BUCK-BOOST CONVERTER
8 WATTS, 2.4 – 5.0 VOLT OUTPUT | BB905p0

INTRODUCTION

The BB905p0 buck-boost voltage converter is a self-oscillating DC/DC converter that transforms power at input voltages of 0.9 to 4.5 volts into a regulated output voltage. The default setting is Vout=5.0 volts and is specifically targeted for USB appliance applications. An output power of up to 8 watts can be obtained for input voltages of 2 volts and higher. Although the BB905p0 has been designed specifically for relatively low internal resistance sources, such as thermoelectric modules, the circuit can be applied to boost and regulate virtually any suitable source that meets the voltage input requirements. Figure 1 depicts the VB805p0.

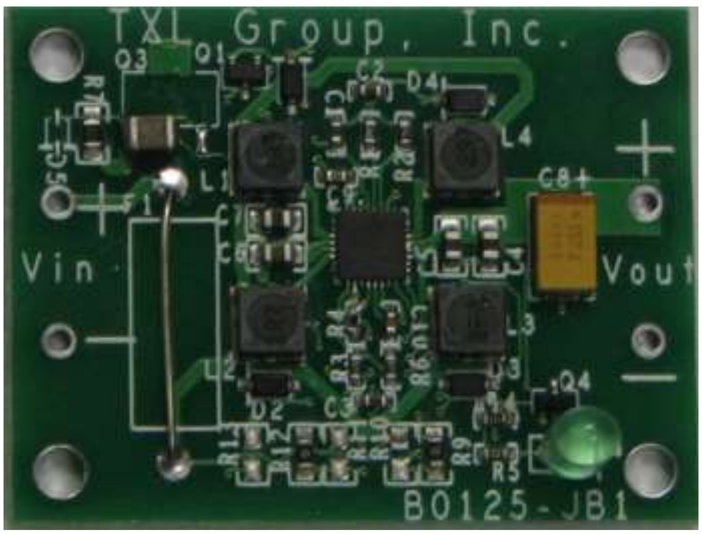

Figure 1 – The BB905p0 Converter

DIMENSIONS & RATINGS

Size: 2.0” X 1.5”

Output Voltage: 5.0 volts (factory setting), can be adjusted to 2.4V, 3.0V or 3.3V with the addition of an 0805 resistor.

Input Voltage: 0.9V to 4.5V. **DO NOT EXCEED Vin=4.5V**

Max Output Current: Depends upon input voltage and setpoint output voltage, For Vin=2.0V and Vout =5.0V, Imax =1.5 amperes.

Max Output Power: 8 watts

Max Device Power Dissipation (free air): 3 watts

THEORY OF OPERATION

The BB905p0 uses a four phase architecture to convert power at a relatively low input voltage to a regulated output power. By having four phases, each 90° apart, the output ripple frequency is increased by a factor of four while amplitude is decreased, both features enhancing the ability of capacitive filtering to smooth the output for low noise applications. For light loading, the circuit automatically switches to a discontinuous operating mode where some phases are skipped, thereby reducing quiescent power requirements and resulting in a more efficient operation.

OUTPUT REGULATION

The BB905p0 includes an independent start-up oscillator that is designed to begin oscillation at input voltages as low as 0.9V. Once Vout exceeds Vin by 0.3 volts, the integrated circuit powers itself from Vout rather than Vin and the start-up oscillator is disabled to reduce quiescent power draw. The input voltage can then drop to as low as 0.5 volts (depending upon load) without affecting circuit operation. In “buck” mode, the input voltage value will be above the setpoint output voltage and the internal oscillator will continue to drive the conversion.

The BB905p0 has a green, “power good” LED as shown in the lower right in Figure 1. When the output voltage attains 90% or more of the setpoint voltage, the LED turns on.

Although the default output setting is Vout=5.0 volts, the output voltage can be set to any arbitrary voltage between 2.4 volts and 5.0 volts by populating an 0805 resistor in the R13 spot (shown in lower left in Figure 1. For example, by using R13=390K, the output voltage is set to 3.3 volts. By using R13=150K, the output voltage is set to 2.4 volts. Since the BB905p0 is a buck-boost style converter, the input voltage can exceed the output voltage setpoint and be “bucked down” to achieve the desired regulated output.

Figures 2-7 give operating curves for the BB905p0 for output setpoint voltages of 5.0, 3.3 and 2.4 volts with different output loads,R_L.

