LOW VOLTAGE DC-DC UP/DOWN CONVERTER

DATASHEET X0122

rev 1.1

INTRODUCTION

The X0122 is a self-oscillating DC/DC converter that accepts input power with voltages ranging from 400 millivolts to 5 volts and converts it to a switch-selectable 1.8 volts, 3.3 volts or 5.0 volt output with up to 200 mA of current sourcing capability. This device will work with DC input voltages from any source including photovoltaics and electrochemical cells, but it is particularly designed to boost the relatively low voltage output of thermoelectric generators into power levels suitable to drive microcontrollers (1.8 volts), recharge electrochemical cells (3.3 volts) or deliver power to USB type rechargeable electronic devices (5.0 volts).

ELECTRICAL SPECIFICATIONS

Table 1 expresses the input and output ranges for different output setpoints.

Vin Range		Vout		Output Current
Min	Max	Min	Max	Max
0.4 V	5.1 V	1.75 V	1.85 V	200 mA
		3.20 V	3.40 V	200 mA
		4.85 V	5.15 V	200 mA

Table 1 – Electrical Specifications

THERMOELECTRIC GENERATION

A thermoelectric (TE) generator is constructed by connecting multiple n-type and p-type thermoelements in electrical series with all elements in thermal parallel between a heat source and a heat sink. A scaffolding is often used on the top and the bottom of a device to lend mechanical support to the thermoelements. Figure 1 depicts a commercially available device with the top scaffolding removed.

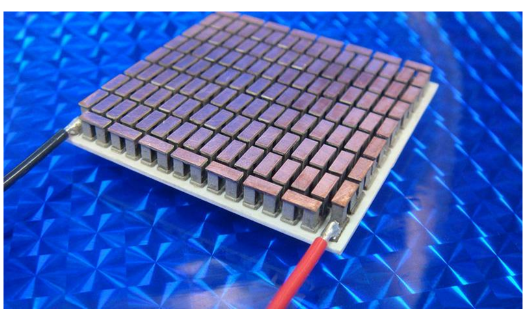

Figure 1 – A 254 Element TE Module

TE-GENERATED VOLTAGE

The open circuit voltage that is generated from a temperature differential across a thermoelectric module is a function of the temperature gradient, ΔT, the number of series connected elements, j, and a material constant called the Seebeck coefficient, S. If it is assumed that the n-type and p-type thermoelements have the same magnitude of S, then the open circuit voltage may be written as

$$V_{OC} = j \times S \times \Delta T \qquad (1)$$

The ΔT in eq. (1) will always be less than the difference between heat source and heat sink temperatures due to "parasitic" thermal resistances between source and the actual thermoelements and between the sink and the actual elements. Much of the challenge for a successful implementation of thermoelectric generation lies in the thermal circuit design.

OBTAINING MAXIMUM POWER

Every generator has an internal electrical impedance, often referred to as the source resistance, R_S. In a thermoelectric generator this source resistance is primarily due to the electrical resistance of the individual thermoelectric elements. Assuming a constant resistance, $R_{element}$, for both n-type and p-type thermoelements, then for a generator having a total of j elements, the source resistance is

$$R_s = j \times R_{element} \qquad (2)$$

The source resistance serves to reduce the power that can be delivered to an electrical load. This is an important consideration in designing a thermoelectric generator. For any given element size, having many series-connected elements means more voltage can be generated from a given ΔT (eqn. 1). But having more elements yields higher source resistance (eqn 2).

THEORY OF OPERATION

The X0122 provides an automatic transition between boost and down conversion modes, incorporates short circuit protection and boasts up to a 90% conversion efficiency. The X0122 measures 0.83" by 1.1" and is depicted in Fig. 2.

