Complementary-pair dc/dc converter simultaneously doubles, inverts supply voltage

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The circuit in this Design Idea uses an intrinsic property of collector voltages in one-transformer push-pull dc/dc converters: They have a swing of twice the supply voltage. When you implement these circuits with an NPN device, the collector swings from 0V to twice the supply-rail voltage. When you use PNP devices, the collector voltage swings from V_{CC} to an equal amplitude but negative V_{CC} (**Reference 1**). In this circuit, a complementary pair of transistors, simultaneously implementing a voltage doubler and a negative-voltage source, drives the two windings of the transformer.

One of the windings of transformer T_1 connects to ground, driven by PNP transistor Q_1 from V_{CC} (**Figure 1**). The other winding of T_1 connects to V_{CC}, and NPN transistor Q_3 drives the lower end to ground. Q_2 and Q_4 drive Q_1 and Q_3, respectively. The collectors of Q_3 and Q_1 through resistors R_4 and R_3 provide cross-coupled drives to Q_2 and Q_4. R_1 and R_2 form the collector loads for Q_2 and Q_4. D_1 and D_4 prevent the reverse breakdown of Q_1 and Q_3. The drive configuration and the transformer's winding polarity provide regenerative feedback and self-oscillation so that the transformer alternates between positive and negative saturation, inducing voltages to drive transistors Q_1 and Q_3 alternately on and off.

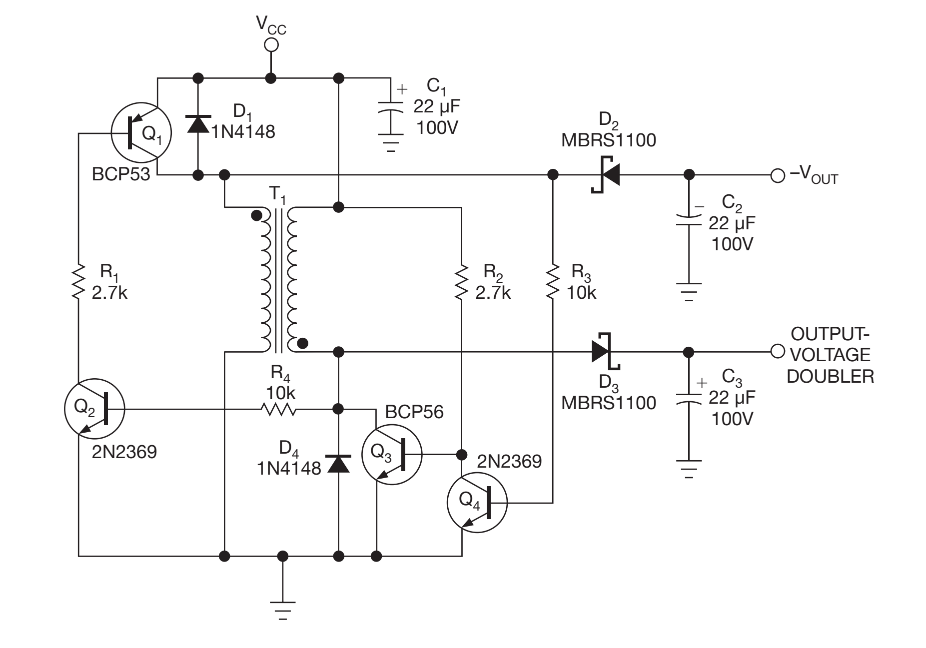

Figure 1 Cross-coupled regeneration drives switching transistors Q_1 and Q_3 and the windings of the transformer. The resulting voltage swings at their collectors are rectified to twice the positive and the negative power-supply rails.

A square wave with an amplitude twice V_{CC} is generated at the collector of Q_1, which swings nominally from V_{CC} to the equal but negative output voltage. Simultaneously, a square wave with an amplitude twice the supply-rail voltage is generated at the collector of Q_3, which swings nominally from 0V to twice the supply-rail voltage.

D_2 and C_2 provide half-wave rectification and filtering of the Q_1 collector waveform generating the negative voltage output. Half-wave rectification and filtering of the Q_3 collector waveform using D_3 and C_3 generate the doubler's output.

