

# Unique “Squaroid” Design Gives DC Inductors Low-Profile, Compact Package

*VOLTA Series From Pulse Is Ideal For Use As Output Filters  
For High Frequency DC to DC Power Converters*

*By Victor Renteria  
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In seeking to accommodate the need for a low cost, low inductance value, high DC current rated inductor in a compact, low-profile SMT package, engineers at Pulse designed a custom-shaped ferrite core called a “Squaroid.” The “squarish” or rectangular-shaped, single-piece core uses a single turn to create inductance and eliminates the need for a header or bobbin to accommodate windings and surface mount capability. The use of a ferrite core minimizes core loss that can increase exponentially as switching frequencies increase toward 1 MHz. The single-turn design keeps copper losses to a minimum as current ratings increase to the 15 to 50 ADC range. The design results in a highly efficient DC inductor with low profiles in the 0.125” to 0.25” range.

Called the VOLTA Series, the Squaroid-based inductors have been designed for use in DC to DC switch mode power supplies. The VOLTA series will offer inductance values ranging from 100 nH to 1000 nH with direct current (DC) ratings of 10 to 50 ADC for switching frequencies between 300 kHz and 1 MHz. Although specifically designed for switching power supply output filters, a Squaroid design can be successfully applied to any type of electronic filter -- especially those requiring DC capability. Other applications may include EMI, transmission line, and signal processing filters up to 1 MHz.

Basically, the Squaroid is a square or rectangular shaped ferrite core with a square hole going through it. Since the Squaroid design does not use a bobbin or header, assembly is faster and easier, while costs are significantly lower. The Squaroid shape accommodates a flat piece of foil Pulse calls a staple. The staple is bent around the core automatically, much as a stapler bends a staple to hold paper together. The thin wide copper staple keeps the winding resistance low for both AC and DC and is naturally suited to dissipate heat very efficiently. A gap is cut into the core to accommodate DC and maintain inductance. All soldering and hand work has been eliminated. The result is a very simple, highly efficient process that delivers higher yields and a more reliable product at a lower cost.

Typically a Squaroid inductor is a one-turn coil but it can also be designed with multiple turns to minimize the core size. When a Squaroid is designed with multi-turns the turns are completed on the printed circuit board as shown in the printed circuit board layout in Fig. 1.

