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Keywords: switchmode, switch-mode, power supply controller, negative supply current, MAX774, regulated charge pump, inductorless, op amps, LCD bias

APPLICATION NOTE 146

DC-DC Switch-Mode Power-Supply Controller Drives Regulated Charge Pump

Jul 09, 1998

Abstract: Inductor-based switch-mode power supplies can take significant design effort and increase size, especially for generating negative supply currents for op amps or LCD bias. This application note describes how a switch-mode power-supply controller such as the MAX774 and a diode-capacitor network can generate modest negative supply currents without the use of inductors.

A switch-mode power-supply controller and diode-capacitor network can generate the modest negative supply currents required for op amps or for LCD bias, without the design effort and size penalty associated with inductors (**Figure 1**). The circuit of Figure 1 accepts inputs of 2V to 6V and produces a digitally adjustable output voltage. The diode-capacitor charge pump is driven by the switching action of DHI and DLOW, which normally drive an external MOSFET or pnp transistor in an inductor-based switch-mode power supply.

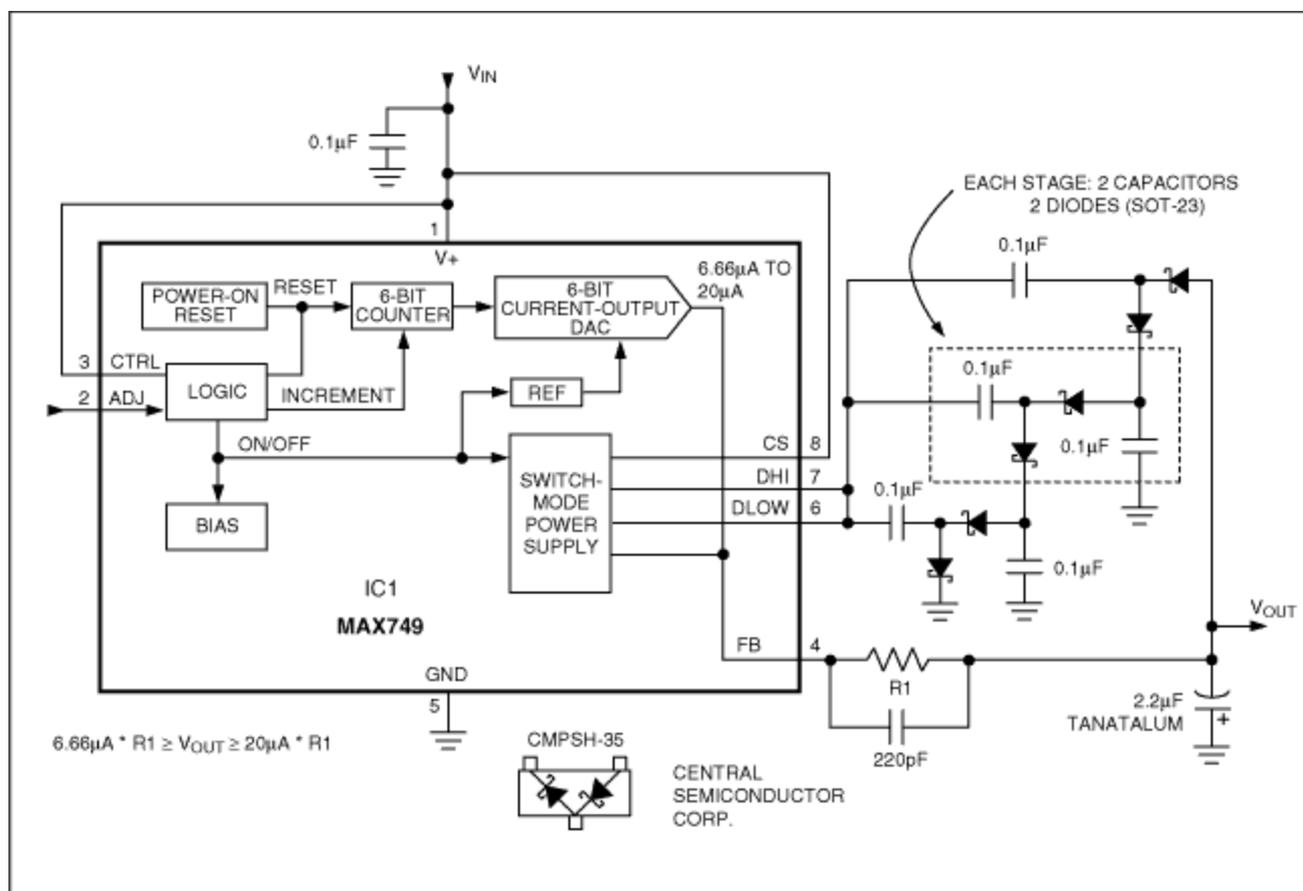


Figure 1. Driving a diode-capacitor network instead of an inductor, this DC-DC controller IC produces a regulated negative output with modest I_{OUT} capability.