REGULATION, EFFICIENCY AND LOADING

Although output voltage can be higher than the input voltage, output power can never exceed the input power --- there are always conversion losses. The BB095p0 has built-in heat sinking to a backplane on the reverse side of the PC board. This allows the unit to dissipate a continuous 3 watts in free air. If the unit is enclosed, then it will have to be derated. If the unit is operated on an intermittent duty schedule, is exposed to forced air flow, or is attached to a heat sink, then power conversion capability increases.

Conversion efficiency is a complicated function of input voltage, setpoint voltage and load impedance. For this reason, the use of a graphical analysis using Figures 2-7 is needed to determine circuit performance and suitability for a specific application. Of particular interest is that the highest operating efficiency occurs when the input voltage is about 0.3 volts below the output voltage. This is seen in the dips in input current (corresponding to a reduction in input power) in Figures 4-7. These "low points" represent the highest efficiency operating points.

A DESIGN EXAMPLE

As an example, suppose the BB905p0 is set in the default mode (Vout = 5.0 volts) and the desired output current is 1.25 amperes. This corresponds to an output load of 4 Ω and an output power of 6.25 watts. If the input voltage is Vin=2.0 volts, then from Figure 3, the input current is 4 amperes. So, input power is 8 watts. The converter efficiency is calculated as the ration of output power over input power, so at this operating point the unit is 78% efficient. The power that needs to be dissipated by the converter is the difference between input power and output power which is 1.75 watts. Since this is less than the maximum power dissipation limit of 3 watts in open air, the unit can deliver a continuous 1.25 amperes to a regulated 5.0 volt output with a 2 volt input.

