Inductor selection for SEPIC designs

Overview/Basic operation

The single ended primary inductor converter (SEPIC) allows the output voltage to be greater than, less than, or equal to the input voltage in DC-DC conversion. Some typical applications include digital cameras, mobile phones, CD/DVD players, portable devices and GPS systems.

Figure 1 depicts a typical SEPIC circuit. During the switch (SW) ON time the voltage across both inductors is equal to V_{in}. When the switch is ON capacitor C_p is connected in parallel with L_2. The voltage across L_2 is the same as the capacitor voltage, $-V_{in}$. Diode D_1 is reverse bias and the load current is being supplied by capacitor C_{out}. During this period, energy is being stored in L_1 from the input and in L_2 from C_p.

During the switch (SW) OFF time the current in L_1 continues to flow through C_p,D_1 and into Cout and the load recharging C_p ready for the next cycle. The current in L_2 also flows into C_{out} and the load, ensuring that C_{out} is recharged ready for the next cycle. During this period the voltage across both L_1 and L_2 is equal to V_{out}. The voltage across C_p is equal to V_{in} and that the voltage on L_2 is equal to V_{out}, in order for this to be true the voltage at the node of C_p and L_1 must be $V_{in} + V_{out}$. The voltage across L_1 is $(V_{in}+V_{out}) - V_{in} = V_{out}$.

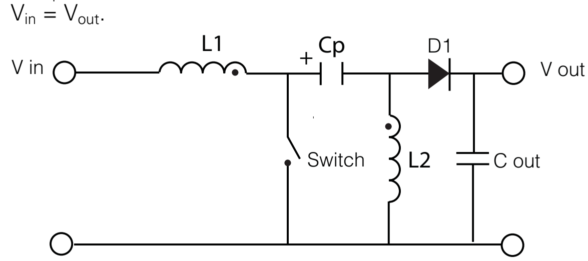


Figure 1. Simple SEPIC circuit

Inductor selection procedures

Case 1: Two separate inductors

Application conditions:

- Input voltage (Vin) – 2.8 V – 4.5 V
- Output (Vout & Iout) – 3.3 V, 1 A
- Switching Frequency (Fs) – 250 kHz
- Efficiency - 90%

Step 1. Calculate the duty cycle

D = Vout/(Vout + Vin)

The worst case condition for inductor ripple current is at maximum input voltage **D = 3.3/(3.3 + 4.5) = 0.423.**

The output inductor is sized to ensure that the inductor current is continuous at minimum load and that the output voltage ripple does not affect the circuit that the converter is powering. In this case we will assume a 20% minimum load thus allowing a 40% peak-to-peak ripple current in the output inductor L2.

Step 2. Calculate the value of L2

V = L di/dt

- V is the voltage applied to the inductor
- L is the inductance
- di is the inductor peak to peak ripple current
- dt is the duration for which the voltage is applied

L = V.dt/di

- dt = 1/Fs x D
- dt = 1/(250 x 10^3) x 0.423 = 1.69 µ-sec
- V = Vin during the switch ON time so;
- L2 = 4.5 x (1.69 x 10^{-6}/0.4)
- L2 = 19 µH

Result: Using the nearest preferred value would lead to the selection of a 22 µH inductor. It is common practice to select the same value for both input and output inductors in SEPIC designs although when two separate parts are being used it is not essential.

Step 3. Calculate RMS and peak current ratings for both inductors

Input inductor L1

- Irms = (Vout x Iout)/(Vin (min) * efficiency)
- Irms = (3.3 x 1)/(2.8 x 0.9) = 1.31 A
- Ipeak = Irms + (0.5 x Iripple)
- Iripple = (V.dt)/L
- Iripple = (2.8 x 2.2 x 10^{-6})/22 x 10^{-6} = 0.28 A
- Ipeak = 1.31 + 0.14 =1.45 A

Although worst case ripple current is at maximum input voltage the peak current is normally highest at the minimum input voltage.

Result: 22 µH, 1.31 Arms and 1.45 Apk rated inductor is required. For example the Eaton DR73-220-R which has 1.62 Arms and 1.67 Apk current ratings.

Output inductor L2

Irms = Iout = 1 A

Iripple = (4.5 x 1.69 x 10^{-6})/22 x 10^{-6} = 0.346 A

Ipeak = 1 + 0.173 = 1.173 A

Result: A 2 2µH, 1 Arms and 1.173 Apk rated inductor is required, which for simplicity could be the same DR73-220-R

Case 2: Coupled inductor

Step 1. Perform Step 1 and the Irms Portion of Step 3 from the two separate inductor selection.

