AND8395/D

A Simple Secondary Side Vcc Source for Low Power, Constant Voltage, Constant Current (CVCC) Power Supplies

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APPLICATION NOTE

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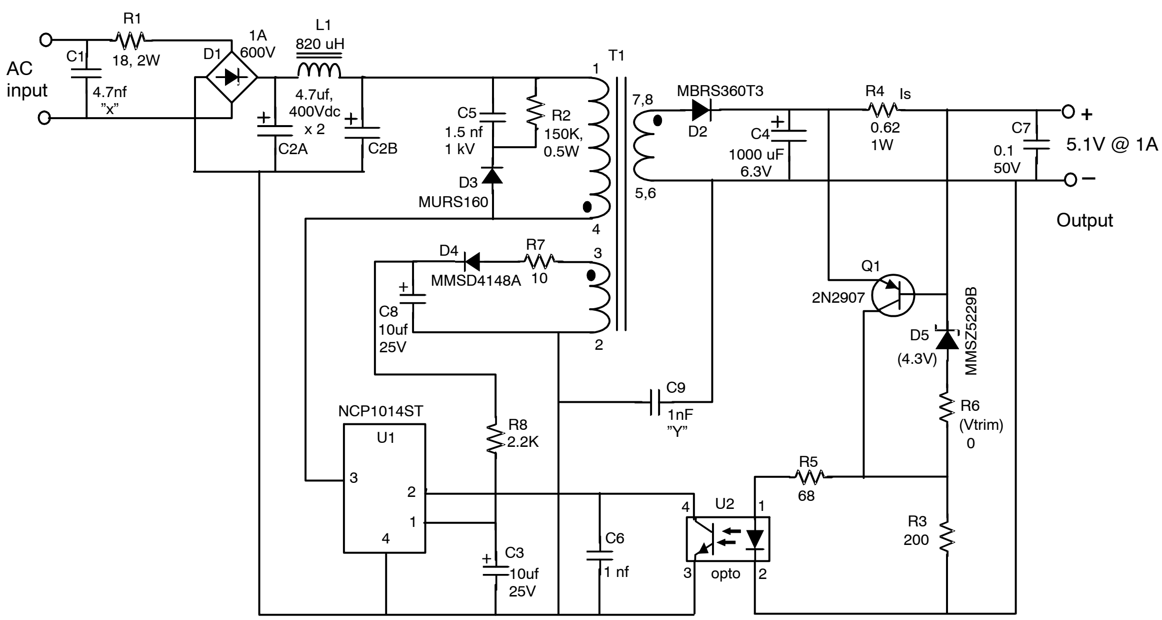
Introduction

The design of off-line constant voltage, constant current (CVCC) power supplies for cell phone, hand tool, and similar battery chargers can present several challenges if low cost and circuit simplicity are necessary, yet good performance and high efficiency are required. One typical problem is associated with deriving a simple yet effective Vcc source for the secondary control circuitry without resorting to additional circuit complexity, more secondary windings on the high frequency switching transformer, and using high value current sense resistors. Most chargers that fall in this category typically require an output voltage of 3 to 15 volts and are implemented with simple, low cost flyback switchmode topologies.

Typical Application

Figure 1 shows a typical CVCC charger implementation which is described in detail in ON Semiconductor's Reference Design TND329/D (5 W CCCV AC-DC Adapter GreenPoint™ Reference Design).