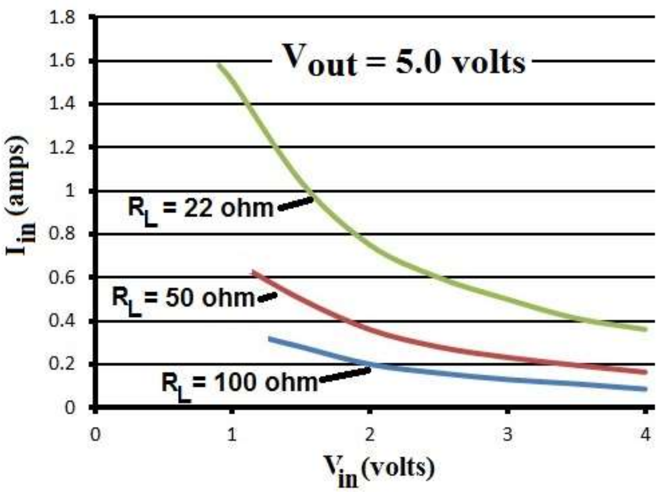

Figure 2 --- Performance Curves for Vout=5.0 Volts Under Light Loading

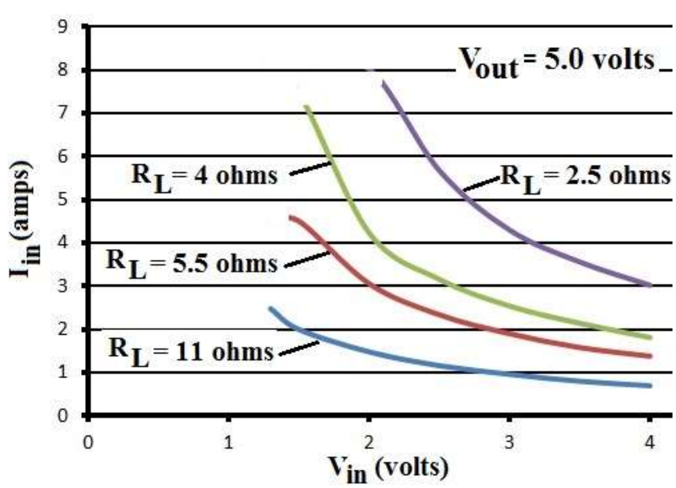

Figure 3 – Performance Curves for Vout=5.0 Volts Under Heavy Loading

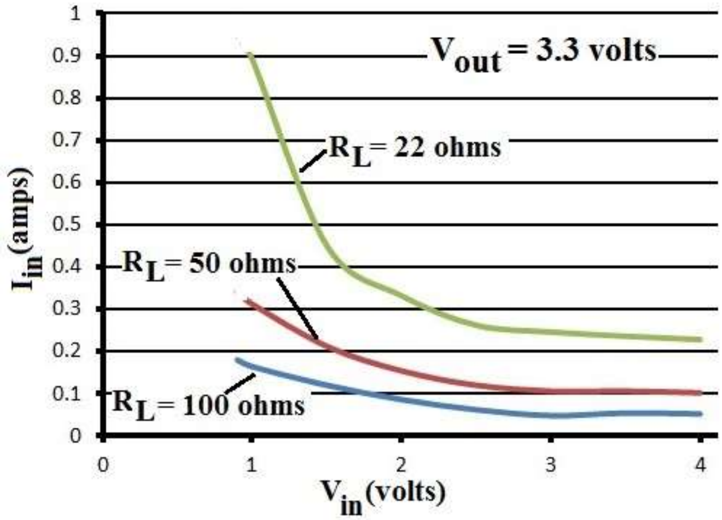

Figure 4 – Performance Curves for Vout=3.3 Volts Under Light Loading

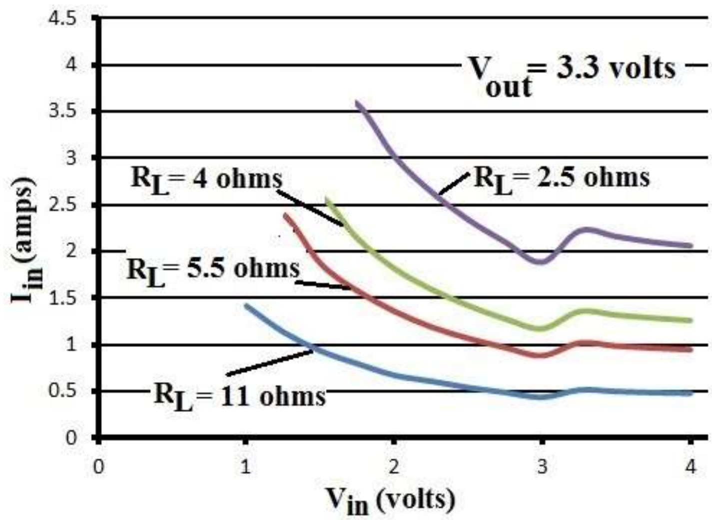

Figure 5 – Performance Curves for Vout=3.3 Volts Under Heavy Loading

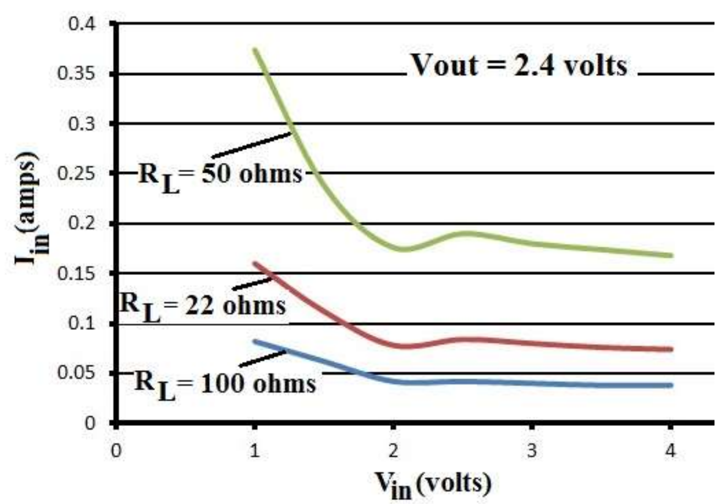

Figure 6 – Performance Curves for Vout=2.4 Volts Under Light Loading

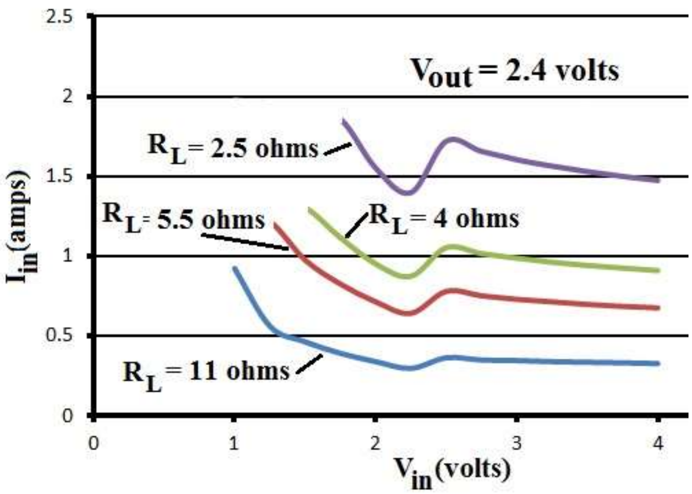

Figure 7 – Performance Curves for Vout=2.4 Volts Under Heavy Loading

DESIGN GUIDELINES

The BB095p0 was specifically designed to boost thermoelectrically generated power but it can work with an arbitrary power supply on the input, as long as that supply has sufficient power delivery capability. Best results are obtained when acknowledging the interaction between the source, the converter and the load.