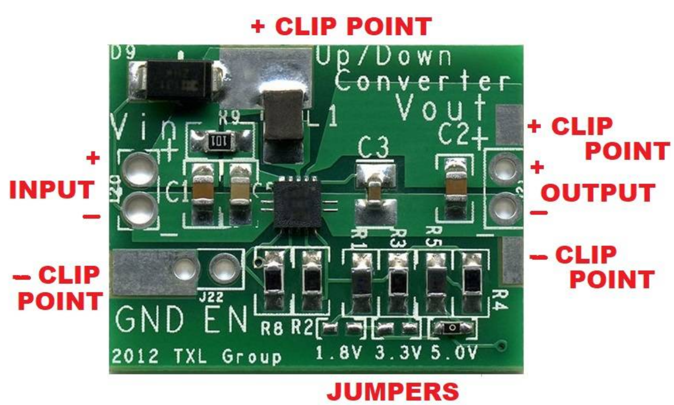

Figure 2 – The X0122 Up/Down Converter

In Fig. 2, the input is applied at the two hole terminal on the left and the output is obtained from the two hole terminal on the right. Clip point pads for the input and outputs have been provided for ease of clip lead connection during test. The input and output share a common ground. On the bottom of the board are pads to which a zero jumper (or solder blob) can be connected to hard program the output voltage. The X0122 is shipped with a resistor that preprograms the unit to an output of +5.0 volts. This is the resistor depicted in the lower right in Figure 2, above the “5.0” designation. Exactly one jumper should be used at any given time.

A schematic for the X0122 is shown in Figure 3. The input voltage range is 0.4 volts to 5 volts. A Zener diode serves to clamp the input to 5.1 volts to protect the X0122 from damage due to input overvoltage. An enable port allows external control of the converter. This line is tied onboard to V_{IN} through a 22K resistor, allowing the converter to start-up whenever V_{IN} is sufficiently high. When the enable line is held low, the converter is turned off. When the X0122 is used as part of a microcontrolled system, the enable port can be left in a high impedance mode to enable the converter or can be grounded to turn off conversion.

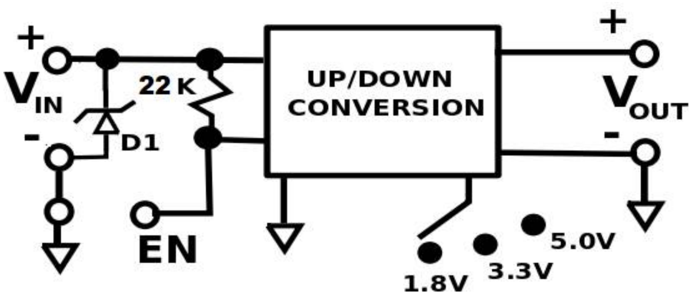

Figure 3 – Electrical Schematic for X0122 Converter

The amount of output power that can be obtained from any thermoelectric device depends upon the open circuit voltage V_{oc}, the internal resistance of the module, R_S, and the nature of the load. Typical R_s values for commercially available thermoelectric modules range from 0.5 Ω to 5 Ω. Lower values of R_s make it possible to deliver more power to the X0122 and enable output voltage regulation for lower input voltages.

APPLICATIONS

The X0122 up/down converter may be used in a variety of settings when a fixed output voltage of 1.8V, 3.3V or 5.0V is desired to be generated from a DC input voltage. When used with an electrochemical cell on the input, the converter can be turned on or off at the enable port as power is needed. This allows enhanced battery management. When set for a 3.3 volt output (by shorting the pads corresponding to 3.3V), the X0122 can be used to maintain the charge on rechargeable lithium cells having a nominal voltage of 3.3 volts or, when used with a dropping resistor, can charge cells of a lower voltage. Many common electronic devices, particularly those which can be powered from a USB port, require a 5.0 volt charge voltage. For these devices, the X0122 can play a role, delivering up to 200 mA of output current[1].

BATTERY CHARGING

The X0122 can be used for battery recharge applications. This is particularly useful in conjunction with thermoelectric energy harvesting from environmental sources that may fluctuate over the course of the day. Two example circuits are depicted in Figure 4. In Figure 4(a), the X0122 output setpoint is 3.3 volts and it supplies recharging current to a 3.0 volt rechargeable cell. The diode D1 is a low forward drop diode which serves to prevent discharge of the cell back through the X0122. Resistor R1 serves to limit the current into the 3.0 volt cell and may be optional (that is, 0 Ω) for some applications. Figure 4(b) depicts a charge circuit for a nominal 3.3 volt cell. In this example, the output is jumper selected to be 5.0 V. Diode D1 prevents back discharge of the battery. Optional resistors R2 and R3 serve to limit the charge current and Zener diode D2 serves to prevent the charge voltage from ever exceeding 3.3V. Figure 4 is meant to illustrate general guidelines. The preferred charging configuration and component values depends upon the battery technology and manufacturers recommendations.

