PROGRAMMABLE BOOST CONVERTER

DATASHEET Y0701

INTRODUCTION

The Y0701 programmable boost converter is a self-oscillating DC/DC converter that can be hardware programmed to convert an input voltage as low as 2.8 volts into a selectable, regulated DC output voltage. On-board resistors are provided to allow jumper selectable voltages of +9, +12, +14 or +24 volts. By adding a single 0805 style resistor, an arbitrary output voltage of between 6 to 36 volts may be selected. These converters are specifically designed for use with thermoelectric generators, where thermoelectrically generated voltages may be either variable or too low for direct use.

THERMOELECTRIC GENERATION

Thermoelectric (TE) phenomena arise from the intercoupled electrical and thermal currents in a material. A thermoelectric 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 white alumina scaffold is often used on the top and the bottom of a device to lend mechanical support to the thermoelements.

Any thermoelectric device can be used for either generation or for heat pumping. In a heat pumping application, the TE device is often referred to as a Peltier module or cell. When an electrical current is applied, heat is moved from one side to the other side of the device. The Y0701 Programmable Boost Converter can work with TE devices that have been designed for either generation or heat pumping.

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 thermoelectric properties, then the open circuit voltage may be written as

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

The ΔT in eq. (1) will always be less than the difference between heat source and heat sink temperatures due to thermal resistances between source/sink and the actual thermoelements. These "parasitic" thermal resistances should be minimized to the greatest extent possible.

OBTAINING MAXIMUM POWER

Every generator has an internal electrical impedance, often referred to as the source resistance, R_S. When a thermoelectric module is used for generation, 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

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

The source resistance serves to reduce the power that can be delivered to an electrical load.

THEORY OF OPERATION

The Y0701 is a unipolar DC/DC up-converter that takes a DC voltage and converts it to a higher, preselected, regulated voltage. The approach is based upon a pulse width modulation (PWM) control scheme whereby input power is stored within a magnetic field in an inductor and then released into an output capacitor to supply load current and maintain a selected output voltage.

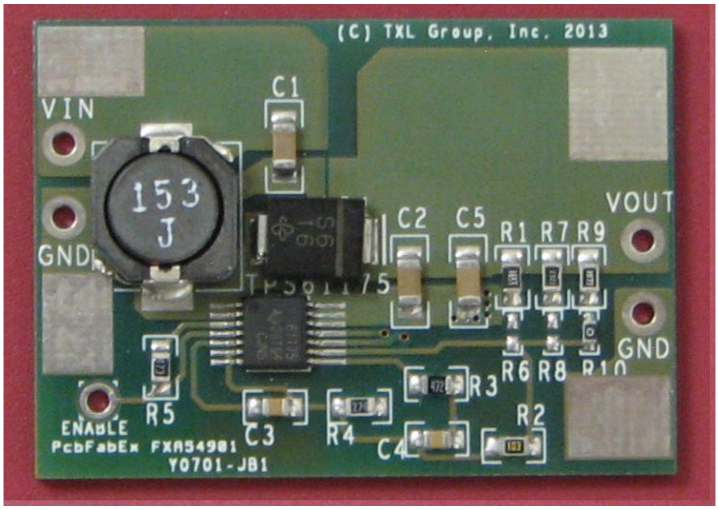

Figure 1 – The Y0701 Programmable Boost Converter

Figure 1 depicts the Y0701. There are five external connections. The input voltage is applied at the nodes labeled VIN and GND. The nodes labeled VOUT and GND are the output. Pads above and below these four nodes allow easy clip lead and solder attachment. The GND nodes for the input and output are electrically connected. In a correct application, VIN and VOUT will have a positive polarity with respect to ground. The node labeled ENABLE in the lower left represents a means to turn on and off the converter. This has an internal pull-up. When the enable input is pulled to ground, the device is disabled and no power will be supplied at VOUT.

PROGRAMMING THE OUTPUT VOLTAGE

The Y0701 has a preprogrammed jumper selectable output voltage. By placing 0 Ω, size 0604 shorting resistors in positions R6, R8 and/or R10, it is possible to program an output voltage of +24, +14, +12 or +9 VDC. Equivalently, R6, R8 and R10 may be shorted with a wire or solder blob to select the output voltage. All units are shipped from the factory with R6 and R8 open and R10 shorted to provide a default voltage of +24V. Table 1 lists the different setpoint voltages that can be obtained by opening (o) or shorting (s).