NOTES:

1. L1 is Coilcraft part RFB0807− 821L (820 uH @ 300 mA)
2. U2 is 4 pin optocoupler with CTR of 50% minimum
3. See Magnetics Data Sheet for T1 construction details
4. U1 is 100 kHz version
5. D7 zener sets Vout: Vout = Vz + 0.85V
6. R4 set max current: Imax = 0.65/R4
7. R6 allows for Vout trimming (increase only)
8. Fuse resistor recommended for R1
9. Crossed lines on schematic are not connected

5V/1A CC/CV Power Supply with Universal AC Input (Rev 3)

Figure 1. Simple 5 V, 1A Cell Phone Charger Schematic

Although this charger circuit meets previous energy efficiency requirements, the constantly evolving standards are moving toward even higher efficiency limits. On of the largest sources of inefficiency in this circuit is the large value of the current sense resistor R4, particularly when the charger is operating in the constant current (CC) mode. When the current reaches one amp, the voltage drop across R4 turns on Q1 which bypasses zener D5 (which controls the charger when in the constant voltage (CV) or float mode) and regulates the current at a constant value. Note that the voltage source which supplies current to the feedback optocoupler U2 is just the output voltage of the supply and this voltage will fall as the load resistance drops during overload. At some point approaching a "hard" short circuit, the output voltage level will fall below the forward drop of the optocoupler's photo diode. At this point the output voltage is too low to power the opto and the V/I load line profile will show a current "tail" in which CC operation is not longer functional. Fortunately batteries and similar loads do not drop this low in normal operation, however, safety agencies may require testing with a hard short circuit and if the current tail is excessive or can cause component failure due to overheating or excessive current, the charger will fail approval. In the case of the 5 volt, 1 amp reference design, the current tail is shown in Figure 2 for operation at 50°C and was insufficient to cause any problems due to the high value of the overcurrent sense resistor and the accumulated overall circuit impedances.

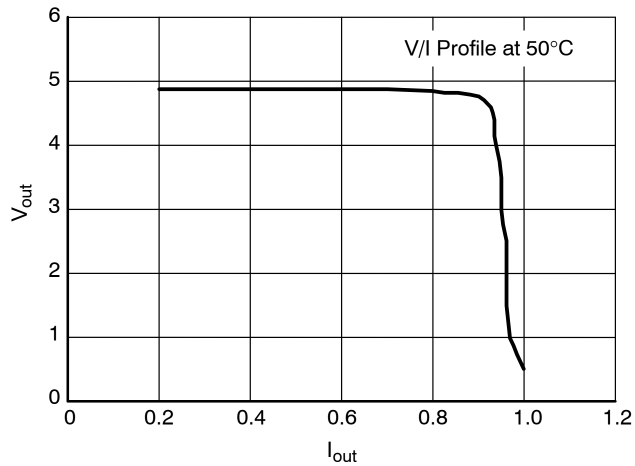
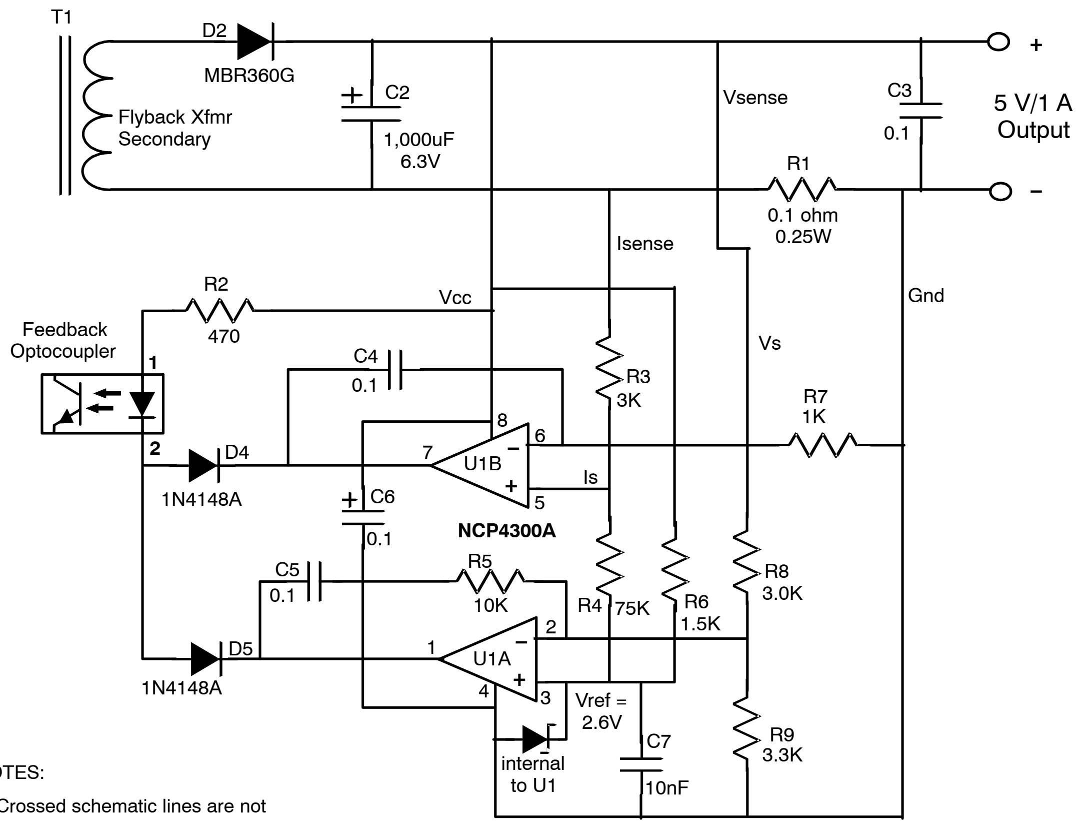


