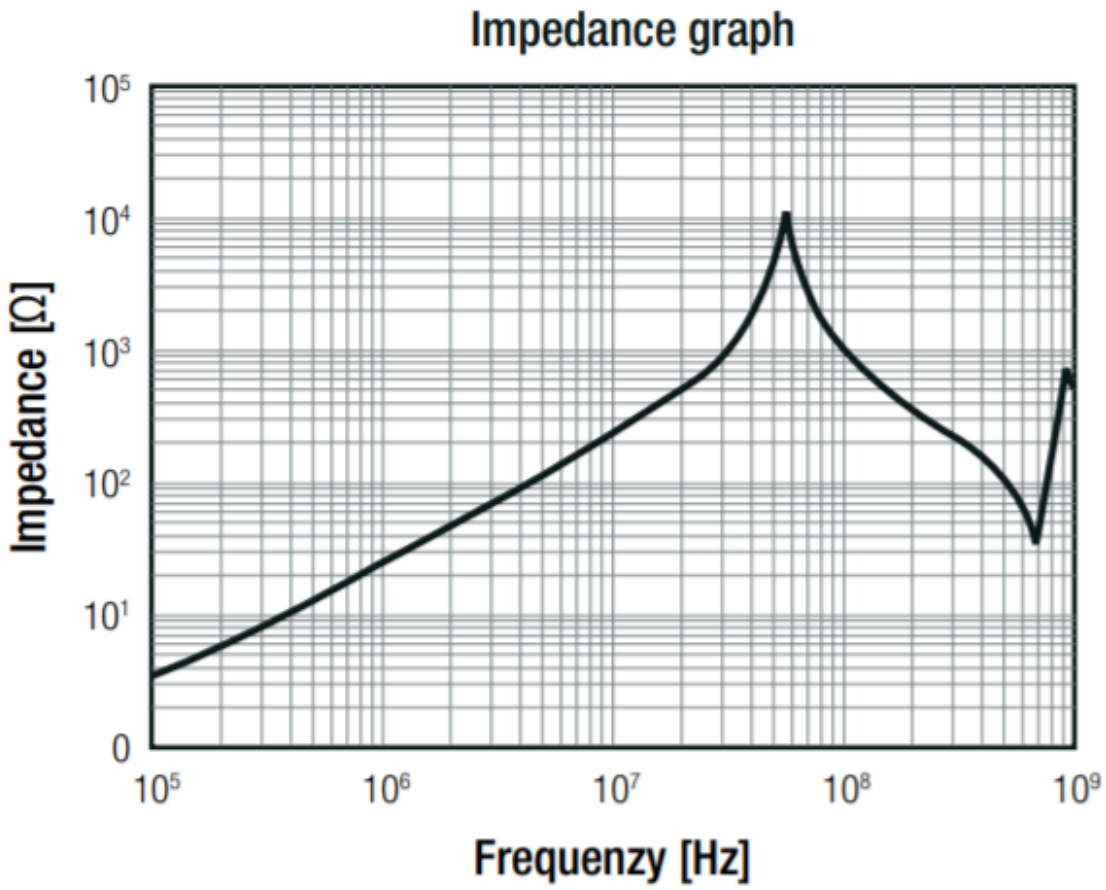
Additional information

If you think you have found an alternative to the TRACO TCH-141 (for example), you need to be very cautious about its self resonant frequency (SRF). At the SRF (about 35 MHz in the pictures above), it will act as a high blocking impedance and this may be high-up on the list of reasons for choosing it - that blocking impedance may very well coincide with some high spectral noise content from the converter and choosing say an inductor with a significantly different SRF may not work well at all.

For the RLS-126, it has an SRF at about 25 MHz: -



For the RLS-397, it has an SRF around 50 or 60 MHz: -



If you show due-diligence in selecting alternatives that largely meet the saturation current requirements, inductance value, ESR, SRF and SRF blocking impedance, I think you'll be OK.