R6	R8	R10	Vout
O	O	S	+ 24 V (default)
O	S	O	+ 29.7 V
O	S	S	+ 14 V
S	O	O	+ 21.5 V
S	O	S	+ 12 V
S	S	O	+ 13.1V
S	S	S	+ 9 V

Table 1 – Jumper Configurations to Select Vout

DO NOT OPERATE WITH ALL OPEN! It is possible to program other output voltages over the range of +6 to +36 volts by keeping R6 and R8 open, R10 short, and changing the value of R9 according to the equation

$$R9 = 10{,}000\left(\frac{Vout}{1.229} - 1\right) \qquad (3)$$

So, for example, to select an output of +36 V, use the default configuration with R9 changed to a value of 283 kΩ.

ELECTRICAL SPECIFICATIONS

VIN: +2.8 VDC to +18 VDC
VOUT: + 6 VDC to +36 VDC
PMAX: 8 Watts

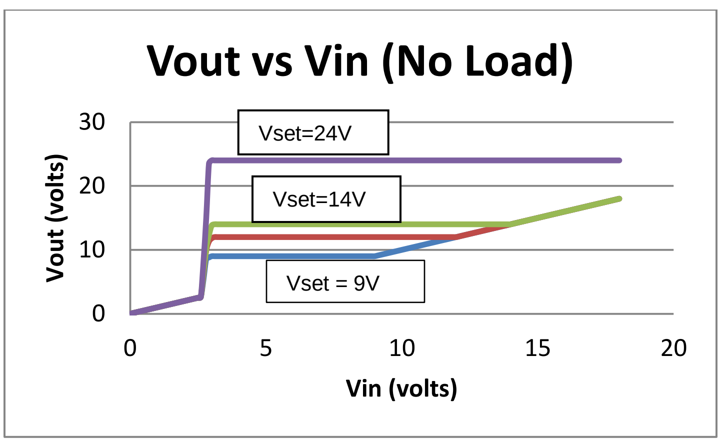

Figure 2 – Vout vs Vin Under No-Load Conditions

It is important to note that the Y0701 converter module can only step up a voltage. When the input voltage exceeds the setpoint voltage, then the output voltage will exceed the setpoint voltage and will track the input voltage. This is seen in Figure 2.

CONVERSION EFFICIENCY AND RIPPLE

Conversion efficiency is highly dependent upon source impedance, input voltage, output voltage and the power drawn by the load. The maximum power at all programmed voltages is 8 watts, corresponding to 333 mA at 24 volts, 667 mA at 12 volts, etc. For light loading of under 4 watts, the efficiency will typically exceed 90%.

Conversion efficiency and output regulation, particularly at relatively heavy loads, are dependent upon the source resistance and the load characteristics. In particular, for heavy loads, a ripple voltage may be observed at the output. This can be reduced by adding output capacitance in parallel with the load.

TYPICAL APPLICATIONS

When the input power is thermoelectrically generated, the voltage will vary with the temperature gradient. In these cases, if the desired voltage is higher than the thermoelectrically generated voltage, the Y0701 converter can serve to deliver power at a known regulated voltage. This is well suited for rechargeable battery applications either with or without a dropping resistor. The enable pin on the Y0701 may be a useful feature for controlling power to the load.

The starting point for any design is to determine if the input can source enough power to boost and furnish to the load. From circuit theory, the maximum power that can be drawn from a source is obtained when the load impedance matches the source impedance. So, for example, if the open circuit (no load) voltage from a thermoelectric module is + 4 volts and that module has an input resistance of 1 Ω, the maximum power that can be delivered by that source occurs for a load of 1 Ω, in which case the load would have 2 volts and the power delivered to that load would be 4 watts. So the maximum power that can be delivered by the source in this example is 4 watts, irrespective of the output voltage setpoint. Of course, the power delivered to a load at any given voltage setpoint will be somewhat less than the maximum possible input power due to efficiency losses.

Each application will present its own challenges and should be tested for extreme cases of anticipated input voltage and loading. In particular, the input voltage must be clamped to a not-to-exceed voltage of +18 V.

ABOUT TXL

TXL Group, Inc. is an El Paso, Texas company developing industrial Waste Heat Harvest® solutions[1]. In many applications, thermoelectric generation alone does not directly provide the desired voltage level. As such, high efficiency conversion is an important part of any design as an arbitrary X% improvement in conversion efficiency has the same overall impact on systems efficiency as an X% improvement in thermoelectric generation. This has led TXL Group to investigate a range of solutions for scalable thermoelectric power generation from microwatts and up.

1 *Waste Heat Harvest®* is a U.S. Registered Trademark of TXL Group, Inc.