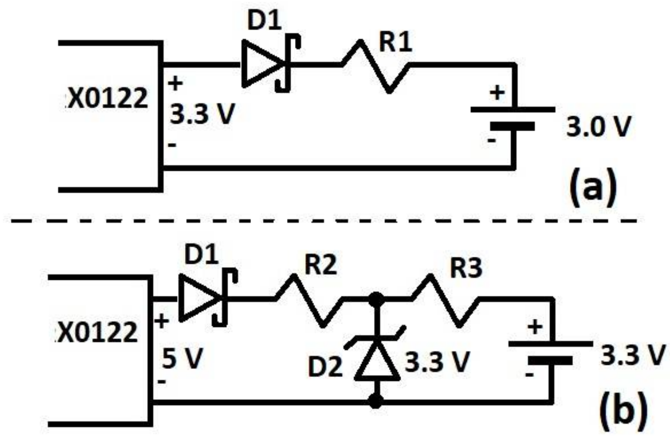

Figure 4 – Two Representative Charging Configurations

Figure 5 depicts the start-up voltages required for delivering different output current to a **resistive** load. The same curves are valid for output setpoints of 1.8V, 3.3V or 5.0V. Note that while the start-up voltage when the output is a rechargeable cell is 0.4 volts, when the output is a resistance, more voltage is required on start-up.

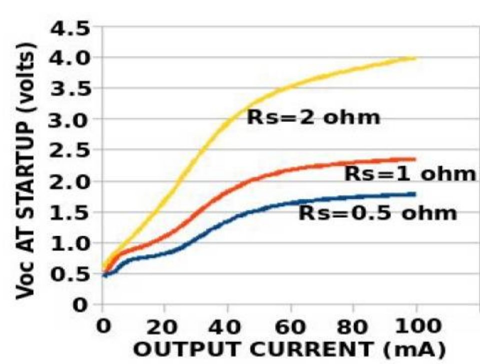

Figure 4 – Voc for Start-up Into a Resistive Load

[1] The X0122 may not be suitable for some electronic devices and care must be taken when evaluating any candidate application.

EXAMPLE

A successful thermoelectric generation application requires a systems perspective. Assume a model 1261G-7L31-05CQ TE generator module which is manufactured by Custom Thermoelectric[2] and has an internal resistance of R_s=1 Ω. This device has j=252 thermoelements connected in electrical series. Each element has a Seebeck coefficient of magnitude 200μV/°C so by equation (1), the module can produce 50 mV/°C. Since the electronic converter needs at least 0.4 volts in order to operate, this means that ΔT = 8°C is the minimum required temperature gradient across the module in order to turn on the converter under no-load conditions. So if the load is a rechargeable cell, recharging begins as the temperature gradient approaches 8°C.

Suppose the converter is set for a 5 volt output into a resistive load with a load requirement of 30 mA. From Figure 4, a load current of 30 mA will require an open circuit start-up voltage of about 1.5 volts. This voltage is obtained for ΔT=1.5/.05=30°C.

For a resistive load, the required start-up voltage is always higher than the voltage needed to sustain regulation. In the above example, even though the start-up voltage is 1.5 volts, once the converter starts oscillation, it can sustain a regulated 5.0 volt output when the input Voc drops as low as 1.1 volts. The relatively high start-up voltage requirement can be avoided if the load is added after regulation begins. Alternatively, a 100 μF capacitor can be added at the input of the X0122 and then the enable port pulsed to allow the capacitor to charge with the converter disabled and then when the converter is enabled, the capacitor supplies the pulse of start-up power required for converter operation.

ABOUT TXL

TXL Group, Inc. is an El Paso, Texas company developing Waste Heat Harvest® solutions[3]. High efficiency conversion of generated electricity to desired voltage levels is an important part of any thermoelectric generation design since an arbitrary X% improvement in conversion efficiency has the same system impact as an X% improvement in TE generation. This has led the Company to develop a range of high efficiency conversion solutions from microwatts and up.

[2] www.customthermoelectric.com

[3] *Waste Heat Harvest®* is a U.S. Registered Trademark.