Additional Negative Output With TPS601xx

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ABSTRACT

In addition to a main positive supply voltage, some applications also require a negative voltage at low current. The power-supply circuit should easily be able to provide the application with this additional supply voltage. This note discusses a simple way to derive a negative voltage from a charge pump dc/dc converter. An easy solution to stabilize the negative voltage is to use a shunt regulator. The regulated negative output can be adjusted from \(-V_{\text{ref}}\) to \(-3\) V, where \(V_{\text{ref}}\) is typically 1.24 V.

The application describes a solution for biasing a LC-Display with \(-2\) V at 1 mA.

Design Problem

With inductive dc/dc converters, it is easy to generate several voltages by additional windings on the inductor. Charge pumps do not allow this direct solution. The solution proposed is based on being able to use the voltage ripple at the flying capacitor to generate a negative voltage at low current. Because the voltage ripple is very low and is also highly sensitive to the input voltage and the output current of the main output, the voltage ripple must first be multiplied, then stabilized. This is done with a cascade, followed by a TLV431 shunt regulator. One advantage of this solution is that the negative voltage can be adjusted easily to another voltage level. This circuit has been tested with all TPS601xx devices. The TPS6010x and TPS6011x-devices must run in skip mode to ensure a voltage ripple at \(C_{\text{fly}}\) that is high enough; hence, SKIP is connected to \(V_{\text{in}}\).

Solution

Figure 1 shows the application, which consists of the TPS601xx charge pump, a cascade of Schottky diodes, and the 3-terminal adjustable shunt regulator TLV431. In order to minimize losses, Schottky diodes are used for the cascade which inverts the input voltage of the cascade and doubles it. To increase the amplitude of the input to the cascade, small 1-\(\Omega\) resistors are added in series with the flying capacitors, \(C_{\text{fly1}}\), and \(C_{\text{fly2}}\).
Figure 1. Schematic of Application Circuit

$V_O$ is the negative output voltage at the cascade. The negative output voltage, $V_O$, is determined by the resistor network $R_1 / R_2$ as follows:

$$V_O = - \left(1 + \frac{R_1}{R_2}\right) \cdot V_{\text{ref}} - R_1 \cdot I_{l(\text{ref})}$$

where $V_{\text{ref}}$ is typically 1.24 V. Here, $I_{l(\text{ref})}$ is the reference input current, which is typically about 0.15 µA.

The resistor, $R$, should provide a cathode current of $|I_{ca,\text{min}}| \geq 0.08$ mA to the TLV431 at the minimum voltage, $V_I$.

Application Hints:
- For best performance, connect the input of the cascade with C1- (PIN 8) when using the TPS60140.
- Use low-voltage Schottky diodes for the cascade. Examples are BAT54S (double diode), LL103A, and MBRM120LT3 (for highest performance).

- The value of R in series with \( C_{\text{fly1}} \) and \( C_{\text{fly2}} \) must be the smallest resistance that is just sufficient to provide all three of
  - Maximum input voltage of the charge pump
  - Minimum output current at the main output
  - Maximum output current at the negative output

The procedure for determining the right resistance is as follows: (i) To the input, connect the lowest input voltage to be used in the application, (ii) Load the main output (OUT) with the minimum current that can occur in the application, (iii) Load the negative output with the maximum current that can occur at the negative output in the application, (iv) Keep increasing the value of the resistors in series with \( C_{\text{fly}} \) until the negative voltage and current can be provided by the negative output. The lowest resistance possible should be used, because increasing the value of these resistors decreases the main output current.

- In some applications using the TPS6012x, TPS6013x and TPS6014x, the resistors in series with the flying capacitors may (both) be unnecessary.

- At low input voltages, the resistor in series with \( C_{\text{fly}} \) limits the maximum current at the main output of the charge pump, but it increases the performance of the negative voltage. Use the lowest value sufficient for the application.

Because the charge pump generates a regulated output voltage, the resistors in series with the flying capacitors do not decrease the efficiency of the inverter over a wide range of input voltage and output current.

Free samples can be ordered from http://www.ti.com. Type the complete device name in the quick-search box and select check stock or order under Availability/Samples. For more detailed information about the device, see the TPS6010x data sheet [SLVS213B], or TPS6010x/TPS6011x Charge Pump [SLVA070].

References

1. TPS60100 Regulated 3.3-V 200-mA Low-Noise Charge Pump DC/DC Converter, Data Sheet, Texas Instruments Literature Number SLVS213B.

2. TPS6010x/TPS6011x Charge Pump, Application Report, Texas Instruments Literature Number SLVA070.
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