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edited May 19, 2020 at 15:09

answered May 14, 2020 at 14:22

Andy aka
462k ● 28 ● 376 ● 820

Thanks Andy, yes I had found those. What I'm after is the generic description for this kind of inductor, so I can find parts from other manufacturers and distributors. Also: could you comment on how critical the values are? Ie, if design says 12uH, can I choose 10uH or 15uH if that's what supplier has? How do I determine suitable saturation current? (Other than inferring from mfr's recommended parts?)
– jonathanjo May 14, 2020 at 15:20

@jonathanjo You have to use the inductance values as stated if you want to avoid doing your own EMC testing and therefore rely on the statements in the Recom and Traco data sheets. All devices are surface mount type with the Recom parts being what is called as unshielded. The Traco part is shielded. For saturation current, you can choose an alternative device that has a higher value. You should also try and match the self-resonant frequencies shown in the data sheets because these will highly block EMI noise and may actually be designed to do this. – Andy aka May 14, 2020 at 15:43

Unfortunately, I think you are in a slightly compromised area if you try NOT to use these parts. The converter data sheets do not say why these inductors allowed the EMC tests to be passed nor how close a pass they were. – Andy aka May 14, 2020 at 15:46

1

The main issue in selecting the inductor isn't going to be the values, but will instead be the current requirement vs. the inductor's saturation current, I(sat). This will reduce its effectiveness as a filter.

The EMI issues with DCDC arise from the the from the output, via the output filter cap, back to the DCDC low side. This has a very high-current spike when the coil input switches from Vin to GND. Minimize this loop area as much as possible, and use low ESR caps for the output filter.

The input on the other hand has a step sawtooth-like current waveform with lower currents than the output, and so isn't as critical for EMI. Use the recommended input bypassing with good low-impedance connections to Vin and ground. For a regulator this size I'd use about 10uF.

More here: https://www.electronics-notes.com/articles/analogue_circuits/power-supply-electronics/switching-step-down-buck-regulator-dc-dc-converter.php

While the linked datasheets recommend some kind of an LC filter, a system-level solution to the problem can make use of a common-mode input filter to block switcher noise to the external supply. I've never had to employ one however, as bypassing the Vin plane proved adequate to meet conducted EMI using a DC input.

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edited May 7, 2020 at 21:23

answered May 6, 2020 at 20:17

hacktastical
54.4k ● 2 ● 49 ● 154

Many thanks thatt's very helpful. But could I ask you to elaborate on the exact loop you mean "Minimize this loop area". And I'm sorry but could you provide a link to explain "common mode input filter" Lastly, concretely, am I looking at the right kind of inductors? – jonathanjo May 8, 2020 at 12:22

Loop area means that an outbound and return current path should try to be short, and as close to each other as possible. The farther apart, the more the area. A common-mode filter is like a transformer, but flipped on its side. It strongly rejects same-polarity currents, while allowing opposing currents through. Some use lossy ferrite cores to absorb noise and turn it into heat. – hacktastical May 8, 2020 at 14:10

Thank you again @hacktastical, but it's hard to understand your answer. My question really is: what kind of inductors are the datasheets speaking about? – jonathanjo May 9, 2020 at 18:01

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to give more details on physical placement, to minimize EMI:

That capacitor on input side should have its GROUND lead as close as possible to the Source pin of the switching FET or the GROUND lead of the schottky flyback diode.

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answered May 6, 2020 at 22:16

analogsystemsrf
34.5k ● 2 ● 19 ● 48

The question is about small all-in-one modules with three terminals: there is no way to get close to any particular internal component. – jonathanjo May 7, 2020 at 10:41

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The type of Inductor at that part of the circuit is called a "choke", already mentioned above, the input rail sees a sawtooth drain due to the switching frequency of the device, this input coil (inductor/choke) is somewhat tuned to this switching frequency and smooths the sawtooth effect to prevent possible interference to other parts of the circuit on the same power rail. i hope this helps you understand the dynamics. ;)

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answered May 17, 2020 at 10:49

InTheShed
31 ● 4