T_1 is 200 turns of bifilar AWG 37 enameled wire

TABLE 1 EXPERIMENTAL RESULTS

Input voltage (V)	Input current (mA)	Frequency (kHz)	Voltage doubler (V)	Current doubler (mA)	Negative voltage (V)	Negative current (mA)	Input power (W)	Output power (W)	Efficiency (%)
5	253	2.1	7.68	81.7	–3.41	–72.5	1.27	0.87	69
9.97	360	4.05	17.33	115.5	–8.65	–86.5	3.59	2.75	76.6
15	420	6.02	27.2	136	–13.58	–90.5	6.3	4.93	78.2
19.4	400	7.37	34.9	145.4	–18.33	–61.1	7.76	6.19	79.8
25	340	10.47	48.5	97	–23.8	–79.3	8.5	6.59	77.5
30	410	12.07	56.5	113	–27.6	–92	12.3	8.92	72.5

wound 1-to-1 on a ferrite toroid core (**references 2** and **3**). **Table 1** shows the experimental results with the voltage doubler and negative-voltage-generation circuit operating over an input voltage of 5 to 30V, demonstrating operation over a wide input voltage range and providing power at both outputs simultaneously at moderate efficiency. EDN

REFERENCES

1. Raman, Ajoy, "Voltage doubler uses inherent features of push-pull dc/dc converter," *EDN*, Aug 16, 2007, pg 72, http://bit.ly/GTlveF.
2. "T503125," Ceramic Magnetics Inc, http://bit.ly/L3FzeW.
3. MN60 manganese-zinc material specs, Ceramic Magnetics Inc, http://bit.ly/KoyO4Y.

Adjust power-efficient LED switch to any light intensity

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You can use an LED as a photoelectric sensor. A previous Design Idea shows that such a switch is highly power-efficient, consuming almost no power (**Reference 1**). However, you cannot adjust that configuration to switch at the desired light intensity. You can adjust the circuit in this Design Idea to any threshold level of light intensity necessary to maintain the on state of the photoelectric switch while retaining almost the same power efficiency of the original circuit (**Figure 1**).

Illuminating the reverse-biased green LED with ambient light causes the small current that flows through the LED to form the base current of the BC549 NPN transistor, which is amplified and passed on to the base of the BC177 PNP transistor. A magnified version of this current flows through the emitter of the BC177. The voltage drop across the emitter resistor depends on its value and the current flowing through it, which in turn determines the voltage drop across the CE terminals of the BC549.

By adjusting the value of the series emitter resistor you can set a voltage corresponding to logic zero of a CMOS gate for any desired intensity of light falling on the green LED. This intensity depends heavily on the response of the green LED and the current gains of the two transistors, so you select the resistor value by shorting out combinations of the series string of resistors and use the 10-MΩ potentiometer as a fine adjustment. Once you find a suitable value,

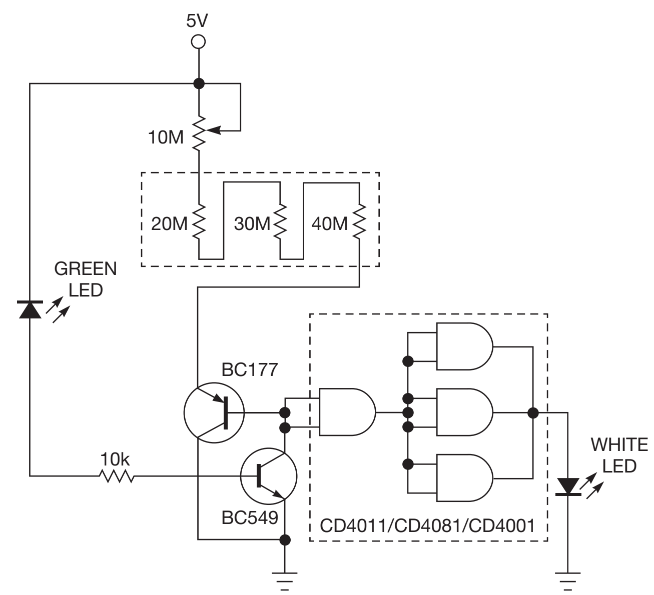

Figure 1 The photocurrent through the green LED amplifies to CMOS-logic levels to turn on the white LED when ambient light falls.