Figure 2. Slight Current Tail Due to Hard Short Circuit

For output of 12 or 15 volts this may cause a more prominent current tail which may not necessarily pass a hard short circuit condition.

Despite the simplicity of the current sense circuit and the minimal current tailing, the power dissipation in R4 at 1 amp output is 620 milliwatts. Considering that the total power output is 5 watts, this accounts for a 12% degradation in the efficiency of the circuit alone. A better approach would be to utilize a much smaller value sense resistor and some type of operational amplifier with reference to do the current and voltage sensing. A typical circuit is shown in Figure 3 below using ON Semiconductor's NCP4300A dual opamp with internal 2.6 volt reference.



NOTES:

1. Crossed schematic lines are not connected.
2. R8 sets Vout.
3. R4 sets Iout (set for 2A).
4. U1 Vref (pin 3) is 2.6V

NCP4300A CVCC Feedback Control For Flyback Converter

Figure 3. A Possible Solution for CVCC Charger Efficiency Improvement

This circuit may initially appear as a solution to the excessive current sense resistor dissipation exhibited by the circuit of Figure 1 since the value of this resistor has been reduced from 0.62 ohms to 0.10 ohms, however, since amplifier U1's Vcc is derived directly from the output voltage, and the specified minimum operating voltage for the chip is 3.0 volts, this circuit will likely develop a significant and unacceptable current tail in the CC mode when the output drops below 3 volts.

A Better Solution

A solution which could employ the circuit of Figure 3, and provide a secondary Vcc that is independent from the deterioration of the charger output voltage when in CC mode, would be optimal as long as the overall circuit complexity and cost is not significant. Adding an additional secondary winding on the flyback transformer would work, however, this would definitely impact the transformer cost, winding construction, and pin-out requirements. Since what we need here is a voltage that is not dependent on the flyback output voltage, we can access the so-called forward voltage of the transformer's existing secondary flyback winding by utilizing the capacitive charge pump circuit shown in Figure 4.