Most sources (and all thermoelectric generators) can be modeled by a so-called "Thevenin source" which consists of an ideal voltage source in electrical series with a source resistor. This is the dotted box in Figure 8.

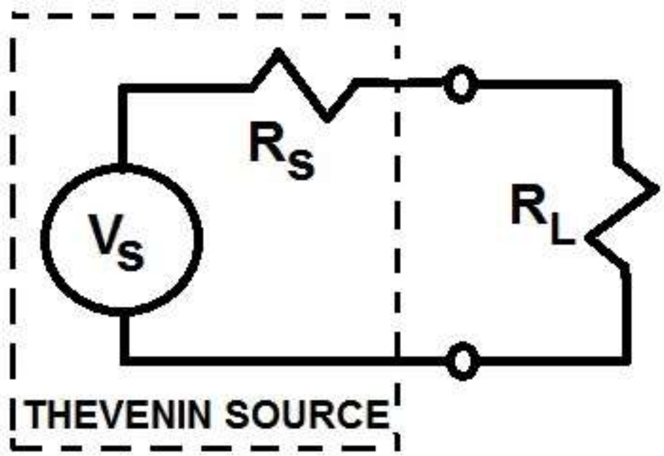

Figure 8 – A Thevenin Power Supply Model

Vs is often referred to as the open circuit voltage since in the absence of a load (ie: open circuit) the voltage that appears across the terminals in Figure 8 is Vs. In Figure 8, with an attached load, R_L, the power delivered to that load is given by

$$P_L = \frac{V_S^2 R_L}{(R_S+R_L)^2} \qquad (1)$$

and the total power dissipated by the system, including losses in Rs is

$$P_s + P_L = \frac{V_S^2}{R_S+R_L} \qquad (2)$$

and the efficiency with which power is delivered to the load is

$$\eta = \frac{P_L}{P_S+P_L} = \frac{R_L}{R_S+R_L} \qquad (3)$$

So, for a given source with source resistance, R_s, using equation (1), it can be seen that the load which will result in the maximum power transfer is R_L = Rs, a well known result known as impedance matching. On the other hand, for the maximum efficiency of power transfer from the source to the load, the smaller the value of source resistance, Rs, the better, with Rs=0 corresponding to 100% power transfer efficiency. When a voltage regulator like the BB095p0 is used in a system, in the Thevenin model, R_L represents the regulator together with the actual load.

EFFICIENCY & OVERVOLTAGE PROTECTION

In reference to the design example presented earlier, if it is desired to use a BB905p0 to deliver a regulated Vout=5.0 volts to a 4 Ω load when Vin=2 volts, this requires 4 amperes of input current. That means that the load that is "seen" by the source is R_L=2/4 = 0.5Ω. If the power source that is used has an internal resistance of Rs=1 Ω, then the open circuit voltage must be Vs=6V. If the source is a thermoelectric source, this allows a determination of the temperature gradient that must be applied. It also allows a determination of overall efficiency since power is lost in the source through losses in Rs and in the BB905p0. Using equation (3), the efficiency of power delivery to the regulator is 33%. If the load on the regulator output is removed, then the voltage going to the BB905p0 will be close to Vs=6.0 volts which will damage the regulator. In this scenario, it is critical to provide input protection to limit the input voltage. One method is to use a Zener diode clamp.

As noted in equation (3), power delivery from the source is always more efficient for smaller Rs. So, with the example above, if the source has Rs=0.1Ω of resistance, then Vs=2.4 volts and there is no problem if the load on the regulator output is removed ---- the regulator input voltage then rises to about 2.4 volts.

ABOUT TXL

TXL Group, Inc. is an El Paso, Texas company developing industrial Waste Heat Harvest® solutions[1]. Part of this effort entails developing electronic devices for efficient energy power conversion from the low voltages typical of thermoelectric generation devices. TXL offers a range of thermoelectric devices and electronic conversion solutions from microwatts and up.

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