Converter in feedback loop improves voltage regulation

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One of the most frustrating experiences a designer faces is to discover that his TTL or complementary-MOS circuit, which he intended for single-supply operation, actually requires a minus potential at some miniscule current for one or two of its integrated circuits. A new chip, Intersil's 7660 voltage converter, now enables the designer to obtain the minus voltage at low currents from a positive supply without the need for a transformer or other complicated inverter circuitry, and at low cost. In addition, placing the converter in a feedback loop that includes the chip's power—or driving—source permits a degree of voltage regulation that is not possible with the conventional stand-alone driver configuration.

As shown in (a), the 7660 can supply −3.5 volts to a single chip in a C-MOS or TTL system. The chip requires +3.5 V, which is generated by the LM10 operational amplifier from the +5-V supply. Although some other low-voltage op amp and an external reference could be substituted, the LM10 will run off a single supply, has its own reference, and has an output stage that can swing within ½ V of the supply while delivering −20 milliamperes to the 7660.

Though this circuit performs well at very low load currents, its output voltage drops rapidly as load currents increase (see table) because its output impedance is fairly high. At a no-load output voltage of −3.5 V the converter exhibits an output resistance of about 100 ohms, but it will increase 50% for V_{out} = 2 V. This value will render the 7660 useless in systems where more then a few milliamperes are required.

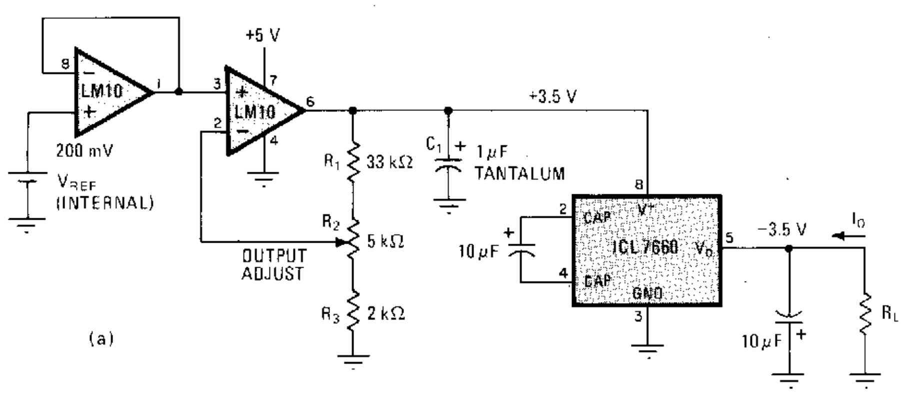
By adding a single resistor and configuring the circuit to the topology in (b), however, the converter can be made to perform much as an ideal voltage source for loads of 1 kilohm or greater. The regulation for loads less than 1 kΩ will be much superior to that in (a), as seen in the table.

Here the circuit works as an inverting amplifier with a gain of −17.5, which is set by $(R_1+R_2)/R_3$. The converter provides a gain of −1, requiring that the noninverting input of the op amp be used as the summing junction. Thus the circuit can still be run from a single supply because the LM10's input common-mode range includes the negative supply (ground, in this case).

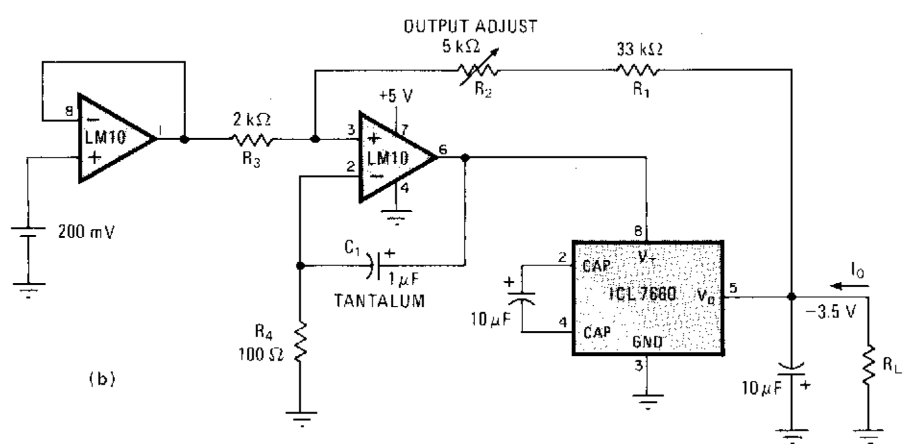
R_4 and C_1 provide local feedback around the op amp to stabilize the loop. Without these components, the delay between input and output voltage changes of the 7660 would cause the output of the LM10 to oscillate between ground and +5 V.

In operation, the feedback loop will force the op amp to try to hold the negative output voltage constant. Even at the higher currents, the output resistance is half of what it is in (a).

The circuit may also be used to supply negative voltages other than −3.5 V. If higher voltages are desired, it is necessary to choose a supply voltage for the LM10 that will provide sufficient output from the op amp under the expected load conditions. In this case, the effective voltage gain of the 7660 drops from −0.99 V to zero, and so the output voltage of the op amp must rise as the load current increases in order to compensate for the loss of gain. □



R_L (kΩ)	I_0 (mA)	V_0
∞	0	3.50
10	0.34	3.45
6.8	0.47	3.37
4.7	0.74	3.36
3.3	1.02	3.34
2.2	1.60	3.30
1.5	2.22	3.26
1.0	2.97	3.20
0.68	4.48	3.08
0.47	6.12	2.94
0.33	8.23	2.73
0.22	10.38	2.48
0.15	13.50	2.06



R_L (kΩ)	I_0 (mA)	V_0
∞	0	3.50
4.7	0.76	3.50
3.3	1.06	3.50
1.5	2.35	3.50
1.0	3.20	3.50
0.68	5.06	3.52
0.47	7.02	3.42
0.33	9.38	3.19
0.22	12.13	3.02
0.15	17.42	2.81

Regulatory loop. Intersil's 7660 voltage inverter provides a negative output from a positive source without transformers (a), but voltage regulation is poor. Placing the 7660 in a feedback loop that includes the driving source (b) improves operation markedly.