Using GBI's 4400 Series to Design Buck Regulators

With the advent of faster switching speed logic, memory and microprocessor microelectronics coupled with lower and lower operating voltage requirements, the need for "close to the load" buck regulators is growing rapidly. The name given to this set of converters placed close to the load they are powering is called "point of load" converters.

Powering these new loads is not a trivial exercise. Power density, size, efficiency, transient response, and adaptability to changing input and output voltage requirements are just some of the challenges the Design Engineer is faced with in the design. Often times the construction of this converter must be made from 100% surface mount components to be consistent with the technology of components used on the PCB it is being mounted.

GBI developed the 4400 series of surface mount inductors with point of load applications in mind. This Application Note can be used as a guideline to help design point of load regulators around GBI's 4400 series surface mount inductors. The datasheet of the 4400 series coupled with the Application Note is all that is needed to design high-density efficient non-isolated DC/DC converters.

To get started, here is a list of important electrical and magnetic properties about the inductors that will be needed later in the Application Note to calculate operating conditions of the device.

Model #	**Turns**	**AWG**	**le**	**Ae**	**Ve**
4415-G	9	2 X #21	2.68 cm	0.099cm ^{2}	0.266 cm ^{3}
4416-G	11	2 X #22	2.68 cm	0.099cm ^{2}	0.266 cm ^{3}
4417-G	15	2 X #25	2.68 cm	0.099cm ^{2}	0.266 cm ^{3}
4418-G	17	2 X #26	2.68 cm	0.099cm ^{2}	0.266 cm ^{3}
4419-G	19	2 X #27	2.68 cm	0.099cm ^{2}	0.266 cm ^{3}
4420-G	27	2 X #25	2.68 cm	0.099cm ^{2}	0.266 cm ^{3}
4421-G	32	2 X #26	2.68 cm	0.099cm ^{2}	0.266 cm ^{3}

4422-G	40	2 X #29	2.68 cm	0.099cm ^{2}	0.266 cm ^{3}
4423-G	44	2 X #29	2.68 cm	0.099cm ^{2}	0.266 cm ^{3}

The following is a step-by-step guideline that can be used to design the output inductor of a buck regulator using the GBI 4400 series of SMT inductors. There are three types of buck regulators: conventional buck regulators, synchronous buck regulators, and complementary switched buck regulators. The conventional buck regulator uses a rectifier, such as a schottky diode, in the free-wheeling path to commutate inductor current, while the other two synchronous type use an electronic switch such as a N Channel Mosfet to commutate the inductor current. Synchronous buck regulators tout higher conversion efficiencies because the forward drop across a saturated Mosfet can be much lower than the forward voltage drop across a low drop schottky diode. Complementary switched synchronous buck regulators differ from synchronous regulators in that the two switches are controlled in a manner to prevent discontinuous output inductor current that can be a control theory advantage but will sacrifice light load efficiency.

STEP 1: Calculate the duty cycle of the Buck Regulator

$$\boxed{D = \frac{Vout}{Vin}}$$

STEP 2: Calculate the minimum inductance required. This calculation is important for the conventional Buck and Synchronous Buck, but is less critical for the complementary switched Buck due to the reasons cited above.

$$\boxed{Lo = \frac{Vo(1 - D)}{2\mathrm{Io\_min}Fsw}}$$

Where I_{o_min} is the minimum load the regulator will see and F_{sw} is the desired switching Frequency. Common switching frequencies for these types of regulators is 100KHz. to 500KHz. Frequencies chosen in this range have advantageous tradeoffs between magnetic losses, switching losses, efficiency, and size.

STEP 3: Select an inductor from GBI's 4400 series selection datasheet

STEP 4: Calculate the Magnetizing Force using Ampere's Law

$$\boxed{Hdc = \frac{0.4pNIo}{le}}$$

STEP 5: Using the following Table and the calculated magnetizing force in Oersteds above, select the percent initial Permeability

Hdc	%µ
0 oersteds	100%
5 oersteds	100%
10 oersteds	95%
20 oersteds	85%
30 oersteds	75%
40 oersteds	65%
50 oersteds	60%

Operating these inductors above 50 oersteds is not recommended because the initial inductance due to the dc bias on the core will have dropped significantly.

STEP 6: Calculate the inductance of the device at full load Io.

$$\boxed{Ldc = Lo * \%m}$$

STEP 7: Calculate the DC Flux in the core using Faraday's Law of induction:

$$\boxed{Bdc = \frac{Ldc * Io * 10^8}{Ae * N}}$$

Where N is the number of turns on the inductor taken from the table above. The saturation flux density of the core used is 10,000 Gauss. Care should be taken to ensure that the DC plus the AC flux density should not exceed Bsat. Designers will find that this number is difficult to reach based on the drop of inductance with DC bias.

STEP 8: Calculate the AC flux

$$\boxed{\Delta B = \frac{Vo * (1 - D) * 10^8}{Ae * N * Fsw}}$$

STEP 9: Calculate the peak flux density in the core from the peak to peak flux density ΔB.

$$\boxed{Bpk = \frac{\Delta B}{2}}$$

STEP 10: Using Core loss curves for Powdered Iron –52 material, look up core loss using Bpk and make sure it meets your power dissipation budget for this device. Also, to get a first order approximation of the wire loss due to the current flowing through it, use the following equation:

$$\boxed{Pwire = Io^2 * Rwire}$$