The application information listed for the two inductor selection will be used.

Step 2. Calculate the inductance value

L = V.dt/di

From our earlier example the output ripple current needs to be 0.4 Apk-pk, so now we calculate for 0.8 A as the ripple current is split between the two windings

L = 4.5 x (1.69 x 10^{-6}/0.8) = 9.5 µH

- A coupled inductor has the current flowing in one inductor and if the two windings are closely coupled the ripple current will be split equally between them.
- Using a coupled inductor reduces the required inductance by half.
- Since the two winding are on the same core they must be the same

Step 3. Calculate the peak current

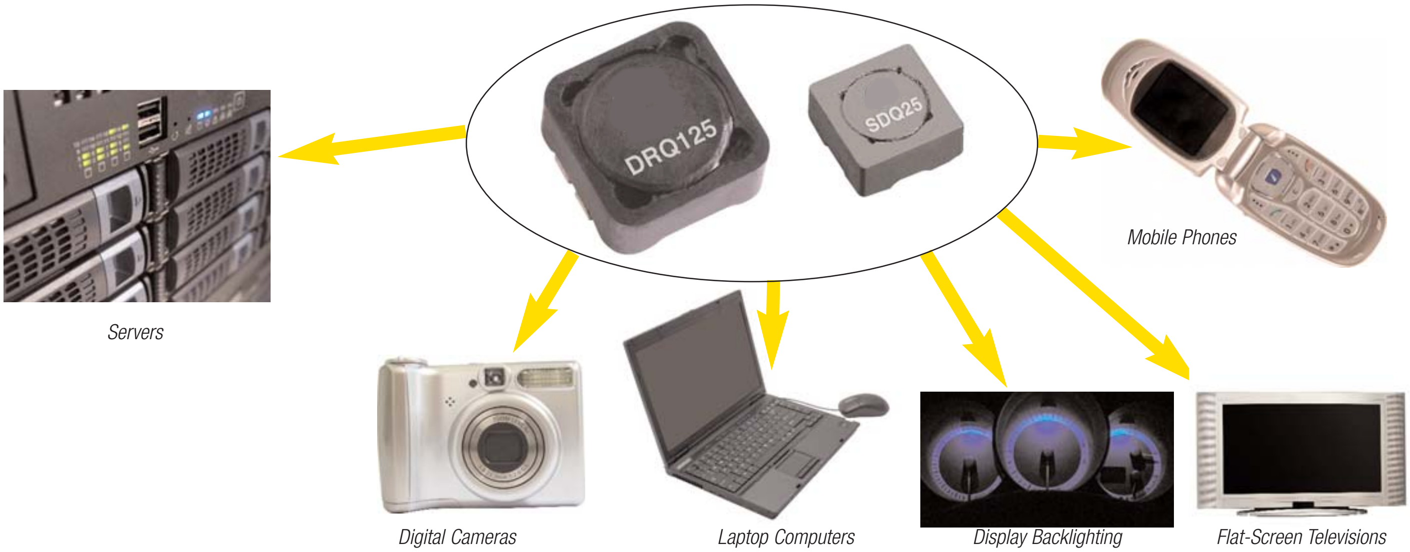
Continuing with the example using an inductance value of 10 µH we now need to calculate the worst case peak current requirement. The RMS current in each winding is already known.

- Input inductor RMS current = 1.31 A
- Output inductor RMS current = 1 A
- Ipeak = Iin + Iout + (0.5 x Iripple)
- Iripple = (2.8 x 2.2 x 10^{-6})/10 x 10^{-6} = 0.62 A
- Ipeak = 1.31 + 1 + 0.31 = 2.62 A @ minimum input voltage

Result: A 10 µH coupled inductor with 2.31 Arms and 2.62 Apk current ratings is required, for example the Eaton DRQ74-100-R.

Using a coupled inductor takes up less space on the PCB and tends to be lower cost than two separate inductors. It also offers the option to have most of the inductor ripple current flow in either the input or the output. By doing this the need for input filtering can be minimized or the output ripple voltage can be reduced to very low levels when supplying sensitive circuits.