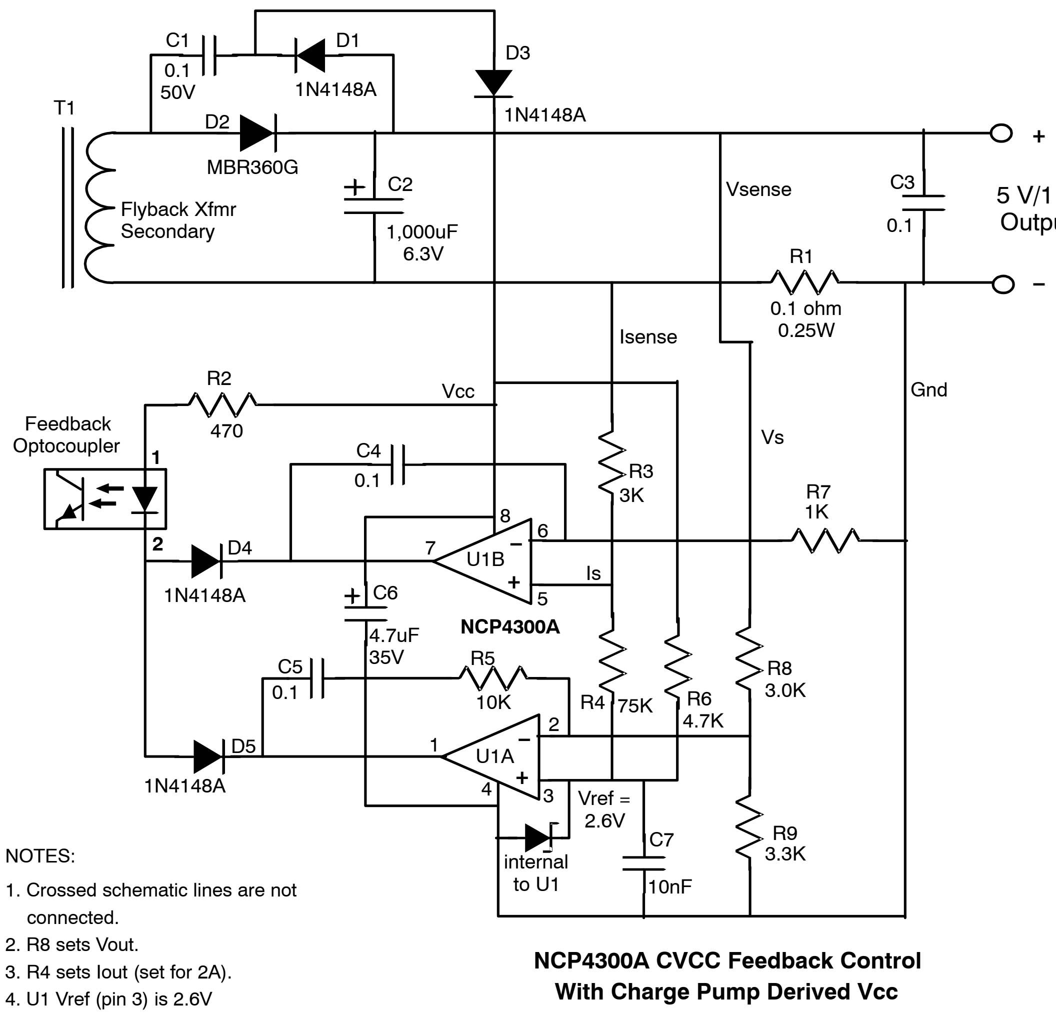


Figure 4. Secondary Vcc Bias Circuit Using Capacitive Charge Pump

Circuit Operation

During the switching period when the primary side MOSFET is on, flyback output diode D2 is non-conducting. Charge pump diode D1 is conducting and charging capacitor C1 to a voltage which is equal to the primary side dc bulk voltage divided by T1's turns ratio. In this case the primary-to-secondary turns ratio is 11:1, so at 120 Vac input the primary bulk voltage will be 165 Vdc and C1 will charge to approximately 15 volts. When the primary side MOSFET turns off and D2 conducts due to flyback action, D1 will be reversed biased and the charge on C1 will be "pumped" via diode D3 to Vcc capacitor C6. Because C2 and C1 appear in series during the flyback period, the voltage on Vcc filter capacitor C6 will be the sum of that on C1 and C2, namely 15 V plus 5 V = 20 volts. The actual value on this capacitor will show some variation due to transformer leakage inductance effects but will typically be in the range of 20 to 24 volts at 120 Vac input with the charger operating in CV mode. Keep in mind that this Vcc voltage is AC line dependent and will go to approximately 35 or 40 volts for 230 Vac input during normal CV operation. Under these latter input conditions a small resistor in series with D3 is recommended along with a 30 or 32 volt zener diode in shunt with C6 to limit the maximum Vcc to below the specified 36 volts for the NCP4300A.