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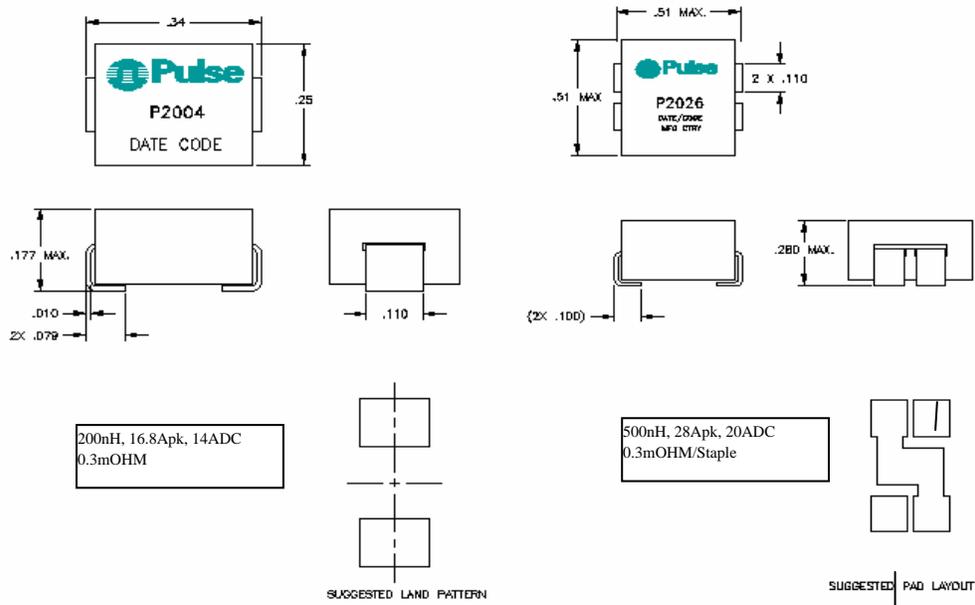
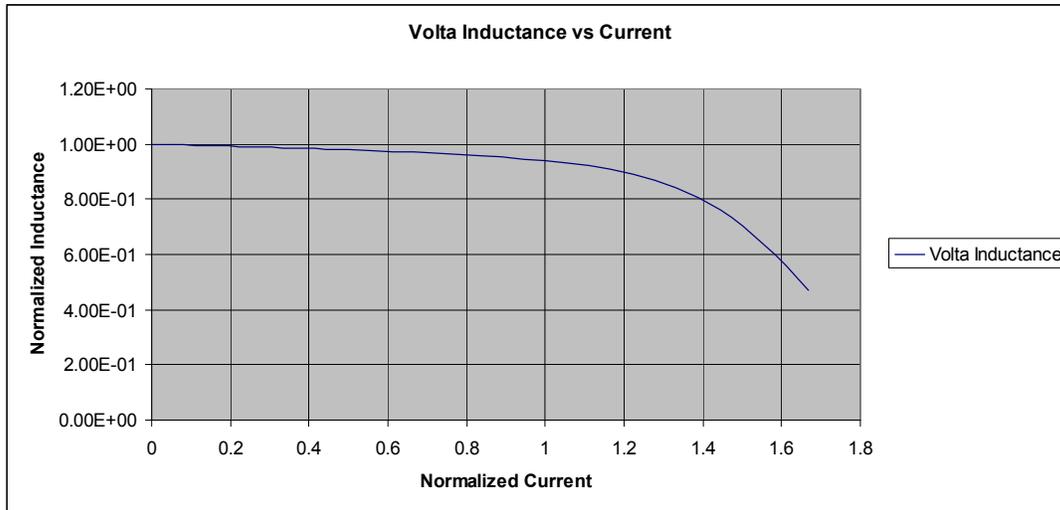


Fig. 1

A one-turn 200 nH Squaroid versus a two-turn 200 nH Squaroid

## Electrical Performance

Since the Squaroid inductor is wound on a gapped ferrite core the value of inductance will change less than -5% from 0 to rated DC. The change will be less than -10% at rated peak current.



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## Inductor Losses

### Core Loss Calculation, CL

$$\text{EQ1} \quad CL = .044 * F_{sw}^{1.6341} * Bpk^{2.2115} \quad (mW / cm^3)$$

Where Fsw is the switching frequency in kiloHertz and Bpk is one half the change in flux density dB in kiloGauss.

$$\text{EQ2} \quad dB = \frac{(V_{in} - V_{out})}{N * Ae(cm^2)} * \frac{V_{out}}{V_{in}} * \frac{10^8}{F_{sw}(KHz)} \quad (Kilo - Gauss)$$

(Ae is the cross-sectional area of the core.)

$$\text{EQ3} \quad Bpk = \frac{dB}{2} \quad (Kilo - Gauss)$$

Therefore the power lost in the core, Pcore is:

$$\text{EQ4} \quad P_{core} = CL(mW / cm^3) * V_e(cm^3) \quad (mW)$$

Where Ve is the volume of the core in cm<sup>3</sup>.

### Winding Loss, Pw

$$\text{EQ5} \quad P_w = 1000 * I_{rms}^2 * DCR \quad (mW)$$

Where DCR is the staple or winding resistance in Ohms. Irms is the heating current through the staple and is:

$$\text{EQ6} \quad I_{rms} = \left( IDC^2 + \frac{dI^2}{12} \right)^{\frac{1}{2}} \quad (Arms)$$

Where IDC is the rated direct current of the inductor. dI is the change in current through the inductor which =

$$\text{EQ7} \quad dI = \frac{(V_{in} - V_{out})}{L(H)} * \frac{V_{out}}{V_{in}} * \frac{1}{F_{sw}(Hz)} \quad (Amps)$$

Where L is the inductance in Henries of the part.