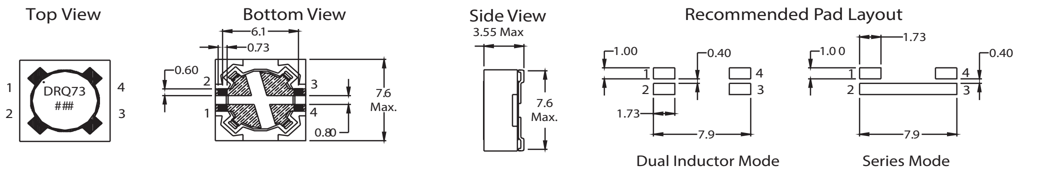
Typical applications using inductors for SEPIC designs



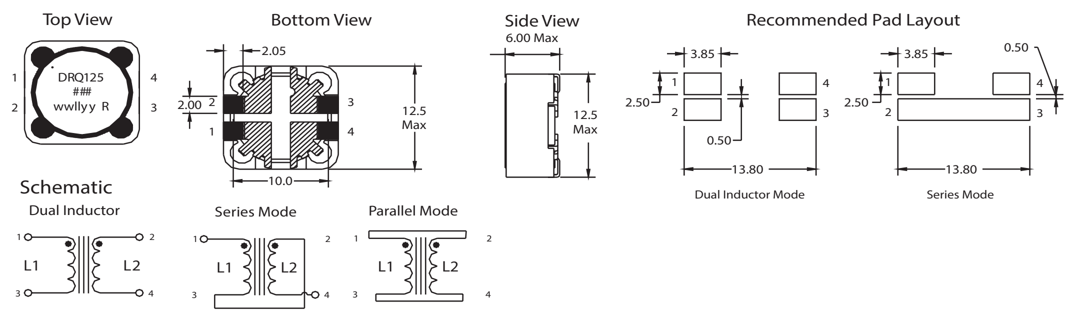
DRQ Family		Parallel Ratings				Series Ratings			
Part Number	Rated Inductance (µH)	OCL +/-20% (µH)	I_{rms} (A)	I_{sat} (A) Peak	DCR Ω Typ.	OCL +/-20% (µH)	I_{rms} (A)	I_{sat} (A) Peak	DCR Ω Typ.
DRQ73-1R0-R	1.00	0.992	5.25	7.97	0.0103	3.968	2.63	3.99	0.0411
DRQ73-2R2-R	2.20	2.070	4.11	5.52	0.0167	8.280	2.06	2.76	0.0669
DRQ73-3R3-R	3.30	3.540	3.31	4.22	0.0259	14.16	1.66	2.11	0.1035
DRQ73-4R7-R	4.70	4.422	3.09	3.78	0.0297	17.69	1.55	1.89	0.1188
DRQ73-100-R	10.0	10.30	2.08	2.47	0.0656	41.20	1.04	1.24	0.2623
DRQ73-220-R	22.0	22.65	1.62	1.67	0.107	90.60	0.811	0.83	0.429
DRQ73-330-R	33.0	34.41	1.31	1.35	0.166	137.6	0.653	0.68	0.665
DRQ73-470-R	47.0	48.62	1.08	1.14	0.241	194.5	0.542	0.57	0.965
DRQ73-680-R	68.0	68.91	0.89	0.96	0.358	275.6	0.444	0.48	1.43
DRQ73-101-R	100	101.4	0.73	0.79	0.527	405.6	0.367	0.39	2.11
DRQ73-221-R	220	223.3	0.52	0.53	1.05	893.2	0.260	0.27	4.20
DRQ73-331-R	330	325.5	0.42	0.44	1.59	1302	0.211	0.22	6.36
DRQ73-471-R	470	465.8	0.35	0.37	2.36	1863	0.173	0.18	9.44
DRQ125-1R0-R	1.00	0.894	15.0	23.6	0.0024	3.576	7.51	11.8	0.0096
DRQ125-1R5-R	1.50	1.478	13.8	18.3	0.0029	5.912	6.89	9.15	0.0114
DRQ125-2R2-R	2.20	2.208	10.9	15.0	0.0045	8.832	5.46	7.50	0.0182
DRQ125-3R3-R	3.30	3.084	9.26	12.7	0.0063	12.34	4.63	6.35	0.0253
DRQ125-4R7-R	4.70	5.274	7.18	9.71	0.0105	21.10	3.59	4.86	0.0420
DRQ125-100-R	10.0	9.654	5.35	7.17	0.0189	38.62	2.67	3.59	0.0757
DRQ125-220-R	22.0	22.36	3.70	4.71	0.0396	89.44	1.84	2.36	0.159
DRQ125-330-R	33.0	33.74	3.28	3.84	0.0505	135.0	1.64	1.92	0.203
DRQ125-470-R	47.0	47.47	2.71	3.24	0.0740	189.9	1.35	1.62	0.297
DRQ125-680-R	68.0	67.91	2.22	2.70	0.101	271.6	1.11	1.35	0.440
DRQ125-101-R	100	102.7	1.78	2.20	0.170	410.8	0.892	1.10	0.682
DRQ125-221-R	220	216.8	1.19	1.51	0.384	867.2	0.594	0.755	1.54
DRQ125-331-R	330	332.6	1.06	1.22	0.482	1330	0.530	0.610	1.93
DRQ125-471-R	470	473.1	0.87	1.02	0.718	1892	0.434	0.510	2.87

Note: DRQ74 and DRQ127 not shown. For full product information and a listing of all available inductor values, visit http://www.eaton.com/electronics, Data Sheet number DS4311.