When the power supply is operating in the constant current mode, the secondary Vcc will obviously be less than the voltage when in CV mode because the voltage on C2 will be lower due to the collapse of Vout. Under a hard short circuit the theoretical output voltage could be zero, however, there will also be some additional collapse of the forward voltage of C1 due to the very short converter duty cycle demanded by the short circuit. This voltage, however, will still be sufficient (typically greater than 8 volts) to allow proper operation of U1 and the rest of the secondary logic. Figure 5 shows the CVCC V/I profile of the 5 watt charger using the NCP4300A and charge pump Vcc bias circuit. Note the virtual "textbook" V/I profile right down to Vout = 250 mV with no current tail.

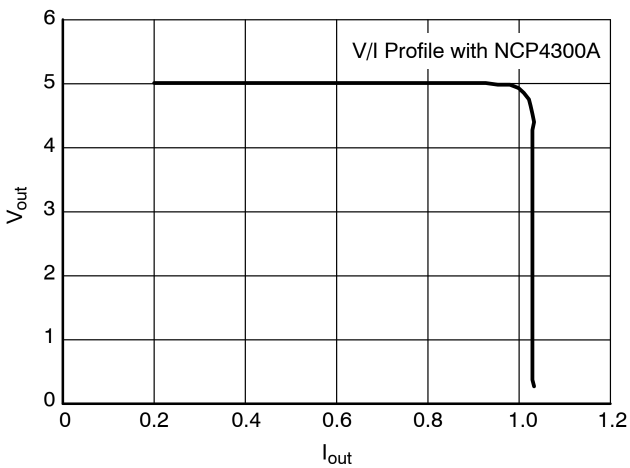


Figure 5. CVCC V/I Load line Profile with NCP4300A and Charge Pump Bias Circuit

Efficiency Impact

The original 5 V, 1 A cell phone charger circuit of Figure 1 and TND329 is compared to the upgraded circuit using the NCP4300A plus charge pump Vcc circuit of Figure 4. Efficiency measurements were made for 120 and 230 Vac inputs. The efficiency was measured per recent Energy Star criteria for low voltage power supplies at 25%, 50%, 75% and 100% of the charger's rated load, and the average of these measurements was calculated to determine the average efficiency. The average efficiency results are shown in the table below.

An efficiency improvement of about 5% was achieved which is significant at this low of output power level, particularly in light of the latest updated Energy Star requirements. Lower efficiencies at 230 Vac input are attributed to increased switching losses in the NCP1014's internal MOSFET due to the higher voltages involved.

Circuit Configuration	120 Vac Input Efficiency	230 Vac Input Efficiency
Original circuit (TND329 & Figure 1)	70%	65%
NCP4300A plus charge pump Vcc (Figure 4)	75%	69.4%

References

(See ON Semiconductor website: www.onsemi.com)

– ON Semiconductor Datasheet NCP4300A/D.

– Reference Design TND329/D: 5 W CCCV AC-DC Adapter GreenPoint™ Reference Design.

– Application Note AND8042/D: Implementing Constant Current Constant Voltage AC Adapter by NCP1200 and NCP4300A.

– Application Note AND8132/D: Performance Improvements to the NCP1012 Evaluation Board.

– Application Note AND8296/D: Increasing the Efficiency of Low Power Converters with Resonant Snubbers.

– Application Note AND8134/D: Designing Converters with the NCP101X Family.

– Design Note DN06009/D: 5 W, CCCV Cell Phone Battery Charger.

– Design Note DN06013/D: 3.6 W Auxiliary Power Supply for Appliances / White Goods.

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