### Temperature Rise Calculation

A general equation for temperature rise is:

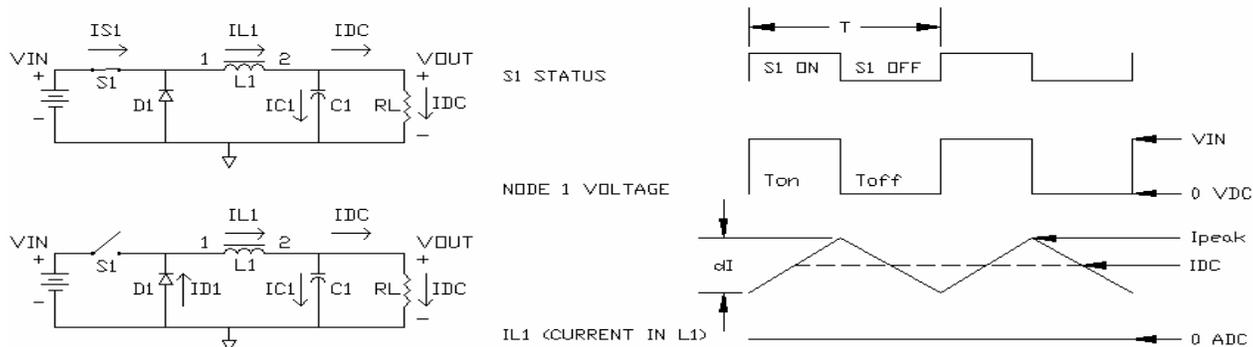
$$\text{EQ8} \quad Trise = \left( \frac{Pd(mW)}{As(cm^2)} \right)^{.833} \quad (^\circ C)$$

Where Pd is the total power (core loss plus copper loss) dissipated in the inductor and As is the effective surface area of the inductor. However the actual operating temperature at the staple is dependent on PCB trace width and thickness. We recommend the trace width to be as wide as the part and have a minimum trace thickness of 3 ounce copper for rated currents > 15 ADC. This will ensure temperature rises on the staple to <35° C above ambient.

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## Calculating Inductance

Before designing a Squaroid inductor, Pulse engineers must investigate and understand the application. Squaroid inductors are designed to be used as a DC output choke in the output LC filter for a DC to DC power converter. See the Schematic in figure 3.



**SCHEMATIC DIAGRAM AND INDUCTOR CURRENT WAVEFORMS**

**FIG. 3**

## Condensed Theory of Operation

Assuming the voltage-drops across S1 and D1 are negligible, the voltage at node 1 is +Vin for the time S1 is closed (ton), and is at ground for the time S1 is open (toff = T-ton). The L1-C1 filter averages out the voltage at node 1 and produces a constant DC output voltage (Vout) whose average value is:

**EQ9** 
$$V_{out} = V_{in} * \frac{ton}{T} = V_{in} * ton * F_{sw}(Hz)$$

The inductor current (IL1) waveform is shown above. The DC or average value of current flowing in L1 must always equal the DC load current. When S1 is closed the current in L1 ramps upward linearly. When S1 is open the current in L1 ramps down linearly. Since this change in current dI is linear, we can define it in terms of Iout :

**EQ10** 
$$dI = K1 * IDC \text{ (Amps)} \quad \text{(Where IDC = Load current (ADC))}$$

Where K1 is a constant and is typically: 0.2<K1<0.4

Now from EQ7 we can solve for the inductance L:

**EQ11** 
$$L = \frac{(V_{in} - V_{out}) * V_{out}}{K1 * I_{out}} * \frac{1}{V_{in} * F_{sw}(Hz)} \text{ (Henrys)}$$

With the Squaroid design, Pulse’s VOLTA Series DC inductors offer a smaller, low-profile surface-mounted device that meets the needs of switching power supply manufacturers who are also under pressure to deliver compact products. VOLTA inductors, because of their simple and efficient construction, provide a reliable and low cost solution.