DRQ73 Dimensions - mm



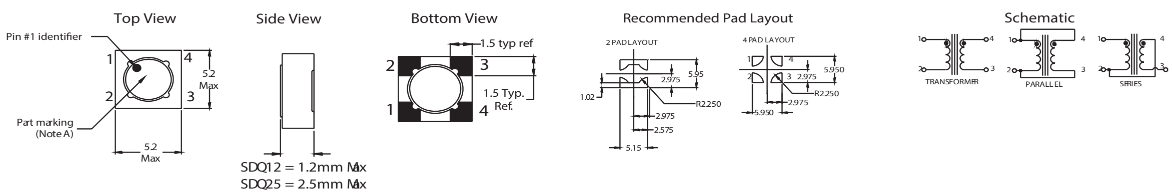
DRQ125 Dimensions - mm



SDQ Series			Parallel Ratings				Series Ratings			
Part Number	Rated Inductance (µH)	Part Marking	OCL +/-20% (µH)	I_{rms} Amps	I_{sat} Amps	DCR Ω Typ.	OCL +/-20% (µH)	I_{rms} Amps	I_{sat} Amps	DCR Ω Typ.
SDQ12-1R0-R	1	B	0.81	2.49	3.38	0.0403	3.24	1.25	1.69	0.1611
SDQ12-2R2-R	2.2	D	2.25	1.60	2.03	0.0977	9.00	0.800	1.01	0.3908
SDQ12-3R3-R	3.3	E	3.61	1.28	1.60	0.1527	14.44	0.640	0.800	0.6106
SDQ12-4R7-R	4.7	F	4.41	1.12	1.45	0.1990	17.64	0.560	0.724	0.7959
SDQ12-100-R	10	J	9.61	0.831	0.981	0.3620	38.44	0.416	0.490	1.45
SDQ12-220-R	22	L	22.09	0.548	0.647	0.8332	88.36	0.274	0.323	3.33
SDQ12-330-R	33	M	32.49	0.439	0.533	1.29	130.0	0.220	0.267	5.18
SDQ12-470-R	47	N	47.61	0.401	0.441	1.55	190.4	0.201	0.220	6.21
SDQ25-1R0-R	1	C	0.97	3.15	4.09	0.0252	3.87	1.58	2.05	0.1007
SDQ25-2R2-R	2.2	E	2.31	2.67	2.65	0.0351	9.25	1.34	1.32	0.1402
SDQ25-3R3-R	3.3	F	2.89	2.50	2.37	0.0399	11.55	1.25	1.18	0.1595
SDQ25-4R7-R	4.7	G	5	1.96	1.80	0.0653	20.00	0.98	0.900	0.2612
SDQ25-100-R	10	K	9.8	1.53	1.29	0.1068	39.20	0.765	0.643	0.4273
SDQ25-220-R	22	M	22.47	1.01	0.849	0.2431	89.89	0.507	0.425	0.9724
SDQ25-330-R	33	N	33.8	0.812	0.692	0.3795	135.2	0.406	0.346	1.52
SDQ25-470-R	47	O	47.43	0.749	0.584	0.4461	189.7	0.374	0.292	1.78
SDQ25-680-R	68	P	69.19	0.603	0.484	0.6865	276.8	0.302	0.242	2.75
SDQ25-101-R	100	R	98.57	0.499	0.405	1.00	394.3	0.249	0.203	4.02
SDQ25-221-R	220	T	223.1	0.326	0.269	2.36	892.4	0.163	0.135	9.42
SDQ25-331-R	330	U	329.7	0.292	0.222	2.93	1318.7	0.146	0.111	11.71
SDQ25-471-R	470	V	472.4	0.243	0.185	4.25	1889.6	0.121	0.093	16.99

Note: For full product information and a listing of all available inductor values, view http://www.eaton.com/electronics, Data Sheet number 4339.

SDQ12 and SDQ25 Dimensions - mm



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