At power-up, the internal 6-bit current-output D/A converter produces a nominal V_{OUT} of R₁ × 13.33µA. Then, by holding CTRL high and toggling ADJ, you can adjust V_{OUT} over a 3:1 range in 64 equal steps, according to the value of R₁: R₁ × 6.66µA ≤ V_{OUT} ≤ R₁ × 20µA. If digital adjustment is not required, ground the ADJ pin and connect CTRL to V₊. Or construct a similar circuit with the MAX774 DC-DC controller, which accepts inputs up to 16.5V. For positive outputs greater than V_{IN}, a step-up controller and modified charge-pump network (not shown) can do the job.

The maximum output current depends on V_{IN}, V_{OUT}, and the number of diode-capacitor stages, each of which consists of two diodes and two capacitors. Though only a few microamps are available at the maximum V_{OUT}, which equals V_{IN} - (0.6V × the number of stages), you can draw more current at the lower output voltages (**Figure 2**).

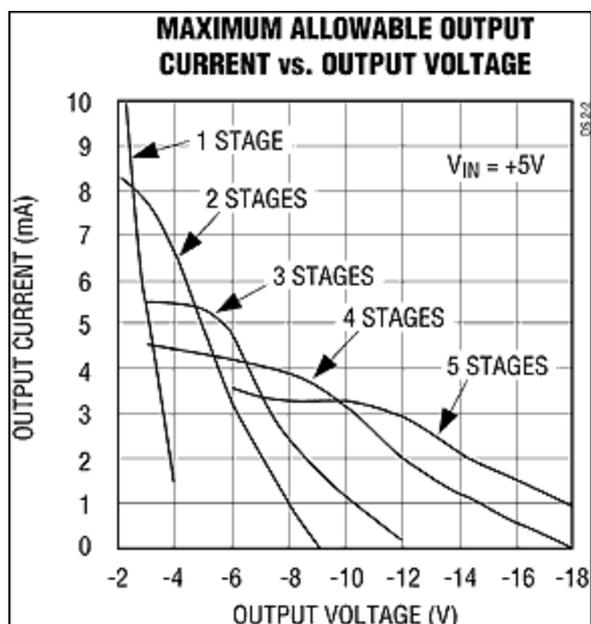


Figure 2. The available output current in Figure 1 depends on V_{IN} (5V for this graph), V_{OUT} , and the number of diode-capacitor stages.

The number of diode-capacitor stages determines the maximum I_{OUT} for a given V_{IN} and V_{OUT} . Too few stages will not achieve the desired voltage, but too many degrades the efficiency: I_{IN} equals (approximately) I_{OUT} times the number of stages. For V_{IN} less than 5V, the circuit delivers less output current than is indicated by the curves of Figure 2. For example, a 4-stage circuit produces an output current of 1mA at -2V out from $2V_{IN}$, at -7V from $3V_{IN}$, at -11V from $4V_{IN}$, and at -14.5V from $5V_{IN}$. Larger pump capacitors can provide higher I_{OUT} .

The controller changes its behavior when V_{OUT} is much lower than the voltage programmed by R1. Designed for inductor-based circuits, it compensates for impending dropout by increasing the switching transistor's "on" time at the expense of "off" time. This action normally ramps up the inductor current, but it has an opposite effect for the circuit shown. Because short off times (DHI high) don't allow the capacitors to discharge fully, the available output current actually decreases instead of increasing. Thus, when V_{OUT} loses regulation due to overload, you must reduce the load current considerably before regulation can be regained. A reliable maximum output current is the level at which V_{OUT} recovers from dropout, not the higher level at which it enters dropout.

For stable operation, bypass R1 with 220pF, keep the connections between R1 and IC1 very short, and place the input bypass capacitor directly across the input pins of IC1. Output ripple is typically less than 1% for the component values shown, but ripple can be higher if the circuit includes more stages than that required by the programmed output voltage. Ripple can be lowered by increasing the output capacitance.

Related Parts

[MAX774](#)

-5V/-12V/-15V or Adjustable, High-Efficiency, Low I_Q
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APPLICATION NOTE 146, AN146, AN 146, APP146, Appnote146, Appnote 146

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