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### **About Pulse**

Headquartered in San Diego, Calif., Pulse, a Technitrol (NYSE: TNL) company, has been an international leader in magnetic components for over 40 years. The company, winner of Intel’s coveted SCQI award, is one of the largest manufacturers of magnetic components in the world with a global reputation for technical excellence coupled with outstanding quality.

Pulse produces a complete line of passive magnetic components and modules for use in Internet/broadband access, power, telecommunications and datacom applications. Meeting the highest quality standards, the company has ISO 9000 registered manufacturing facilities located in the Far East, United States, and Europe. Pulse’s products are available through direct sales as well as authorized distributors and representatives.

In North America, contact Pulse’s worldwide headquarters in the United States at 858-674-8100. The Pulse European headquarters can be reached in the United Kingdom at +44-1483-401700, and its Asian headquarters can be reached in Singapore at +65-287-8998.

For more information, visit the Pulse web site at <http://www.pulseeng.com>.

### **By Victor Renteria**

Engineer Manager, Pulse

Victor has been with Pulse since 1984 designing switch mode power supplies, converters and magnetics.

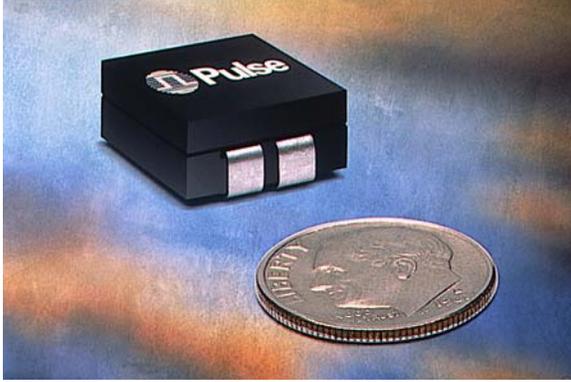
He received a Bachelor of Science in Electrical Engineering from San Diego State University, San Diego, Ca.

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Product Images, Pricing and Availability:

	
<p><b>About:</b> Pulse announces two new surface mount (SMT) power inductors for use with low-voltage power delivery semiconductors developed by Volterra. As thin as 0.125 inches (3.17mm), these compact, surface-mount power inductors are designed for high-current, low-voltage, low-profile DC/DC power converter applications with the latest generation of microprocessors. In addition, their unique <b>Squaroid-core design</b> has exceptionally low DC resistance that offers improved circuit efficiency and high-current capabilities.</p> <p><b>Pricing and Availability:</b> This line of SMT power inductors are currently available in tape-and-reel packaging. Prices range from \$0.39 (P1681T) to \$0.52, (P2004T and P2005T) each in quantities of 100,000. Various volume discounts are offered.</p>	<p><b>About:</b> Pulse announced four new surface-mount (SMT) power inductors for use with next-generation low-voltage, high-performance microprocessors. These new devices require significantly higher power to operate, which in turn requires higher supply currents. With a maximum height of 0.280 inches (7.11mm), these compact, surface-mount power inductors are designed for low-profile DC/DC power converter applications. The unique <b>Squaroid-core design</b> of these inductors has exceptionally low DC resistance that offers improved circuit efficiency and high-current capabilities.</p> <p><b>Pricing and Availability</b> This line of SMT power inductors are currently available in tape-and-reel packaging. Pricing is \$0.93 per unit in quantities of 100,000. Various volume discounts are offered.</p>

### Quotes:

“The market demand for these SMT inductors is increasing as the new high-speed processors are incorporated into a myriad of computer-based products,” said Eric Tan, product manager, Pulse. “The new processors run at higher frequencies at lower voltages (between 1.0 and 3.8 volts DC) and much higher current levels than previously. The voltages must be stepped down from either the five- or 12-volt bus found in desktop PCs or main servers, or from the six- or 12-volt DC battery level of portable devices.”

“The Volta inductors are designed to handle inductance values ranging from 85nh to 1,000nh with current rating up to 40 amps,” said Eric Tan product manager, Pulse. “Pulse offers the industry’s only flat-top, self-leaded design with a fixed clip, ideal for easy pick-and-place applications and higher current ratings. They are magnetically shielded for reduced electromagnetic interference (EMI).”